“Piloting of eco-innovative fishery supply–chains to market added–value Adriatic fish products”

Priority Axis: Blue innovation

D 4.2.2. Guidelines/Technical papers of solutions for innovative production solutions

WP4 - INNOVATING TOOLS AND PROCESSES FOR ADDED-VALUE ADRIATIC FISHERY PRODUCTS/
A4.2. DESIGN, DEVELOPMENT FEASIBILITY OF SPECIALIZED POLYVALENT-MULTIUSE PROCESSING PACKAGING SOLUTIONS

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REPORT EVALUATION	mr.sc. Mario Lovrinov	
MEMBERS OF EXPERT TEAM	mr.sc. Mario Lovrinov	MARIBU d.o.o
	prof. dr.sc. Pietro Rocculi, prof. dr.sc. Luca Camanzi	University of Bologna
	Ivan Matijašević,MBA, dipl. ing. Ana Brala Gospić, bacc. oec. Lovre Vidov; Sandi Fonović, dipl.oec. Mauro Viro, Melanie Savian, prof. dr sc. Pietro Rocculi	Omega 3 RZ Istra Bivalvia
CONSULTATION	mag.ing. Valentina Andrić, dr.sc. Lav Bavčević doc.dr. sc. Tibor Janči	Ministry of Agriculture- Fishery department, University of Zadar; University of Zagreb
PRODUCTION	MARIBU d.o.o. Marine consultancy company	

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Content

I. Fisherman's cooperative "Omega 3"

Executive summary – FC "Omega 3"

The Guidelines/Technical papers will describe the production solutions (i.e., equipment, procedures, and practices) to be implemented for the harvesting of small pelagic fish as a chosen process. There will also be an introduction to new technical/technologic solutions for product handling which consider fishing operations.

Raising the quality of fish is an imperative for fishermen and breeders to collide with consumers. A significant increase in quality in the catch of small pelagic fish began with the use of ice. The use of ice started in the Republic of Croatia with the need to shock anchovies for processing a little over twenty years ago. At the same time, mainly agricultural tanks were used for shocking fish, where the ratio of water and ice was placed in them, thus shocking and killing the fish. After the shock, fish went for sorting, switching to plastic or Styrofoam boxes. Development processes followed the installation and use of hydraulic cranes, which made handling the catch easier. The use of cranes also enabled the lifting of heavier objects, so 5-7 years ago it started with the use of thermo-bins (insulation tanks), which were first introduced in aquaculture. The use of thermo-bins enabled the direct transport of fish in slurry ice to the facilities without the need for cosseting on board.

This significantly increased the quality of the catch, but as an unresolved category, the transfer of fish from the closed net via brailer to boats or tanks remained recognized as the riskiest and most difficult category in fishing for small pelagic fish.

Based on the conducted experiments, critical points in the process from catch to processing were identified that have a significant impact on the quality of fish. It is generally known that fish must be cooled as soon as possible after catching and the cold chain maintained until the moment of consumption or processing. Although recommendations for proper handling of fish after catch are available in several places, these recommendations in practice are not always easy to

implement during the catch due to various factors such as weather conditions, limited work, i.e. manipulative space on vessels, in the case of very large quantities of catches and the like. Even if the general recommendations for avoiding physical damage, using adequate amounts of ice and respecting the ratio of water, ice and fish during cooling and transport are followed, newer technologies offer room for further improvements and improvements in catch quality.

The first identified critical point is the loading of fish from the net into the vessel during which there are significant quality losses if the boarding takes a long time, i.e., the fish stays in the net for a longer period of time. As previously described, the loss of quality during the standing of the fish in the net is constant, but during the first 60 minutes it is extremely mild, after which it accelerates and can result in significant losses. For this reason, it is recommended that the total catch be loaded on board and cooled within 60 minutes of the fish being compacted within the net. This is difficult to achieve in the case when large quantities of catch need to be loaded by the traditional method using brailer.

Implementing the imagined testing involves finding a company that is reputable in the production and implementation of fish transfer systems in aquaculture as well as that is willing to participate in a pilot study of the possibility of using pumps to catch small pelagic fish. It is necessary to devise a system with a common approach that would provide a complete and functional framework for pumping fish out of the net using already known solutions in aquaculture. Examining the possibilities that the company would be interested in, the French company Faivre S.a. came forward and expressed its readiness to follow this project and make resources available for the pilot project. Fishing vessel Galo will be a demonstration field for implementing new technologies.

As a product for processing analysis project will make packaging of fresh sardines in inert gas. Implementation of new technology on boats will be done in Croatia and packaging in inert gas for the shelf-life extension of small pelagic in Italy. Product shelf-life analysis for inert gas and any analysis adequate to prove the quality and freshness of the packed product will follow.

1. Introduction

Raising the quality of fish is an imperative for fishermen and breeders to collide with consumers. A significant increase in quality in the catch of small pelagic fish began with the use of ice. The use of ice in purse seine vessels started with the need to shock anchovies for processing a little over twenty years ago. At the same time, mainly vineyard bins and tanks used for shocking, where the ratio of water and ice was placed in them, thus shocking and killing the fish. After the shock, the fish went for transfer to cassettes. Daily development processes followed the installation and use of hydraulic cranes, which made handling the catch easier. The use of cranes also enabled the lifting of heavier objects, so 5-7 years ago it started with the use of thermal insulation bins, which were first introduced in aquaculture. The use of thermo-bin enabled the direct transport of chilled fish to the facilities without the need for cashing on board. This significantly increased the quality of the catch, but as an unresolved category, the transfer of fish from the closed net via **scoopnet called the "brailer" (brailing operation)** to boats or tanks remained recognized as the riskiest and most difficult category in fishing for small pelagic fish. The official term in fishery literature, “breiler” will be used in the rest of this document.

Figure 1. Use of thermal insulation bins and hydraulic cranes (photo Andrić V.)

The category of such catch and landing on board can significantly affect the quality of the fish, and piloting the use of suction pumps will be selected for further project activities. Fishing for small pelagic fish in the Adriatic is defined by traditional fishing models that in some segments can significantly decrease the quality, as well as practice hard and inefficient work. For the purposes of this project, an aquaculture pump model will be used due to its smaller dimensions and adaptation to the transfer of live fish with special adaptations of fish transfer and the use of a water separation unit. It is planned to use pumps without an additional dimensional vacuum tank in order to take up as little space on board as possible and facilitate overall handling.

The procedure will represent a certain innovation that should adopt procedures, and the same system will represent a certain innovation and another quality improvement and as such should be adopted on fishing vessels.

The main goals of this project are:

• Examine the possibility of using an aquaculture pump for fishing on different structures and sizes of fishing vessels

• Testing in the direction of raising the quality, efficiency and welfare of fish

• Testing that new fish transfer practices can replace the one currently in use,

• Examination of the possibility of pumps in vertical and horizontal transmission of fish with simultaneous replacement of existing fishing methods,

• Conduct a comparative study of the pump system for fishing on board with classical methods and replacement cost.

Figure 2. Squeezing sardines in a fishing net (photo Andrić V.)

2. Description of equipment, procedures and practices in the process of catching small pelagic fish

The fishing technique and the course of the fishing operation are identical on all vessels of the Adriatic Purse Seine Fleet except pelagic trawlers. In short, vessels leave the port in the afternoon (16 - 17 PM in summer, 14 - 15 PM in winter, depending on the distance from the fishing area). During the voyage through the fishing area, flocks of fish are searched by sonar and echo sounders, and the vessel is anchored at the place where a sufficient quantity of fish is located. Collecting and keeping fish near the vessel is achieved by means of strong lights (up to 16 kW) which are switched on throughout the night. Before dawn, the lights on the ship gradually go out and the light on the auxiliary boat remains on. Then the main ship, with the help of another boat, surrounds the fish flock with a net in a very short time (up to 10 minutes). One end of the net is held on the surface by cork, while the other end is loaded with plumb and metal rings that ensure that the bottom of the net sinks quickly around the surrounded flock. Upon completion of the net setting, the steel rope passing through the rings at the lower end of the net is pulled onto the boat by means of a hydraulic winch thus closing the bottom of the net under the surrounded flock and preventing the fish from escaping. The net is then gradually pulled to the deck of the boat with a hydraulic winch, which reduces the volume inside the net and compacts the fish flock to the density needed to transfer the catch from the net to the deck.

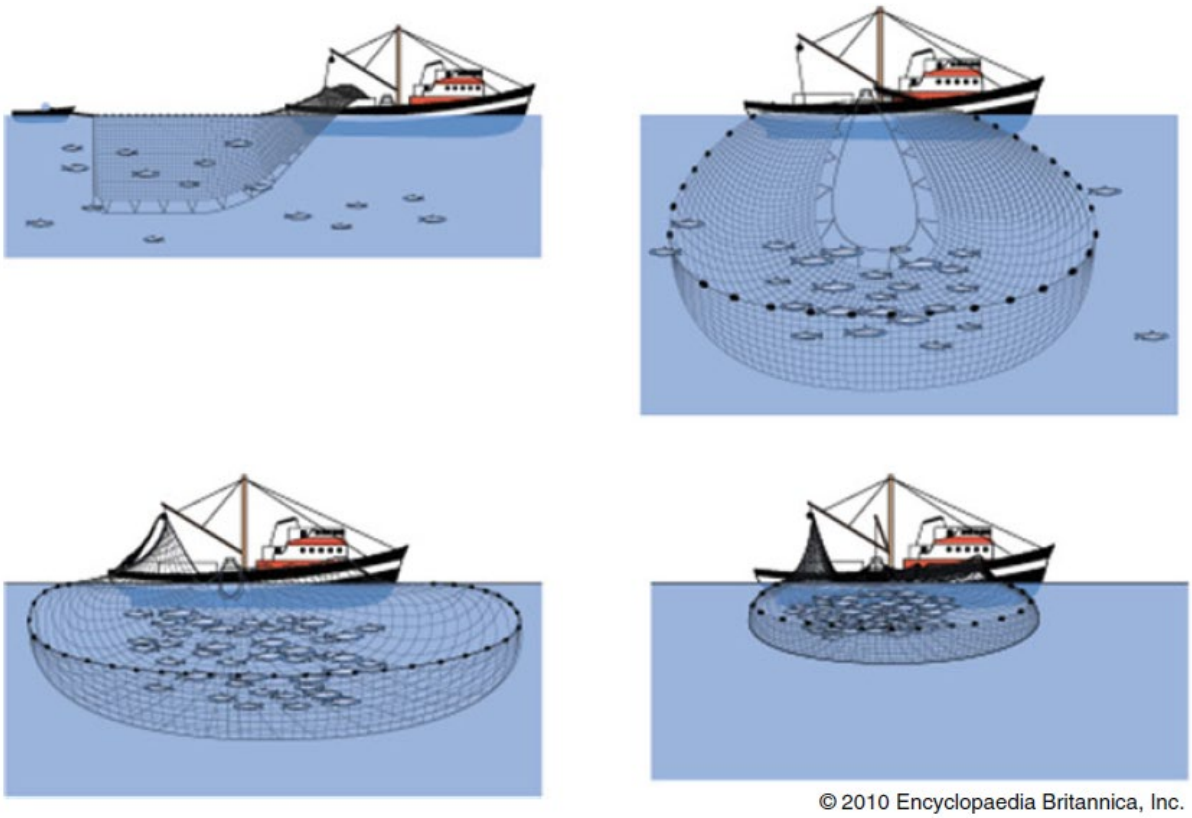
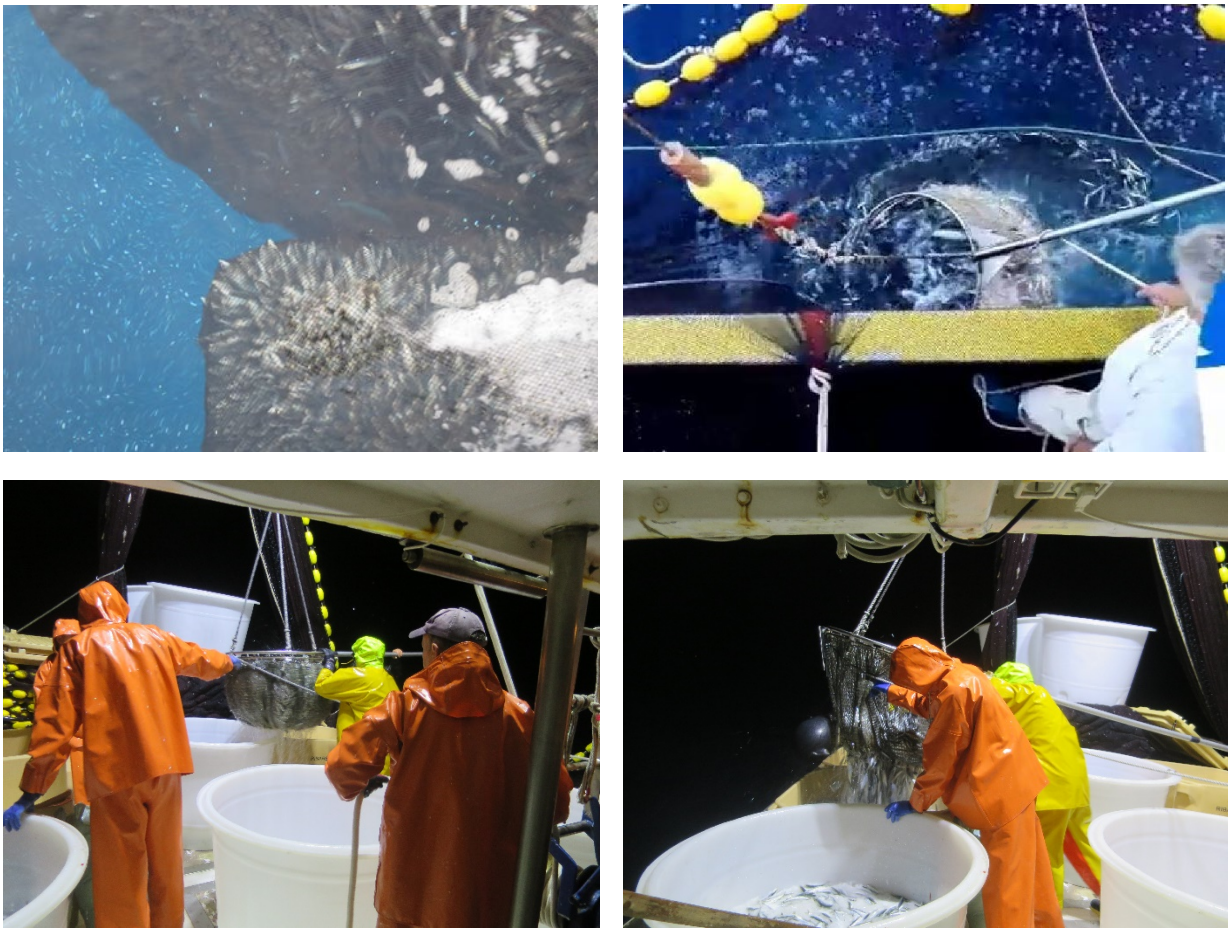


Figure 3. The course of operations in catching small pelagic fish with a purse seine net (Source: Encyclopaedia Britannica)

Figure 4. Stacking the net at the stern of the ship (photo Andrić V.)

3. Description of the traditional catch of small pelagic fish by squeezing and transferring with a brailer

The next phase in trawler method in the Adriatic involves the transfer of fish from the net to the deck of the purse seine vessels by the traditional method of transferring catches using brailer. The traditional method of transferring catches using a catching gear begins by compacting a fish flock inside the net to a high density after which the compacted fish is grabbed by the brailer and transferred to cooling tanks with a mixture of seawater and ice on deck. The capacity of the brailer ranges from 100 - 300 kg of fish and the manipulation with the brailer requires the engagement of 4 crew members where one member controls the hydraulic winch which lifts the net on deck, one member manipulates the with it during the loading process and two members manipulate the net during lifting on deck and catch discharges into refrigerated tanks.



Figures 5,6,7 and 8. Transfer of fish by the traditional method using brailer - compacted fish flock in the net, filling the brailer, transfer of catch to the deck, release of catch into the cooling tank (photo Jančí T.)

On the deck of the ship, the fish is quickly cooled in tanks with a mixture of chilled seawater and ice. The mixture is prepared immediately before transferring the catch to the deck by mixing sea water cooled to a temperature of -1 to 1 ° C and ice, and after mixing the fish is transferred into the tanks to the final water version: ice: fish ratio of 1: 1: 2. After filling the tank, the contents are thoroughly mixed to facilitate the cooling of the fish and to avoid the formation of layers of different temperatures inside the tank after which the fish is transported to the unloading point and further to the processing plant.

The transport of fish is done, depending on the equipment of the ship and the available manipulative space on deck, in two ways - in isothermal bins or in cassettes. When transported in isothermal crate, the caught fish is transferred from the net directly to isothermal bins with a volume of 700 L in which a mixture of water and ice is prepared, and after mixing, the bins are closed, transported to the unloading point where more ice is added, moved to trucks with refrigerated cargo space and transferred to a processing plant.

Figures 9,10 and 11. Transport of fish in isothermal bins - preparation of a mixture of water and ice, filling and mixing the contents of the crate, transport to the landing place, unloading the catch in the truck (photo Jančí T.)

When transporting fish in cassettes, the fish is transferred from the net to tanks with a volume of 700 - 800 L where it is cooled with a mixture of water and ice and after filling all tanks on deck the fish is transferred into cassettes to release the tanks for the remaining catch from the net. After stacking on deck, the fish cassettes are covered with plastic wrap to protect them from the

effects of the sun and warm air during transport to the landing site. Unloading of fish in cassettes is done manually and when unloading, about 1 kg of ice is added to each cassette. The frozen cassettes are stacked in a truck with refrigerated cargo space and transported to the processing plant.

Figures 12,13,14 and 15. Transport of fish in cassettes - mixing during cooling of fish in tanks, filling of cassettes, transport of cassettes on deck, unloading, icing and stacking in a truck (photo. Jančí T.)

Road transport of the catch is performed by trucks equipped with a cooling device, where the temperature of the cargo space reaches a value of 0 - 1 ° C within approx. 20 minutes from the end of loading. The reception of fish in the facility takes place on the unloading ramps, without

exposing the fish to external conditions. The fish is unloaded in a short time using a forklift, weighed, the fish size and by-catch content are determined and the catch transported in cassettes is stored in a cooling chamber at 0 - 3 ° C while the catch transported in isothermal bins is stored inside the plant until processing.

4. Possibilities of raising the quality of caught fish

Fish is classified as a perishable food and the changes that lead to loss of quality begin to take place immediately from the moment of death. The intensity and rate of quality loss are significantly influenced by all aspects and methods of fish handling during all operations up to processing, including the catch itself (Maeda et al., 2014).

The most important changes in quality during the post mortal period of fish are well known and are the result of microbiological activity, endogenous enzyme activity, and oxidation processes (Huss, 1995). The intensity and speed of these changes depend on a number of factors that affect the proportion of individual substrates and metabolites in fish tissue, the activity of endogenous enzymes, the composition and abundance of microflora and the conditions in which fish are found after catching (Sikorski et al., 1990). Although the described changes cannot be completely eliminated, they can be significantly slowed by proper handling of fish immediately after catch, which means cooling to a temperature as close as possible to the freezing point in the shortest possible time after catch (Shawyer & Pizalli, 2003). Lowering the temperature by 5 ° C results in approximately a twofold reduction in the spoilage rate, i.e., the shelf life of the fish is doubled (Gokoglu & Yerlikaya, 2015). In addition to cooling, it is extremely important to avoid physical damage that causes the release of enzymes from the digestive tract into muscle tissue, the release of enzymes from damaged cells into the surrounding tissue and open the way for microorganisms and oxidation processes to accelerate fish spoilage. All these parameters have been known for many years and in accordance with them, recommendations have been formed

for handling fish after catching and maintaining a cold chain until the moment of consumption or processing.

In addition to the described parameters that primarily start post mortem, factors that act in the ante mortem period, such as the method of catching and the method of loading the catch into the vessel, are also important for preserving the quality of the fish. Studies have shown that during the last phase of fishing, the density of a flock surrounded by a net can be more than 250 kg / m^3 (Tenningen et al., 2012.) and that in these conditions fish are exposed to potentially fatal stressors such as hypoxia, exhaustion and physical injuries from contact with net or residual catch (Marcalo et al., 2019.). The fish mortality rate depends on the conditions within the network and increases with increasing flock density and time spent in the net (Lockwood et al., 1983.; Tenningen et al., 2012.; Marçalo et al., 2010.). The action of these stressors results in physiological changes and loss of homeostasis that have consequences for the quality of meat raised (Poli et al., 2005.; Stien et al., 2005.; Lerfall et al., 2015.) and wild, i.e., caught fish (Rotabakk et al., 2011.; Hattula et al., 1995; Brinkhof et al., 2018.). Due to intense physical activity in fish, there is a reduced supply of oxygen to cells and the transition from aerobic to anaerobic metabolism, which leads to reduced concentrations of ATP within cells, lactate production and proton accumulation (Driedzic et al., 1978.; Robergs et al., 2004.). The state of acidosis with low ATP concentrations leads to faster onset and higher intensity of rigor mortis, which in combination with lower tissue pH and stress affects physical, autolytic and metabolic post-mortal processes (Poli et al., 2005.; Anders et al. , 2020.) and ultimately on quality parameters such as texture (Lerfall et al., 2015.; Skjervold et al., 2001.; Bahuaud et al., 2010.), color (Kiessling et al., 2004.; Erikson & Misimi, 2008.;), the ability to bind water (Marx et al., 1997.; Roth et al., 2005.) and the separation of myotomes within muscle tissue that leads to a rupture in the structure of the fillet - the so-called „Gaping“ (Roth et al., 2005.; Burt et al., 1970.; Robb et al., 2000.).

Following all the above, it can be concluded that for maximum preservation of fish quality, in compliance with standard recommendations for handling fish after catch, it is necessary to pay

attention to the treatment of fish in the final stages of fishing that should be performed in a way that ensures minimal stress for fish, minimal physical damage and performed operations in the shortest possible time in order to avoid the death of fish in the net and the deterioration of quality, both due to physiological changes due to stress and due to the standing of dead fish in relatively high temperature of the water.

In the case of large quantities of catch, the loading of fish on deck by the traditional method using a brailer can take longer than 2 hours, where the fish must be compacted to a high density in order to board as quickly as possible. As a result, there is a high mortality rate of fish in the net and the inevitable loss of quality. In addition, in the case of using large sacks (capacity 100 - 300 kg) there is physical damage due to the crushing of fish inside the brailer. These damages do not have to be immediately visible, but they can have an impact on the final quality of the fish.

5. Description of vessels in the pre-pilot project and their fishing characteristics, cooling systems and usage of ice

In addition to the previous production procedures, the Prizefish project enabled the use of a pre-construction version of the pilot unit of the fish extraction pump as a basis for testing the quality of small pelagic fish caught in the traditional way. In order to assume the piloting of marine suction pumps, which should be installed on the ship, 4 ships were selected under the names ship A, B, C and D.

Ship A

Ship A is the largest and best equipped of the four ships included in this study, with a total hull length of 25 m. The spacious deck allows the placement of 22 isothermal bins in a single row and enough manipulative space for undisturbed work and boarding of fish. The total capacity of the vessel is 55 isothermal carets with a volume of 700 L, which corresponds to a total catch of 16.500 kg. The vessel is equipped with an ice production device, a seawater cooling device, ice and cold

seawater tanks, a first version of a pre-pilot pump for loading fish and a crane for handling isothermal bins.

Figure 16. Deck of ship A with isothermal bins and crane (source: WWF Adria)

Figures 17 and 18. Ship's seawater cooling device and ship's ice and cold seawater tanks (source: WWF Adria)

Although the vessel is equipped with an ice production device (from sea water), a certain amount of ice (from fresh water) is provided by the FC “Omega 3” at each landing of the fish. Ice obtained from the cooperative is loaded into isothermal bins after the catch is unloaded, and this ice is primarily used to cool the fish. In case of higher needs for ice, after the ice obtained from the cooperative has been used, the ice prepared on the vessel is used.

Ship B

Ship B is smaller than ship A, with a total hull length of 18.5 m. The dimensions of the deck allow the placement of 9 isothermal bins in one row, which leaves enough manipulative space for undisturbed work and loading of fish. The total capacity of the vessel is 26 isothermal bins with a volume of 700 L, and in the tanks located below the deck can be placed an additional amount of fish equivalent to the content of 12 bins, which corresponds to a total catch of 11.400 kg. The vessel is equipped with a device for the production of a mixture of ice and sea water on which it is possible to regulate the proportion of ice in the mixture. The device discharges the obtained mixture of ice and sea water in two tanks located under the deck, from where the water (from the mixture) is recirculated through the device, thus increasing the proportion of ice in the mixture. During the loading of the fish, chilled seawater is taken from the described tanks and mixed in isothermal bins with ice obtained from the cooperative. Boarding of fish is done using a brailer. Manipulation of bins is performed using two hydraulic motors located on the saddles.

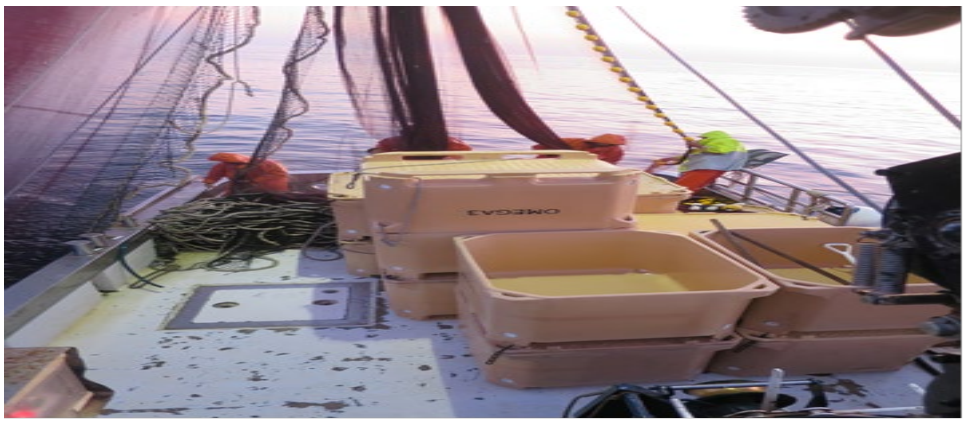


Figure 19. Deck of ship B with isothermal bins and opening of the tank for receiving fish below deck (source: WWF Adria)

Figure 20. Plant for the production of a mixture of cold sea water and ice on board B (source: WWF Adria)

Ships C i D

Fishing boats C and D are completely identical, so the organization of work and the way of handling fish on them is the same. The boats have a total length of 14 m and due to the limited space on the deck and lower carrying capacity, the fish is transported in cassettes. The total capacity of each vessel is 1.400 cassettes, which corresponds to a total catch of 9.800 kg. Cooling of the caught fish is carried out in 6 plastic containers with a volume of 750 L and three isothermal

bins with a volume of 700 L in which ice from the cooperative was delivered. The vessels are equipped with an ice production device with a capacity of 2 t / 24 h and with two tanks located below deck which are used to accommodate catches that cannot be placed in plastic containers with a mixture of ice and sea water. Boat C is equipped with a device for cooling sea water to a temperature of -1 - 1 ° C, while on board D sea water is cooled by placing approximately 1.350 kg of ice in the tank and after estimating the amount of catch, sea water is poured as needed. For the preparation of a mixture of sea water and ice, cooled sea water and ice obtained from the cooperative are used, and if necessary, ice produced on the vessel itself is added. Boarding of fish is done by usage of brailer. Vessels are not equipped with cranes for manipulating isothermal bins.

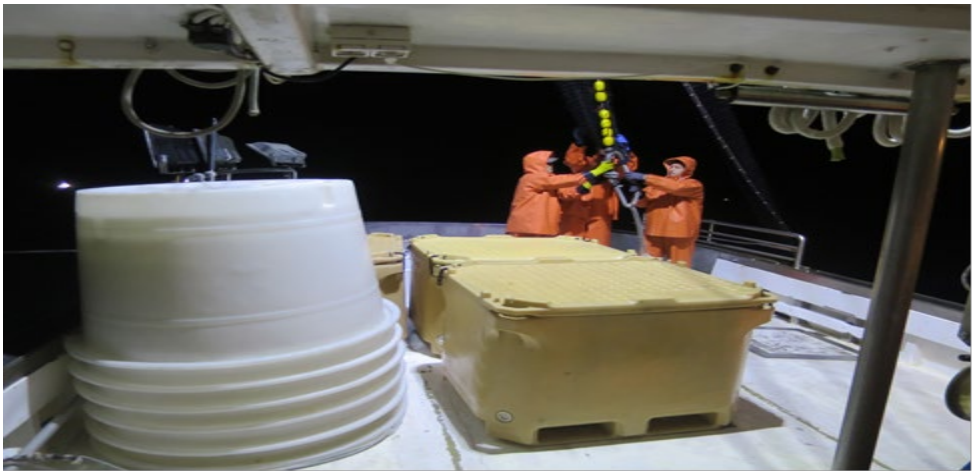


Figure 21. Deck of ship C with vessels and isothermal bins for cooling fish and the opening of the tank for receiving fish below deck (source: WWF Adria)

6. Analysis of operational cooling procedures - maintenance of the cold chain through the use of thermo bins and cassettes - description of the approach

Fish is a perishable food and preserving the quality of fish and fishery products in the distribution chain is crucial for both local and export markets. Cooling is a process of lowering the temperature to the melting ice temperature (0 ° C) which is carried out with the aim of prolonging the shelf life of the fish. Prolongation of durability is achieved by slowing down the activity of enzymes and microorganisms and physical and chemical processes that affect the quality of fish. Since the mechanisms of loss of freshness and quality begin to act from the moment of death, it is extremely important to start cooling immediately after the catch, in an adequate way to achieve a temperature as close as possible to 0 ° C, in the shortest possible time. Although various methods of cooling fish are used on fishing vessels, which include the use of ice, chilled seawater, mixtures of chilled seawater and ice, slurry ice and chilled salt solutions, in Croatia the most commonly used methods are a mixture of seawater and ice with subsequent maintenance of the cold chain by means of ice or by means of a mixture of water and ice.

The oldest method of cooling involves cooling the fish with sufficient amounts of ice, which, taking heat from the fish, melts at 0 ° C, lowering the temperature of the fish. Heat transfer takes place in direct contact of fish with ice and in contact with water formed by melting ice which also takes heat from fish (Gökoglu and Yerlikaya, 2015.). Although ice has a large cooling capacity, this method does not give the best results as rapid cooling requires close contact of the fish with ice over the entire surface which can be achieved by carefully stacking the fish so that each fish is completely covered with ice on all sides. Even in this case, a significant amount of air is retained inside the ice layer, which acts as an insulator and slows down heat transfer, i.e., cooling of the fish. In addition, in the case of catching small pelagic fish, it is not possible to ensure adequate contact between ice and fish, i.e., the proper packaging of a large number of caught individuals.

Due to these shortcomings, in the catch of small pelagic fish today is almost exclusively used the method of cooling using a mixture of sea water and ice, the so-called "Shock". The process begins with the preparation of a mixture of chilled seawater and ice in adequate containers or tanks into which the fish is transferred directly from the net. After the individual tank is filled, the contents are periodically stirred to avoid the appearance of layers of different temperatures inside the tank and to achieve uniform cooling of the fish. Since during cooling the fish is completely in contact with the cooling medium within which there are no spaces filled with air, in a very short period of time a reduction in the temperature of the fish close to 0 ° C and maximum preservation of quality is achieved.

After cooling, it is necessary to maintain a cold chain, i.e., the temperature as close as possible to 0 ° C until the moment of consumption or processing. The most commonly used method is to pack the fish in cassettes with the addition of ice and transport it on the deck of the ship to the unloading point. The chilled fish is grabbed from the cooling tank into cassettes, a certain amount of scaly ice is added, the cassettes are stacked on deck and covered with canvas or foil to protect them from direct sunlight and warm air currents. A newer method that is increasingly used is transport in isothermal bins in a mixture of sea water and ice. In this method, both cooling and transport to the plant are carried out in insulated tanks with a mixture of water and ice in which the fish has been cooled with occasional mixing, after which the tanks are closed and transported for processing.

The main disadvantages of transporting fish in cassettes include the inability to maintain a constant temperature despite the addition of ice since under the influence of the sun and the flow of warm air around the cassettes inevitably increases the temperature of the fish during transport. In addition, packing fish in cassettes requires additional manipulation of the fish, which can lead to physical damage that accelerates spoilage (Moral, 1985.). Physical damage can also occur in direct contact of the fish with sharp pieces of ice or due to crushing due to overfilling of the cassette. In addition, with large catches on a fishing vessel, it is often not possible to add ice

to each cassette during packaging, which can result in a marked increase in temperature during transport and have significant consequences for the quality of the fish.

The method of transporting fish in a mixture of water and ice effectively solves some of the described problems and provides certain advantages over the transport of fish in cassettes (Hansen & Jensen, 1982.; Garcia & Careche, 2002.; Careche et al., 2002.). During the transport of fish in tanks with a mixture of water and ice is much less likely to cause physical damage as this procedure does not require additional manipulation of fish after insertion into the tanks and the fish is transported in a liquid medium that reduces the possibility of physical damage due to crushing or vibration during transport (Garcia & Careche, 2002.; Careche et al., 2002.). In addition, the liquid medium inside the tank acts as a cooling tank and thermostat that prevents temperature fluctuations during fish transport (Gökoglu & Yerlikaya, 2015.). Studies conducted on anchovies and sardines showed that the observed quality parameters such as trimethylamine content (TMA-N), total volatile base nitrogen (TVB-N), microbiological parameters and sensory quality scores were better in fish transported in a mixture of water and ice compared to frozen fish transported in cassettes (Garcia & Careche, 2002.; Careche et al., 2002.). The same research also confirmed better cold chain maintenance in the case of transporting fish in a mixture of water and ice.

Although the transport of fish in isothermal bins with a mixture of water and ice has significant advantages and a favorable impact on quality, it is still used on a smaller number of vessels. The main reasons for this are the fact that this mode of transport requires more manipulative space on deck, reduces the total amount of catches per vessel that can be disposed of in this way, handling equipment and unloading of full bins (using cranes) which requires additional space on board and is an additional investment. Therefore, this system of transport and maintenance of the cold chain is mainly applied to larger vessels in the fishing fleet of the Republic of Croatia.

7. Temperature profile from the moment of catch to processing

The temperature in the center of the samples was measured at intervals of 10 s from the start of cooling (transfer of catch to deck) to the beginning of processing with a thermometer / day logger TC-309 (Dostmann electronic GmbH, Germany) equipped with four measuring probes. The thermometer probes were placed to measure the temperature in the center of the fish and 4 samples were fixed to the support at regular intervals to obtain temperature data at different depths in the isothermal bins and cooling vessels. The samples in which the temperature was measured underwent the same procedure from catch to processing as the rest of the catch.

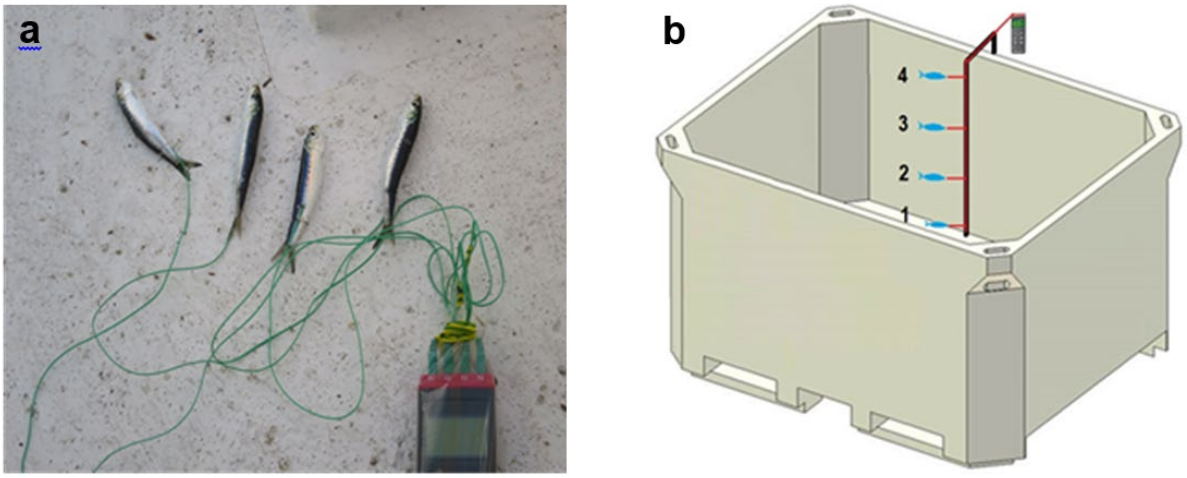


Figure 22. Sardine samples with installed probes for measuring temperature (a) and arrangement of samples inside the isothermal bins (b) (source: WWF Adria)

Influence of time elapsed from death to onset of cooling

In order to examine the influence of the time spent in the sea after death on the quality of the fish, an experiment was conducted during a tour of ships C and D, where an insulated bins of 50 L was placed in approximately 10 kg of live fish was 17.5 ° C during the experiment on board C and 18.5 ° C during the experiment on board D. The fish samples were then taken every 20 min, packed in PVC mesh bags and placed to cool in containers with the rest of the catch to simulate the usual procedure that a fish goes through after boarding. After cooling for 30 min in a mixture

of water and ice, the samples were stored in a travel refrigerator with the addition of ice. Upon arrival at the processing plant, the samples were frozen under the same conditions as the rest of the catch and their quality was assessed after freezing.

Fish quality assessment

The quality of the samples was assessed according to the quality assessment system applied within the FC "Omega 3", which assigns points to the samples in the range of 1 - 10 based on external appearance, i.e., the presence of yellow and red shades (blood) on the gill covers and abdomen after freezing. Samples with a rating in the range 1 - 2 are considered the third category and are used for feeding tunas on tuna farms. Samples with a rating of 3 - 5 are considered the second category, which is primarily intended for processing into canned fish, while samples with a rating of 6 - 10 are considered the first category, i.e., fish with the highest quality. The presence of abdomen damage (belly burst) automatically classifies samples into the third category and such samples are awarded 1 point, regardless of other parameters that are evaluated. The presence of other physical damage is determined by visual inspection.

Temperature profile from the moment of catch to processing

The review of a temperature measurements results from the moment of catch at the beginning of processing showed that cooling with a mixture of sea water and ice effectively lowers the temperature of the fish in the short term. Immediately after placing the fish in the cooling tanks, a sharp drop in the temperature of the samples has been recorded, reaching a temperature in the range of -2 to 2 ° C in vessels A and B in the period of 15 - 17 min from the initial temperature in the range of 17 - 18 ° C and 1.5 - 7.5 ° C for ships C and D. The differences in the achieved cooling temperature are due to the different ratio of water, ice and fish in the cooling tank, which in ships A and B was 1: 1: 2, while on ships C and D were 1: 1: 2.8. Significant differences were observed in the temperature profile during transport and storage until processing, where in the samples from ships A and B (transport in isothermal bins) the sample temperatures were almost constant, ranging from -2 to 2 ° C and gradually approaching 0 ° C. During the transport of fish in

cassettes (ships C and D), a sudden jump in temperature has been recorded after packing the fish in cassettes, which was also contributed by the fact that no ice was added to the cassettes due to the relatively large amount of catch. During transport to the unloading point, with the air temperature in the range of 15 - 18 ° C, the temperature of the samples increased to 7 - 10 ° C (ship C) and 10 - 14 ° C (ship D). With the addition of ice when unloading the cassettes into the truck and transporting them in a refrigerated cargo space, the temperature of the samples decreased to 1 - 2 ° C (ship C) and 2 - 6 ° C (ship D).

The described temperature oscillations can have a significant impact on the fish quality, which has been confirmed by the assessment of the quality of fish in the plant, which was carried out immediately before the start of processing. In vessels A and B, the fish had the highest quality level and was classified in category 1, while in vessels C and D the fish was classified in category 2 although the total time from catch to processing was shorter (about 7 h) than in the case of vessels A and D (about 9 h). Since the temperatures of the sea (17 - 18 ° C) and air (15 - 18 ° C) were almost the same during all 4 experiments, these differences can be attributed to differences in the method of cooling and maintaining the cold chain during transport and storage. It should be noted that the temperatures during the experiments were relatively mild and that during the summer months the sea and air temperatures can be more than 25 ° C, which is why a much greater impact on fish quality can be expected during the summer months.

Influence of time elapsed from death to onset of cooling

An experiment which has been simulated, during which the compacted fish in the net spent more time in the net, affected the quality of the fish. The average fish quality assessment shows a constant decline during the standing of the fish in the sea, immediately from the moment of a catch. During the first 60 minutes, the decline in the average quality score is very slight (average score in the range of 9 - 10), after which there is a faster decrease in the average score, i.e., loss of quality. The limit score (6 points) for the transition to the second quality category was achieved

by the samples at about 140 minutes in the case of ship C and about 170 minutes in the case of ship D. 1 point was awarded and they were automatically classified in category 3. The first abdominal injuries (10 – 20 % of the examined samples) appeared in samples that stood in the sea for a period of 100 - 120 min, after which the number of such samples increased rapidly with further standing in the sea and in the period of 140 - 180 min the share of damaged samples ranges from 40 to 47 % of the examined samples.

As the samples in these experiments were transported separately from the rest of the catch after cooling, in an isolated container with a large amount of ice, larger changes in quality due to manipulation and temperature fluctuations during transport can be expected from samples undergoing the usual transport procedure. In addition to the above, the fact that the samples stood in the sea at a temperature of 17 - 18 ° C during the experiment and that in the summer months due to the higher sea temperature can be expected a significant and much faster loss of quality. From the above, it can be concluded that fast boarding from the net to the vessel is crucial for the quality of the fish in order to minimize the time from catch to cooling the catch.

Physical damage

Although during the assessment of current fish handling practices no physical damage was observed due to inadequate fish handling, i.e., human influence, it can be expected that the method of loading and transporting fish has a certain impact on the possibility of physical damage. The fact that the damage is not visible to the eye does not exclude the possibility of internal damage due to shocks, crushing and vibration during transport, which expose the tissue to enzymes and microorganisms and accelerate the process of quality loss.

The highest probability of such damage occurs during the removal of fish from the net using a brailer, since a full net can hold about 100-300 kg, and even more fish, and the fish at the bottom of the net can be crushed. In the case of loading fish with a pump, there should be less possibility of crushing since live fish is continuously transported in a water stream and there is no possibility of accumulating a large mass of fish in one place.

There is a certain possibility of damage to the fish due to shocks or scraping during the transfer of fish into cassettes and transport in cassettes, since the fish is transported without the presence of water, which can mitigate vibrations and shocks. This is not the case with the transport of fish in isothermal bins, since after placing the fish in bins with a mixture of water and ice and mixing, there is no further manipulation until the moment of processing. In addition, the fish is immersed in water with less ice during transport and the likelihood of damage due to vibration is minimal.

8. Critical points and recommendations in the definition of catch handling

Based on the conducted experiments, critical points in the process from catch to processing were identified that have a significant impact on the quality of the fish. It is generally known that fish must be cooled as soon as possible after catching and the cold chain maintained until the moment of consumption or processing. Although recommendations for proper handling of fish after catch are available in several places, these recommendations are not always easy to implement during fishing due to various factors such as weather conditions, limited working space on vessels, in case of very large catches and similar. Even if the general recommendations on avoiding physical damage, using adequate amounts of ice and respecting the ratio of water, ice and fish during refrigeration and transport are followed, newer technologies offer space for further improvements and improvements in catch quality.

The first identified critical point is the loading of fish from the net into the vessel during which there are significant quality losses if the boarding lasts a long time, i.e., the fish stays in the net for a longer period of time. As previously described, the loss of quality during the standing of the fish in the net is constant, but during the first 60 minutes it is extremely mild, after which it accelerates and can result in significant losses. For this reason, it is recommended that the total catch should be loaded on board and cooled within 60 minutes of the fish being compacted within the net. This is very difficult to achieve in the case when large amounts of catch need to be loaded by the traditional method using a brailer.

The next critical point is the cooling of the catch, which should be carried out in such a way as to enable the fish temperature to reach around 0 ° C as quickly as possible. This is achieved by following the recommendations in terms of using an adequate ratio of chilled seawater, ice and fish, which is 1: 1: 2. Also, during cooling, it is necessary to periodically mix the contents of the cooling tank to avoid the formation of layers of different temperatures inside the tank. The cooling process should be carried out until a satisfactorily low temperature is reached in the center of the fish (0 - 2 ° C).

The last critical point is to maintain the cold chain, i.e., the temperature of the fish as close as possible to the temperature of 0 ° C, from the moment of cooling to the moment of processing. As mentioned earlier, during this step, the method of transporting fish in isothermal bins with a mixture of water and ice showed a great advantage over the traditional way of transporting fish in boxes or cassettes. This method ensures minimal temperature fluctuations during transport and reduces the possibility of physical damage due to manipulation and vibrations and shocks during fish transport.

9. Improving existing operational procedures

Following all the above, it is recommended, in strict compliance with previous recommendations for fish handling, the implementation of newer methods of loading and transporting catches that include the use of loading pumps and isothermal bins for transport on all vessels where conditions allow, since the combination of these methods' adherence to standard recommendations for fish handling, ensures maximum preservation of catch quality. In addition, the implementation of the pumps, the assumed speed and efficiency allow it to act indirectly on the other two critical points as well as the possibility of collecting without excessive compression of the fish which is also a new moment of the assumed operation.

The following priorities are important when fishing and catching:

- Achieve the maximum quality of catch or landed raw fish

- Improve working conditions by eliminating all work that causes physical exertion and fatigue of fishermen, so that workers can work longer and stay healthy
- Improve fish welfare conditions through faster operations

To achieve these goals, it is necessary to introduce the use of equipment and procedures that will eliminate difficult lifting, uncomfortable body positions of workers and rough handling of fish. This speeds up catch processing and reduces the time required to cool the fish (Olsen, 1992.). (Source: (Olsen, KB, K. Whittle, N. Strachan, FA Veenstra, F. Storbeck, and P. van Leeuwen (1993.). Integrated Quality Assurance of Chilled Food Fish at Sea. Technological Laboratory, Technical University, Lyngby, Denmark. 58-60.). It is also necessary to reduce anoxic phenomena in fish and shorten the time of killing.

Pelagic trawlers and purse seiners, catching small pelagic fish, lift the entire catch using cranes to the deck by various methods. The total weight to be lifted can be up to 4 tons in the surrounding net which poses a high risk of cracking of the net, loss of catch, damage to equipment and injury to workers, especially in case of worse weather conditions.

There are several methods to make it easier to transfer the catch to the boat. The simplest is to use a brailer, then there are conveyor belts with partitions or spoons that grab the fish and transfer it from the net to the deck. In addition, dry and wet pumps are used. Wet pumps do much less damage to the fish as they carry a mixture of fish and seawater that protects the fish from shocks.

For this reason, it is desired to pilot the use of pumps that pull the fish into the pipe and transfer it to the deck or tanks. Source: http://www.fao.org/3/V7180E/v7180e08.htm

The pumps used are so-called P / V pumps (pressure / vacuum). The principle of operation consists in creating a vacuum and increasing pressure by means of a pump in an accumulation tank of about 500-1500 liters. The fish is sucked together with the water through the pipe and valve to the tank. When the tank is full, the direction of pumping is changed from vacuum to

pressure and the fish is transferred through another tube to the strainer. P / V pumps do not damage the fish too much, but work relatively slowly due to the change in pumping direction and pressure. This can be avoided by installing two P / V tanks that work alternately and use a common pump.

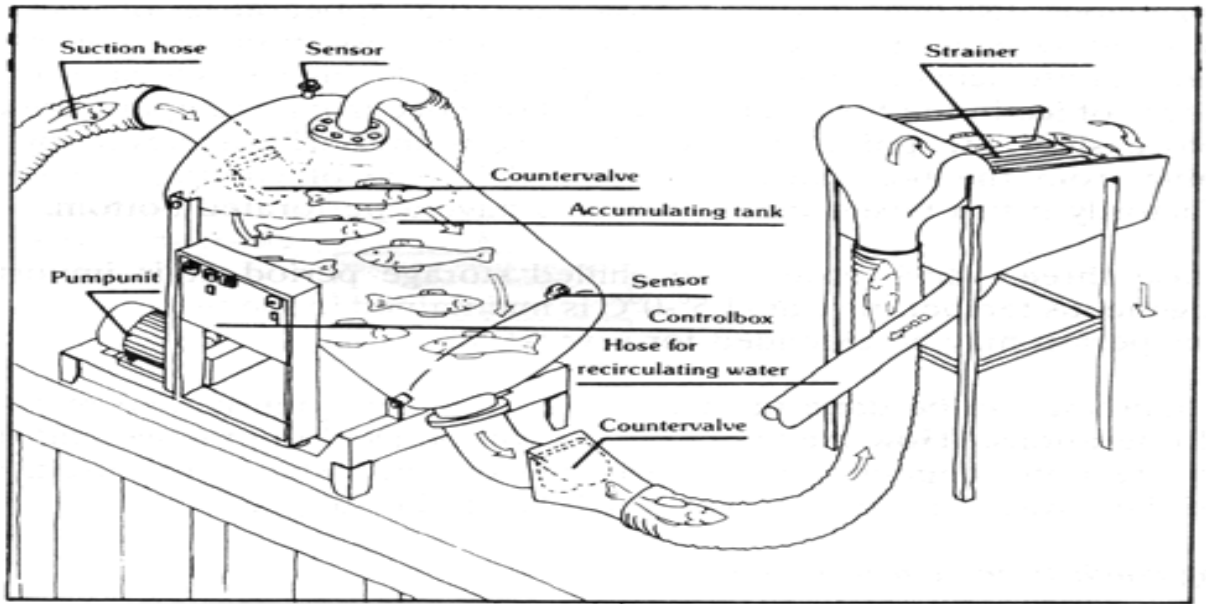


Figure 23. Principle of operation of P / V pump (Source: [http://www.fao.org/3/V7180E/v7180e08.htm)](http://www.fao.org/3/V7180E/v7180e08.htm)

Such pumps, depending on the size of the catch, require large dimensions that are not present in the traditional purse seine fleet.

Figure 24. The space needed for high-dimensional pumps tanks and pipes (Source: Aursand G et all., 2011-SINTEF-Norway)

Such use of pumps in aquaculture has been replaced by inlet pumps with non-return valve, semicircular turbine, vanes and creating vacuum in the pump itself where the need for large tanks is lost and fish go continuously without touching dangerous areas of the pump. Once a fish arrives on deck, it is usually necessary to sort it by size or species. Inclined vibrating gratings, inclined rollers rotating in opposite directions or conveyor belts with V profiles are used for sorting. As these techniques actually sort the fish by thickness rather than length, it is important to properly load and density the fish that comes to the sorting device.

Once the vessel arrives in port it is necessary to unload the catch from the tank. If the tanks are installed below deck, the fish is re-unloaded by pumping. The pump capacity is important in order to make the unloading as short as possible. The fish needs to be mixed with water for the pump to work. In fishing ports, unloading can be arranged so that the fish is pumped directly into the processing plant.

10. Examples for handling new tools and fish maintenance requirements

From the previous practice of developed fishing countries such as Norway, it is known that the quality of fish is given the greatest possible attention, especially in catches.

Today, modern fully automated industrial systems for handling, storing and unloading fish have been developed on large ships. One example is from the Norwegian company SINTEF, which specializes in technological innovation, which we will describe in more detail. (Source: New concept for gentle and effective catch handling and storage of pelagic fish onboard; da G Aursand1, Leif Gjelseth2, Morten Bondø1and John Reidar Mathiassen11 -SINTEF Fisheries and Aquaculture, 2MMC Tendos, Norway.

The innovative SINTEF industrial concept consists of sucking up the catch in such a way that the fish does not pass directly over the pump blades, which would cause damage to the fish and blood stains on the fillets. After suction, the fish and water are separated by a process of vacuum and squeezing, and this water is pumped out again by special systems. The fish comes in cylindrical RSW tanks that have flow and cooling, so cooling of the catch is quick and stable. The tanks have automatic cleaning which makes the job easier for fishermen. The system has automatic fish sampling and weight measurement of individual fish so that it is possible to make an estimate of the weight before landing and prepare for the auction. Upon arrival at the port, unloading is done by creating pressure in the tanks. The pipes do not have additional valves which reduces damage to the fish.

A review of this innovative study concludes that the method of collection on industrial models can also have a significant impact on fish quality. Mechanical damage to the outer and inner tissues of the fish and the consistency and hardness of the meat and fillets were examined. There is a significant difference in the use of individual catch systems. Collections of different models in the reception of fish, the use of separators and the type of pumps were examined.

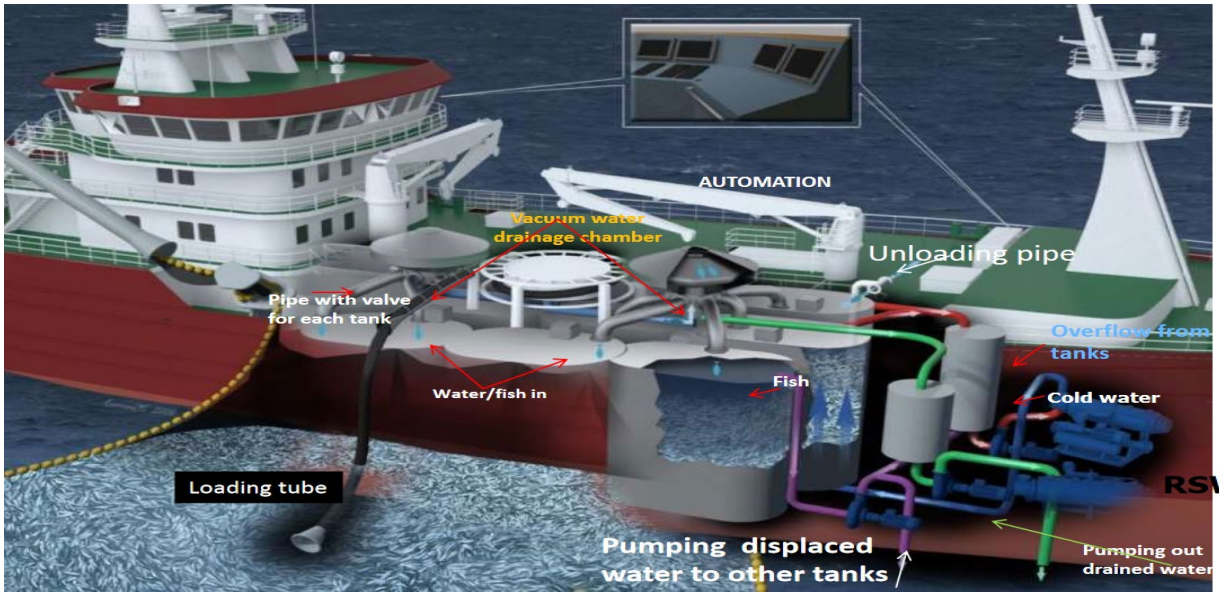


Figure 25. Schematic of an industrial fish pump system on a vessel - (Source: Aursand G et all., 2011.- SINTEF-Norway)

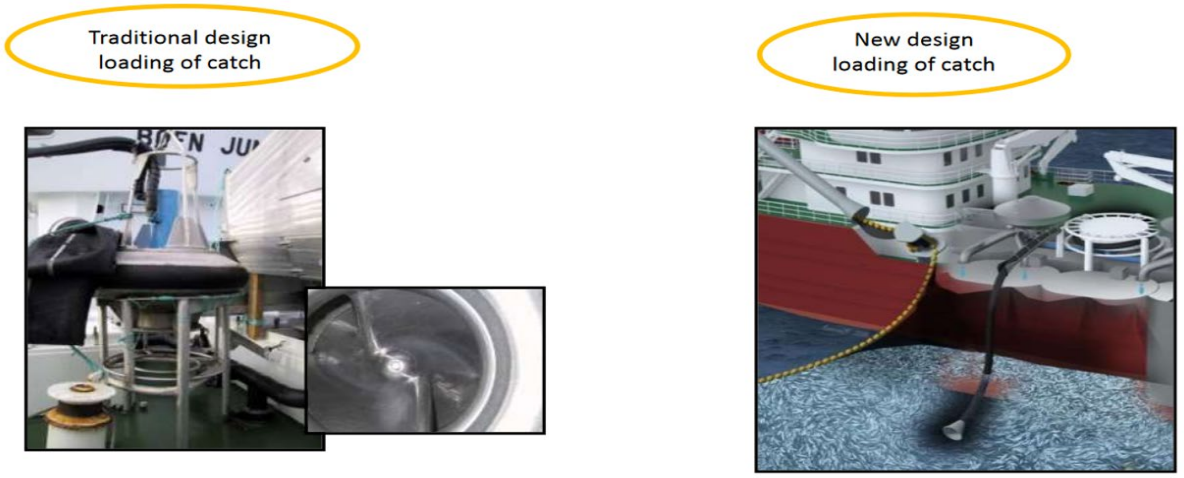


Figure 26. Illustration of the use of older submersible pumps versus the new simpler model of fish suction (Source: Aursand G et all., 2011-Sintef-Norway)

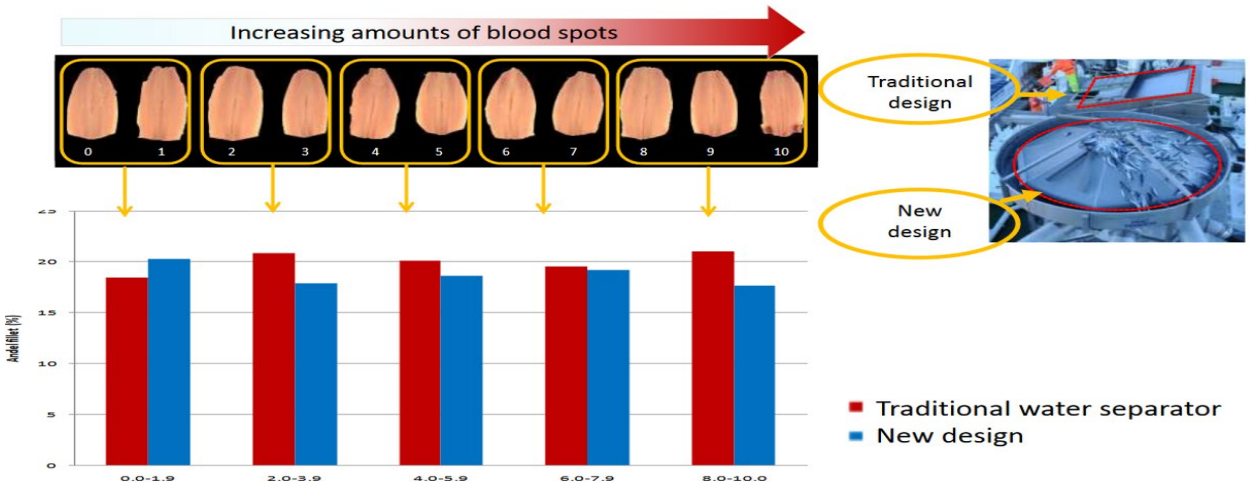


Figure 27. Proportion of fillets of different quality (0 - best, no bloodstains, 10 - bad, large bloodstains) in the catch using old and new technology. (Source: Aursand G et all., 2011-SINTEF-Norway)

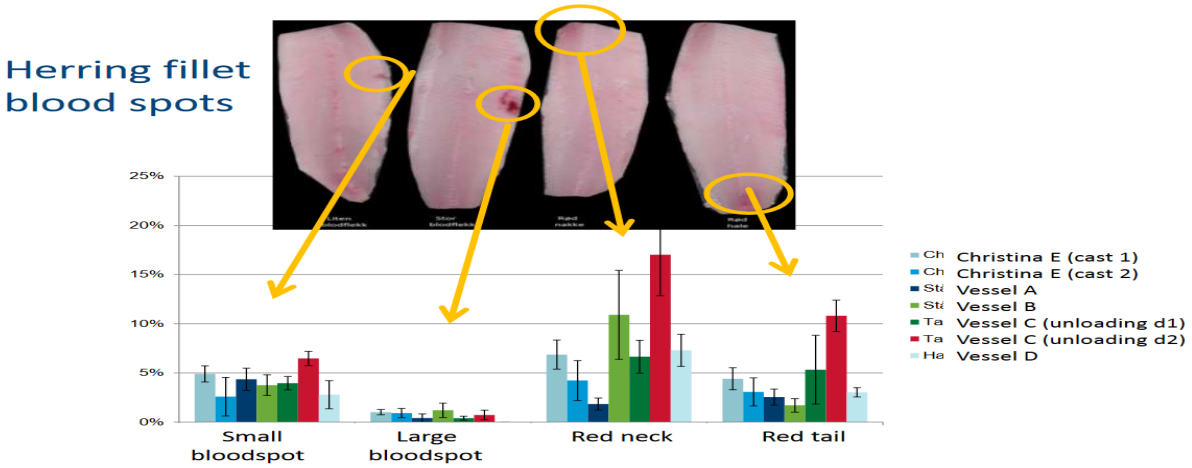


Figure 28. Physical damage caused by the use of different pump systems. (Source: Aursand G et all., 2011-SINTEF-Norway)

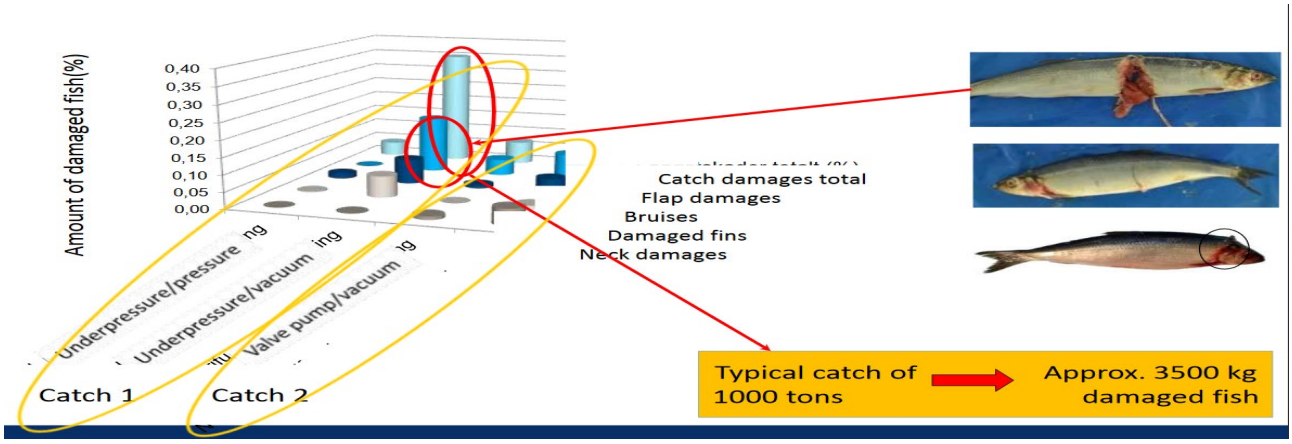


Figure 29. Estimation of the share of damaged catch after landing by the old and new system. (Source: Aursand G et all., 2011-SINTEF-Norway)

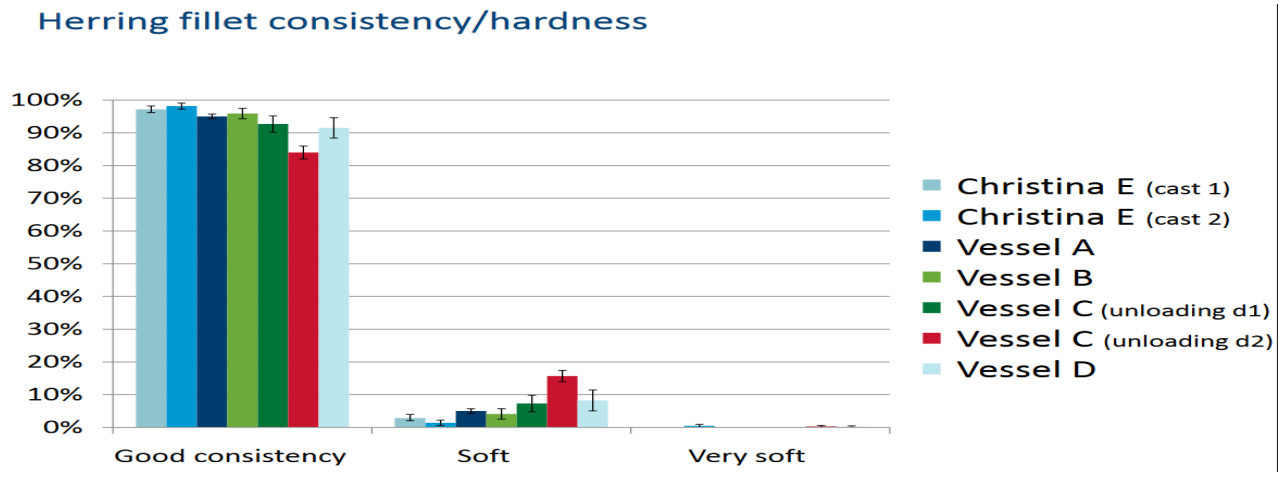


Figure 30. Example of quality control in fillet consistency-strength and comparison of catch handling methods (Source: Aursand G et all., 2011-SINTEF-Norway)

11. Description of the selected production solution

It has been established that operations in the traditional catch of small pelagic fish in our country, but also in industrial fishing, carry risks of damage and decline in quality. The development of fish conservation from catch to farm and to the final consumer of small pelagic fish has had significant strides throughout history. Preservation of fish as well as growth of quality is directly related to the application of modern technical and technological achievements and application on the ship, i.e., the quality of fish can be preserved in the initial phase immediately at the catch. The use of ice in shocking and killing fish in the Republic of Croatia began with anchovies some twenty years ago, so that the use of thermo-bins and shocking in them began approximately five years ago and is not yet applied systematically. The installation and use of hydraulic cranes for lifting catches has also led to the fact that thermo-bins are used more frequently as part of the recent development history of quality improvement, which touches on a total of the last twenty years of gradual application. What is missing in this process is further handling of the catch because it is subject to damage, squeezing and biochemical spoilage processes.

A more significant solution to the problem of damage and efficiency could be solved by the use of fish boarding pumps that allow much higher boarding speeds and shorten the time that fish spend within the net. In addition, according to fishermen's experience, pumping does not require as high a flock density as the method of boarding, reducing the impact of stress, mortality and the possibility of physical damage to the fish. Also, the fish is pumped to the deck in a stream of water, which eliminates the possibility of damage due to crushing and further contributes to the quality of the fish since it is possible to transfer live fish directly from the net to the cooling tanks. The use of pumps is known worldwide, but in large industrial fishing where systems of suction and separation of fish from water are used, which occupy large dimensions and can be implemented only on large vessels and vessels with built-in tanks as fish tanks.

Figure 31. View of the arrangement of thermo insulation tanks and cramped space at the stern of the ship (photo Andrić V.)

The same systems load fish into built-in tanks and the use of pumps is used in industrial fishing, but even with such systems there is partial damage to the fish. Most of the fish caught in this way, intended for conversion into fishmeal as well as processing, should take care to reduce the damage to a minimum.

Given that in fishing for small pelagic fish it is very important to get premium quality in terms of entering the market of fresh and chilled fish, the damage must be minimized. There are several types of systems used on such industrial factory ships however the systems through mainly use of vacuum pumps take up too much space on board and it is not easy to implement them on the Adriatic purse seine Fleet. The Adriatic purse sine fleet requires the possible installation of pumps

of smaller dimensions, portable, easy to install and operate, high suction capabilities and minimal damage to fish that is very sensitive to manipulation. At the same time, it is necessary to arrange an efficient model of the pump and the water discharge unit so that the need for fast cooling of the fish in the thermo-bins is not disturbed. The Adriatic fleet currently does not use fishing pumps precisely because of the larger dimensions as well as the greater damage that occurs on industrial frames or the use of known industrial solutions.

Figure 32. View of the arrangement of thermo bins and aft part for stacking the purse sine net (photo Andrić V.)

Therefore, by studying the fishing industry in the world as well as by studying the possibilities of implementation, it was decided to make innovative solutions through the use of existing solutions from the aquaculture industry. Namely, the aquaculture industry has been developing pumps for years, which transfer live fish from the minimum size of a few grams to several kilograms of individual weight. This switching system knows the transfer of live fish from one pool to another as well as selection, but always in the presence of water.

In our case, it is necessary to adapt the system so that it can be placed on a ship that has movement, and it is necessary to make suctions of suction and discharge of water before entering the thermo-bins. Such an assumption has become a hypothesis in terms of making a complete unit.

12. Possibility of implementation in the current production process

By studying the capacity and capabilities of existing pumps on the market, the primary goal was to avoid double vacuum systems that require more units and are very difficult to implement on existing dimensions of test purse seine vessels because they take up a lot of space and must be fixed. It is necessary to have small portable units so that the decision was on the selection of aquaculture pumps and their adaptation to use in sucking small pelagic fish. The newer units we come across in aquaculture are units that are simple and have significantly smaller dimensions than existing vacuum units.

Figure 33. Pump of smaller dimensions for transfer of live fish in aquaculture (Source: Faivre web)

Classic equipment on board, which in addition to the usual engine rooms has classic winches and a significant part of fishing equipment and bin takes up considerable space, so there is a need to use a pump on deck where a pipe from a fish net with water would be dragged to the pump at least one and several meters and ascended to a water separation unit that would be located on the ship's cabin.

Figure 34. Overview of equipment when going fishing (photo Andrić V.)

In this way the space would be significantly reduced, at the same time it should be ensured that the thrust from the pump to the water separation unit is sufficient to overcome a difference of at least three or more meters where then the fish comes to the water separation plateau and later returns to bins. The whole system requires a more significant level of combinations to obtain

a unique implementation solution on multiple ship types. By reviewing the dimensions as well as making technical sketches and experimental units, it was determined that it is possible to assemble a system that will not interfere with most operational processes and passages and that it will be effective.

Figure 35. Stern equipment inspection and winch control (photo Andrić V.)

Implementing the imagined testing involves finding a company that is reputable in the production and implementation of fish transfer systems in aquaculture as well as that is willing to participate in a pilot study of the possibility of using pumps to catch small pelagic fish. There is a need to devise a system with a common approach that would provide a complete and functional framework for pumping fish out of the net using already known solutions in aquaculture. Examining the possibilities that the company would be interested in, the French

company Faivre was approached and expressed its readiness to follow this project and make resources available for the pilot project.

Faivre is known as a company that brings innovation. The founder of the company in 1950- Claude Faivre was a miller and fish farmer. Making mechanization of mills, he decided to make machines in aquaculture to make it easier for fish farmers to do the work on the farms. Thus, he created the first automatic calibrator for trout "Calibromatic". Inspired by the mill, he had the idea to transfer fish in tubes and so they started and opened the basis of mechanized fish farming. Since 1958, the story has continued through a series of innovative solutions for the transfer and selection of fish, elevators and pumps, meters, aerators and mechanical filters for wastewater treatment, among other things. It was this company that pioneered the aquaculture industry that agreed to invest its resources free of charge to create a pilot testing project.

Figure 36. Pump when transferring live fish in aquaculture (Source: Faivre web)

A short presentation of the company can be found at the following link;

https://www.youtube.com/watch?time_continue=102&v=YU5tfzAgWuY&feature=emb_logo

With a range of high-quality innovative machines for aquaculture professionals, today FAIVRE is the first French manufacturer of aquaculture equipment in France and continues to be the world's leading manufacturer, generating a significant share of its revenue in exports.

By choosing the manufacturer of the equipment, it is necessary to choose the boat, i.e., the owner and captain of the boat who achieves the best results in traditional fishing in order for testing to make sense and to see the possibility of applying new operational procedures to the best operational ship.

In agreement with the manager of the FC “Omega 3” Mr. Šime Kosor, in terms of setting the experiment to the level of plausibility of the experiment, and looking for superior experience in catching the Adriatic and other seas, recognizable size and quality of catch, knowledge of fishing issues, desire for innovation, we addressed the captain of the fishing boat Galo-Damir Mišlov who gladly accepted the preparation and implementation of a pilot project within its vessel.

Figure 37. Fishing boat Galo in Batalaža-Kali marine (photo Lovrinov M.)

On this occasion, it is important to express our gratitude to all participants who, based on the recognized innovative ideas, showed the desire to actively participate in the implementation of the pilot project by engaging a large part of their own resources.

Figure 38. FC "Omega 3" truck ready to load the fish (photo Andrić V.)

13. Technical schemes for the implementation of the pilot project

Through this chapter we will provide the basic technical schemes that were used and modified for assembly before the research categories of mechanical components that are planned to be installed on the ship taking into account dimensions, positioning, height differences for pumping and assumed pumping efficiency. Given the completely new experiences in this segment of all participants, two options were considered regarding the suction power and the required speed

of fish extraction, so that in the primary development, two pump options of 5.5 and 11 kW were considered, respectively larger or smaller pump. Due to the possible evaluation and the speed of pumping and lifting, a lower variant of the Pescamotion 6 pump was selected for pilot testing. Inlet size 150 mm.

Technical documentation of equipment to be adapted to the pilot project

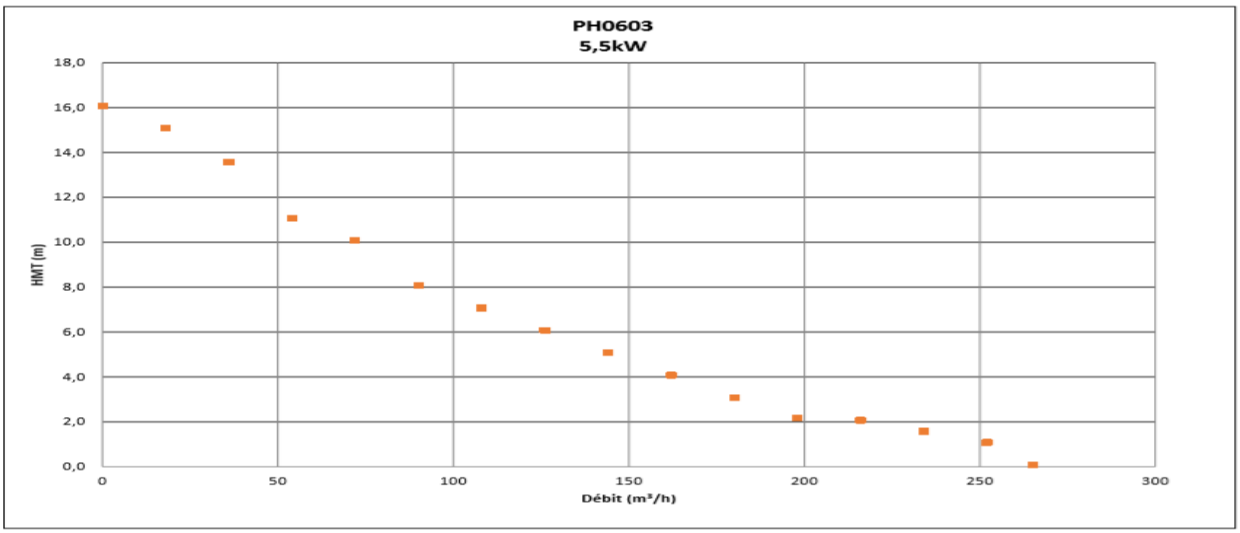


Figure 39. Display of the power of the Pescamotion 6 pump (Source: Faivre documentation)

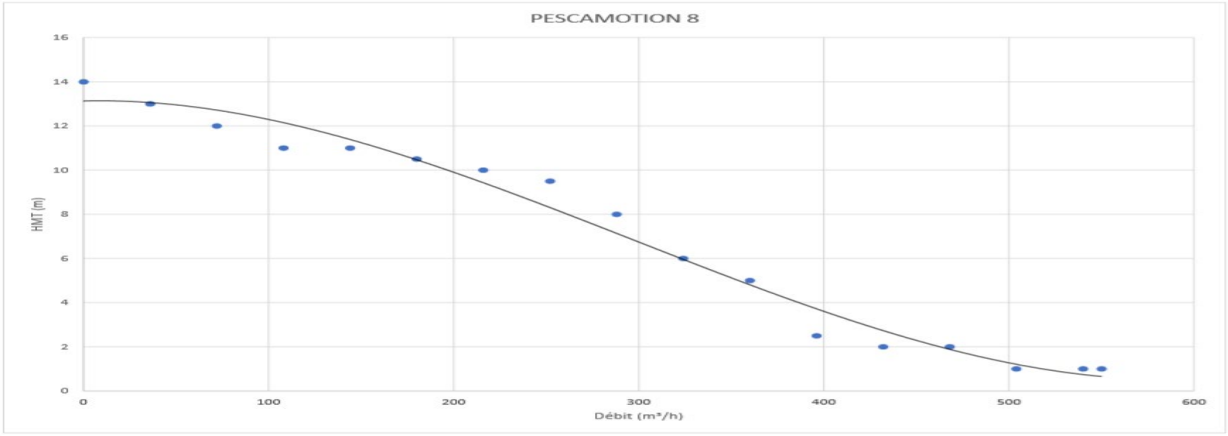


Figure 40. Display of the power of the Pescamotion 8 pump (Source: Faivre documentation)

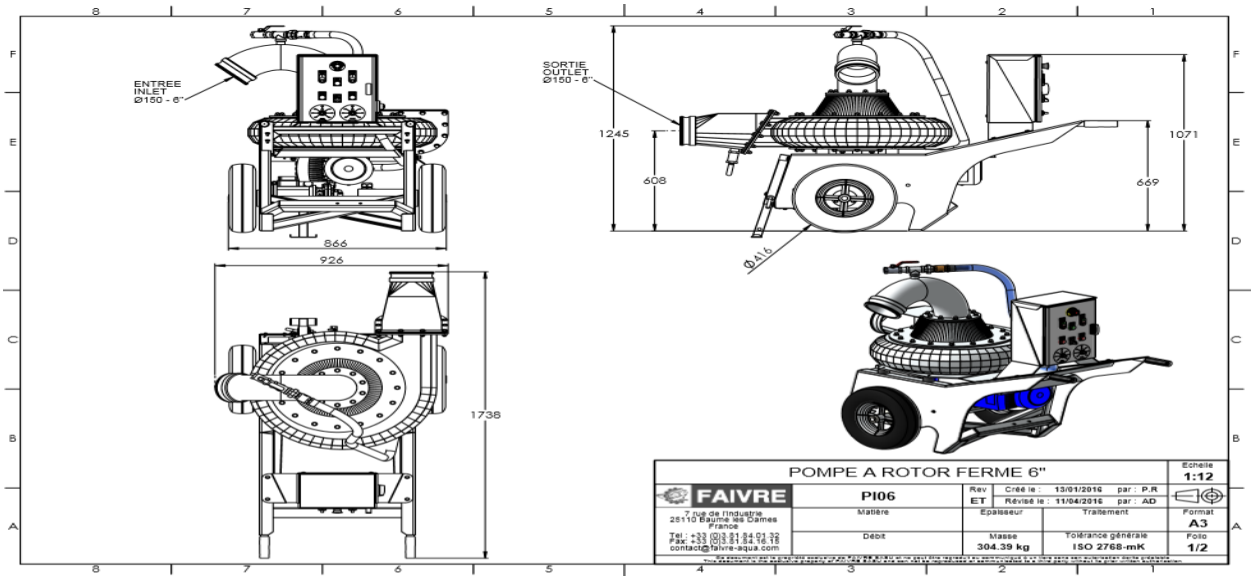


Figure 41. 6 inch pump size - 150 mm Pescamotion 6 (Source: Faivre documentation)

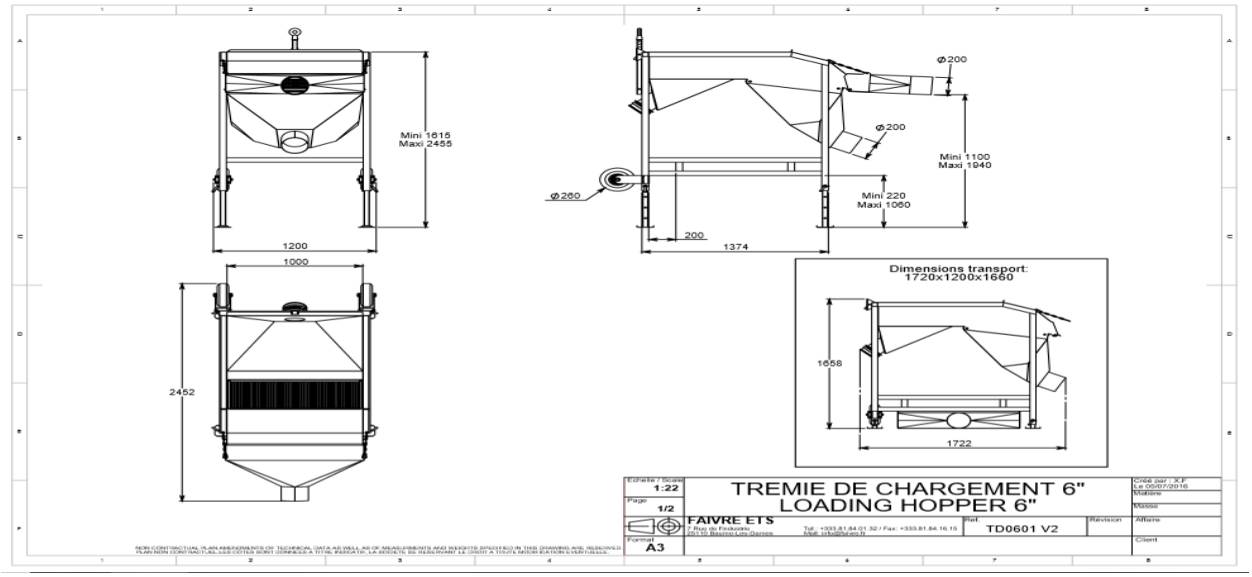


Figure 42. Water discharge unit (Source: Faivre documentation)

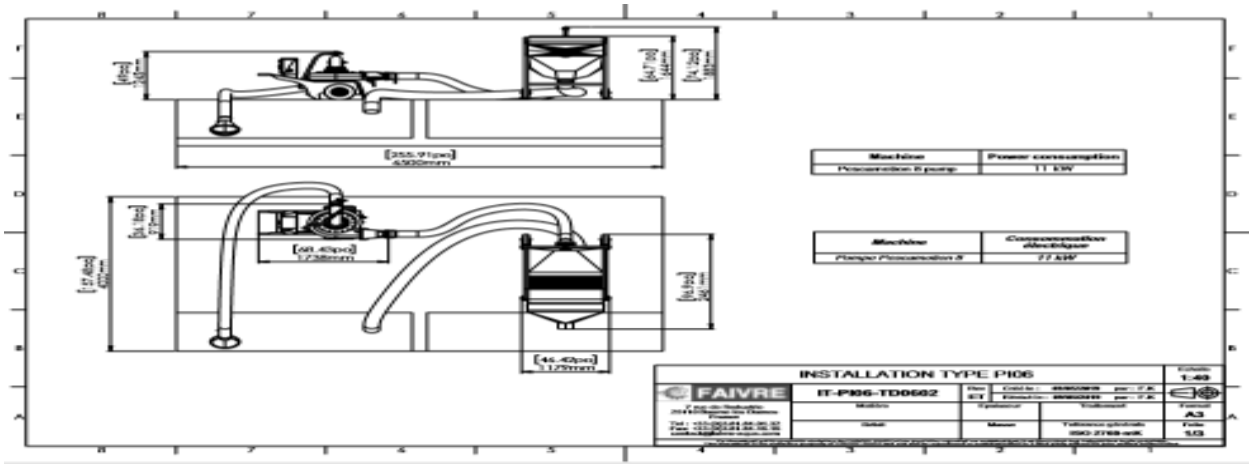


Figure 43. Overview of connections for which it is necessary to report height differences (Source: Faivre documentation)

Selected fishing system equipment such as pump, drain unit, pipes and fittings will be delivered from Faivre and taken on board the Galo and research into best assembly practices as well as monitoring efficiency in catch speed and fish quality. Analyzes will be performed on site and at the reference institution.

14. Processing part

Among the possible innovative processing technologies, 3 solutions have been identified as promising for developing eco-friendly innovative fish products.

- **Modified atmosphere packaging (MAP) with novel gas mixture (e.g., argon, nitrous oxide).**

Modified atmosphere packaging (MAP), along with refrigeration, has become increasingly popular preservation techniques, which have brought major changes in storage, distribution, and marketing of raw and processed products to meet consumer demands. MAP extends shelf-life of most fishery products by inhibiting bacterial growth and oxidative reactions. MAP effectiveness in extending fish product quality/shelf-life depends on species, fat content, initial microbial load, gas mixture, the gas/product ratio and the storage temperature. A wide range of atmospheres

has been examined for use with fish. However, the reported increases in shelf-life for fish and fish products vary markedly and are small in comparison with those reported for several other products. The correct combination of gasses in the package headspace has proven to be able to protect fatty blue fish like mackerel, horse mackerel and sardine products from oxidation phenomena, increasing their shelf-life.

Generally, MAP for fish products is obtained by partial or total removal of oxygen and increased CO2 concentration, allowing it to inhibit lipid oxidation and microbial growth. Beside the traditional gasses used for MAP (O2, CO2 and N2), novel gasses such as Argon (Ar) and nitrous oxide (N2O) have been approved for food use in the EU.

Ar is an inert gas that was shown to have some biological effects, attributed to its physical properties, in particular its enhanced solubility in water compared to nitrogen and the ability to interfere with enzymatic oxygen receptor sites. According to previous studies, the use of Ar allowed to improve the overall acceptability of packaged meat products through the reduction of CO2 levels in addition to the benefits of reduced O2 level. Ar has been tested for MAP of fish products only on rainbow trout and herring fillets. However, contrasting results have been found regarding the increase of shelf-life related to this gas.

Nitrous oxide (N_2O) has been found to have effect on inhibition of respiration and senescence in higher plants showing high potentiality for the packaging of fresh-cut fruits. However, N_2O has never been tested for the packaging of fish products.

From a technical point of view, the use of a quaternary gas mixer mod. KM100-4 (Witt-100 Gasetechnik, Witten, Germany) (Fig. 1) combined to a gas-flushing welding machine mod. Multiple 315 (Orved Srl, Venezia, Italy) allow to obtain different combinations of selected gasses. The use of Ar and N_2O is related to the replacement of N_2 as filler gas in the package headspace.

Figure 44. Quaternary gas mixer mod. KM100-4 (Witt-100 Gasetechnik, Witten, Germany), Source: Web

Before packaging, fish are headed, gutted and filleted, then placed in polypropylene (PP) trays. For sealing, a high barrier PP film that inhibits gas exchange with the external environment is needed.

After packaging, packed products are stored at refrigeration temperatures.

The demo company Economia del Mare di Casali Roberto (Cesenatico, FC, Italy) has been selected for performing all the fish preparation activities (heading, gutting and filleting) and the MAP.

II. Fisherman's Cooperative Istria

Executive summary – FC Istra

In addition to the basic activity of buying and selling fish for its cooperatives, Fishery cooperative Istra bases its future development on starting the process of innovative processing channels, managing seasonal market surpluses in the period of unfavorable market price and confectioning products that represent a higher degree of added value in fish processing. and relate to the production of semi-finished and ready meals and partial preparation. Through previous analyses, such new products have not yet been determined and it is necessary to make intensified efforts to identify and achieve them with higher cost-effectiveness.

Today, the cooperative, in addition to the classic processing mainly based on cleaning fish and other marine organisms, is trying to make production technological steps to be competitive in production for the placement of new products. The initial lower price of raw materials burdened by the high cost of manual cleaning as well as the lack of labor due to the needs in tourism indicates that the need to work on the production characteristics of machines and the use of machines and automation in primary fish processing.

In conceiving the content of future production, the starting point is the following assumptions:

- Develop new innovative production based on existing lines and innovative application of machinery, in order to make better use of seasonal fish and other marine organisms from their own catch, purchase and restructuring of current business as an example of possible diversification and dissemination to other fishing segments.
- Studying product preservation and concept for market

After possible implementation in the factory to produce separate meat pulp, future steps for piloting will be to develop a Product Ready-to-eat (and ready-to-cook) burger with enhanced shelf-life and quality. This activity is more complex from a logistic point of view. The use of machinery will be done in Croatia and Italy and burger preparation in Italy. After shaping and preparation with packaging the packed burgers have to be moved to HPP treatment and the shelf-life study.

1. Introduction

Fisherman's Cooperative Istria was founded in 2004. During a difficult situation in the fisheries sector, mostly due to the high price of fuel and low purchase prices for fishermen, with the question of permanent sales activities on the market, which led fishermen to the first associations. More than 15 years have passed since then and there is still a need to fill organizational and market segments in terms of higher profitability for the fishermen, and thus reduced pressure on resources.

The Fishermen's Cooperative operates as a functional unit, and in terms of fish trade of its members, it presents itself as a respectable business entity in the local and regional fish market. However, production volumes vary from year to year, especially due to smaller and sometimes larger seasonal catches. The cooperative goal is to achieve added value on fishery products by processing seasonal high catches in its own processing plant.

In addition to the basic activity of buying and selling fish for its cooperatives, FC Istria bases its future development by starting innovative processing channels, managing market surpluses in the period of unfavorable market price and confectioning products that represent a higher degree of added value in fish processing, related to the production of semi-finished and ready to cook meals and partial preparation. Through previous analyzes, such new products have not yet been determined and it is necessary to make intensified efforts to identify and achieve them with higher cost-effectiveness.

Today, in addition to the classic processing mainly based on processing the sea products for consumption, the cooperative is trying to make technological strides in order to be competitive in production for new products. The initial lower price of raw materials burdened by high prices of manual processing and lack of labor due to tourism needs, indicates the need to work on production, characteristics of machines, i.e., application of machines and automation in primary fish processing.

Creating the content of future production processes, the starting point are the following assumptions:

-Develop new innovative production based on existing lines and innovative application of machines, in order to make better use of seasonal fish and other marine organisms from their own catch, purchase and restructuring of current business as an example of possible diversification and dissemination to other fishing segments.

-Develop an innovative product and method of preservation through project working package 5

2. A brief summary of the market and production from previous analysis

As explained, the project activities rely on the current situation in the purchase and marketing of marine fish and other marine organisms. In order to be able to organize future operational activities, with emphasis on market competition and increased revenues, as well as disposal of possible market surpluses, it is necessary to upgrade technological operations or upgrade the use of machines that needs to be considered. Open thinking about possible applications of innovative machines and applications to new species and development of new innovative processing technology is very welcomed.

It is planned to design a new range of products based mostly on its own catch and partially by the purchase from other distributors, which offers a complete range of semi-processed and processed products ready to serve in restaurants and hotels as well as the possibility of sale in wholesale chains. Modern lifestyle, extended working hours and the consequent lack of time to prepare fish brings this category to the very top of suitable products for quick preparation.

As can be seen from the above, the project should introduce a range of new products combined to meet demand when looking for a complete fish meal that will not spend time preparing, and will retain all the properties of originality and high-quality seasonal catches.

The total EU market for fishery products is over 12 million tons, or about 10 % of world consumption of fishery products. The five largest consumption markets in the EU are Spain,

France, Italy, Germany and the United Kingdom, accounting for more than 70% of total EU consumption. The average consumption per capita is 24 kg. The largest consumers are generally the Mediterranean and Scandinavian countries.

Central and Eastern European countries do not have a strong tradition of consuming fishery products. Most of these countries are surrounded by land and lack a significant marine product sector, recording the increased consumption of freshwater species. However, in these countries there is an increase in the consumption of sea fisheries products with the expansion of the market as well including increase in personal income - especially recognizable forms of products, rather than traditional imported species in not processed form for which no preparation is known.

Predictions are that the total consumer volume will grow modestly, but prices and consumption of new types of products such as burgers, chopsticks, dumplings, other ready to cook meals, delivering of high-value added products for quick and easy preparation for a wider consumer profile are expected to grow.

Consumption of crustaceans and mollusks is expected to grow as well. Markets in the new EU member states such as Romania and Bulgaria, along with Latvia and Slovenia, show the highest growth rates in consumption. High growth rates are also present in Austria. Their growth values are above the EU average. Germany, Portugal and Slovakia also show good growth rates, while the markets of Poland, Ireland and the Netherlands are growing below the EU average.

Although these countries have a weak tradition of consuming fishery products and are at the lowest level of consumption, they are partly an interesting development market.

In the long run, consumption of fishery products in the EU recorded good trends. Consumers have an increased interest in special products, culinary delicacies, luxury products, value-added ones, fish fillets and fishery products related to sustainable development and as one of the more important categories those fish products for quick and easy preparation.

With its reflections, the Fishermen's Cooperative Istria wants to offer a range of products ready to be served in restaurants and hotels, as well as the possibility of selling in wholesale chains.
It is planned to define all important determinants of launching a range of new products combined to meet demand when implementing a pilot of this scenario, when a complete fish meal is required, which will not take time to prepare, and will retain all elements of originality and high quality.

Opportunities

- Consumption in the EU has showed growing trends, especially in the new members
- Consumption in the new Member States is growing strongly, the market is growing, and at the same time the net wages are recording growth as well
- Growing demand for added value, luxury and special fishery products
- Acceptance of new fish species as a substitute for traditional species
- Fishery products have a positive health image and coincide with the health trend in almost all EU member states
- Consumer demand for sustainable catch and aquaculture products is growing
- Selected species (shrimp, mussels and mullets) can be a good raw material base for penetrating new markets
- The EU relies heavily on imports of fishery products to meet required market demand. This change is structural because production in the EU is declining and consumption is rising.
- Imports from third countries are increasing
- New tropical species are becoming increasingly popular and can replace increasingly endangered traditional species and introduce a balance in supply - the ability to procure additional quantities of raw materials
- Demands for crustaceans and mollusks will remain strong especially in southern European countries

- Demands for value-added products from third countries will increase, especially as they are very competitive in price compared to EU products
- Competition between suppliers from third countries will intensify as they raise their production
- Growing demand for food safety and traceability will impose more rules and regulations on exporters from third countries.

Red shrimp, mullet and musky octopus are defined as seasonal and very interesting products for further processing.

Production begins with the primary processing required for the production of the final product and refers to the following basic technological units and steps in the primary processing and partial processing;

1. Evisceration and filleting of white fish - mullet

- cleaning and processing of fish to fillets - **manually and mechanically**
- fillet finishing
- **disposal of fish remains after filleting**
- basis for further production

2. Cleaning, washing, cooking and cutting cephalopods

- cleaning and cutting cephalopods
- cooking cephalopods
- cutting cephalopods
- basis for further production

3. Extraction of meat from crab shell

- **Separation of meat manually or by machines**
- basis for further production

4. Line processing into final ready main dishes and appetizers

5. **Fish Burger making line, dumplings**

6. Freeze-thaw

In the course of production or operational procedures, segments that are not in use today are especially marked in the FC Istria, and the emphasis will be placed on the development of innovative solutions and applications.

3. Special framework of FC Istra - definition and preparation of species for piloting

The basis for the project and piloting is the definition of species and it consists of species with a high seasonal concentration of catches and thus the distribution of products in larger quantities with consequently low prices. The main target species are *Parapenaeus longirostris, Elodone Moschata*, species from the family *Mugilidae*.

The basis of the projection is an increase in revenue and profit through the utilization and added value of seasonal species.

Products for the target category:

Production of burger and dumplings (shrimp, musky octopus, mixed mullet fillets and meat after deboning) using complementary machines for other products. This is about adopting innovations because the machines are not recognized by the availability of new products in processing. HPP (High pressure preservation) will be tested on the manufactured product to see the durability and consistency of the product.

Designed product for HORECA, retail and alternative market -

Background of such initiative

Quality and price management of seasonal market surpluses and alleviation of pressure on resources through higher profitability and employment. Shrimp are generally one of the world's most famous species, and there is a growing consumer demand for them. It is considered a luxury product.

(tonnes)	Imports	Exports	Apparent market
FRANCE	77.158	6.445	70.713
SPAIN	66.157	15.726	50.431
ITALY	28615	424	28.191
UNITED KINGDOM	27.127	1.304	25.824
GERMANY	25.937	7.687	18.250
NETHERLANDS	30.422	20.686	9.737
PORTUGAL	9.718	1.459	8.259
BELGIUM	25.612	18.188	7.425

Table 1. Apparent market for frozen Penaeus species by Member State in 2015. (tons) - COMEXT source

The EU provided less than 1 % of global shrimp catches in 2017., excluding cold-water shrimp. The catch consists mainly of deep red shrimp (*Parapenaeus longirostris*) with 57 % of catches in the EU. Other important species are *Aristaeomorpha foliacea, Penaeus kerathurus* and *Aristeus antennatus*. The main producers from the EU are Italy, Spain and Greece (Source EUMOFA-species report). Most shrimp imported into the EU are from farming, and the value of the domestic product is falling.

	2012	2013	2014	2015	2016	2017	2018	Source
Deep-water rose shrimp	6,41	5,29	5,36	4,98	4,42	3,92	3,97	EUMOFA

Table 2 - Negative price trends for Parapenaeus longirostris - first sales prices - Italy for the whole product (EUMOFA source)

	2013	2014	2015	2016	2017	2018	Source
France	12,5	13,5	13,1	13,9	14,6	14,1	FranceAgriMer

Table 3. Positive price trends for Parapenaeus longirostris - retail / consumption) Cooked-chilled) prices-France for the prepared value-added product (source EUMOFA)

Apparent per capita consumption in 2017. of various shrimps: 0.71 kg live weight equivalent and deep-water red shrimp: 0.05 kg and hot water shrimp: 0.68 kg live weight equivalent (source: EUMOFA)

Market segmentation - There are different types of segments in the cooked shrimp market, based on:

• size category;

• presentation and preservation;

• certification

Segmentation by size

can be found in retail in a wide range of sizes, set in the number of shrimps in 1 kg:

• whole: 10-20; 20-30; 50-60; 60-70; 60-80; 70-80; 80-100; 100-120; 120-150;

• head (yield 65%), peeled (yield 80-85%): 31-35, 36-40, 41-50, 51-60, 61-70, 71-90, 91-110.

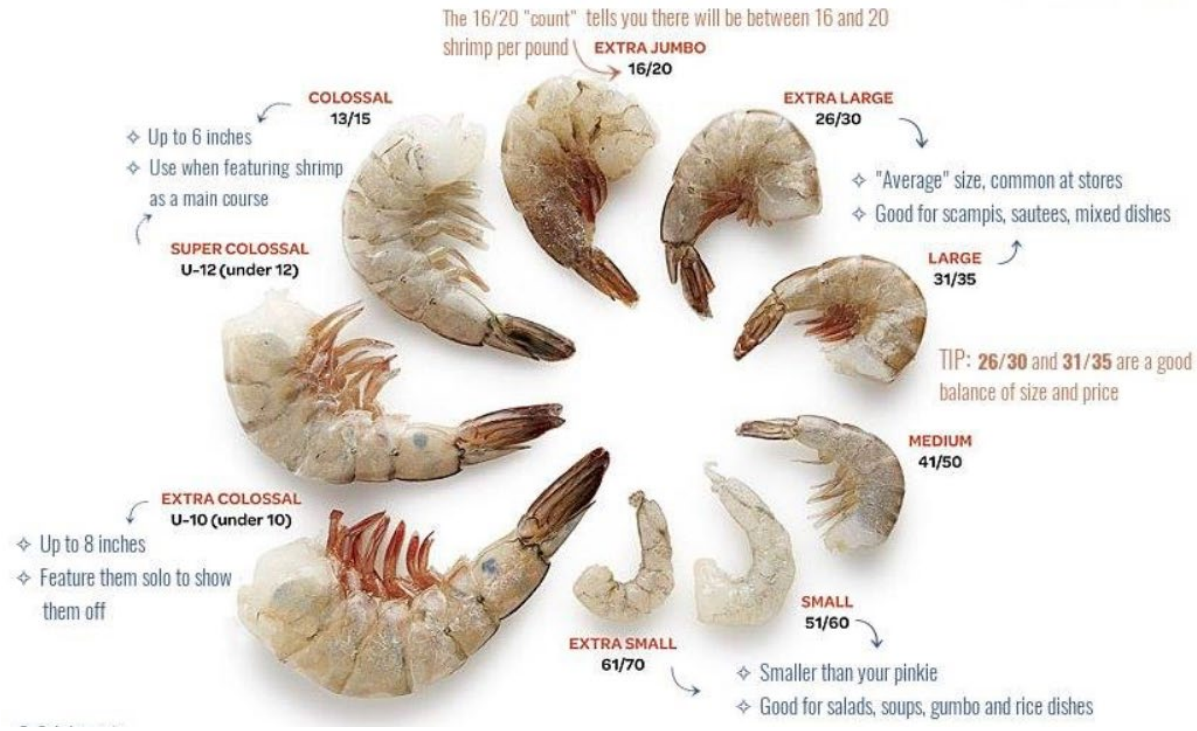


Figure 1. Distribution of shrimp size in the United States (https://www.finecooking.com/article/with-shrimp-size-matters)

Segmentation by presentation/preservation

The French shrimp market (the main market in Europe for shrimp species) is segmented according to the presentation and preservation of:

• Cooked and chilled / frozen - Most shrimps are placed on the market cooked and chilled. According to experts from the cooking industry, in 2015., on all shrimp products, 50.000 to 60.000 (70 %) tons were placed cooked and chilled, and 25.000 to 30.000 tons (30 %) were placed on the frozen market.

• Wholesale / packed in large cartons-Despite a slight decrease in the last 3 years, bulk products are the main presentation for cooked and chilled shrimp.

• Whole / decapitated / peeled / prepared- Most tropical shrimp are still sold as whole, but new consumption habits and demand for food products that are affordable to prepare and consume,

as well as new value-added processing strategies (often diverted to developing countries), began to change the retail offer with new innovative packaging.

Purchased cooked and chilled shrimp, as well as marinated shrimp products, purchased in the last few years are increasing.

Segmentation according to certification

EUMOFA reports/chapter: - "The shrimp sector, especially in Asia, has received negative comments from the European media in recent years. Aquaculture has been criticized for its negative impact on communities and the environment, such as illegal child labor and pollution of groundwater and agricultural land. In this context, consumer awareness of the potential negative social and environmental impact of shrimp farming is also increasing. European buyers are therefore looking for shrimp suppliers who can demonstrate sustainability and responsibility in the production of the product they market. Although organic and fair-trade markets are built on the basis of certification requirements, in recent years sustainability certificates have become commonplace in the European market as well.

This is especially visible in large supermarket chains in northern and western Europe. Currently, Global G.A.P certifications are often required. and (ASC) for aquaculture. Such certifications represent a response to the trend of increasing attention to food security, sustainability and responsible supply. In recent years, the production of organic and eco-shrimp has started in all major production regions (Madagascar, Vietnam, Honduras, Ecuador, etc.). The first example is the Penaeus monodon from Madagascar, the first framework of the Label Rouge certificate as well as the certificates for organic shrimp.

Other target species are musky octopus and mullets. These species have not reached the standards other than the local ones and it is necessary to start working on them and define the standards.

4. Description and composition of basic raw materials - shrimp, musky octopus, mullet fillets

4.1. Red shrimp (Parapenaeus longirostris)

The Adriatic red shrimp is a demersal species from the crab family. It inhabits the entire Mediterranean on a sandy and muddy bottom at depths of 20 to 500 meters. It is grayish pink in color and grows up to 130 mm in length. In commercial fishing, it is fished with a deep trawl, mainly in the waters of the central and southern Adriatic. The share of shrimp in trawl fishing has increased in recent decades in relation to shrimp, and has become the main prey for many trawlers. Especially since 2016., the catch of shrimp has increased from year to year, so that some vessels unloaded up to 1.000 kg of shrimp during the three-day fishing, and the catch of shrimp in 2019. has fallen again. Given the far lower demand compared to shrimp, fishermen have found themselves at a disadvantage because it is difficult to commercialize larger quantities of shrimp, especially in a period when there is no tourism. It has therefore emerged as the most effective solution for disposing of market surplus by cleaning shrimp tails and canning by freezing. Fishermen classify shrimps into 2 categories by size, shrimp I and shrimp II. Shrimp I mainly manage to be commercialized as a fresh whole product while Shrimp II is processed. In Croatia, the model of categorization of pieces in kg common in the world is not applied to shrimp meat (processed tails). This is probably due to the fact that shrimp tails in Croatia are not frozen individually by the IQF method, so they are glazed with a certain percentage of water and up to 30%, but mostly pure meat is vacuumed into ready-made clothes up to 500 grams.

Figure 2: Deep-sea red shrimp (Parapenaeus longirostris) Source: Sohou Z. & Djiman R. (2011.)

Shrimp availability is generally ensured throughout the year, and the best fishing months are in spring. Temporary suspensions of fishing should be taken into account, which are used mainly by fishermen who fish in the central and southern Adriatic, because then the purchase of shrimp is difficult or even impossible. For now, it is the period from September 15 to October 15, and due to unforeseen circumstances (Covid 19 crisis), this year fishermen were allowed to temporarily suspend fishing from April 15 to June 15 for a fee. To achieve continuity in production, fresh whole shrimp can be frozen, preferably glazed, stocked and then, if necessary, thawed and used in the processing process.

The principle of a continuous cold chain should be strictly adhered to throughout the production process from the catch to the final freezing of the product, because shrimp is very sensitive to temperature and the head and body turn black, which reduces its quality.

In the production of shrimp meat, it is processed by hand, by separating the tail from the body and then peeling the tail from the shell with one stroke. The efficiency is 43-45%. The processed tails are then packed in bags or adequate packaging without further treatment, and the product is vacuumed and frozen in a "shocker" or in a quick-freeze tunnel at -40 ° C. Processed tails should not be washed because they lose their flavor and fade (visually, the dark pink color is more attractive to the customers).

Such a product is of top quality and is a favorite of caterers and households, but it is uncompetitive in price with comparison to imported similar products. Buyers are not aware that such imported products are mostly of lower quality, primarily because farmed shrimps with insufficient transparency in the field of feeding and housing conditions, and a large percentage of glaze are used in production and are produced using cheap labor in third countries.

The purchase price of shrimp II ranges from € 2.4 to € 3.57 depending on supply and demand, and the selling price of shrimp meat on the market currently ranges around € 10.00 (prices excluding VAT). When we calculate that one person can process an average of 15 kg of shrimp meat per day, we come to the realization that the selling price of shrimp meat is not high in relation to the cost of production.

If we want to use shrimp meat to create products where the structure of the raw material is not important, we can increase the percentage of usability with the machine separation process. The main guideline of this project is to find innovative process alternatives that would enable work on types with machines that are intended for other purposes, and their use and adaptation gives the desired effect and work on new unrecognized types and possibilities. A previously purchased deboning machine model Bader 601 will be used to pilot the possibility of meat separation. The assumption is that in this way a quality raw material can be obtained as well as a price that can be used for the production of fish burgers and preparation for further processing.

Today, red shrimp (Parapenaeus longirostris) is manually processed from shell within the Adriatic industry and only processed tail meat is used for consumption. It is mostly sold fresh or frozen after processing.

We have already mentioned that soon after the catch, shrimp spoils with melanosis. It is the appearance of dark spots on the body of shrimp, which for aesthetic reasons customers consider undesirable and lead to the fact that the product is not suitable for placing on the market. Melanosis occurs due to the action of the enzyme polyphenol oxidation, which oxidizes phenols

and as a result produces a dark pigment. Pigmentation begins to appear on the head of the shrimp and eventually progresses towards the tail.

Figure 3. Occurrence of melanosis on shrimp tail (source: https://www.aquaculturealliance.org/advocate/4-hexylresorcinol-sulfite-free-control-for-melanosis-in-crustaceans/)

This process can be slowed down by cooling, but dipping in sodium metabisulfite solution is traditionally used. Sodium metabisulphite acts as an antioxidant and as an antimicrobial agent, but due to the sulfur residues remaining in the meat, its use must be indicated on the final product according to EU legislation (E223). Sulfites in food can cause allergic reactions in some people and pose a health risk. In addition, sodium metabisulfite is corrosive, can cause damage to equipment, and is also harmful to workers on fishing vessels who handle it (irritates the eyes and respiratory system).

There are also alternative treatments that do not contain sulfites, and are based on the inactivation of the enzyme polyphenol oxidase. One of them is the product Prawnfresh (https://www.xyrex.com/products/prawn-fresh/) which does not leave any residues in shrimp

meat and also ensures a long shelf life of shrimp. By using these alternative preservatives, crabs can have a "sulfite-free" quality label.

Figure 4. Shrimp without treatment and treated with Prawnfresh additive (source: http://www.royalfish.dk/en/images/prawn_fresh/presentation_prawn_fresh.pdf)

Seafood, including crabs, is among the 10 strongest allergens. An allergic reaction to crabs is most often caused by tropomyosin, arginine kinase and hemocyanin. Symptoms of allergies can be various, from a tingling sensation in the mucous membrane of the mouth, indigestion, a stuffy nose to the appearance of rash on the skin. Some people may also get an anaphylactic reaction with loss of consciousness or even death.

Shrimps are an extremely valuable food rich in nutrients. They have relatively few calories (106 in 100 g,) and do not contain carbohydrates. About 90% of the calories in shrimp come from protein, and the rest is from fat. Shrimp, like other seafood, is rich in calcium and iodine, which is important for thyroid and brain function. Shrimp have a high content of cholesterol (about 3 times more than fish), but as they contain almost no saturated fat, they are still considered

healthy for the circulatory system because they have a beneficial effect on the ratio of LDL and HDL cholesterol and lower triglycerides. They contain about twenty different vitamins and minerals, including selenium, which helps reduce inflammatory processes and has a beneficial effect on health.

Shrimp are a good source of omega 6 and omega 3 fatty acids and contain astaxanthin, an antioxidant that has a number of beneficial properties for human health. Astaxanthin is a carotenoid pigment found in algae that shrimp feed on and give them their orange color. Astaxanthin protects the body from inflammatory processes and free radicals, strengthens arteries, increases the level of "good HDL" cholesterol and reduces degenerative processes in brain cells.

Figure 5. Prepared shrimp and mullet meat Figure 6. Mixed burger of mullet and shrimp, Source: Web

4.2. Musky octopus (Eledone moschata/cirrhosa)

Musky octopus (also called folpo or mushun) belongs to the cephalopod family (lat. Cephalopoda), and the species is an octopus based on 8 arms located around the body. The musky octopus has a body built of the main part (with the uterine sac), a head with attached arms, and a sac-like mantle located on the abdominal side. The cavity inside the mantle ends in the shape of a funnel (hypony) outside the body. In the cavity of the mantle, they have two gills and a bag of ink next to the digestive and reproductive tract. The mouth is surrounded by extensible arms with tentacles of which they have eight. The arms on the inside have grips and partly serve for movement, but above all the muskrat uses them to catch the prey in which it is very skilled. They feed through the so-called a beak that is similar in shape to the beak of a parrot with an upper and lower jaw, and a trench (radula), a toothed plate that serves to catch and chop prey.

Unlike the octopus, the musky octopus is considered a short-living organism. It grows up to 50 cm and rarely reaches a weight greater than 1,000 gr. The arms have only one row unlike an octopus which has two rows of tentacles. It is brown with black spots. Irritated, it easily changes color from pale gray to brown and blackish. It is a predator, lives on a solid and sandy bottom and is distributed in the waters of the Adriatic and Mediterranean Seas.

In the Adriatic Sea there is a black musky octopus (lat. Eledone moschata) and a white musky octopus (lat. Eledone cirrhosa) which is smaller than the black and lives mainly in the waters of the central Adriatic. Black musky octopuses live in our country only in the northern Adriatic. In commercial fishing, it is exclusively fished with bottom trawl tools.

Black musky octopuses are the main catch of Istrian trawlers and their share in the total catches in Croatia is significant on an annual basis. Analyzing the period of the last twenty years, the catch of this species was the highest in the late nineties, when fishing boats were able to catch up to 800 kg of them during one-day fishing in the period of the best fishing season. There were 4 strokes of 2 hours and per stroke would catch 100 - 200 kg of musky octopuses depending on the

area and setting of the tool. Then the price of the product fell to a level of profitability of about 0.4 € / kg. Significant catches, with cyclical variations, lasted until 2010., when the catches constantly decreased, despite the increase in fishing effort. This fact was greatly influenced by the drastic increase in the population of dolphins who quickly learned to wait for prey in front of the "net" and thus cause great damage to fishermen. Not only do they eat the part of the fish that should be caught but by their presence at the place where the ropes (cavo misti) gather the fish in front of the entrance to the hut, they frighten it and the fish escapes sideways over the ropes. More recently, since the entry into the EU, the provision on increasing the „eye" the catching net from the previous 14 mm to the current 20 mm square or 25 mm diagonally was applied, fishermen have noticed that dolphins stay around the net even during pulling them out and because of their musculature, its physiognomy, musky octopuses escape through the larger eye. Measures for the preservation of the fish stock and the establishment of sustainable fishing, such as the removal of trawl fishing 3 miles from the shore, the increase of the eye on the net weight, temporary suspensions for a fee and the permanent suspension of so-called fishing activities. "Scrapping" has been applied since 2012. and should have yielded positive results for fish stock recovery. Unfortunately, these results can only be monitored today, and due to the aforementioned impact of Dolphins on fishing, it is likely that previous catches will never be repeated. After all, sustainable fishing implies the rational use of resources while creating opportunities for the fisherman to make a good living from his work, and this should by no means mean a large catch at a low purchase price.

We must mention that the purchase price of musky octopus in accordance with supply and demand improved in 2019. when it did not fall below 2.4 € / kg I. It is common for musky octopus II to be 0.26 € more expensive, which means 2.66 € / kg and the lowest prices from category III and extra were around 5.33 and 8.00 € / kg.

From a commercial point of view, primarily due to the high price of small sizes and also due to ignorance and non-use in gastronomy, the domestic market is not interested in musky octopuses,

so larger quantities cannot be placed in Croatia. Given that it is a highly prized species in Italy, 90 % of catches end up on the Italian fresh fish market.

When catching musky octopuses, they are already classified into 4 sizes of so-called “pecature”, and interestingly. They are one of the few species in which smaller juvenile individuals achieve a better price than older adult individuals.

- Pecatures are as follows:
- Musky octopus and (Folpo) up to 7 individuals per kg,
- Musky octopus II (Folpetto) from 8 to 14 individuals per kg,
- Musky octopus III (Muškardin) from 15 to 25 individuals per kg
- Musky octopus extra (Muškardin extra) over 25 individuals per kg.

In order to achieve a constant fair price on the Italian market, it is crucial along with the freshness of the product and correct sorting by size, so when taking the catch from fishermen should carefully control the seals because fishermen tend to put larger specimens in smaller pecatures due to the high purchase price.

The main catches of juvenile individuals are realized during the spring, mainly off the west coast of Istria, although the catches were modest at that time due to the large percentage of small individuals in relation to adults. In autumn, the situation changes completely because during the summer the catch ratio of smaller specimens gradually changes in favor of larger ones. Then comes the best fishing season, which can last until mid-November, and fishermen, depending on the fishing effort, can catch up to 500 kg of musky octopuses after going out. Since fishermen often stay in fishing for a longer period of time (up to 72 hours) due to the cost-effectiveness, attention should be paid to the quality of the caught resources taken over during the purchase. Although as a species they are not too sensitive to spoilage because they are mostly caught alive and know how to live longer after catching, they quickly get a "smell" if the catch is not manipulated properly (they are not frozen enough, cassettes are overcrowded, fishing effort period is too long, poor equipment on the ship).

It is important for longer periods of fishing that the vessels are equipped with a functional cooling chamber and that the fishermen have a sufficient amount of ice, and that after a certain time they freeze over the musky octopuses at least once more. In this context, fishermen should be educated and should be made an agreement with them about the duration of the fishing effort in accordance with the equipment and capabilities of the vessel. In optimal maintenance conditions and with strict adherence to the cold chain starting from the catch, fresh musky octopus can be maintained for several days (recommendation up to 5 days) without changing the organoleptic properties.

Cleaning the entrails before keeping them in the cooling chamber would certainly contribute to longer preservation. This is an important factor if the musky octopuses are to be further processed e.g., to cook and due to the large quantities caught and the limited capacity of the engaged machines (cookers), a delay in the technological processing. In agreement with fishermen, the possibility of cleaning the entrails on a fishing vessel should be considered, which would bring multiple benefits from increasing the quality of the catch through saving working time in processing to reducing the cost of disposing of by-products. Of course, the purchase price of the cleaned musky octopus would be higher than the price of the uncleaned. It would only clean up the big muzzle which shouldn’t be a problem for the fisherman considering other types of fish like hake, sharks, rye and monkfish are also cleaned on board. In countries with a developed fisheries sector, even on smaller vessels, fish are gutted and decapitated, decapitated and even filleted and cooked on board. This is how the processed fish is of the highest quality and thus better prices can be achieved with the customer. Such possibilities have yet to be considered in a number of new legal regulations.

It is clear from the mentioned that only two larger pecatures are interesting regarding the processing of musky octopuses, category I and II. Processing technology can be simple, from cleaning, eventual curling and freezing to more sophisticated ones such as cooking and smoking to finalizing products such as ready-made salads or burgers.

Figures 7. and 8. Fresh and cooked musky octopus, Source: Web

Musky octopus processing

In any case, the musky octopus should be cleaned regardless of whether it happened on board or in operation. During the cleansing procedure, one should enter the abdominal cavity with one stroke of the pointing finger next to the hypon (the funnel opening of the mantle located opposite from eyes) and turn the mantle upside down. In the continuation of the same stroke, the entrails, reproductive tract, gills and sack of ink are grasped with the thumb and forefinger, and they are separated from the mantle and torn from the head. The eye is then removed by holding the head and cutting the eye socket with a sharp knife, which allows the contents to be squeezed out by moving the thumb over the eye cavity towards the arms. The cleaning process ends by removing the beak with a sharp knife in such a way that with one hand the head of the musky octopus is held with the arms arranged in a circle upwards and the tip of the knife is passed under the centrally located beak.

Such a cleaned product loses about 20 % in weight and is ready for further processing. If it is placed on the market as a fresh product, it is advisable to curl it in a curling machine, which means

that according to the principle of operation of the concrete mixer, it is rotated in a special machine in salt water with the addition of water and air pressure. This fades the meat, breaks the structure of the meat and becomes softer, and the shorter arms (tentacles) curl into the shape of an open flower, which is visually appealing to customers. The product prepared in this way can also be frozen, and this technological procedure can be applied to a greater or lesser extent even before cooking if the price calculation allows it.

Cooking is done depending on the possibilities in the stove or autoclave. Traditionally, according to the instructions of the public kitchen, it is cooked for 45 minutes on a low heat, and a cork is added, which allegedly softens the meat of the musky octopus.

The fact is that the product loses a further 45 % of weight by traditional cooking for 45 minutes on low heat after squeezing and cooling, which ultimately means a yield of 42-45 % compared to the raw material taken from the fisherman who calibrates a certain percentage during storage in the cold room before further processing.

This cooked raw material can be cut with a machine cutter and with the addition of spices and other "cheaper" ingredients such as potatoes or vegetables processed into ready-made salads made according to customer requirements or can be minced and added binders and spices to make burgers, dumplings or croquettes. As an ingredient in this "paste", a portion of the meat of cheaper white fish can be added, which would reduce production costs, or minced shrimp meat can be added as a more expensive and refined variant.

In any case, it will take a lot of experimentation to run the technological processes until the product is finalized. The Eledone moschata is first washed and then cleaned by removing its entrails, gills, teeth and eyes, and using arms and a cloak for consumption ("head").

Octopus and musky octopus are specific by losing a large proportion of water during cooking and reducing the volume, so the nutritional values are concentrated. For this reason, cooked octopus has twice the caloric value of raw octopus.

u 100g	raw	Cooked
Calories	82	164
proteins/g	14,9	29,8
fats/g	1	2,1
carbs/g	2,2	4,4
water/g	80,3	60,5
ash/g	1,6	3,2
cholesterol/mg	48	96

Table 4. Nutrition facts of raw and cooked octopus (source: https://nutritiondata.self.com/facts/finfish-and-shellfish-products)

Musky octopuses must be cooked before further processing to expel this excess water and ensure a better texture of the product.

4.3. Mullets (Mugilidae)

Mullets belong to the family Mugilidae, which numbers about a hundred different species, of which 8 inhabit the Mediterranean and only 6 live in the Adriatic. They belong to the coastal white fish and mostly live in smaller or larger flocks. They are silvery gray, have a spindle-shaped body, and a light belly. Depending on the species, they can grow up to 70 cm in length and up to 6 kg in weight. They like the confluence of rivers because of the brackish water and muddy shoals up to 15 m deep, and sometimes they know how to go far into the rivers as well.

A classic example of mullet habitat is the water area of the west coast of Istria, especially the fish habitat "Tarska bay", which is why the traditional fishing for mullet with a trawl has been carried out there for centuries.

The most common species of mullet on the western coast of Istria are Liza aurat, Liza ramada, Liza saliens, Mugil cephalus and Chelon labrosus. In commercial fishing, they are caught continuously with standing nets and often with small coastal boats. The main catches are made during the spring and autumn, when boats can catch several tons of mullet at night. Of these species, the golden mullet (Liza aurat) is certainly the most valued, and the quality of meat does not lag far behind the Mugil cephalus and Liza ramada, while the mullet Liza saliens and Chelon labrosus are less valued mainly due to the fact that they are mostly habited in ports. As a market for commercialization, Dalmatia occupies a significant place and then Italy for resolving market surpluses. Since mullet is sold exclusively as fresh fish, its price drops sharply during large catches, and it can even happen that at one point when the market is saturated it can no longer be sold and wholesalers stop buying mullet.

The purchase price of mullet varies depending on the type, supply and demand from a maximum of € 2.40 to a minimum of € 0.66 (prices excluding VAT) in the period when it is in abundance. When forming the price for export to Italy, the price depends on the quantity and the method of catch, how the fish is treated and whether it has a lot of stomach contents, which is not desirable for the buyer. It is most appreciated if the fish is caught with a small coastal boat, live shocked and frozen, because then it can be sold longer for up to 10 days in optimal maintenance conditions and with strict adherence to the cold chain. Therefore, the assessment of quality at purchase is extremely important for further commercialization because at the time of large catches can be negatively affected by relatively poor equipment of small vessels such as lack of ice machines and cooling chambers on the vessel, insufficient ice due to lack of storage space, insufficient number of fishermen to handle large quantities of fish, etc.

Quality should definitely be taken into account if the mullet wants to be processed. Although it is not usually processed in Croatia, it is suitable as a raw material for several processed products, which provides space for creating added value and disposing of market surpluses. Starting with fresh and frozen mullet fillets that can be further enriched by smoking and marinating, through

the use of leftovers after filleting as an ingredient in fish pate, and fish stock through the use of eggs that can be dried or smoked. It offers a variety of usage with good usability.

Of course, it is necessary to carry out adequate marketing activities, given that the products are unknown on the market.

Mullet filleting

The mullet can be filleted manually or mechanically and both methods require prior de-shelling. The shell is removed with a knife, a special serrated tool or a special device with a rotating drum. The methodology, regardless of the type of tool used, consists of uniform hand movements from the tail to the head of the fish, first on one side and then on the other. Care should be taken to clean the shell of the problematic abdominal part without too much pressure to damage the skin of the fish or even lead to spillage of eggs from the abdominal cavity if we want to use it. The fish is then ripped on the belly from the tail to the head, starting from the anal opening to the root of the lateral fins, and first the envelopes with the caviar are carefully removed and placed in a special container cooled by scaly ice. The entrails are then removed by pulling the index finger into the abdominal cavity and pulling the entrails towards the head with one stroke, breaking the connection with the esophagus. If, after filleting, we want to use the head along with the spine, it is necessary to stop and pull out the gills by pulling the index finger under the gills with a sudden movement.

Filleting can be started on fish prepared in this way. There are several filleting techniques and each employee must decide which way is most effective for him/her. A commonly used method of filleting is as follows: The fish is placed on a PVC surface with its back facing the person filleting the fish and its head facing the right side. The person then slides the fingers of the left hand into the abdominal cavity and gently raises the lateral upper side of the abdomen so as not to be damaged by the knife. Then, with the right hand, make an oblique incision with a knife at an angle of approximately 45 ° C from the end of the head to the abdomen, taking care that the root of the lateral fin remains on the right side of the incision with the head. The depth of the cut extends

vertically to the spine, and continues with a continuous movement by turning the blade in a horizontal position towards the tail, cutting as close as possible to the spine to the beginning of the tail fin where the cut ends. In this operation, the joint of the abdominal bones (ribs) with the spine is cut, and the upper dorsal and lower tail fins remain along the spine. The same procedure is repeated on the other side of the fish by turning the fish 180 ° with its head to the left. To complete the filleting process, we need to remove the abdominal bones (ribs) that are left on the inner abdominal part of the fillet. For that, we need a longer knife with which we make an oblique cut in one stroke, gripping all the ribs, making sure that as little meat as possible remains on the ribs. This move also removes the black foreskin that covers the inside of the abdominal cavity. This processed fillet is washed in ice water and placed with the skin on the underside in a squeezing container.

In manual filleting, the percentage of efficiency can vary and depends mainly on the quantity of eggs present in the units and the precision of the staff. Under optimal conditions without the presence of eggs, the efficiency can be up to 47%. In terms of efficiency, a well-established worker can make prepared fish from 100 to 120 fillets per hour. Work engagement can be reduced if the rest of the meat around the spine is not used or if the fish does not have eggs or does not want to preserve them. Then it is not necessary to remove the entrails and gills, but after cleaning the shell, only the previously described abdominal incision is made to facilitate the filleting process.

Fillets can be with or without skin.

The rest of the fish after filleting (head and spine) has a certain amount of meat on it, which can be collected using a separator that we plan to use in the innovative separation of shrimp meat. The machine has a movable strap that presses the fish onto a perforated rotating drum. The meat is pushed through the holes in the drum, while the bones and skin remain on the outside of the drum. If whole fish is used, it must be de-gutted, headless, halved and without a part of the spine above the abdominal cavity that can spoil the quality of the minced meat.

	Intestines%	Head %	Bones %	Skin %
Salmon	9%	18%	8,6%	2%
Trout	8%	12%	3,1%	1,2%

Table 5. By-products of salmon and trout production as a percentage of body weight (Ramírez, 2007.)

5. Potentials of using targeted raw materials

The basic intention is to get quality minced meat from shrimp, mullet and musky octopus for further preparation. Minced fish meat varies by class. The highest class is meat prepared from fresh raw material and it is light in color with only a few darker parts or pieces of the abdominal cavity. The lowest class of minced meat is obtained by deboning the residue after filleting and results in a darker color of the meat.

There are strict hygiene requirements for the production of minced meat. Raw materials must be clean and fresh, and the deboning machine should be cleaned every 2 hours. The meat should be frozen immediately or processed into a product that will be frozen or stabilized by some other method. Minced blue fish meat requires the addition of antioxidants and texture-enhancing additives.

Minced meat can be used for the production of fish sticks, burgers, burger, pate, sausages. In Japan, it is used to make surimi sticks and fermented sauces.

Due to the high price of raw materials, but also the very intense taste, the production of shrimp burgers requires the addition of white fish meat. Hake fillet can be used, but also mullet meat, and even the rest of the meat that is created by filleting.

The database lacks data for some species (musky octopus and hake), so the composition of similar species (octopus and cod) is shown. For shrimp, mixed species are shown.

Data from the U.S. Department of Agriculture website were used (USA Department of Agriculture https://data.nal.usda.gov; https://data.nal.usda.gov/dataset/composition-foods-raw-processed-prepared-usda-national-nutrient-database-standard-reference-release-28-0).

	in 100g	shrimp	octopus	mullet	cod
Calories		106	82	117	82
Proteins /g		20,3	14,9	19,4	17,8
Fats /g		1,7	1	3,8	0,7
Carbs /g		0,9	2,2	0	0
Water /g		75,9	80,3	77	81,2
Ash /g		1,2	1,6	1,2	1,2
Cholesterol /mg		152	48	49	43
Vitamins					
vitamin A/IU		180	150	123	40
vitamin C/mg		2	5	1,2	1
Vitamin D/IU		152			44
Vitamin E/mg		1,1	1,2	1	0,6
Vitamin K/mcg		0	0,1	0,1	0,1
Tiamin/mg		0	0	0,1	0,1
Riboflavin/mg		0	0	0,1	0,1
Niacin/mg		2,6	2,1	5,2	2,1
Vitamin B6/mg		0,1	0,4	0,4	0,2
Folat/mcg		3	16	9	7
Vitamin B12/mcg		1,2	20	0,2	0,9

Pantothenic acid /mg	0,3	0,5	0,8	0,2
Colin /mg	80,9	65	65	65,2
Omega-3 fatty acids /mg	540	163	449	195
Omega-6 fatty acids /mg	28	9	88	5
Calcium /mg	52	53	41	16
Iron/mg	2,4	5,3	1	0,4
Magnesium/mg	37	30	29	32
Phosphor /mg	205	186	221	203
Potassium /mg	185	350	357	413
Natrium/mg	148	230	65	54
Zinc /mg	1,1	1,7	0,5	0,5
Copper /mg	0,3	0,4	0,1	0
Manganese /mg	0,1	0	0	0
Selenium /mcg	38	44,8	36,5	33,1

Table 6. Nutritional composition of certain types of fishery products in the raw state (Source: https://nutritiondata.self.com/facts/finfish-and-shellfish-products)

All these raw materials have a high proportion of water (75-80 %) and a high proportion of protein (15-20 %). Mullet meat is the richest in fat and calories.

Figure 9. Mullet peeled off before filleting, Source: web

Shrimp have a lot of cholesterol in their meat, about 3 times more than other species. They are also the richest in vitamins A and D, as well as omega-3 fatty acids. Compared to raw chicken breast meat, these seafood products have 10 times more vitamin A and 10 to 20 times more omega-3 fatty acids.

Octopus meat has five times more iron than white fish meat.

Compared to chicken, these products have 2 to 7 times more calcium, 2 to 10 times more iron, and 2 to 3 times more selenium.

6. Considerations on the usability of raw materials (example musky octopus)

In this chapter, we will briefly rely on the initial considerations on the utilization of raw materials, while a full view will be obtained after the implementation of the pilot project. The biggest unknown fact in this regard is the usability of musky octopus. The cost price of musky octopus processing is variable not only because of its purchase price in the purchase, but also because of the engagement of labor, which can vary greatly.

If we want to process only a large musky octopus due to the cost of procurement and the cost-effectiveness, when calculating the cost of labor, we come to the problem that the work engagement of cleaning is measured per unit which by definition can vary from 1 to 7 pieces per piece and per kg, which means that the cleaning process is always the same, that only the same quantity can be cleaned in a unit of time.

Therefore, it follows that in the planning of production, the most important thing is to stock the musky octopus when it is the cheapest, paying attention to the pecature as well, because the higher it is, the less work engagement is reduced per kg. Since we have mentioned the possibility of cleaning on board, in case of realization, the price of cleaning could be constant.

Another option would be to introduce the XL size, for example up to 3 pcs (kg, which would also help keep the cost of cleaning under control because it would be easier to take an average. According to empirical assessment, the employee could clean 50 - 60 kg / hour considering the usability with the cost of manipulation (moving the raw material during the curling and cooking process) would mean a load of approximately 0.40 € / kg.

If we hypothetically pay a fisherman a musky octopus € 2.66 according to the formula for the usability of the raw material of 43 %, it turns out (2.66: 43 x 100 = 6.20) that the final price is € 6.20. This formula should include the cost of redemption because the musky octopus needs to be taken from the fisherman, given a cassette (plastic returnable packaging would be ideal for processing) and supplied with ice.

Then the labor cost of 0.40 € should be added, energy cost, the cost of disposal of by-products, depreciation and assembly. Given the many variables in imports, it is complicated to show a realistic result when production is not established and there is no clear capacity input.

The same approach can be simplified. The export price of that musky octopus should be taken as relevant at the moment when the fisherman is paid (from the example) 2.66 € / kg, which is 3.60 €. This eliminates the cost of redemption, cassette and ice, and the calculation is correct because we can really sell it for that price at that moment. The following calculation is made 3.60: 43 x 100 = 8.37 + 0.40 (labor price) + 0.13 (energy price estimate) + 0.03 (disposal of by-products) + 0.40 (flat rate of the package) and we come to the final production price of 9.34 € / kg, which is not small and significantly calls into question the possibility of using musky octopus for raw materials in the production of burgers, but also other products.

To summarize, the largest share in the price is certainly raw materials (and processing framework) and here we can only hope for a drop in prices due to catches of large quantities, which is questionable in terms of sustainable use of resources or to take catches from fishermen on days when there is no redemption the musky octopus can be paid a little less. In recent years, the lowest export price at one point was € 2.80 but this did not happen in 2019. Savings in cleaning on board, and thus savings because waste disposal of by-products is useful but unfortunately insignificant.

Considering all the above and the high cost of the product, the option of adding cheap natural ingredients, such as headless hake, which was procured at 1.7 € / kg and processed on the separator into the mixture, can certainly cost about 2.53 €, should be considered. The texture of the burger could thus be a double, finer mixture of hake and the musky octopus.

All these considerations are in the direction of creating new innovative products as well as primarily the use of technologies. A lot of experimentation is needed with existing machines to obtain the desired structure, which can satisfy primarily the end consumer, but with an acceptable cost price. The pilot project will consider the effects and processing of all these raw

materials, shrimp, musky octopus and mullet in order to reach a conclusion on the rational application of processing technology and the creation of innovative products.

7. Description of equipment, procedures and practices in the production of minced fish categories

As already pointed out, the cost of a product is sometimes the main obstacle for a high-quality product to end up on the market. The food industry knows that consumers have never tasted some of the excellent and quality products that did not end up on the market precisely because of the high-cost price. That is why the chapter on usability will be given special attention and try to see what can be gained with new technologies. In the case of FC, it is the use of a de-boning machine that has not been recognized for use on shrimp, and a polyvalent filler that can easily service a larger range of fish from 200 g to 1 kg without the need for adjustment. The emphasis is to select machines in the pilot phase for which we have assumed efficiency in the desired direction, even if there are other manufacturers on the market with the same quality machines, but it is noted that all machine manufacturers have focused on other fish species. It is important to adapt the processing of species according to the existing machines in terms of creating new technical and technological innovations on the species of interest and the initial preparation for new production.

De-boning- Type similar to Baader 601 soft separator

For the purposes of de-boning examples, we tested a de-boning machine from the German process equipment manufacturer (Bader). This highly efficient machine is made of the highest quality stainless steel aisi 316 and is designed for use in the food industry. It is compact and can be used in both the meat and fish processing industries. It is used primarily for the separation of meat remains from bones. In the manufacturer's recommendations, we cannot find that it is used to extract shrimp meat, and shrimp are still cleaned/processed by hand in most industries today.

The frame of the end product related to making a burger makes the use of this machine the perfect choice to lower the cost price.

The technical principle of operation is simple and is based on creating pressure with a movable flexible pvc tape on the perforated drum. The perforation can be 1.3 mm, 2 mm, 3 mm, 4 mm or 5 mm depending on the needs of the user. As standard, the machine is equipped with a 3 mm perforation drum, but a 2 mm perforation will be tested for the separation of Adriatic shrimp. The same perforation can be used to process fish waste after filleting or whole fish. The machine is served by 1 person and the processing capacity depends mainly on the raw material we use and is higher if the raw material is as adapted as possible to the opening of the raw material reception. The capacity for shrimp is estimated at up to 300 kg per hour.

The machine features are the following:

- The highest quality of processed products due to the gentle process of processing the so-called "soft processing"
- Compact versions in high quality stainless steel
- Easy manipulation - reduced labor costs
- Easy cleaning and maintenance of the machine - time saving
- The highest world-class hygiene standard
- Minimal wear of machine parts
- CE / ETL certificate and USDA approval
- "Heavy duty" control handles for easier machine control

The assumption of using the machine goes in the direction of extruding shrimp meat and the definition of usability as well as usability from filleting residues which will be implemented in the pilot project on the given framework of innovative technological operation.


Figure 10. Filler for a larger range, Figure 11. De-boning machine, Source: FC Istra

Filleting- type similar to machine for fish filleting Movinox model FM 90

Filleting different size categories can sometimes be a huge challenge in customizing a machine. Therefore, in categories that are caught in different seals and without the need for prior selection, it is necessary to have machines that can fillet a larger range of size categories of fish as it is the case with mullet. As an example of the possibility, we tested a filleting machine from an Italian process equipment manufacturer (Movinox). This semi-automatic machine is made of quality stainless steel aisi 316 for food purposes and is designed exclusively for use in the fish processing industry. It is compact and easy to use, and for its operation, in addition to the electricity connection, a connection to the water supply network is also required. The technical principle of operation is simple and is based on two technological procedures. The first procedure involves cutting the head and tail fin of the fish and the second procedure is the filleting process. The cutting of the head and tail is done with a circular saw that rotates constantly and which is located on the front right side of the machine with a stand (cutting pad).

The second procedure is the filleting process that takes place inside the machine in such a way that after inserting the decapitated fish through the feed opening in the receiving transport mechanism consisting of PVC stopper and rubber bands the fish is transported between the stoppers (pulled through the center created by two rotating circular blades) The blades rotate on the shaft and their mutual distance and cutting angle are adjusted depending on the type and size of the fish. All technological procedures are accompanied by rinsing with water through nozzles provided for this purpose.

The machine is served by 1 person and the processing capacity (fillets / hour) depends mainly on the engagement of the operating person. For mullet, a capacity of up to 500 fillets per hour is estimated.

The machine features are the following:

- Compact design in high quality stainless steel aisi 316
- High efficiency compared to manual filleting
- Possibility of filleting different size categories without the need to adjust the machine
- Mobility in space through built-in wheels
- Easy handling / maintenance - reduced labor costs
- Easy cleaning and maintenance of the machine - time saving
- The highest world-class hygiene standard

Summary:

With these machines, innovative changes will be introduced in the technical and technological course of previous operations as well as applications on completely new types. These machines and the course of technological operations will be the basis for the production of burgers as a selected product, and burgers will be processed separately in the work package 5 in terms of duration and canning procedures.

8. Preliminary technological description of the production of burgers and dumplings

The technological process of production begins, if necessary, with thawing, washing and cleaning of raw materials if they have not been purchased already cleaned (e.g., hake fillet as an additive). If raw materials are used in the plant, then it is necessary to store the raw materials, preferably by freezing, or cleaning/processing and then freezing in order to collect a sufficient amount to start the technological process of making burgers and dumplings. It is necessary to plan the production flow from the receipt of raw materials, its cleaning and its processing in terms of the best utilization of the plant and labor and the most optimal cost.

This is where the greatest emphasis is placed in terms of cleaning and preparation with the greatest usability using innovative machine technologies.

The preparation of raw materials is followed by weighing the ingredients needed for the recipe. After that, the individual ingredients need to be chopped separately (vegetables and spices, fish, shrimp or musky octopus). When making musky octopus burgers, they need to be blanched before grinding. The ingredients are then mixed and, if necessary, ground again to the desired texture.

The ingredients are pressed into the mold of special machines to form burgers. The production line includes immersion in the mixture, breading, squeezing and packaging and eventual freezing in relation to the target market.

Figure 12., 13. and 14.; Parts of a burger machine, Source: web

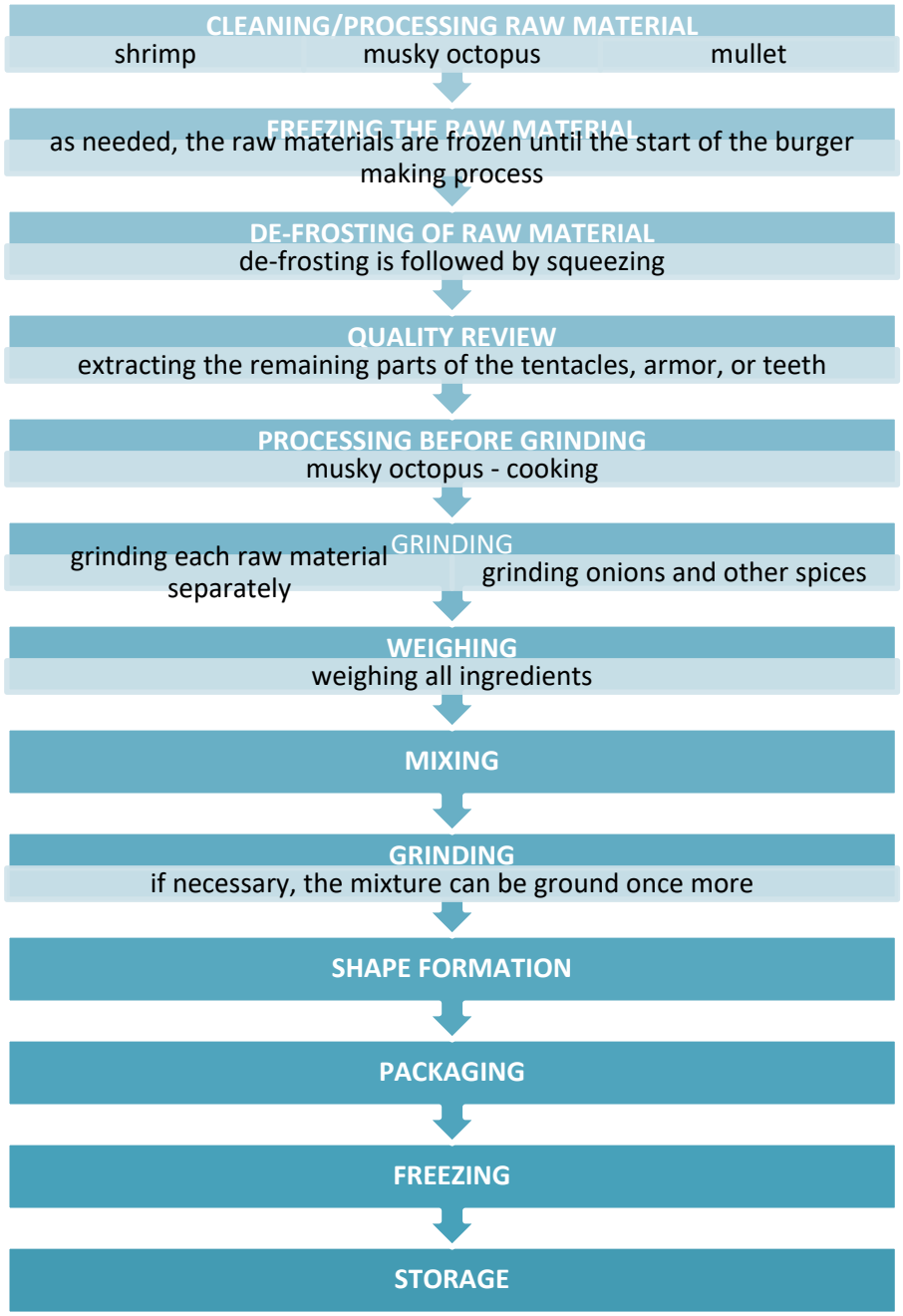


Figure 15. BURGER PRODUCTION DIAGRAM - shown below

Burgers can be shaped using a machine, VER Forming machine can make different shapes using a removable mold.

Figure 16. VER burger shaping machine (Source: https://www.verfoodsolutions.com/products/coating/forming-machine/automatic-burger-forming-machine/)

The main advantages of this processing machine are that it is compact in shape, the molds can be replaced quickly and easily, has the ability to different pressure, does not produce noise, easy to clean, has the ability to make a burger up to 130 mm in diameter, while the thickness can be adjusted from 5 to 18 mm. The capacity of the machine is processing 200-600 kg of raw material per hour.

The shapes that can be produced are, in addition to circles, the shape of fish, other animals, oval shapes, the shape of sticks, etc.

Production of fish dumplings

It has almost the same procedure for preparing a burger mixture, and grinding is done to a certain texture. The balls are specially shaped. At the end of the process, the balls are boiled (about 10 minutes), cooled and packed.

Figure 17. Machine dumplings design (Source: https://www.meat-machinery.com/meat-processing-lines/meatball-production-line.html)

9. Further adaptation and processing steps planed

Mechanical deboning for the separation of flesh

As already mentioned, mechanical separation is a technology that has demonstrated to be successfully applied in the fish sector, although the loss or modification of the normal structure of the muscles is often observed during this operation. Mechanical separation of fish flesh could represent an opportunity for the development of fish-based innovative products based on seafood that would otherwise be discarded.

The flesh obtained by a belt-drum separator can be used for the production of semi-finished seafood products that can be frozen and/or be further used for the production of sauces, fish burger, pasta filling etc.

However, such a preparation process could lead to increased degradation reaction rates of an already highly perishable product. In fact, besides microbial proliferation, fish is also highly

susceptible to lipid and protein oxidation phenomena, which can give rise to the production of biogenic amines and other compounds considered to be toxic. Storage under deep-freezing conditions greatly increases the shelf-life of seafood products by arresting microbial growth and, in general, slowing down the speed of all other degradation reactions.

Freezing could help provide high quality products constantly throughout the year and prevent product waste. However, even at freezing temperatures, the enzymatic activity and oxidation, even if slowed down, are still present. The main limiting factor of the shelf-life of frozen fish products is, in fact, represented by lipid degradation, due to both oxidative and hydrolytic reactions.

The demo company Economia del Mare di Casali Roberto (Cesenatico, FC, Italy) has been identified for this operation to be carried out through a mechanical deboner mod. 600 (Baader, Germany).

An example is shown in Figure 18.

Figure 18. Mechanical deboner mod. 600 (Baader, Germany) with detail of the separating drum, Source: Web

Fresh seafood products are forced by means of a rubber conveyor belt through a perforated drum (holes diameter 3 mm) and collected from the inside of the drum, while by products (carapaces, bones etc.) are discarded on the outside.

In Figure 19 an example of the frozen flesh obtained by mechanical separation of mantis shrimp is shown. After separation flesh was portioned in 100 g trays and frozen at -18°C.

Figure 19. Mechanically separated and frozen Mantis shrimp flesh, Source: web

- High-pressure pasteurization (HPP) for increasing products shelf life.

HPP is a technology based on the application of high hydrostatic pressure to a packed product. The equipment for the HPP processing is composed from a pressure chamber, a pressure generation system, a device for temperature control, a material handling system and a system for data acquisition, controls and instrumentation. For food treatment, pressures between 300 and 800 MPa are generally applied for a few seconds to a few minutes.

Foods need to be packed in a flexible material; therefore, the characteristics of the packaging material are fundamental. The packaged food subjected to high pressure treatment undergoes a volume reduction of 20% during compression and in the same amount the decompression will follow, causing considerable distortions in the package. Therefore, the packaging must be able to compensate for this distortion without irreversible deformations, loss of seal or modifications to the barrier properties.

The company identified for the HPP treatment is HPP Italia (Parma, Italy). The treatment will be applied on fish products previously frozen at -18°C for at least 24 h and thawed. The Freezing step is aimed at inactivating parasite and allowing the consumption of the raw product.

The preparation of the fish products involves the portioning and packaging under vacuum in flexible materials. Pre-formed PP trays containing 6 mono-portions of 15-20 g have been identified for the production of seafood tartare products, intended for raw consumption.

Following the treatment, the obtained products, stored at refrigeration temperatures can be intended as ready-to-cook and/or ready-to-eat with different shelf-lives that need to be determined for each specific product.

Figure 20. shows an example of PP trays containing 6 mono-portions of 15-20 g of fish flesh and subjected to HPP process.

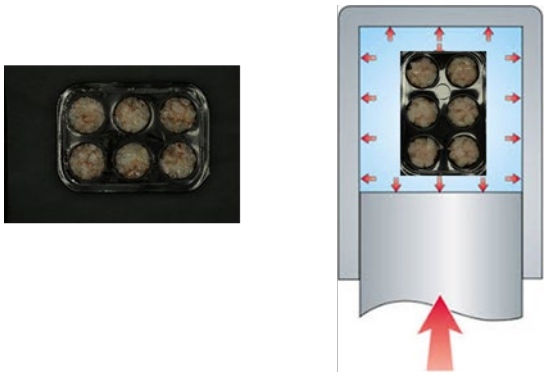


Figure 20. Trays of fish flesh subjected to HPP treatment, Source: Web

III. OP Bivalvia

Executive summary – OP BIVALVIA

OP Bivalvia bases its future development on continuing the selection program on board using and adapting old and new innovative selection technology.

Given the responsibility towards new generations of fishermen and society, it is necessary to continue working on the selectivity of tools in terms of securing livestock and its reproductive potential. To this end, Bivalvia will work in a pilot project on new selective methods as well as methods of returning live bivalve mollusks to the sea.

The next category to be monitored is cold chain extension. Given that today the cold chain begins on land or in the process facility, the idea is to start the cold chain itself immediately after removing the shell from the sea. This would extend the shelf life of the shellfish as well as the possibility of its processing.

For the application of the cold chain, it is necessary to conduct a pilot of quality checks as well as to introduce standardization in the possible equipment on board. When defining the shelf life, a comparison with other ways of extending the shelf life of the product may be made.

1. Introduction

OP Bivalvia as a well-organized legal entity for clam harvesting in North Adriatic wants to preserve environmental sustainability and they define themselves as environmental entrepreneurs. They want to bring more experience to the sea and consider the sea as their main home. Making use of innovative technologies that allow the coexistence between fishing and the precious balance of the ecosystem is a major goal. Cooperative practice rotational fishing that does not damage the natural habitat in any way. Use of selective fishing started many years ago, in which only

licensed fishermen can regularly carry out the activity, in order to protect the fish species from devastating behaviors.

OP Bivalvia also created a system to safeguard the fishing people and offer to their members maximum support and support in every activity acting as an institutional reference point. There is a strong interaction between members listening to the voices of fishermen and all the players in the supply chain, because the goal is a product that is better every day. History of their fishing while keeping traditions alive contributes to maintaining social balance.

From an economical point of view, collectively cooperatives demonstrate strength to have managed to transform traditional fishing into an advanced managed collection system using more and more innovative tools. In that scenario they are trying to minimize the economic risks associated with fishing. Each year the fishermen move the sowing, or transfer the juveniles to less productive areas and close the area to allow the reproduction of the species. From that moment on, the mollusks are followed in all phases of growth, until the minimum size for fishing is reached.

2. The requirements for improvement of clam fishery and its processing solutions

For the next projecting step, exploring the adaptation of machinery for catching striped venus and selection on board will be the course of action for possible gear innovation.

Following premises previously it can be stated that shellfishes are an excellent nutrition product but very sensitive to treatment and environmental changes. Human health issues are becoming more and more important and thus the need to improve standards in the food chain are essential. Penetrating the market with new unique products, shelf-life extension, packaging and processing for HORECA segmentation, certification is the second part of achievement. Selection of young clams and higher shelf life extension followed by prolonged cold chain for new processing segmentation is a primary goal for OP Bivalvia.

3. Description of existing processing solution and production line

The fishery of the striped venus

The production of the stripped venus (Chamelea gallina) includes the activities at sea on board fishing vessels and later on land in processing facilities. In the present, the stripped venus fisheries in the Adriatic Sea use the hydraulic dredge for catching the clams.

Nowadays, more than 90 % of the caught stripped venus come from the northern and central Adriatic, for a total catch over 50.000 tons. Traditionally, the tools used for catching the clams were hand grabs and manual dredges. Later, following the economic importance of the species the fishing gears evolved and from the 1930's there was already a wide use of hydraulic dredges. The hydraulic dredges proved to be an efficient gear for catching the stripped venus, and combined with a high fishing effort it led to fluctuating production of catches. The stocks in shallow coastal water are the most vulnerable, exposed to changes in environmental conditions (temperature and salinity), river run-off (a very low salinity) and pollution.

The modern hydraulic dredge allowed an increasing fishing effort on striped venus, making it economically relevant. At the beginning the improved fishing technique led to increasing landings, and later, given the high fishing effort a reduction of the catches was observed by the fishermen. The striped venus fishery needed an efficient management of resources, being these later sensible to environmental changes. In the following period a set of solutions are adopted to limit the fishing effort and favor adopting fishing techniques that will preserve the juveniles and the stock during the reproductive period. The management of the resources was given to consortiums for managing clams (Consorzi di Gestione Vongole; Co.Ge.Vo.), which plan the fishing activities based on the available resources and define the quotas, regulate the fishing effort in terms of number of fishing days per week and daily fishing hours and a temporary interruption of fishing activities, minimally for two months during year.

4. Fishing technique

The dredges used for catching shellfish are fixed width bottom fishing gears, towed either by hand or by boat. There are three types of dredges based on the scale of penetration into the bottom. The first type are dredges with a blade, usually a sharp metallic bar, able to penetrate into the bottom sediments and "detach" a few centimeters of it from the bottom, moving both the sediments and the organisms back through gear. The second type are dredges with teeth, having a structure similar to a rake, that penetrate into the bottom, but separate only the organism and move them into the gear. The third type is a dredge without a blade or teeth, having a rudimentary construction, usually just a simple cage that collects the organisms.

There are four different types of dredges based on the towing methods, included into the EU Common Fishery Policy regulation (CE 1967/2006). The dredges towed by boats are active gears towed by the main engine of the boat. Mechanical dredges are towed by winching up the anchor cable of the anchored boat. Hydraulic dredges are gears that use the hydraulic pressure of the water to penetrate and move the sediments. The last are the hand dredges, manually towed in shallow waters with or without a boat.

5. The hydraulic dredge

The hydraulic dredge is a metallic cage that has several lines of nozzles that shoot pressurized water to liquefy the sediments allowing the penetration into the bottom, and help with the transport of the sediments and the organisms through the gear. The high-capacity water pump is located in the engine room, near the water inlet, from which pumps water to the fishing gear through a large rubber hose. All the dredging boats have their dredges located at the bow supported by a hoisting frame and hoisted the dredge using a steel cable. The catch contained in the dredge is unloaded below the hoisting structure and moved using a flow of water to the sorting machines for further selection and cleaning.

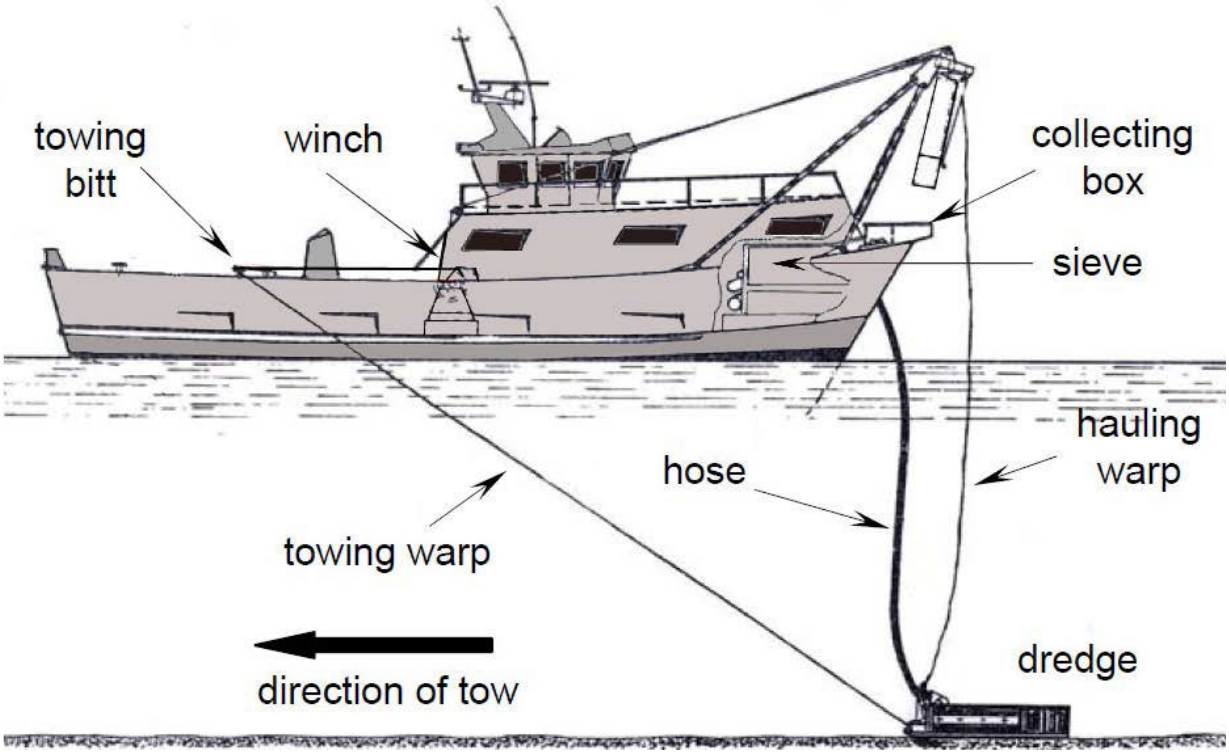


Figure 1. Examples of different interchangeable sorting screens, and combinations of different sorting meshes, Source: Web

The standard hydraulic dredge cage has its lower, upper and side panels made of sieving screens. These screens are usually made from parallel metallic rods, where the space between rods is regulated based on the species and desired size selection. At the front part of the lower panel is located the blade, while on the top side are several lines of nozzles, first one for liquefying the sediment and the following for its transportation to the sieves at the back of the dredge. The regulation (IT D.M. 22/12/2000) defines the specifications of the dredge, having the maximum width of 3 meters, maximum pressure at nozzles 1.8 bars and maximum weight of 600 kg. The most common configuration uses parallel metallic rods at the lower sieving panel, and the distance between rods is restricted to a minimum of 12 mm. Alternatively, the lower screening can have a squared mash (of minimum 17 mm per side), a rectangular mesh (of minimum sides

12 and 25 mm) or a perforated mesh (with round holes of minimum 21 mm diameter and a perforated surface of at least 2/3 of the total). The on-board sorting sieve needs to follow the same restrictions.

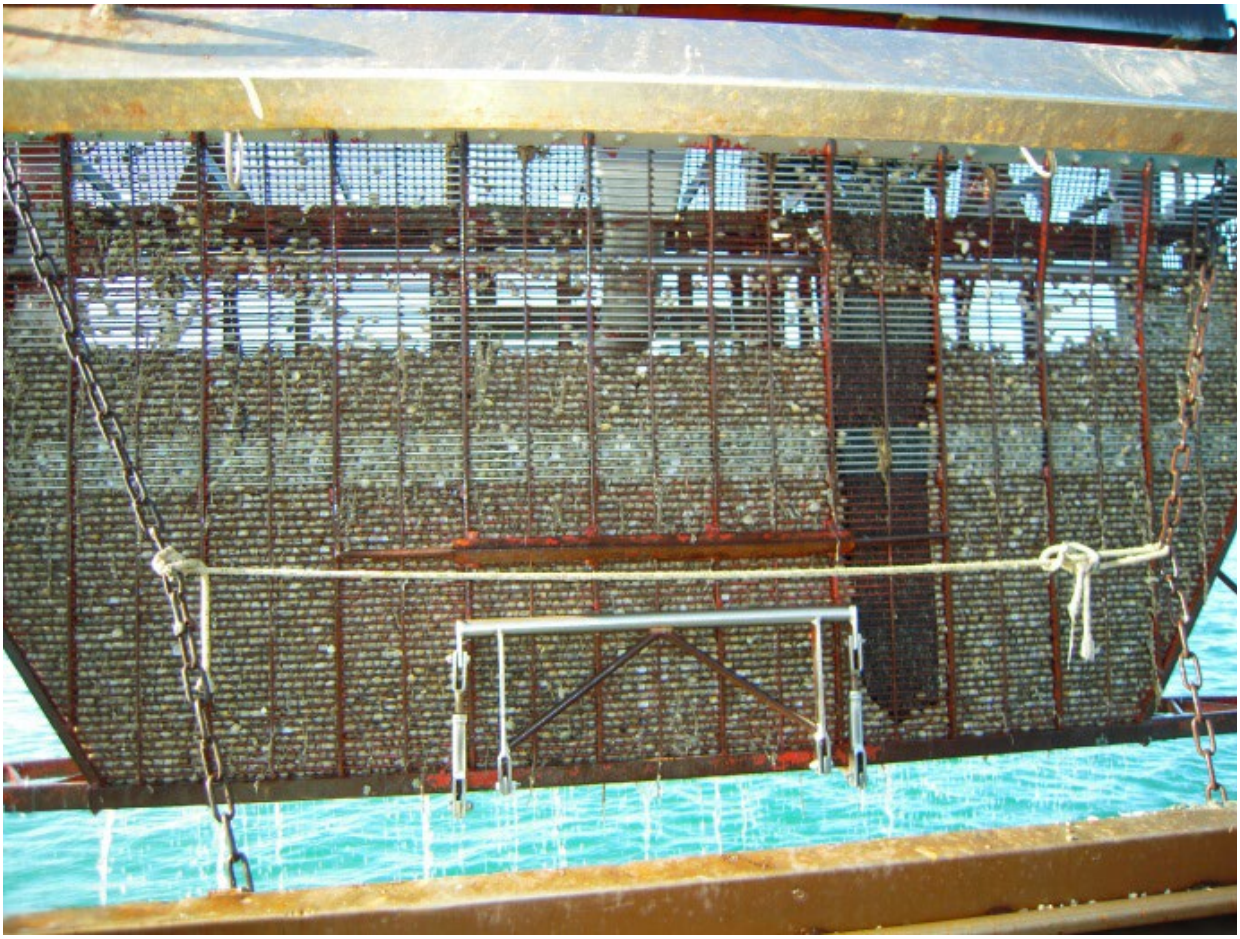


Figure 2. A detail of the construction of the hydraulic dredge cage and the sieving screens used.

Source: web

6. The sorting machine

The sorting machine used in the stripped venus fishery is a horizontally slightly inclined vibrating multi-level sieve. The vibrations move the clams on the sieve, and help in the selection and passing of smaller specimens from a higher sieve to a lower one. The highest sieve has the largest holes for retaining larger specimen, while the lowest has the smallest holes for the smallest specimens. The sieving screens are interchangeable and the fishermen can use the appropriate screen type for his needs. The selection performance of the vibrating sieve is influenced by the vibrating intensity regulated by the rotation speed of the vibrating element, the inclination of the sieve screens and the quantity of the clams that are brought to the sorting machine.

Figure 3. A multi-level vibrating sorting machine used on-board hydraulic dredge fishing vessels, Source: web

Figure 4. Examples of different interchangeable sorting screens, and combinations of different sorting meshes, Source: Web

7. Classification and scoring of clams

The grading process of the striped venus has multiple steps throughout the production process. First, there is a selection process directly carried by the hydraulic dredge cage during fishing. The following selection is done on-board by the sorting machine, differentiating the caught clams in different size categories and the undersized ones thrown back to the sea. The sorting of clams by size can be carried in the production facilities. During the sorting procedures, the operators check the integrity of the clams and other non-conformities, and remove them.

Figure 5,6,7,8 Details of the sorting multi-level sorting machine used on-board striped venus fishing vessels in Italy, Source: web

8. Transportation and conservation of the clams

The caught clams are transported on-board in bags, usually stored in the aft, although not in a temperature-controlled space. Further, once on land and in the production facility, the striped venus follow a cold-chain, where they are stored in a chilled room and transformed and packed.

Figure 9. Examples of temporary packaging of striped venus in bags for on-board handling, Source: web

9. Motives for improving the existing processing solutions

The status of the striped venus fishery in Veneto region has improved compared to the past and the adoption of such management has led to a MSC certification. The certification itself provided valuable guidelines that were used in shaping the management solutions of the fishery. Although the present resources allow a stable and constant fishing activity, there is a need to preserve the stock in good health. Moreover, the Reg. (EU) 1380/2013 disciplines the obligation to land the discards in an attempt to limit the by-catches of species regulated by quotas or minimum conservation reference size. Therefore, it is vital to reduce the ratio of undersized specimens of striped venus in its total catch. Preserving the habitat where the striped venus lives is an additional concern, since the species is susceptible to environmental changes and the fishing activity of the hydraulic dredge impacts considerably the stock and benthic fauna community and the structure of the sediments. The water jets and the tumbling of clams inside the fishing activity induces physiological stress to clams that negatively affects their vitality. Increased physiological stress can further decrease the stock's population by decreasing the burrowing rate of

undersized clams back into the sediments and increasing their mortality rate. Moreover, increased level of stress negatively affects the quality of the fresh products by reducing their shelf life and losing weight. The caught organisms are also subject to stress in the following steps of the production chain, both on-board and in the production facility during the sorting procedure. Therefore, reducing the stress of the caught specimen will positively affect both the stock status and the fresh products quality.

10. Product quality and freshness

Developing a fishing gear with an improved selectivity will allow reducing the by-catch of striped venus right at the first step of the production chain. A better selectivity will release right away the juvenile clams back to the bottom instead of bringing them on-board and later releasing back to the sea after the sorting procedure. Removing this step allows not only the juveniles to burrow in the sediments right away, but will also reduce the stress of the organism and therefore reduce the mortality and improve the stock. Moreover, an improved fishing gear can also reduce the stress on all caught specimens, not only the juveniles, but also on commercial sizes. Reducing the stress will improve the longevity of striped venus fresh products and obtain a longer shelf life.

Other than improving the selectivity of the fishing gear, an additional possibility for reducing the stress of striped venus is in improving the sorting machine, both on-board and in the production facility.This improvement will further reduce the stress level that the clams are subject to by tumbling and vibrations through the sorting machine. The resulting benefits are a better vitality of the organisms allowing lower mortalities of organisms thrown back to in the sea and a longer shelf life of freshly packed clams, similarly as described before for the hydraulic dredge.

11. Cold chain

When seafood is freshly caught, the quality is high, but over time quality will deteriorate and eventually will become unsuitable for consumption. Maintenance of the cold chain and careful handling are a fundamental part in minimizing seafood spoilage. The cold chain in the seafood industry is a temperature chain and begins once the seafood is caught. From the quality and regulatory perspective fresh seafood means that it has been stored at 0°C and for frozen seafood it means-18°C or colder (from the sea to the consumer). The cold chain is broken every time the temperature of the seafood rises above 1°C. Fluctuations in the cold chain increase quality loss, these losses cannot be reversed by any means after the event. There are many avoidable and unavoidable occurrences that cause fluctuation in the cold chain. Good chilling and/or freezing practices on board harvest vessels are a condition sine qua non for maximizing the best possible quality of all seafoods. Best practices on seafood handling and the minimization of temperature fluctuations are paramount for seafood distributed under refrigeration (i.e., chilled and/or frozen) to maintain its quality and maximize its shelf-life.

The quality of the freshly produced clams is an important selling point since the shellfish need to be alive when sold or consumed. The temperature influences the vitality of the clams, other than the stress induced by the fishing and production processes. It is important that after the fishing the clams should be conserved in a controlled temperature environment and avoid sudden large temperature changes. A temperature similar to the water where the clams were harvested should be maintained during on board selection and transportation. The clams should not be put in direct contact with ice. Maintaining the cold chain is fundamental for blocking or slowing down the multiplication of bacteria and for securing the food safety standards. The optimal temperature for preservation of shellfish is between 6 and 8°C, and should not be lower than 4°C. A critical limit for clams is being exposed for more than 4 hours at temperatures higher than 10°C. The production facility is usually the first point where the cold chain for the shellfish begins.

However, the production facility also holds water tanks for degritting and cleaning the clams. If clams need depuration the optimal temperature of the water should be between 11 and 20°C.

12. High pressure processing (HPP)

High Pressure Processing (HPP) is a cold pasteurization technique by which products, already sealed in its final package, are introduced into a vessel and subjected to a high level of isostatic pressure (300–600MPa) transmitted by water. Pressures above 400 MPa psi at cold (+ 4°C to 10°C) or ambient temperature inactivate the vegetative flora (bacteria, virus, yeasts, moulds and parasites) present in food, extending the products shelf life importantly and guaranteeing food safety. High Pressure Processing respects the sensorial and nutritional properties of food, because of the absence of heat treatment, and maintains its original freshness throughout the shelf-life. Thermal methods, traditionally used in the food industry for food preservation, carry disadvantages like vitamin destruction or flavor changes that can be avoided with HPP. High Pressure Processing Technology has several advantages. For example, it improves the food quality, the characteristics of the fresh product are retained, sensorial and nutritional properties remain almost intact. Food safety and exportation date are also improved because the high pressure destroys pathogens (Listeria, Salmonella, Vibrio, Norovirus, etc.). The product shelf life is extended, which should lower returns, and improve customer satisfaction. There is a higher quality along product shelf life and a reduced overall microbiological spoiling flora. The treatment avoids or reduces the need for food preservatives, enabling the possibilities to create clean label foods (natural/additive Free). New innovative food propositions can be exploring as products that cannot be thermally treated can now be high pressure processed, innovating the product portfolio and providing competitive advantages. The treatment should reduce hand labor, increase yields and maintain the fresh flavor, as well as it can be applied to shuck mollusks or extract crustacean meat without boiling. The high-pressure processing is environmentally friendly as it requires only water, recycled at each use, and electricity.

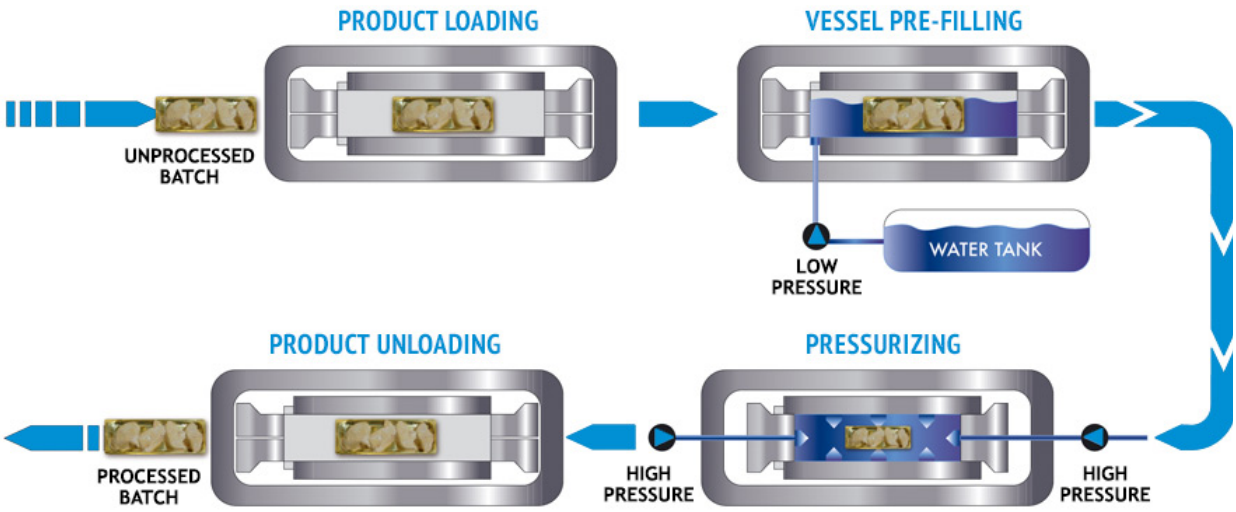


Figure 10. A diagram of operation of the high-pressure processing. (Source: https://www.hiperbaric.com)

13. Examples of similar technologies

Clam fisheries in the sense of fishing gears around the world use several techniques, from a less sophisticated hand rake, to a more evolved hydraulic dredge. For example, in Portugal the dredge fleet uses different dredge types for fishing the species *Spisula solida*. The more traditional is a towed tooth dredge, with a wide mouth and an attached net for collecting the shellfish. An improved dredge is the grid dredge that employs a metallic grid instead of using a net. These dredges were designed to dig clams out of the sediment, impacting on the benthic habitat, both in terms of its physical structure and its biological communities. The more modern improved dredge brought many benefits. Most importantly, smaller (juvenile) clams are able to escape through the gaps between the bars of the grid, and this greatly reduces the amount of catch discarded. It also allows juvenile fish to escape, decreasing unwanted mortality on valuable coastal fish resources. The old-style dredge gear was inefficient and environmentally damaging.

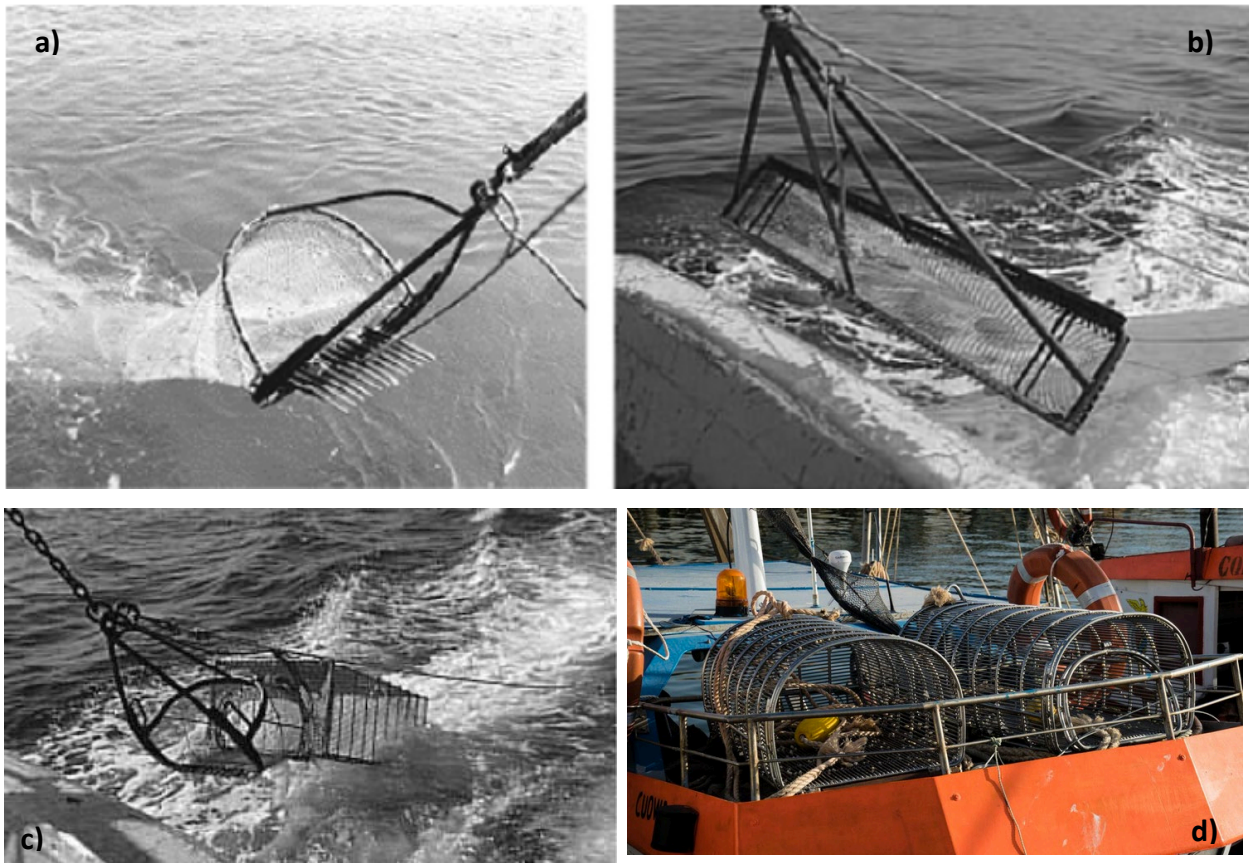


Figure 11. Examples of dredges used for clam fishery in Portugal: traditional dredge (a), dredge used in the north of Portugal (b), grid dredge, an improvement of the traditional dredge (c), modified fishing gear to reduce discards (d). Source: web

A hydraulic dredge is also employed in Mid-Atlantic (USA) and New England (USA) waters where bottom conditions will permit it to harvest surf clams and ocean quohogs. The dredge has a similar construction as in the Adriatic, but is operated differently. It has a large steel construction, and is dragged along the bottom by the clam boat. A large pump on the boat pumps sea water through a large hose to a manifold on the front of the dredge. The manifold jets the water into the sand, temporarily fluidizing it and allowing the dredge to pass through. Due to the carefully

set spacing of the bars making up the body of the dredge most of the smaller clams and other organisms pass through, the larger clams being retained. The fishery is regulated and has mechanical restrictions that the gear imposes, hose length, pumping pressure, limiting their use to shallow water. The sandy bottom environments in New England areas are normally exposed to perturbations during winter storms and take such disturbances in stride. The surf clam/ocean quohog fishery was one of the first in the United States to be managed by individual transferable quotas (ITQs). The right to catch a certain number of clams each year is given to each member of the fishery depending on his prior performance in the fishery. Individuals who own rights to harvest these clams may sell or lease these rights to others.

Figure 12. An example of a hydraulic dredge vessel in New England (USA) clam fishery. Source: web

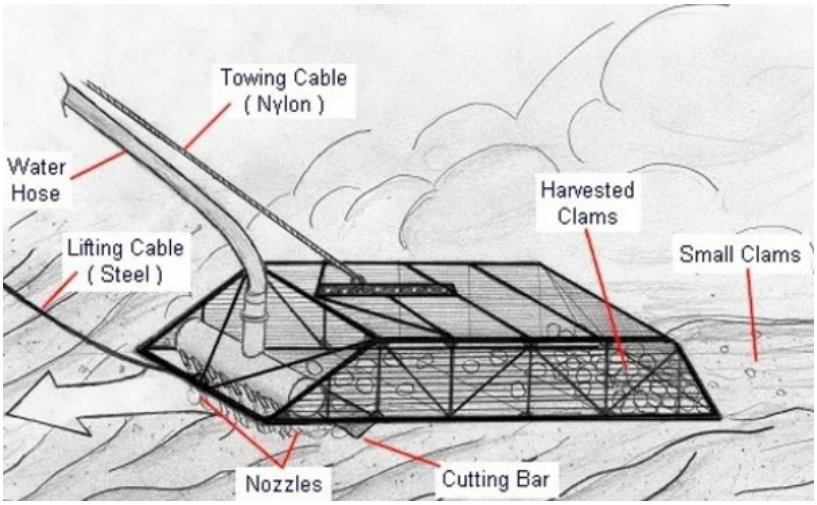


Figure 13. The details and the use of a hydraulic dredge in New England (USA) clam fishery, Source: web

14. Sorting machines

In the shellfish sector, there are several different sorting procedures for selecting and grading shellfish. The different solutions vary in properties such as the speed, the sorting volume, the induced stress on specimen, the flexibility and the cost

In clam fisheries in Italy, the most common sorting solution is a vibrating sorting machine. This machine has a relatively simple construction; it is cost effective and easy to use. The multiple stacked sieving screens allow obtaining different product grades in a compact solution that allows processing large quantities of clams in short time. It is possible to install it both on-board fishing vessels and in land facilities, since it can be powered either by electricity or attached to a hydraulic system. The machine is reliable because it is mechanically operated and without electronic or digital parts. The drawback of the solution is that it can induce a physiological stress on the specimen because of the vibrations it needs to operate.

Figure 14. An example of a vibrating sorting machine used in Adriatic clam fishery, Source: web

Rotating sieves are another common solution used in the shellfish industry. This kind of sieve is already in use on-board striped venus fishing vessels. Their construction is simple and robust, and the continuous rotation keeps the sieves clean and efficient. Two different types of screening mesh can be used, rectangular and round holes, based on the requirements of the fishermen. The rotation gently sieves the smaller specimen and moves them through the sieve. The installation and the operation are simple and are powered electrically or hydraulically. A drawback of this sorting machine can be their large size, which can hinder the space on-board fishing vessels.


Figures 15., 16. Examples of rotating sorting machines for shellfish with rectangular (left) and round (right) mesh. Source: web

An alternative for sorting shellfish is a sorting machine using parallel rollers. This machine is very simple and compact, has a simple and reliable construction and is easy to operate. An advantage of this type of sorting machine is a very precise sorting by size and gentle handling of specimens. The machine is suitable for installing both on –board fishing vessels and in production facilities.

Figure 17. An example of a roller sorting machine, Source: web

Optical sorting machines represent the most advanced sorting machines. The use of the machine allows inspecting the quality of the products and detecting defects in products. The machine uses computer assisted visual inspection by scanning the products carried on the transporting tape, and identifies non-conforming products using artificial intelligence, and removes them using short bursts of air. The machine itself does not sort the product by size, but assures its quality. The delicate electronics contained inside makes the solution more suitable for production facilities than fishing vessels. The implementation of the sorting machine requires adaptation to existing production lines and providing electricity and compressed air supply. A disadvantage of the optical sorting machine is its higher cost than other mechanical only solutions, and the need for more maintenance.

Figures 18., 19. Optical sorting machine for shellfish (left) and example of removed mussels by the sorting machine (right), Source: web

15. Description of implementation of innovative processing solutions

Description of the vessels and existing conditions for new equipment

The selected innovative processing solutions described below all fit in the existing specifications and spaces on board fishing vessels. The innovative fishing gears need to follow the same law regulations for gear structure and specifications, like the width, weight and sorting screens. Therefore, the innovative testing gears are compatible with the existing equipment on board fishing vessels, such as water pumps and hoisting structure.

The different piloting gears have each of them a different specification to reduce the impact of the gear on the stock and the benthic habitat. There are several features that can be modified on the hydraulic dredge cage, like the configuration of the blade, the type, numbers and direction of the nozzles and the sorting screen. Among different variations, there are fishing gears with:

- double row of nozzles above the blade, and set of frontal nozzles for stimulating the closure of the shell;
- metallic bars of the bottom screen panel oriented perpendicular and parallel to the direction of the gear;

- double row of nozzles above the blade and metallic bars of the bottom screen panel oriented perpendicular and parallel to the direction of the gear, and with inverted collector;
- nozzles and the frontal blade with single curtain water flow;
- added nozzles at the bottom for improved transportation and washing of sediments;
- internal sorting screen powered by a wheel;
- internal sorting screen powered by water pressure;
- frontal sorting screen with larger round holes.

A selection of these features will be tested and assessed the effects on the caught stripped venus.

Figures 20., 21. Examples of modifications of hydraulic dredges with added nozzles or without nozzles with a single water blade, Source: web

16. Requirements and limitations of the improved sorting machine

Improvements of the sorting machine have to follow the same regulations as for the fishing gear. The selected solution will tackle the structure of the sorting screens, as the most flexible and easy modification for the fishermen, allowing them to continue using the existing sorting machines. Changing the speed of vibrations is one of the possibilities to reduce the impact on the stripped venus, and has been studied in the past. The inox steel sorting screens are a very efficient and durable solution for sorting clams, with an advantage of maintaining their screening properties. However, the material might be too rigid and contributes to inducing physiological stress to clams. A sorting screen of different materials and configurations are possible candidates to be tested. Teflon is a plastic material already used in various components in machines used in the fishery and shellfish industry. A sorting screen of Teflon can provide a softer impact on the striped venus, while still providing the functionality of a sieve.

Figure 22. A preliminary implementation of sorting screens made of Teflon, Source: Web

17. Other new applications during the processing procedure

A whole cycle cold-chain will be tested for the stripped venus fishery, where the clams will be stored in a controlled temperature environment right from on-board the fishing vessel. This solution requires the installation of a refrigeration unit to store up to 400 kg of striped venus at mildly cold temperatures that will not hamper the vitality of the clams. Larger refrigeration storages could require the installation of the refrigeration equipment, such as the compressor and the heat exchanger plates in the engine room, and a storage with a chiller on deck of the fishing vessel. A carefully controlled temperature should be should gradually decrease allowing the newly caught clam to acclimate, but not too fast and too cold as it will induce physiological stress and reduce the vitality and shelf-life of the fresh product. The future destination of the clams in the production cycle determinates the lowest temperature on board the vessels. The final temperature range between 6-8°C may be suitable for clams going to be directly packed as a fresh product or processed. However, if the clams need additional treatment after fishing and before commercializing or processing them, like for example depuration or de-gritting, the final lowest temperature should be in accordance with the temperature of the treatment in order to prevent thermal shocks.

Later during the production processes, a controlled temperature is required for preserving the freshness and vitality. The fresh product line should maintain the temperature between 6-8°C for optimal vitality of the mollusks.

The effects of the controlled temperature will be tested by piloting the small scale-controlled temperature storage on-board fishing vessels and the adoption of cold rooms during the packaging process.

Figure 23. Examples of a small scale refrigerated cell that could be used on board fishing vessels (left) and the cold room used in the production facility for processing the products (right). Source: web

18. Additional treatment for extending shelf-life of the product

An improvement of shelf life will be researched by testing the application of high-pressure processing procedure on fresh striped venus clam. For the treatment, the stripped venus will be contained in a sealed package and further processed with a high pressure. The goal is to test the possibility to create new extended shelf-life products that are easy to cook and that resemble the local culinary traditions. A selection of receipts will be examined and some of them tested. Among them the fresh striped venus will also be treated with high pressure determining the effects on the treatment on the properties of the product. Pressure and the duration of the treatment are also two factors that can influence the final product, its properties and its appeal. An excessive pressure or a prolonged treatment can in fact improve the shelf life, but it may come at a cost of the product properties.

Figure 24, 25. Examples of preparation of shellfish for high-pressure procedure treatment (left) and the presentation of a desired potential finalized product (right), Source: web

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