Project title:
Sustainable packaging of fish and seafood based on marine bioresources

Acronym: SeaSusPack

Lead beneficiary: Agricultural University of Athens (AUA)

Duration: 36 months

Pillar 1 Blue Growth
Topic 1.2. Fisheries and aquaculture

Food waste

Food waste in Europe

Total amount of food produced for human consumption per year

654 million tons

Total amount of food wasted per year

205 million tons

Waste by consumer: **34%**

Waste during production, harvesting, processing and trade: **66%**

2012 © Wageningen World, magazine of Wageningen UR Illustration: Jenny van Driel, Wageningen UR Source: FAO

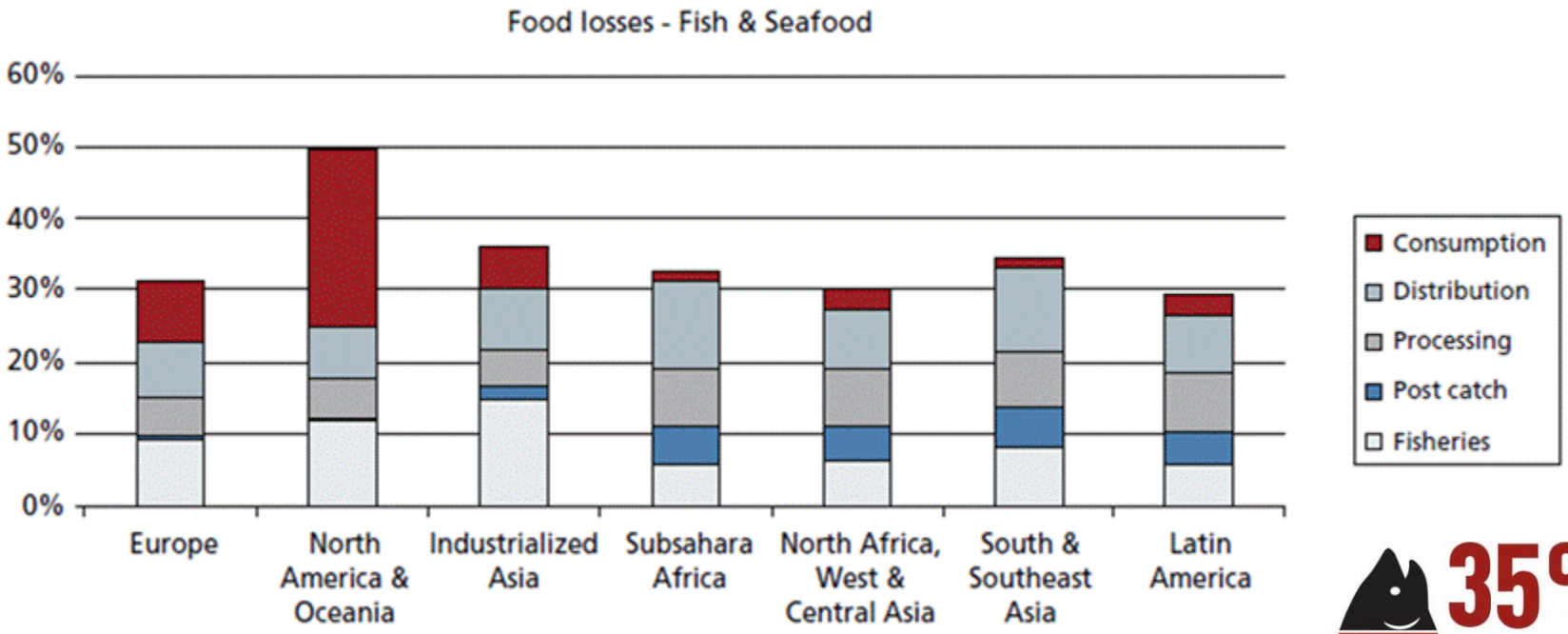

The Food Waste Iceberg
what we see
Bill at producer price:
$750 000 000 000
Bill at retail price:
$1000 000 000 000
Eroded Land
GHG Emissions
Cleared Forests
Increase in Food Prices
Increased Water Scarcity
Bill from nature:
$700 000 000 000
what we don't see
Loss of Wetlands
Loss of Biodiversity
Climate Change Damages
Food and Agriculture Organization of the United Nations

Food waste enough to feed world's hungry four times over

If we could decrease by 25% the current food wastage, that could feed more than 800 million people suffering from hunger.

FAO Save Food 2013

Food waste in the cold chain – Fish & seafood

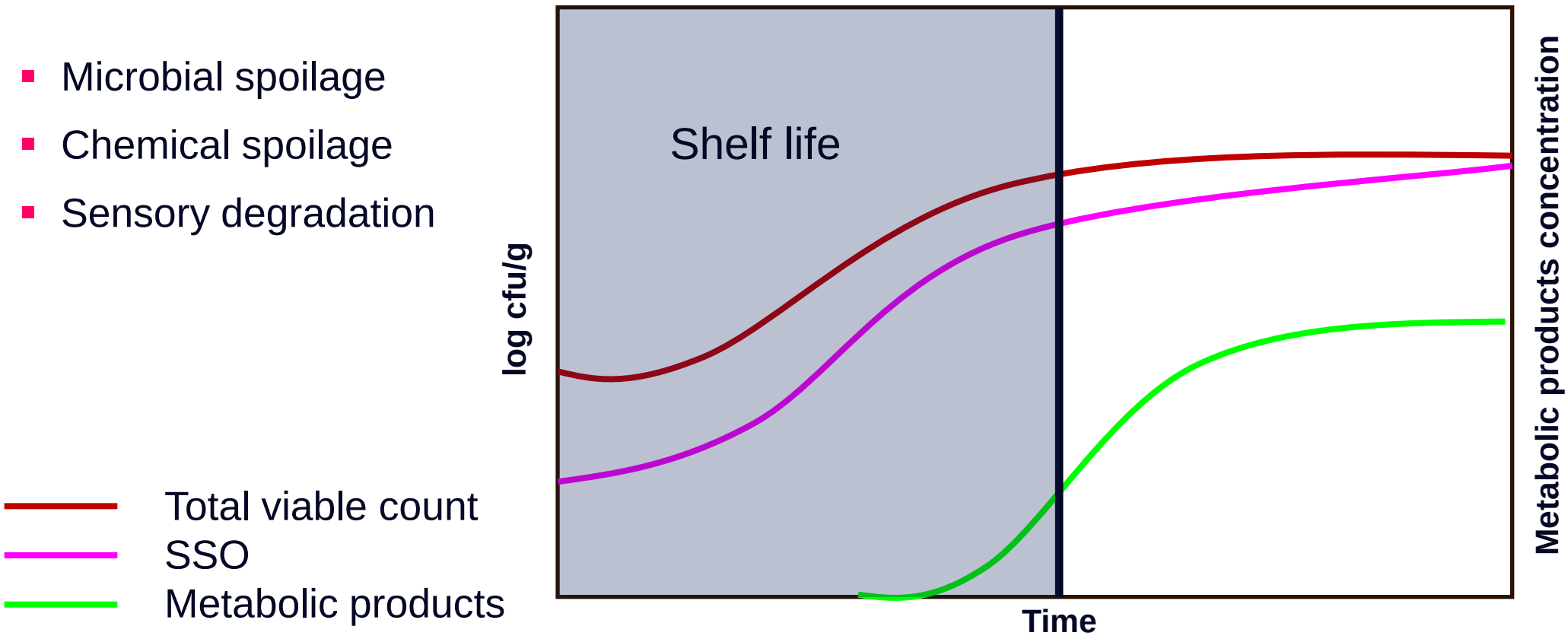


save FOOD solutions for a world of its resources

Food and Agriculture Organization of the United Nations

Spoilage of fish

- Microbial spoilage
- Chemical spoilage
- Sensory degradation



(Source: www.fao.org)

Challenges to be addressed

✓ Innovations in processing and packaging → effective quality preservation → shelf life extension

✓ Fresh fish - minimal processing – better retention of sensory parameters

Packaging:

Nowadays, polystyrene, polyethylene and PET are the main packaging materials used for fish and seafood storage and transportation, either bulk or in individual packages.

The recent **EU Directive 2019/904** refers to the **replacement of plastic packaging materials** and **elimination of the environmental impact**.

Biopolymers are an environmentally friendly alternative to synthetic plastics because they are not based on fossil resources and can easily be biodegraded.

Tsironi T., Taoukis P. (2018). Current practice and innovations in fish packaging. Journal of Aquatic Food Product Technology, 27, 1024-1047.

General objective

The overall aim is to **optimize novel value-chains for fish and seafood** to reach the EU market and **develop an integrated sustainable approach for product handling and transportation**, to **improve quality** and **reduce post-harvest losses** along the supply chain.

The specific objectives are:

(i) to **introduce economically and environmentally sustainable packaging materials based on marine biomass**, that can appropriately preserve quality of fish and seafood from harvesting to the consumption level;

(ii) to **improve the sustainability** of the fish and seafood sector by extending shelf life of highly perishable products and thus reduce food waste;

(iii) **reduce waste of packaging materials** by applying non-plastic, biodegradable packaging solutions;

(iv) **assess the sustainability** of the new packaging solutions in comparison to commonly used packaging for fish and seafoods;

(v) to contribute to the **implementation of the objectives of Blue Growth** and the European integrated food safety policy;

(vi) to **provide cross-cutting interdisciplinary knowledge e**xchange, to improve employability and career prospects in and outside academia and contribute to the knowledge-based economy and society, to boost regional and EU competitiveness and growth, promote food security and exports.

Work plan and activities of the project idea

The project focuses on the **development and the evaluation of the effect of novel biodegradable packaging systems** on the **quality and shelf life of fish and seafood** in the supply chain.
In order to successfully complete its objectives, the proposed project project brings together 2 academic partners located in 2 EUSAIR member countries (Greece and Croatia).

The proposed work plan is organized into 3 complementary and multi-disciplinary workflows, including

(1) Customized packaging technologies based on marine biomass
(2) Development of novel packaged fish and seafood prototypes
(3) Evaluation of the sustainability of biodegradable packaging systems

The project consists of **6 WPs** that encompass basic science, product development and safety, transfer-of-knowledge, dissemination and outreach activities and feasibility studies.

Agricultural University op Athens (AUA) research team

Department of Food Science and Human Nutrition, Laboratory of Food Process Engineering

Theofania TSIRONI, Assistant Professor

Quality and shelf life modelling of food (mainly seafood), active and intelligent packaging, predictive modelling, nonthermal processing, active packaging and cold chain management.

Apostolis KOUTINAS, Associate Professor

Biorefinery development using renewable resources to separate value-added components followed by microbial bioconversion of remaining fractions to produce bio-based chemicals and polymers within a circular economy context.

Department of Agricultural Biotechnology, Laboratory of Molecular Biology

Emmanouil FLEMETAKIS, Associate Professor.

State-of-the-art gene cloning (genomic and cDNA) applications, transcriptomic and metabolomic methods, and plant and microalgae genetic transformation technologies.

Energy Institute Hrvoje Pozar (EIHP) research team

Department for Renewable Energy Sources, Climate and Environmental Protection

Biljana KULISIC, PhD, Senior expert, biomass, bioenergy and bioeconomy
Designing circular and sustainable business models for transition from linear to circular bioeconomy; creating industrial synergies for carbon neutral and bio-based solutions; evidence-based policy; transforming bioenergy plants (biogas, solid biomass) to biorefineries

Matko PEROVIC, BSc Mechanical engineer
Employing energy efficiency and renewable energy solutions to SMEs, industry and farmers

Ana MANDARIC, BSc Chemical engineer
Facilitating utilization of waste and side streams in novel value chains to create circular and sustainable bioeconomy business models

Work plan and activities of the project idea

- ✓ Recently, much attention has been focused on research to replace petroleum-based commodity plastics, in a cost-effective manner, with biodegradable materials offering competitive mechanical properties → Biopolymers have been considered as promising materials for this purpose.

- ✓ Fish and shellfish are highly prized commodities by European consumers. However, fish and seafood are highly perishable, which limits their commercialization and leads to waste due to their short shelf life.

The proposed project through its complimentary WPs will:

(a) take an integrated approach to develop low-carbon solutions to **prolong the shelf life of fish and seafood** and guarantee their quality and safety and **globally advance TRL from 2-7**;

(b) enhance cooperation and transfer of knowledge between sectors and disciplines and strengthen intersectorial collaboration. This will be possible through research-related and transferable skills training, which will increase the impact of research and innovation and be a vehicle to convert ideas into products and services.

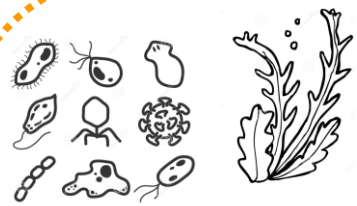
DIRECTIVE (EU) 2019/904 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 5 June 2019

on the reduction of the impact of certain plastic products on the environment

Incorporated into National Regulation (Greece) at October 2020 – 4736/20.10.2020

Work plan and activities of the project idea



WP4 sustainability will be assessed in to ensure carbon-neutrality dimension and just transition

Carbohydrates

Proteins

Fatty acids

Bio-based plastics

Edible films and coatings

>3 innovative packed fish and seafood prototypes with improved quality and extended shelf life

WP1 Selection of suitable marine bioresources (micro- and macro-algae)

WP2 Design and development of environmentally friendly packaging materials

WP3 Evaluation of the applicability of the packaging systems from WP2 on fish and seafood (shelf life modelling)

WP5 Dissemination and outreach activities
WP6 Project Management

Expected results/outcomes

The outcomes of the project will contribute to scientific and technological breakthroughs in the wide scientific area of fish and seafood and valorization of aquatic organisms:

- ✓ **Develop innovative and safe fish and seafood product prototypes** of high and desired sensory characteristics;
- ✓ **Extend the shelf life of fish and seafood**, which will strongly reduce energy usage, food waste and the related costs;
- ✓ **Valorize of low-trophic aquatic organisms** for the development of novel biobased packaging materials, tailor-made for preserving fish and seafood products;
- ✓ **Improve the sustainability of the fish and seafood** sector by extending the shelf life of these highly perishable products and so reduce waste;
- ✓ Build a critical mass to drive the development of **innovations for the end of the fish and seafood supply chain** by bringing together an interdisciplinary group of partners in areas of food science, food technology, biotechnology, biochemistry, molecular biology, engineering, bioprocessing, microbiology, aquaculture and fish and seafood technology, to maintain the European competitiveness.

Contribution to the all 5 goals of the European Bioeconomy strategy: food security, managing natural resources sustainably; reducing dependence on non-renewable resources, mitigating and adapting to climate change and creating jobs, particularly in coastal areas.

Relevance to the following priority actions from the EUSAIR ACTION PLAN for Pillar:

Topic 1.2. Fisheries and aquaculture

The proposed project will contribute to:

1) the **European demands** for the production of **safe fish and seafood of high quality**,
2) the **protection of consumer** health by establishing microbiological and toxicity risk levels associated with fish and seafood packaging and storage,
3) the development and application of **packaging systems**, that improve quality and shelf life of the final product,
4) prolong the shelf life of fish and seafood and reduce waste and therefore contribute to **improve sustainability of fisheries and aquaculture**, and
5) establish the applicability of **bio-based, biodegradable and active packaging to fish and seafood** and stimulate the uptake of innovative solutions by industry
6) Raising awareness to the sustainable inclusion of **marine resources into national bioe**conomies.

Macro-regional impact

Added value will come from:

i) harnessing the **research progress** and **expertise** that each partner institution brings to the project,

ii) having **access to infrastructures** and **equipment** that partners have acquired to optimise their research progress,

iii) development of **solutions adjusted** and **applicable** to the differing realities in the partner countries,

iv) access to a **multidisciplinary consortium**, their combined expertise and their networks of collaborators and contacts with industry,

v) **training opportunities** that will be interdisciplinary and multi-cultural and will prepare a new generation of scientists ready to address basic and applied research question and challenges,

vi) elaboration of transverse solutions to contribute to **address pressing socio-economic** problems across the Adriatic region and the Mediterranean.

vii) The present project brings together for the first time **a unique combination of experts from the Adriatic region** to develop new and innovative solutions for fish and seafood packaging, quality preservation along the fish and seafood supply chain and shelf life extension to reduce food loss and waste while creating added value from marine biomass.

To what extent does the project comply with the Broad Criteria of EUSAIR?

1. Address priorities and well-substantiated needs expressed by countries, regions and stakeholders or Commission services and be widely supported

- ✓ According to the Action Plan concerning the EU strategy for the Adriatic and Ionian Region, aquaculture is a key sector in the blue economy of countries like Croatia and Greece. There is significant potential for **increasing capacity**, and thereby **reducing EU dependency on imports**, and for **decreasing the pressure on wild stocks**, provided this is done in a **sustainable** manner. This activity is one of the most promising in the seven coastal countries of the macro-region and can play a pivotal role in the entire area.
- ✓ The proposed project will introduce to the aquaculture and fisheries sectors novel bio-based packaging systems, by utilizing marine biomass, with the aim to preserve the quality and extend the shelf life of fish and seafood for efficient quality and shelf life management and waste reduction at all stages of the cold chain.

To what extent does the project comply with the Broad Criteria of EUSAIR?

2. Demonstrate a transnational, if not macro-regional, scope or impact

Designing and applying innovative packaging materials to optimize quality and shelf life of fish and seafood within the value chain will tackle major contemporary issues and especially:

will **contribute to better health and well-being** for the growing world population via the increase of essential resources (SDG 3);

considering locally available clean energy sources (SDG7) in production of the innovative packaging materials **contributes to the climate actions** (SDG13);

will build **resilient infrastructure** within the food sector, promote **inclusive and sustainable industrialization**, and **foster innovation** within the food industry (SDG 9);

will enable industry and consumers to follow more **responsible and sustainable production and consumption** patterns (SDG 12);

will **conserve and use sustainably the aquatic resources**, promote the **circular economy** of packaging and supporting the development of processes and systems that turn waste into resources (SDG 14)

To what extent does the project comply with the Broad Criteria of EUSAIR?

3. Be realistic and credible

The proposed project is a **relatively low risk project due to the TRL of the innovations and the expertise of the networ**k.

4. Build on existing initiatives and have reached a fair degree of maturity

Interdisciplinary group of partners with **extensive experience** in areas of food science, food packaging, biotechnology, biochemistry, molecular biology, engineering, bioprocessing, microbiology, aquaculture and fish and seafood technology.

5. Pay attention to cross-cutting aspects

The **Communication** strategy and outreach activities build on those already in place in the partner institutions and will promote awareness and understanding of the role of science and innovation in society.
Training and mobility actions foreseen, and the staff hired will strongly benefit the **Research and Innovation** capacity of all partners.

6. Be coherent and mutually supportive

According to the Action Plan concerning the EU strategy for the Adriatic and Ionian Region, aquaculture is a key sector in the blue economy of countries like Croatia and Greece. All partners apply a non-discriminatory policy and the project consortium is fully committed to supporting and furthering equal opportunities for researchers.

Compliance with the Guiding Principles/Priorities of the respective Pillar[20]

1.To promote research, innovation and business opportunities in blue economy sectors, by facilitating the brain circulation between research and business communities and increasing their networking and clustering capacity.

- Cross-cutting intersectorial and interdisciplinary knowledge exchange and training
- Exploitation activities and events → raise awareness of technical opportunities + promote networking and partnering between academic and industrial scientists
- Participation of women in specific actions and their internal policies

2. To adapt to sustainable seafood production and consumption, by developing common standards and approaches for strengthening these two sectors and providing a level playing field in the macro-region.

In the context of globalization, European countries are now facing complex and difficult challenges such as the sustainable supply of food and energy, climate change and environmental degradation, human health and aging populations. SeaSusPack can make an important contribution towards meeting these societal challenges and in supporting economic growth in Europe and worldwide by delivering new knowledge, products and services.

3. To improve sea basin governance, by enhancing administrative and institutional capacities in the area of maritime governance and services.

The Communication strategy and outreach activities build on those already in place in the partner institutions and will promote awareness and understanding of the role of science and innovation in society. Actions will be directed at industrial partners, academics in other related fields, teachers, students, policy makers and the general public.

Compliance with the Guiding Principles/Priorities of the respective Pillar[21]

Smart growth

This highly integrative project aims to disrupt the current status quo and **bridge the innovation gap**. It will convert ideas into products and services, contributing to a knowledge-based economy and society and enhance cooperation and transfer of knowledge between sectors and disciplines.

Sustainable growth

The proposed project aims to increase the availability of sustainable, high quality and safe fish and seafood and establish more diverse ways to process and market these products.

Inclusive growth (considering integrated growth in South East Europe)

- Research and innovation-related human resources and skills will be advanced through hands-on experimental processing trials to improve the safety and shelf life of fish and seafood in collaboration with producers and suppliers.
- Marine bioresources will be utilized and novel packaging materials will be developed and tested that are compliant with EU standards for food safety and quality and will give academic and non-academic stakeholders new business opportunities, greater understanding, training and insight into these priority areas.

Compliance with the Guiding Principles/Priorities of the respective Pillar[22]

1.2. Fisheries and aquaculture

EU compliance and common standards and practices:

A cross-cutting characteristic of the project will be **capacity building**, which will be organised and fitted to the specific target populations.

Diversification and profitability of fisheries and aquaculture:

SeaSusPack will propose approaches that will diversify product availability using novel, environmentally friendly packaging systems, that have the added benefits of safety and quality improvement and shelf life extension, but retaining the fresh characteristics of the products.

R&D platform for seafood:

The proposed project will develop novel, environmentally friendly packaging and transportation approaches for fish and seafood and active packaging technologies, resulting in waste reduction, improved productivity, enhanced safety and quality of the final products and better environmental sustainability of the sector.

Developing skills:

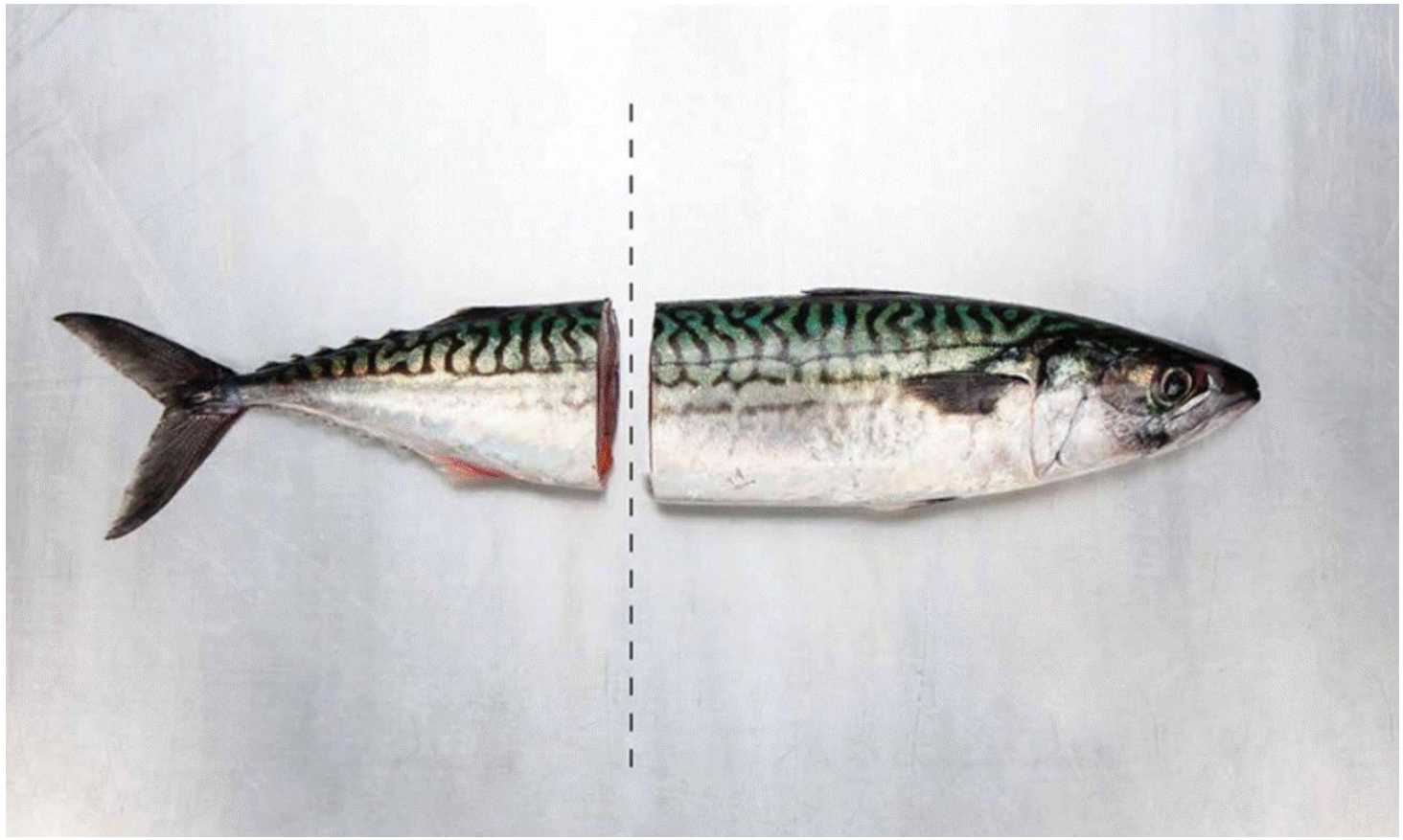
SeaSusPack will create an invaluable and exploitable link between the industry and academia.

Action - Marketing of seafood products:

SeaSusPack aims to promote the marketing aspects of the sector, by meeting the demanding quality requirements of high-end customers, while at the same time complying with the EU and national legislation about food contact material and labelling.

SeaSusPack “Take home message”

One third of all food is thrown away - ***Let’s cut down on food waste!***



SeaSusPack: Sustainable packaging of fish and seafood based on marine bioresources

Assistant Prof. Theofania Tsironi
(ftsironi@aua.gr)

Blue Growth EUSAIR
EU Strategy for the Adriatic and Ionian Region EUSAIR
Interreg ADRION ADRIATIC-IONIAN
European Regional Development Fund - Instrument for Pre-Accession II Fund
EUSAIR FACILITY POINT
EUROPEAN UNION

State of the art

In addition to the protection required for ensuring the safety and integrity of foods and beverages, current packaging technology aims to provide additional functionality.
Edible coatings or films are defined as a thin layer of material used for coating or wrapping different food systems to prevent quality deterioration and extend shelf life. There is a current trend to select appropriate materials for effective packaging of foods targeting oxygen scavenging, moisture absorption, carbon dioxide emission and antimicrobial coatings to control the growth of pathogens and spoilage microorganisms. Apart from microbial growth control, the protection from physicochemical reactions that lead to quality deterioration are also relevant.
The application of “soft hurdles” may reduce the rate of fish and seafood deterioration and spoilage caused by microbial growth. A promising trend in the last years involves the incorporation of eco-friendly biomolecules into packaging materials and into edible films and coatings for the development of added-value functional food products promoting consumers' health.

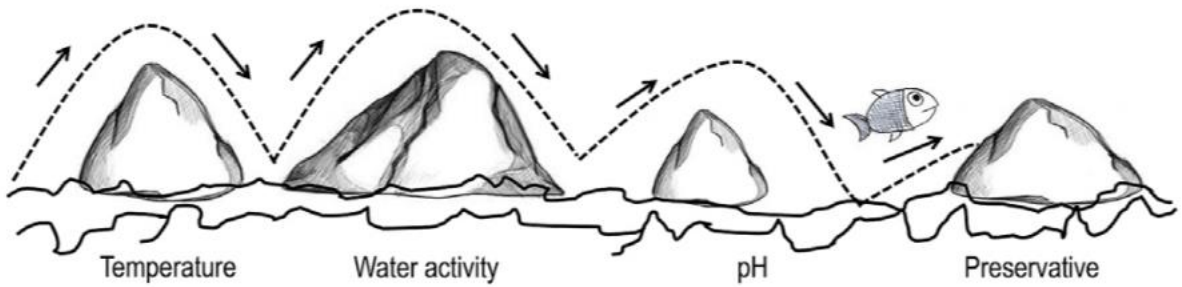


Fig. 1. An example of the hurdle effect in fish preservation.

Tsironi T., Houhoula D., Taoukis P. (2020). Hurdle technology for fish preservation. Aquaculture and Fisheries, 5(2), 65-71.

State of the art

Marine biomass contains significant quantities of polysaccharides, proteins and minerals. During the past years, there has been significant interest in natural products obtained from marine organisms, which may provide valuable components while at the same time promote a state of health and well-being in humans. Both macro- and microalgae are rich primary sources of bioactive compounds and could be used as functional ingredients such as; carotenoids, phycobilins, fatty acids, polysaccharides, peptides, vitamins and sterols.

Marine organisms offer an attractive platform for compounds of several functionalities, because of their rapid growth rate, cost effective culturing, genetic manipulability, and ease of scale-up. Significant research focuses currently on understanding the cellular processes of marine organisms, such as microalgae, for production of different compounds with applications on pharmaceuticals, cosmetics, nutrition or biofuel.

However, marine sources have not been considered extensively as potential source for the production of food packaging materials.

Patelou M., Infante C., Dardelle F., Randewig D., Kouri E.D., Udvardi M.K., Tsiplakou E., Mantecón L., Flemetakis E. (2020) Transcriptomic and metabolomic adaptation of Nannochloropsis gaditana grown under different light regimes, Algal Research, Volume 45, 101735.

State of the art

- ✓ Algae may be a promising source for deriving monomers to be used in plastic production.

- ✓ Several species of marine (micro-) organisms synthesize copious amounts of polysaccharides, which can have interesting biological activities and potential commercial applications as gelling agents, thickeners, stabilizers, and emulsifiers.
- ✓ Many commercially used polysaccharides such as agar, alginates and carrageenans are extracted from macroalgae, however their productio is still not economically feasible and complicated.
- ✓ Microalgae are promising sources of polysaccharides with industrial and commercial applications, producing exo-polysaccharide.

Work plan and activities of the project idea

WP1 will focus on the selection of suitable marine bioresources (micro- and macro-algae) with the aim to obtain appropriate raw materials (carbohydrates, proteins, fatty acids etc.) for the production of biodegradable food packaging systems.

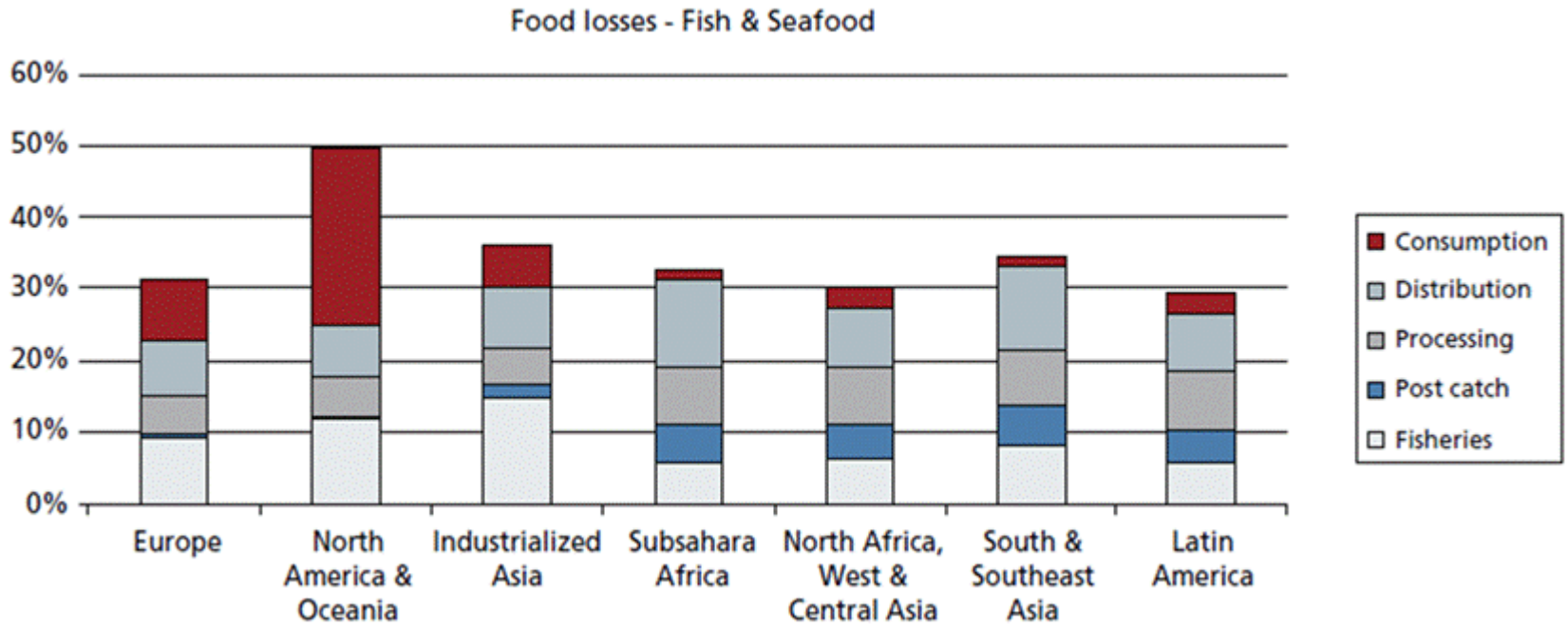
WP2 aims to the design and development of environmentally friendly (a) bio-based plastics and (b) edible packaging materials by using the raw materials obtained from WP1. The mechanical properties, biodegradability and toxicity of the novel packaging materials will be evaluated using appropriate analytical methods.

The applicability of the developed packaging systems will be evaluated within **WP3** by the design and implementation of systematic shelf life tests and mathematical modelling of the quality deterioration of packed fish and seafood under realistic transportation and storage conditions. The incorporation of appropriate natural antimicrobial and/or antioxidant compounds into the developed packaging systems will be also investigated (active packaging).

The sustainability in the broader context as defined in the European Green Deal of the developed packaging systems will be assessed in **WP4 to** ensure carbon-neutrality dimension and just transition.
Two WPs will focus on the dissemination and outreach activities (**WP5**) and project management (**WP6**).

Expected results/outcomes

- ✓ Significant amounts of fish and seafood are wasted worldwide due to spoilage and degradation during icing, packaging, storage and transportation after landing (ranging from ≈30% of the initial catching in Latin America, Africa and Europe to 50% for North America and Oceania, according to FAO).
- ✓ Waste at the end of the food supply chain is also substantial in all three regions, with 15-30% of purchases by mass discarded by consumers.



References needed by the partnership

Selected projects

- ICHTHYS: OptImization of novel value CHains for fish and seafood by developing an integraTed sustainable approacH for improved qualitY, safety and waSte reduction (MSCA-RISE-2019, 2020-2024)
- FRUALGAE: Sustainable technologies and methodologies to improve quality and extend product shelf life in the Mediterranean agro-food supply chain (PRIMA 2, 2020-2023)
- H2020-PEOPLE-2015-RISE project “Development of Microalgae-based novel high added-value products for the Cosmetic and Aquaculture industry – AlgaeA-B”. RISE-2015-GA-691102 2016-2019.
- FP7 ‘Development of phage therapy in aquaculture’. Marie-Curie International Research Staff Exchange Scheme (IRSES)
- FP7-PEOPLE-2011-IAPP project “Exploitation of microalgae diversity for the development of novel high added-value cosmeceuticals-AlgaeCom” PIAPP-GA-2011-286354. 2011-2014.
- Greek National project GSRT "Exproitation of indigenous microalgae species as a source of novel cosmeceuticals", Acronym: PHYCOSMETIC (2019-2022).
- Horizon 2020, "Sustainability transition assessment and research of bio-based products", Acronym: STAR-ProBio (2017-2020).
- Petrobras (Brazil) – Industrial funding, "Production of hydrolase enzymes and bifunctional monomers (1,3-PDO, 2,3-BDO and fumaric acid) in order to produce petrochemicals" (2013-2018).
- FP7, “New tailor-made biopolymers produced from lignocellulosic sugars waste for highly demanding fire-resistant applications”, Acronym: BRIGIT (2012-2016).

References needed by the partnership

Selected projects

- The role of bioenergy in World Below 2 degrees/SDG world, Intertask IEA Bioenergy, on-going, bioeconomy/bioenergy expert
- Forecast report on roles of biomass supply in the post COVID19 economy, IEA Bioenergy Task 43, on-going, lead bioeconomy expert
- Identification of areas and technologies for short rotation coppice, commissioned by Vukovarsko-srijemska country, on-going, bioeconomy expert
- Concerted biofuels policy via fuzzy AHP, commissioned by IEA Bioenergy Task 43, lead scientist, 2018-2020
- Zero Emission Scenario for Croatia, Commissioned by Ministry of Energy and Environmental Protection, 2020. Biomass/bioeconomy expert
- Analysis of actual land availability in the EU; trends in changes (abandoned land, low fertility land, saline land etc.) and options for energy crop utilisation, commissioned by DG ENER (2019-2020), agroeconomist
- BIOEASTsUP: Advancing Sustainable Circular Bioeconomy in Central and Eastern European countries (Grant agreement ID: 862699) 2019-2022, HR lead
- BioEast Initiative: thematic working group for Bioenergy and new value added products: from 2019, lead
- National Energy and Climate Action Plan – draft for Croatia: 2019, biomass/bioeconomy expert
- Croatian Energy Strategy – Green Book, White Book, Strategy: 2018-2019. Biomass/bioeconomy expert
- CELEBIO - CENTRAL EUROPEAN LEADERS OF BIOECONOMY NETWORK, BBI JU (2019), lead expert
- Thematic Working Group on Food and Bioeconomy Strategy for the Republic of Croatia (2018 -), World Bank, bioenergy expert

References needed by the partnership

Selected projects

- Farm Circle: Young Farmers Circrles of Circular Economy: DSPF project 09_ECVII_PA08 (01.01.-31.12.2018) – providing training materials and trainings for agriculture advisory service to raise awareness of farmers on opportunities in bioeconomy; project coordinator
- COST Action CA17128 LignoCost " Establishment of a Pan-European Network on the Sustainable Valorization of Lignin" (4/10/2018 – 3/10/2022), agroeconomist
- IEA Bioenergy Intertask project Measuring, governing and gaining support for sustainable bioenergy supply chains: Objective 3 Case Study BioÉnergie La Tuque: First Canadian forest residues-based refinery – assessing stakeholders' perspective and expectations on the future biorefinery (2016 – 2017)
- Horizon 2020 BiogasAction: Promotion of sustainable biogas production in EU, (2016-2018) – biogas expert, consortium partner, national lead
- Support to the Ethiopian Energy Authority Energy Efficiency and Conservation, Commissioned by Ethiopia Energy Efficiency (2016); bioenergy expert
- RES and EE potentials for Croatia and region (Slovenia, Serbia, B&H, Montenegro, Macedonia, Albania and Kosovo) (2016), commissioned by a private party, bioenergy expert
- Degradation of lignocellulosic complex for improvement of biogas plant economic feasibility – proof of concept, Commissioned by HAMAG BICRO (2016-2017), team leader
- Bioenergy and Food Security Rapid Appraisal Training Centre, Commissioned by FAO (2016 -ongoing), Africa, Middle and Near East – Agroeconomist

Work plan and activities of the project idea

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Expected results/outcomes

By bridging the innovation gap, the proposed project will positively contribute to the competitiveness of SMEs and large enterprises in the Adriatic and Mediterranean, EU and global fish and seafood industry by providing them with novel solutions that will significantly and simultaneously impact:

(a) **innovation**, by moving novel technology into the market,
(b) **environmental issues**, ensuring solutions are sustainable,
(c) **competitiveness**, lowering the barrier for companies to start up or diversify in this sector, and
(d) **social**, encouraging scientists and entrepreneurs to participate in the sector.

At least 3 packed fish and shellfish low-carbon prototypes will be developed with improved quality and extended shelf life, compared to the conventional packaging materials.

Relevance to the following priority actions from the EUSAIR ACTION PLAN for Pillar:

Topic 1.2. Fisheries and aquaculture

- ✓ Growth in the World's population is expected to surpass 9 billion by 2050 and a major challenge is food security.
- ✓ Food production needs to be resource efficient and contribute to economic growth through sustainable use of natural capital.
- ✓ Aquaculture and fishery sectors can complement terrestrial production systems as a source of excellent quality protein with the added benefit of a rich supply of healthy ω-3 fatty acids, vitamin D, iodine, selenium and other micronutrients.
- ✓ The economic growth potential of the sector worldwide is high, and it has a positive social impact in coastal areas that traditionally have a weak commercial base.

However, the sector in Europe is struggling with sustainability issues and although a diversity of measures and policies have been implemented both Nationally and at a European level including projects (both European and national) directed at improving aquaculture sustainability (eg. ARRAINA, TARGETFISH, FISHBOOST, LIFECYCLE, FindIT, PERFORMFish) they have mainly been directed at improving production.

Surprisingly little attention has been paid to improving sustainability by reducing waste post-harvest and extend the shelf life of this highly perishable food source.

Macro-regional impact

- ✓ The countries of the Mediterranean and the Adriatic region face similar challenges in relation to reducing food loss and waste.
- ✓ Funding of Country specific projects is limited in their scope and reach by budget and lack of critical mass.
- ✓ The dimension of the food waste paradigm in the Mediterranean (and globally) is a grand challenge that needs a disruptive and creative approach and a large critical mass of partners.
- ✓ Cooperative research building on the complimentary expertise of partners will contribute to solve specific problems at diverse points of the fisheries and aquaculture sector and will build-in and be sensitive to specific geographic constraints.
- ✓ The benefits for society and (South-East) Europe at large are considerable since the project will contribute to societal challenges, such as health and nutrition, active ageing and well-being, blue growth, Europe's integrated food safety policy and bridging the innovation gap.
- ✓ Moreover, there is an important potential for job creation and socio-economic benefits, as the results will need further development (especially the development and use of active packaging and new, environmentally friendly materials, for other perishable products where microbial contamination and indication of freshness is critical), but have the potential to improve "blue growth" at a level of primary production or high-end innovative products.

To what extent does the project comply with the Broad Criteria of EUSAIR?

3. Be realistic and credible

The proposed project is a **relatively low risk project due to the TRL of the innovations and the expertise of the networ**k. A limited number of risks will be identified and the consortium will address appropriate barriers and provide systematic solutions to change the framework conditions to overcome them (risk management in WP6).

To what extent does the project comply with the Broad Criteria of EUSAIR?

4. Build on existing initiatives and have reached a fair degree of maturity

- ✓ The proposed project will develop innovations for the end of the fish and seafood supply chain by bringing together an interdisciplinary group of partners with extensive experience in areas of food science, food technology, biotechnology, biochemistry, molecular biology, engineering, bioprocessing, microbiology, aquaculture and fish and seafood technology.
- ✓ The design and development of novel, biodegradable materials to enhance sustainability in the food production sector within the scopes of circular economy has received attention during the past years by the SeaSusPack research team.
- ✓ The research team has extensive experience in the development and application of novel food processing and packaging methods, targeting mainly aquatic organisms, and evaluating the interaction between food and packaging materials. Active and biodegradable food packaging systems have been developed and their applicability has been evaluated through systematic shelf life studies. The development of novel biotechnology tools for the utilization of marine organisms (including micro- and macroalgae) for the reinforcement of blue bioeconomy is a major research task of the AUA team.

To what extent does the project comply with the Broad Criteria of EUSAIR?

4. Build on existing initiatives and have reached a fair degree of maturity

Selected publications

Morone et al. (2019). Food waste: Challenges and opportunities for enhancing the emerging bio-economy, Journal of Cleaner Production, 221, 10-16.

Ioannidou et al. (2020). Sustainable production of bio-based chemicals and polymers via integrated biomass refining and bioprocessing in a circular bioeconomy context. Bioresource Technology, 307, 123093.

Tsironi et al. (2009). Shelf life modelling of frozen shrimp at variable temperature conditions. LWT- Food Science and Technology, 42, 664-671.

Tsironi et al (2020). Hurdle technology for fish preservation. Aquaculture and Fisheries, 5(2), 65-71.

Tsironi et al. (2019). High pressure processing of European sea bass (Dicentrarchus labrax) fillets and tools for flesh quality and shelf life monitoring. Journal of Food Engineering, 262, 83-91.

Tsironi T., Taoukis P. (2018). Current practice and innovations in fish packaging. Journal of Aquatic Food Product Technology, 27, 1024-1047.

Tsironi et al. (2017). Developing suitable smart TTI labels to match specific monitoring requirements: The case of Vibrio spp. growth during transportation of oysters. Food Control, 73, 51-56.

Choulitoudi et al. (2016) Antimicrobial and antioxidant activity of Satureja thymbra in gilthead seabream fillets. Food and Bioproducts Processing, 100, 570-577.

Choulitoudi et al. (2017). Edible coating enriched with rosemary extracts to enhance oxidative and microbial stability of smoked eel fillets. Food Packaging and Shelf Life, 12, 107-113.

Chatzikonstantinou et al. (2017). Comparative analyses and evaluation of the cosmeceutical potential of selected Chlorella strains. Journal of Applied Phycology, 29, 179–188.

To what extent does the project comply with the Broad Criteria of EUSAIR?

5. Pay attention to cross-cutting aspects

- ✓ The **Communication** strategy and outreach activities build on those already in place in the partner institutions and will promote awareness and understanding of the role of science and innovation in society. Actions will be directed at industrial partners, academics in other related fields, teachers, students, policy makers and the general public. According to the target group the message and means of communication will be adapted to be most effective (WP5).
- ✓ The multidisciplinary and complimentary expertise in the consortium will create a unique collaborative network that will facilitate and promote transfer knowledge between partners and between the project and stakeholders. Training and mobility actions foreseen, and the staff hired will strongly benefit the **Research and Innovation** capacity of all partners. Partners will work directly with other Enterprises, including **SMEs** (with which strong links exist) to obtain appropriate information and feedback and assess feasibility for market (WP4 and WP5).

To what extent does the project comply with the Broad Criteria of EUSAIR?

6. Be coherent and mutually supportive

According to the Action Plan concerning the EU strategy for the Adriatic and Ionian Region, aquaculture is a key sector in the blue economy of countries like Croatia and Greece. The activities that are planned within the proposed project are the most promising in the seven coastal countries of the macro-region and can play a pivotal role in the entire area. The proposed project strategy is developed in 36 months and organized in 6 WPs. All partners apply a non-discriminatory policy and the project consortium is fully committed to supporting and furthering equal opportunities for researchers.

Compliance with the Guiding Principles/Priorities of the respective Pillar

The overall objective of Pillar 1 "Blue Growth" is about driving innovative maritime and marine growth in the Adriatic-Ionian Region by promoting sustainable economic growth and jobs as well as business opportunities in the blue economy sectors.

- ✓ The proposed project is designed, through the development and testing of novel packaging materials and systems, to improve the shelf life of fish and seafood and in this way reduce waste and improve sector sustainability and so **contribute to Blue Growth**.
- ✓ The deployment of a sustainable European bioeconomy would lead to the creation of jobs, particularly in coastal and rural areas through the growing participation of primary producers in their local bioeconomies.
- ✓ The strong and fast-growing startup ecosystem in the biotechnology sector will play a leading role in realising this potential.

Compliance with the Guiding Principles/Priorities of the respective Pillar

The specific objectives for this pillar are:

1. *To promote research, innovation and business opportunities in blue economy sectors, by facilitating the brain circulation between research and business communities and increasing their networking and clustering capacity.*

- ✓ The proposed project will provide cross-cutting intersectorial and interdisciplinary knowledge exchange and training to improve employability and career prospects both in and outside academia and contribute to the knowledge-based economy and society to boost regional and European competitiveness and growth, promote food security and exports to promote job creation.
- ✓ Exploitation activities and events (scientific publications, conference presentations, press release, newsletters, website, training workshop) will be used not only to raise awareness of technical opportunities, but also to promote networking and partnering between academic and industrial scientists in the consortium but also with groups outside the consortium to widen the project impact. As appropriate these may be organised as special sessions of conferences or trade shows to extend reach and dissemination of the project.
- ✓ All partners will promote the participation of women in SeaSusPack specific actions and their internal policies.

Compliance with the Guiding Principles/Priorities of the respective Pillar

The specific objectives for this pillar are:

2. To adapt to sustainable seafood production and consumption, by developing common standards and approaches for strengthening these two sectors and providing a level playing field in the macro-region.

- ✓ In the context of globalization, European countries are now facing complex and difficult challenges such as the sustainable supply of food and energy, climate change and environmental degradation, human health and aging populations. SeaSusPack can make an important contribution towards meeting these societal challenges and in supporting economic growth in Europe and worldwide by delivering new knowledge, products and services.
- ✓ Sustainability is not only a legal obligation, it is an opportunity for all parts of Europe and underpins most EU priorities. The EU is already a global leader in the sustainable use of natural resources within an efficient bioeconomy, which is essential to most of the Sustainable Development Goals. The SeaSusPack project aims to evaluate the socio-economic aspects and the decarbonization and environmental sustainability of the developed packaging systems, addressing the SDGs and the bioeconomy strategy for the EU.

Compliance with the Guiding Principles/Priorities of the respective Pillar

The specific objectives for this pillar are:

3. To improve sea basin governance, by enhancing administrative and institutional capacities in the area of maritime governance and services.

The Communication strategy and outreach activities build on those already in place in the partner institutions and will promote awareness and understanding of the role of science and innovation in society. Actions will be directed at industrial partners, academics in other related fields, teachers, students, policy makers and the general public. According to the target group the message and means of communication will be adapted to be most effective. The WP6 leader will engage the institutional communication office for the preparation and implementation of the project communication and dissemination plan. The results of SeaSusPack will impact on the public at large, as potential products to be developed on the basis of the proposed results are prepacked or processed seafood.

Compliance with the Guiding Principles/Priorities of the respective Pillar

This pillar strongly supports the Europe 2020 Strategy:

Smart growth

Horizon2020 is directed at improving the capability of firms to innovate, in particular SMEs. This highly integrative project aims to disrupt the current status quo and **bridge the innovation gap**. It will convert ideas into products and services, contributing to a knowledge-based economy and society and enhance cooperation and transfer of knowledge between sectors and disciplines.

Compliance with the Guiding Principles/Priorities of the respective Pillar

This pillar strongly supports the Europe 2020 Strategy.

Sustainable growth

The proposed project aims to increase the availability of sustainable, high quality and safe fish and seafood and establish more diverse ways to process and market these products. It will have a positive impact on sustainability and health, since it will contribute to improve the availability of and extend the shelf life of fish and seafood, which is an acknowledged source of good quality protein with the added benefits of a low saturated fat content but high ω-3 fatty acid content along with iodine and other micronutrients desirable for health.

Compliance with the Guiding Principles/Priorities of the respective Pillar[48]

This pillar strongly supports the Europe 2020 Strategy:

Inclusive growth (considering integrated growth in South East Europe)

- ✓ Research and innovation-related human resources and skills will be advanced through hands-on experimental processing trials to inactivate microorganisms to improve the safety and shelf life of fish and seafood in collaboration with producers and suppliers. At the same time, marine bioresources will be utilized and novel packaging materials will be developed and tested that are compliant with EU standards for food safety and quality and will give academic and non-academic stakeholders new business opportunities, greater understanding, training and insight into these priority areas.
- ✓ The transfer of knowledge between partners will occur through the exchange of scientist and staff reinforced through organization of training and networking activities focused on the key areas of the project and targeting all stake-holders.

Compliance with the Guiding Principles/Priorities of the respective Pillar[49]

1.2. Fisheries and aquaculture

Action - EU compliance and common standards and practices:

A cross-cutting characteristic of the project will be **capacity building**, which will be organised and fitted to the specific target populations. Capacity building is an integral component of the project and is organised in an audience-adapted manner and actions will be interlinking so that knowledge will be “created” within the project, “flow” between all partners and will be used to “feed” all stakeholder (producers, retailers, policy makers and public). Actions will include expert-to-expert skills and knowledge transfer; training of PhD and technicians for future sustainability; training actions and communications for fish and seafood chain operators (through workshops, webpage and through collaborations with existing training organizations); and the public (demonstrations, etc) (WP5).

1.2. Fisheries and aquaculture

Action - Diversification and profitability of fisheries and aquaculture:

SeaSusPack will propose approaches that will diversify product availability using novel, environmentally friendly packaging systems, that have the added benefits of potentially destroying pathogens and toxins, while prolonging the shelf life but retaining the fresh characteristics of the products. The technological advance will be demonstrated both in terms of product quality and also safety using careful experimental monitoring with classical techniques (including sensorial analysis) and modern molecular and cellular techniques. “Proof of concept” will be a fundamental starting point for the transfer of processing technology to European fish and seafood products and will support the EU’s blue growth strategy.

1.2. Fisheries and aquaculture

Action - R&D platform for seafood:

Fish and seafood is an important production sector in Europe particularly for coastal areas and has emerged as a low CO_2 impacting production system. However, the highly perishable character of fish and seafood makes measures to improve commodity lifetime and safety of high interest. The proposed project will develop novel, entvironmentally friendly packaging and transportation approaches for fish and seafood and active packaging technologies, resulting in waste reduction, improved productivity, enhanced safety and quality of the final products and better environmental sustainability of the sector. At the same time, the fish and seafood production sector will increase ability to respond to market needs and comply with the current regulation for the replacement of plastic packaging materials and elimination of the environmental impact.

1.2. Fisheries and aquaculture

Action - Developing skills:

SeaSusPack will create an invaluable and exploitable link between the industry and academia. The academic partners will have the opportunity to work in close collaboration and to form complementary and competitive team which will promote the knowledge and excellence of industrial partners by providing new skills. The project will provide the opportunity for industrial collaborators to initiate or expand RDI activities and to contribute to the advance in the technology readiness level (TRL) of the novel packing systems to be tested. Through joint scientific publications or publications for trade associations the technologies will be show-cased raising company profiles and linking them to innovations and their implementation. Academics will assist in the establishment of procedures in production and supply chains for microbial growth inhibition and high innovation companies will help the aquaculture sector implement innovations in packaging by identifying bottlenecks and critical points for their application in the product supply chain. This knowledge will provide further opportunities for the development of new products and services in the future and will foster research skills and capabilities.

1.2. Fisheries and aquaculture

Action - Marketing of seafood products:

According to the EC No 450/2009, packaging is termed active when it provides functions beyond the traditional protection and inert barrier to the external environment. The main difference between intelligent and active packaging is that active packaging senses modifications of the internal or external environment and responds accordingly and alters its properties. Based on EC/450/2009, intelligent materials are defined as tools that monitor the status of the packed food or its surrounding environment. Additionally, EC 904/2019 refers to the strategies for reduction of the impact of certain plastic products on the environment.

SeaSusPack aims to promote the marketing aspects of the sector, by meeting the demanding quality requirements of high-end customers, while at the same time complying with the EU and national legislation about food contact material and labelling.

Shelf life extension of fish and seafood products can open new distant markets (Far East, America) currently inaccessible to fresh products providing a significant commercial opportunity to exploit the production capacity of European marine culture that currently exceeds demand (due to competition from low cost import species) often leading to waste and below cost selling.