



Deliverable title	D1.7 2nd year (progress) Report
Deliverable Lead:	UNIVPM
Related Work Package:	WP1 - Project coordination and overall management
Related Task:	Task 1.3. Communication with PRIMA call secretariat and the funding Agencies
Author(s)	Lucia Aquilanti
Dissemination level	PU
Due Submission Date:	30.06.2024
Actual submission:	30.06.2024
Start date of project	30.05.2022
Duration	36 months
Summary of Deliverable D1.7 – Second Year Progress Report	Over the past 12 months, partners have consolidated their research, expanded field trials, and brought food prototypes closer to real-world application, while continuing to engage stakeholders and the public. On the scientific side, wild sea fennel populations have now been fully sampled and stored in seed banks, with morphological and chemical characterization nearly complete. Genetic analyses are underway using standardized protocols to ensure comparable results across countries. In the fields, organic cultivation trials in Italy, Croatia, and Türkiye have yielded the first harvests, demonstrating the resilience of sea fennel despite harsh climatic conditions such as drought and heatwaves. Although Tunisia faced setbacks due to extreme weather, replanting is already planned. Biostimulants have also shown promise in improving root development and plant health, opening new opportunities for sustainable cultivation practices. Innovation in food product development has flourished. Partners have created and tested a wide range of prototypes, from fermented kimchi-like preserves and pickled fennel to dried spices, harissa, jams, flavored oils, handmade pasta, and even experimental beers. Laboratory analyses of taste, texture, aroma, and shelf life are ongoing, ensuring that these products are safe, appealing, and scalable. Complementing this, by-products are being valorized in exciting ways: extracts and essential oils with antioxidant and antimicrobial properties have been produced and tested in foods, nutraceuticals, and even confectionery. Initial trials also highlight their potential role in animal feed and functional supplements. Beyond technology and food science, the social and environmental dimensions of the project are advancing. A Delphi survey involving over 70 experts across the Mediterranean provided key insights into drivers and barriers for sea fennel adoption. At the same time, preliminary Life Cycle

	Assessment results show that open-field organic sea fennel cultivation has a relatively low environmental impact, with plastic mulching identified as a critical area for improvement. The project has also made strides in communication and outreach, with videos, school involvement, participation in fairs and exhibitions, and several open-access scientific publications. These efforts ensure that both scientific communities and the wider public are informed and engaged.
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Versioning and Contribution History

Version	Date	Modified by	Modification reason.
v1.0	30/06/2024	Lucia Aquilanti	First version

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1. List of participants

Participant No *	PI name	Organisation	Country
1 (Coordinator)	Lucia Aquilanti	UNIVERSITÀ POLITECNICA DELLE MARCHE (acronym: UNIVPM)	Italy
2	Antonio Raffo	CONSIGLIO PER LA RICERCA IN AGRICOLTURA E L'ANALISI DELL'ECONOMIA AGRARIA -CENTRO DI RICERCA ALIMENTI E NUTRIZIONE (acronym: CREA-AN)	Italy
3	Luca Galeazzi	RINCI Srl (acronym: RINCI)	Italy
4	Ivana Generalić Mekinić	UNIVERSITY OF SPLIT (acronym: UNIST)	Croatia
5	Branimir Urlić	INSTITUTE FOR ADRIATIC CROPS AND KARST RECLAMATION (acronym: IACKR)	Croatia
6	Christian Magné	UNIVERSITÉ DE BRETAGNE OCCIDENTALE (acronym: UNIBRE)	France
7	Abdelhamid Khaldi	INSTITUT NATIONAL DE RECHERCHE EN GÉNIE RURAL, EAUX ET FORÊTS (acronym: INRGREF)	Tunisia
8	Özlem Karahan Uysal	UNIVERSITY OF EGE (acronym: UNIEGE)	Türkiye

2. Explanation of the work carried out by the beneficiaries and overview of the progresses achieved in the monitoring period (from 30.05.2023 to 30.05.2024)

WP1 Project coordination and overall management

OBJECTIVES

The objective of WP1 was to ensure optimal co-ordination and management of SEAFENNEL4MED, as well as collaboration among Partners, with the final aim of maximising progress of knowledge and innovation outputs.

TASKS AND STATUS IN THE REPORTING PERIOD

Task 1.1. Organization of general Project meetings **ON-GOING**

Task 1.2. Project coordination, management, supervision, and quality control **ON-GOING**

Task 1.3. Communication with PRIMA call secretariat and the funding Agencies **ON-GOING**

Task 1.4. Preparation of mid-term and final reports **ON-GOING**

	Deliverable	Status	Comment
WP 1	D1.1 General Project meeting n.1 (Kick off meeting) Report	Delivered	
	D1.2 Quality Assurance Plan	Delivered	
	D1.3 General Project meeting n.2 Report	Delivered	
	D1.4 1st year (progress) Report	Delivered	
	D1.5 General Project meeting n.3 Report	Delivered	
	D1.6 General Project meeting n.4 Report	Delivered	
	D1.7 2 nd year (progress) Report	In progress	
	D1.8 General Project meeting n.5 Report	Not started	
	D1.9 General Project meeting n.6 (Final workshop)	Not started	
	D1.10 3 rd year (final) Report	Not started	

BRIEF DESCRIPTION OF WORK DONE IN THE REPORTING PERIOD

- The Coordinator organized and scheduled the project general meetings:
 - Meeting N3 was held on 22nd November 2023 at 10:00 AM (Rome time), where the Principal Investigators (PIs) and Research Team Members of the SEAFENNEL4MED Consortium met at CREA - Centro di Ricerca Alimenti e Nutrizione (CREA-AN), located at Via Ardeatina 546, 00178 Rome, Italy.
 - Meeting N4 took place on 24th May 2024 at 9:30 AM (Rome time), at UNIEGE, Faculty of Agriculture, 35100, Bornova-Izmir, Turkey.
- The Coordinator reviewed the **periodic reports** prepared by the WP leaders to verify their consistency with the project tasks, in view of their assembling and transmitting to PRIMA-IS and the funding agencies on behalf of the Consortium.

WP2 Multi-actor internal and external communication and technology transfer

OBJECTIVES

Work Package 2 (WP2) of the SEAFENNEL4MED project focuses on stakeholder engagement, as well as the dissemination and exploitation of project outputs. The objectives are divided into internal and external communication efforts. Internally, the goal is to ensure timely sharing of results among consortium partners and to coordinate participatory research prioritization. Externally, WP2 aims to engage stakeholders using participatory methods to guide dissemination, build a knowledge exchange network, support technology transfer, and develop a roadmap for broader application of project results. These activities are designed to meet the needs of Mediterranean small farms and food industries and to enable implementation by various stakeholders including farmers, food producers, entrepreneurs, industry players, associations, NGOs, policymakers, and the general public.

TASKS AND STATUS IN THE REPORTING PERIOD

Tasks:

Task 2.1 Start-up activities **ON-GOING**

Task 2.2 Establishment of a stakeholder-platform and knowledge exchange network **ON-GOING**

Task 2.3 Installation and continuous up-date of SEAFENNEL4MED website **ON-GOING**

Task 2.4 Production of dissemination materials **ON-GOING**

Task 2.5 Documentation of scientific results **ON-GOING**

Task 2.6 Demonstration activities **NOT STARTED**

DELIVERABLES DELIVERED IN THE REPORTING PERIOD

	Deliverable	Status	Comment
WP 2	D2.1 Project logo and communication templates	Delivered	
	D2.2 Public SEAFENNEL4MED website	Delivered	
	D2.3 SEAFENNEL4MED intranet	Delivered	
	D2.4 Press release at Project launch for the wide public	Delivered	
	D2.5 Establishment of a stakeholder platform for knowledge exchange network	Delivered	
	D2.6 SEAFENNEL4MED Data Management Plan	Delivered	
	D2.7 Demonstration activity 1: sea fennel harvesting campaign involving students	Delivered	
	D2.8 Demonstration activity 2: presentation of sea fennel-based recipe book	In progress	
	D2.9 Collection of 12 newsletters	In progress	
	D2.10 At least 2 articles in divulgative journals/magazines	In progress	
	D2.11 At least 4 open access papers published in international peer-reviewed journals	In progress	
	D2.12 At least 4 conference proceedings	In progress	
	D2.13 At least 1 downloadable Project leaflet	In progress	
	D2.14 At least 1 video on new sustainable organic sea fennel cropping systems and applications of the new crops for production of food/food ingredients/nutraceuticals	Delivered	
	D2.15 Press release at Final Workshop	Not started	
	D2.16 Attendance at almost 1 event/exhibition aimed at promoting Mediterranean agri-food products	Delivered	

BRIEF DESCRIPTION OF WORK DONE IN THE REPORTING PERIOD

- A harvesting campaign took place on June 9, 2023, involving students from the Master's program in "Food and Beverages: Innovation and Management" at UNIVPM, as well as students from secondary schools. The campaign was conducted in Rinci's sea fennel fields.
- A video titled "Come si raccoglie il finocchio marino coltivato" (see the image below) was also recorded during the demonstrative harvesting campaign. During the event, the food technologist and agronomist from Rinci explained to the

students how to cultivate, harvest, and use this high-value crop in various food applications. The video is freely available on the project website at <https://seafennel4med.com/video/>

- 5 new papers have been published in open access journals

OPEN ACCESS PUBLICATION IN INTERNATIONAL PEER-REVIEWED JOURNALS	D2.11	An original research paper reporting the exploitation of sea fennel for production of dried spices using different drying methods. Title: Impact of Different Drying Methods on the Microbiota, Volatile, Color, and Sensory Traits of Sea Fennel (<i>Crithmum maritimum</i> L.) Leaves Authors: Macloni, A.; Cardinali, F.; Milanović, V.; Reale, A.; Boscaino, F.; Di Renzo, T.; Ferrocino, I.; Rampanti, G.; Garofalo, C.; Osimani, A.; et al. <i>Molecules</i> 2023 , 28, 7207. https://doi.org/10.3390/molecules28207207	International peer-reviewed Journal: <i>Molecules</i> , MDPI Special Issue "Halophytes: Nutrients, Bioactive Compounds, Chemical Characterisation and Potential Applications"
OPEN-ACCESS PUBLICATION IN INTERNATIONAL PEER-REVIEWED JOURNALS	D2.11	Title: Chemical Profiling of Sea Fennel (<i>Crithmum maritimum</i> L., Apiaceae) Essential Oils and Their Isolation Residual Waste-Waters Authors: Politeo O., Popović M., Veršić Bratinčević M., Kovačević K., Urlić B., Generalić Mekinić I. Journal: <i>Plants</i> 2023 , 12(1), 214. https://doi.org/10.3390/plants12010214	International peer-reviewed Journal: <i>Plants</i> , MDPI
OPEN-ACCESS PUBLICATION IN INTERNATIONAL PEER-REVIEWED JOURNALS	D2.11	Title: Conventional vs. Microwave-Assisted Hydrodistillation: Influence on the Chemistry of Sea Fennel Essential Oil and Its By-Products Authors: Politeo O., Popović M., Veršić Bratinčević M., Koceić P., Ninčević Runjić T., Generalić Mekinić I. Journal: <i>Plants</i> 2023 , 12(7), 1466. https://doi.org/10.3390/plants12071466	International peer-reviewed Journal: <i>Plants</i> , MDPI
OPEN-ACCESS PUBLICATION IN INTERNATIONAL PEER-REVIEWED JOURNALS	D2.11	Title: Comparison of Conventional and Green Extraction Techniques for the Isolation of Phenolic Antioxidants from Sea Fennel. Authors: Veršić Bratinčević M., Kovačić R., Popović M., Radman S., Generalić Mekinić I. Journal: <i>Processes</i> 2023 , 11, 2172. https://doi.org/10.3390/pr11072172	International peer-reviewed Journal: <i>Processes</i> , MDPI
OPEN-ACCESS PUBLICATION IN INTERNATIONAL PEER-REVIEWED JOURNALS	D2.11	Title: Vinegar-Preserved Sea Fennel: Chemistry, Color, Texture, Aroma, and Taste Authors: Radman, S., Brzović, P., Radunić, M., Rako, A., Šarolić, M., Ninčević Runjić, T., Urlić, B., Generalić Mekinić, I. Journal: <i>Foods</i> , 12 (2023) 3812, 13. https://doi.org/10.3390/foods12203812	International peer-reviewed Journal: <i>Foods</i> , MDPI

- 5 conference proceedings have been published thanks to the attendance of the Consortium partners at International/national conferences/congresses.

CONTRIBUTION AT NATIONAL/INTERNATIONAL CONFERENCES	D2.12	Title: Characterization of the aroma of essential oils from sea fennel (<i>Crithmum maritimum</i> L.) leaves and crop by-products. Author: Raffo A., Baiamonte I., Nardo N., Melini V., Nartea A., Pacetti D., Aquilanti L. Oral presentation https://www.wartburg-symposium.de/	International Conference: 13th Wartburg Symposium on Flavor Chemistry & Biology, Eisenach, Germany Eisenach, 03-06/10/2023
CONTRIBUTION AT NATIONAL/INTERNATIONAL CONFERENCES	D2.12	Title: Halophytes- Crops of the future Authors: Slišković L., Ninčević Runjić T., Dumičić G., Runjić M., Politeo O., Urlić, B., Generalić Mekinić I. A poster presentation on the most widespread halophyte species (among which special attention was paid to <i>Crithmum maritimum</i>) growing along the Adriatic coast, their main characteristics, their potential for use in different sectors and their importance for the environment (professional paper planned).	4th International ZORH conference of scientists, professionals and students, 20th-21th of April 2023, Split, Croatia
CONTRIBUTION AT NATIONAL/INTERNATIONAL CONFERENCES	D2.12	Title: <i>Inula crithmoides</i> and <i>Crithmum maritimum</i> – GC-MS analyses of essential oils and hydrolates Authors: Politeo, O., Bakarić, A., Curlić, P., Popović, M. Poster presentation	International Conference: ISEO 2023, 53rd International Symposium on Essential Oils, September 13-16, 2023, Milazzo, Messina, Italy
CONTRIBUTION AT NATIONAL/INTERNATIONAL CONFERENCES	D2.12	Title: Phenolic antioxidants from Adriatic sea fennel wild-grown populations Authors: Skroza, D., Generalić Mekinić, I., Podrug, R., Prga, I., Šantić, I., Veršić Bratinčević, M., Popović, M., Urlić, B., Ninčević Runjić, T., Runjić, M., Dumičić, G., Šimat, V., Brzović, P. Poster presentation	International Conference: 14th International Scientific and Professional Conference WITH FOOD TO HEALTH, 14 – 15 September 2023, Osijek, Croatia
CONTRIBUTION AT NATIONAL/INTERNATIONAL CONFERENCES	D2.12	Title: Influence of harvest location on phenolic composition and antioxidant activity of sea fennel Authors: Mimica N., Generalić Mekinić I., Skroza D., Brzović P. Poster presentation	International Conference: 14th International Scientific and Professional Conference WITH FOOD TO HEALTH, 14 – 15 September 2023, Osijek, Croatia

- 2 new participations at event/exhibition aimed at promoting Mediterranean agri-food products where the supply and demand can encounter each other and the researchers.

ATTENDED EVENT/EXHIBITION	D2.16	Participation in "Festival održivosti 2023" (Sustainability Fair) by Generalić Mekinić I., Šimat V. and Skroza D. - Festival of the promotion of different food products- Project promotion, sea fennel products promotion (Pictures in ANNEX)	Festival održivosti, September 13-19th 2023, Kopačevo, Osijek, Croatia
ATTENDED EVENT/EXHIBITION	D2.16	Participation at 2023 European Researchers Night by Urlić B., Runjić M., Ninčević Runjić T., Generalić Mekinić I., Radman S., Popović M., Veršić Bratinčević M. - Project promotion, sea fennel products promotion (Pictures, flags and bookmarks in ANNEX)	2023 European Researchers' Night , September 29th, 2023, Split, Croatia

WP3 Characterization of Mediterranean sea fennel ecotypes

OBJECTIVES

The objective of WP3 is the characterization of Mediterranean sea fennel populations based on qualitative and quantitative morphological, chemical, and genetic traits, identification and further selection of different ecotypes based on traits of interest for the project purposes.

TASKS AND STATUS IN THE REPORTING PERIOD

Task 3.1 (RES). Sampling and morphological characterization of spontaneously growing sea fennel populations **ON-GOING**

Task 3.2 (RES). Chemical analysis of dried sea fennel aerial parts/seeds **ON-GOING**

Task 3.3 (RES). Molecular analysis of sea fennel aerial parts **ON-GOING**

Task 3.4 (RES). Elaboration of morphological, chemical, and genetic data for potential identification of different ecotypes **NOT STARTED**

DELIVERABLES DELIVERED IN THE REPORTING PERIOD

	Deliverable	Status	Comment
WP 3	D3.1 Dried sea fennel biomass (leaves, stems, flowers) from at least 5 Mediterranean spontaneous sea fennel populations	Delivered	
	D3.2 Catalogued and stored seeds (> 2500) from at least 5 Mediterranean sea fennel populations	Delivered	
	D3.3 Selected Mediterranean sea fennel germplasm (at least 1 ecotype) for cultivation	Delivered	
	D3.4 Report with elaborated data overall collected within WP3	Delayed	Waiting for NGS sequencing results

BRIEF DESCRIPTION OF WORK DONE IN THE REPORTING PERIOD

Concerning the morphometric analyses of the sampled spontaneous populations, the process has been completed in nearly all participating countries. Similarly, the research teams engaged in this work package have almost finalized the extraction of nucleic acids (plant DNA). Additionally, seeds from all sampled populations have been properly stored in national or local seed banks.

As for the genetic analyses planned under Task 3.3, to ensure fully comparable data, the Consortium is utilizing the sequencing services provided by BMKGNE (Germany). This company was selected by WP3 partners based on their quotation (approximately €45 per sample) and the quality of their sequencing service. The coordinator kindly reminds that the optimized protocol, to be used by all partners for DNA extraction and subsequent NGS sequencing, has been drafted by Prof. Simona Casavecchia (UNIVPM).

WP4 Sustainable production of organic sea fennel crop

OBJECTIVES

Starting from previous experiences of the applicants from national and international projects, this WP is aimed to develop protocols for sustainable production of **organic sea fennel crops** within the cooperation area, **in agreement with the zero-pollution ambition for a toxic-free environment**. This objective will be reached by carrying out three-year-cultivation trials in demo and open field **with no chemical inputs according to the principles of organic cropping**.

TASKS AND STATUS IN THE REPORTING PERIOD

Task 4.1 (R). Sustainable production of sea fennel crop in demo field (month 6 – 24). **ON-GOING**

Task 4.2 (D). Sustainable production of sea fennel crop in open field (month 12 – 35). **ON-GOING**

Task 4.3. (D) Analysis of the new sea fennel crops (month 6 – 35). **ON-GOING**

Task 4.4. (D) Statistical analysis (month 18 – 35). **NOT STARTED**

DELIVERABLES DELIVERED IN THE REPORTING PERIOD

	Deliverable	Status	Comment
WP 4	D4.1 Experimental plan design of cultivation trials	Delivered	
	D4.2 Fresh biomass (edible aerial parts) from the new organic sea fennel crops	Delivered	
	D4.3 By-products (old leaves and fibrous stems) from the new organic sea fennel crops	In progress	
	D4.4 Recommendations and guidelines on sustainable production of new organic sea fennel crops in the Mediterranean basin	In progress	
	D4.5 Report with the elaborated data overall collected within WP4	Delayed	

BRIEF DESCRIPTION OF WORK DONE IN THE REPORTING PERIOD

Despite climatic challenges encountered during implementation, promising results were achieved under WP4, which focuses on the sustainable production of organic sea fennel. Seedling production was successfully carried out in Italy, Türkiye, Croatia, and Tunisia. Field transplanting was also completed in Croatia, Italy, and Türkiye, and the first harvest of 1-year-old crops took place during summer 2024.

In contrast, cultivation efforts in Tunisia were unsuccessful due to extreme high temperatures. However, replanting is planned in the coming months. These findings underscore the critical importance of post-transplant irrigation and the need for emergency irrigation measures during prolonged drought periods to ensure crop survival and yield.

Additionally, the effects of biostimulation on *Crithmum maritimum* L. root development were investigated under controlled conditions. The study, recently published in the *Turkish Journal of Agriculture and Forestry* (see: <https://journals.tubitak.gov.tr/agriculture/vol48/iss4/10/>), highlights the potential of biostimulants as environmentally friendly agricultural inputs. When applied to plant root systems, microbial inoculants have shown to enhance both physiological and morphological characteristics of the entire plant.

The findings suggest that biostimulants may play a beneficial role during the nursery phase of sea fennel production, contributing to improved root development and overall plant health.

WP5 Exploitation of sea fennel edible aerial parts for manufacturing of innovative sea fennel-based foods

OBJECTIVES

The main objective of this WP is the development of sustainable innovative foods by exploiting the new sustainable sea fennel crops. More specifically several innovative sea fennel-based food products (shelf-stable fermented and unfermented preserves) will be developed – first at laboratory scale and subsequently at pilot-scale - using edible aerial parts (young leaves and sprouts) of the new organic sea fennel crops produced in WP4. Hence, the pilot-scale prototypes will be analysed immediately after production and during their shelf life (up to 6 months) for their chemical, gross compositional, functional, microbiological, and sensory traits as well as consumer perception through panel tests carried out by trained assessors.

TASKS AND STATUS

Task 5.1 (R) Laboratory scale manufacturing of fermented shelf-stable sea-fennel preserves at laboratory scale (month 1 – 20). **ON-GOING**

Task 5.2 (R) Laboratory-scale manufacturing of unfermented shelf-stable preserves (month 1 – 20). **ON-GOING**

Task 5.3 Pilot-scale manufacturing of fermented and unfermented shelf-stable sea-fennel preserves (D) (month 20 – 35). **NOT STARTED**

DELIVERABLES DELIVERED IN THE REPORTING PERIOD

	Deliverable	Status	Comment
WP 5	D5.1 At least 2 pilot scale prototypes of sea fennel-based fermented shelf stable preserves	In progress	
	D5.2 At least 2 pilot scale prototypes of sea fennel-based unfermented shelf stable preserves	In progress	
	D5.3 Recommendations and guidelines for manufacturing of new sea fennel-based fermented shelf-stable preserves at pilot scale	In progress	
	D5.4 Recommendations and guidelines for manufacturing of new sea fennel-based unfermented shelf-stable preserves at pilot scale	In progress	
	D5.5 Report with elaborated data overall collected within WP5	In progress	

BRIEF DESCRIPTION OF WORK DONE IN THE REPORTING PERIOD

ITALY (UNIVPM, CREA-AN, RINCI)

✓ FERMENTED PRESERVES (Task 5.1)

- Kimchi-like preserve
- Pickled fermented sea fennel

For both the above listed innovative products, 2 production batches each consisting of 2 technical replicates were manufactured at laboratory scale using fresh sea fennel sprouts as an ingredient. The validation of these prototypes (2 batches, 4 technical replicates) through chemical, microbiological, textural, and sensory analysis are still ongoing.

- Beer (addition of extracts produced in WP6 or of fresh sea fennel leaves/flowers during boiling)

For this innovative fermented beverage, a flow chart defining the main steps and operations has been drafted, considering two alternative sea fennel-based ingredient: an extract obtained from sea fennel crop byproduct, or a sea fennel juice obtained from fresh sea fennel crop.

✓ UNFERMENTED FOODS (Task 5.2)

- Shelf-stable pesto-like

Differently from what planned, this prototype will not be produced, being replaced with the prototypes of dried sea fennel spices.

- Dried sea fennel spices

This innovative product was formulated within a previously funded research project (BIO-VEG-CONSERVE) which was aimed at exploring the potential of sea fennel as an ingredient for the manufacture of innovative foods; within the framework of the project SEAFENNEL4MED, laboratory-scale prototypes of dried sea fennel spices were produced testing 4 different drying methods (air drying at room temperature, oven drying, freeze drying, and microwave drying); hence, all the four prototypes were subjected to the analysis of chemical, microbiological, and sensory parameters as well as colour and organic volatile compounds (VOCs).

CROATIA

✓ UNFERMENTED FOODS (Task 5.2)

- Dried spices

Dried spices were formulated with blends of sea fennel and other Mediterranean aromatic herbs, being rosemary, fennel, bay laurel, subjected to drying at 50°C for 4-6 h. The resulting powders were subjected to the analysis of: granulometric traits, color, aroma (VOCs), phenolic compounds, antioxidant activity, antimicrobial activity. They will also be assayed for their oxidative stability after application in different food models.

- Dalmatian patée

Five recipes of Dalmatian patée were formulated using the following ingredients: sea fennel (cooked or pickled), olives (green and black), pickled onions, olive oil.

Validation analyses are on-going.

- Pickled unfermented sea fennel

Laboratory-scale prototypes of pickled sea fennel were formulated using different vinegars: apple cider vinegar, red wine vinegar, alcoholic vinegar. Stabilization was achieved by pasteurization at 95°C for 15 min. The following analyses were carried out: chemical composition, aroma, color, texture, and taste. The stability during the shelf-life is still ongoing.

- Vegetable oils aromatized with sea fennel.

The addition of sea fennel (as dried powder or dried leaves at the following ratio: 1 g of sea fennel into 100 mL of oil) to different vegetable oils (olive oil, sesame oil, sunflower oil, flaxseed oil) to improve oxidative stability and aroma was assayed during 90-day shelf life at room temperature. The following analysis are on-going: determination of free fatty acids (FFA, %), peroxide number (PN, mmol O₂₂-/kg), fatty acid profile, VOCs.

TUNISIA

✓ UNFERMENTED FOODS (Task 5.2)

-Chili puree (Harissa)

The formulation of chili puree was made based on a popular traditional recipe. The main ingredients used were dried pepper (50%), garlic (35%), preparation (salt, coriander, caraway) (15%). Different doses of sea fennel powder were added to harissa to determine the best concentration. Analyses of stability, expiry date and microbiological analyses were carried out. A sensory analysis is also in progress with a panel of experts.

-Orange jam

Sea fennel was incorporated as a powder at different doses (0.5%, 1%, 1.5% and 2%) with the aim of assessing the effect of sea fennel on stability and taste of orange jam. Analyses of stability (pH, Brix evolution and microbiological load of yeasts, molds, and mesophilic aerobes over 60 days at 20 and 37°C, were carried out. A sensory analysis is also in progress with a panel of experts.

-Noodles prepared with durum semolina added with 5% or 10% sea fennel powder.

No activities were carried out in the reporting period for this prototype.

TURKIYE

✓ UNFERMENTED FOODS (Task 5.2)

- Hand made pasta

Different laboratory-scale prototypes of hand made pasta were produced with durum semolina and sea fennel powder added at different levels.

The following properties were evaluated: optimum cooking time, cooking loss, Swelling Index, Water Absorption, Texture Analysis, Sensory Evaluation

- Dried sea fennel

Different drying methods were assayed: vacuum drying, freeze drying, hot air drying. The following parameters were analysed: color, water activity, total antioxidant activity, total phenolic content.

- Snacks obtained by extrusion starting from (a) doughs made with sea fennel and other ingredients and (b) stuffed with sea fennel cream.

Laboratory-scale prototypes of both products have been produced; their characterization is ongoing.

- Spiced noodles with sea fennel

WP6 Valorisation of sea fennel crop by-products for production of functional food ingredients/nutraceuticals/soil amendments

OBJECTIVES

The main objective of this WP is to valorise by-products (damaged or discarded aerial parts, seeds, flowers, autumn mowing) of the new crops for the formulation of functional food ingredients and nutraceuticals, given the acknowledged high content of no edible aerial parts in extractable bioactive compounds (carotenoids, tocopherols, phenolic compounds, vitamin C).

TASKS AND STATUS

Task 6.1 (R&D). Preparation and analysis of extracts from sea fennel crop by-products (month 12 – 18). **DONE**

Task 6.2 (R&D) Exploitation of the extracts as functional food ingredients and nutraceuticals (month 18 – 24). **ON GOING**

Task 6.3 (R&D) Composting of residual sea fennel biomass (month 24 – 35). **ON GOING**

New Task 6.4 (R&D) Production, analysis, and exploitation of essential oils (EOs) from sea fennel as food ingredients with antimicrobial activity/beneficial properties applied to the manufacture of Mediterranean foods (e.g.: cheeses, fermented sausages, ect). (month 24 – 35) **ON-GOING**

DELIVERABLES DELIVERED IN THE REPORTING PERIOD

	Deliverable	Status	Comment
WP 6	D6.1 At least 1 crude extract with antioxidant, antimicrobial and/or health-beneficial activity	Delivered	
	D6.2 Recommendations and guidelines for preparation of crude extracts with antioxidant, antimicrobial and/or health-beneficial activity from sea fennel	Delivered	
	D6.3 At least 1 soil amendment produced by composting of sea fennel crop residual biomass	In progress	
	D6.4 Recommendations and guidelines for preparation of soil amendment by composting of sea fennel residual biomass	In progress	
	D6.5 Report with elaborated data overall collected within WP6	In progress	

BRIEF DESCRIPTION OF WORK DONE IN THE REPORTING PERIOD

ITALY (UNIVPM, CREA-AN, RINCI)

- production of extracts with polar bioactive compounds and analysis of their chemical, antioxidant, and antimicrobial activities (the latter towards key foodborne pathogens: *Escherichia coli*, *Staphylococcus aureus*, *Listeria innocua*)
- production and validation of seasoning edible capsules (from the extracts produced in T6.1 or essential oils produced in T6.3) e.g., example balsamic Modena vinegar (spherification process using sodium alginate)
- application of essential oils produced in T6.3 into the production of fermented salami (es. Ciauscolo salami) to improve sensory traits/safety/functional properties.
- application of essential oils produced in T6.3 into the production of meat-based products (e.g., hamburger) to improve sensory traits/safety/functional properties (example 3)

In the reporting period, a procedure to produce water and ethanol extracts from sea fennel by-product was optimized and then applied to crop by products purchased by RINCI.

The water extracts were assayed for total phenolic content (TPC), total flavonoid content (TFC), and total carotenoids content (TCC) and antioxidant activity by DPPH, ABTS and FRAP tests. The same extracts were also assayed for their inhibitory activity against carbohydrate-hydrolysing enzymes and lipase. Finally, major hydroxycinnamic acids such as chlorogenic acids were quantified by ultra-high-performance liquid chromatography coupled with the photodiode array (UPLC/PDA).

The application of water extracts from sea fennel by products to production of seasoning edible capsules by spherification was also explored in the reporting period, but it still needs optimization.

Regarding the evaluation of the antimicrobial activity of the sea fennel extracts in water and ethanol carried out at UNIVPM, the following indicator microorganisms were used:

Staphylococcus aureus (strains ATCC 29213, DSM 20231, ATCC 25923), *Listeria innocua* (strains Li 1, Li 2, Li 3), *Escherichia coli* (strains ATCC 25922, EC 2).

CROATIA (UNIST)

- extraction and analysis of essential oils (EOs) at laboratory scale;
- addition of EOs to different vegetable oils to prevent their degradation (oxidation) and as flavour components.

In the reporting period, UNIST has explored different green extraction technologies (i.e., ultrasound, microwave) using water/ethanol mixtures to produce extracts from sea fennel leaves, flowers, stems, and seeds, under different conditions (e.g., % of ethanol, extraction temperature, treatment); the extracts (>3) have been assayed for their antioxidant/antimicrobial activities.

TUNISIA (INGREF)

- extraction and analysis of essential oils (EOs);
- application of EOs as food ingredients to improve quality/shelf-life of jelly candies.

Regarding the formulation of NUTRACEUTICALS:

ITALY (UNIVPM, CREA-AN, RINCI)

- Application of the extracts with polar bioactive compounds to produce a new nutraceutical product and validation.

In the reporting period, water extracts from sea fennel crop by products containing polar bioactive compounds were subjected to an optimized spray drying procedure to produce a new nutraceutical. The analyses of the new spray-dried dietary supplement are currently ongoing.

FRANCE (UNIBRE)

- analysis of beneficial effects of the watery extracts with polar bioactive compounds on the human health: antidiabetic and anti-inflammatory activity (UNIBRE is available for carrying out these analyses on the extracts produced by the different CONSORTIUM partners)

In the reporting period, UNIBRE has carried out the hydro-ethanolic (70:30 v/v) extraction of sea fennel powder from fresh sea fennel leaves, flowers, and seeds of 5 different provenances (CR, FR, IT, TUN, TUR). From the analysis of these extracts it emerges that: (i) no phenolic compounds were found in the hydro-ethanolic extracts of Turkish sea fennel wild populations, whereas those of the Croatian populations showed low levels of these compounds; (ii) the extracts of French (Fra) and Italian (Ita) populations were the richest in chlorogenic acid, particularly the extracts produced from the flowers; however, no chlorogenic acid was never detected in the extracts from the fruit envelope. Moreover, a very low antioxidant activity was found in the hydro-ethanolic extracts of the Turkish and Tunisian populations, whereas the extracts from the French and Italian populations were the most active (especially those obtained from flowers and leaves).

Anti-tyrosinase, anti-elastase, and anti-collagenase activities were also measured in the hydro-ethanolic extracts from leaves and flowers of all the provenances. Anti-tyrosinase activity follows antioxidant activities: no anti-tyrosinase activity was seen in the Turkish populations; by contrast, a strong anti-tyrosinase activity was seen in the French and Italian populations (e.g., 234 mgKAE/gDW in the French extract). No anti-elastase nor anti-collagenase activities were found in the different provenances. Anti-inflammatory activity of the different extracts is under evaluation. The freeze-dried extracts have been sent to Centro de Ciências do Mar (CCMAR, Faro, Portugal) for the evaluation (in kind) of additional medicinal properties: neuroprotection, antiobesity and antidiabetic activity.

Hydro-ethanolic extracts (and essential oils) from sea fennel by-products (old leaves and stems, flowers) of each provenance have also been produced by UNIBRE; they will be soon analysed for: (i) anti-diabetic, anti-obesity, and neuroprotective activities (collaboration with CCMAR Faro, Portugal); (ii) anti-inflammatory activity (cytokine production by elicited cell lines).

TUNISIA (INGREF)

- produce EOs and extracts from sea fennel by-products;
- test the antioxidant, anti-diabetic, antifungal, and antibacterial effects of aqueous extracts and EOs of sea fennel by-products;
- application of EOs as food ingredients to improve quality/shelf-life of jelly candies;
- use of sea fennel by-products in animal feed formulas (concentrates or vegetable flours) based on sea fennel or mixed with other products, to test their effectiveness on average daily gain (for the ruminants);
- use of sea fennel aqueous extracts for animal nutrition and evaluation of its effect on meat quality.

In the reporting period, EO was obtained from sea fennel by-product collected from wild plants (flowers, stems, and old leaves) by INGREF. Identification of the essential oils was performed using a Hewlett Packard HP5890 series II GC-MS equipped with an HP5MS column (30 m × 0.25 mm).

EOs showed an important inhibition of alpha amylase. The inhibition rate was estimated to be 82.81%. The evaluation of the EO antifungal, antioxidant, and antibacterial activities are ongoing.

Woody stems, old leaves, and flowers of sea fennel plants collected in September 2023 were dried, and the powder used the production of extracts with different solvents (ethanol, methanol, acetone, water).

As a result, the aqueous extract showed the highest extract yield while acetone extract showed the lowest yield. Moreover, the extract in acetone showed the highest content of total phenols, total flavonoids, and condensed tannins. For the antioxidant activity, the methanolic extract showed the highest value (80%) while the aqueous extract showed the lowest one (36%). Regarding the alpha amylase inhibition, the ethanolic extract showed the highest inhibition. No activity was recorded for the extracts obtained with acetone and water. All the extracts showed an inhibitory effect against all the test microorganisms (moulds) used. Among them, *Alternaria alternata* was the most sensitive whereas *Ulocladium atrum* was the most resistant. Regarding the anti-inflammatory activity, the highest inhibitory effect of albumin was recorded by the aqueous extract (60%). The evaluation of the chemical composition and antibacterial activity of these extracts is still ongoing.

Regarding the application of EOs as food ingredient, the formulation of jelly candies has been defined and different doses of sea fennel EOs were added to the candies. A preliminary physical and physicochemical characterization of candies was carried out.

No activities were carried out by INGREF in the reporting period for the use of sea fennel by-products and aqueous extracts in animal nutrition.

TURKIYE (UNIEGE)

- Encapsulation of standardized crude extract with polar bioactive compounds (one extract obtained at optimum extraction conditions) in micro- and nano-carriers and evaluation of stability (UV, heat).
- Evaluation of health-beneficial traits of a standardized crude extract with polar bioactive compounds (one extract obtained at optimum extraction conditions): anti-diabetic effects using enzyme (alpha-glucosidase) inhibition assays.
- Preparation of mucoadhesive oral films (oral strips) at lab scale for the buccal delivery of polar bioactive compounds in standardized crude extract (only for one extract obtained at optimum extraction conditions).
- Evaluation of the synergistic effects of a standardized crude extract with polar bioactive compounds (one extract obtained at optimum extraction conditions) with selected bio-enhancers.

No activities were carried out by UNIEGE in the reporting period for this WP.

Regarding the production of SOIL AMENDANTS:

CROATIA (IACKR)

- Laboratory-scale composting trials with the residues of sea fennel biomass after extraction of polar/ nonpolar bioactive compounds

No activities were carried out by IACKR in the reporting period for the use of sea fennel by-products in composting.

WP7 Demonstration of socio-economic benefits of the proposed innovations

OBJECTIVES

The aim of the WP is to provide an evaluation of the socio-economic impact of sea fennel sustainable farming along the supply chain (farm to fork) in a context of sustainable production approach.

TASKS AND STATUS

Task 7.1 (D) Identification of drivers and lock-ins for the development of sea-fennel products (month 1– 12). **ON-GOING**

Task 7.2 (D) Assessment of consumer attitudes and acceptance of sea fennel products (month 13–30). **NOT STARTED**

Task 7.3 (D) Business model evaluation (month 24 – 35). **NOT STARTED**

DELIVERABLES DELIVERED IN THE REPORTING PERIOD

	Deliverable	Status	Comment
WP 7	D7.1 Lock-ins and drivers for the development of sea-fennel products	Delayed	Data processing
	D7.2 Report on consumer research on the attitudes and acceptance of sea-fennel products	Not started	
	D7.3 Report on Business Model Evaluation	Not started	

BRIEF DESCRIPTION OF WORK DONE IN THE REPORTING PERIOD

During the current reporting period, the first round of the Delphi expert survey was conducted.

In each partner country, an average of 15 experts identified through the stakeholder platform (Task 2.2) were contacted by phone and informed about the study by members of the respective partner institutions (UNIVPM, IACKR, INGREF, UNIBRE, EGE).

Those who agreed to participate in a series of survey rounds were included in the participant list and an email with a link to the online survey site was sent to all of them on May 30th, 2023.

The expert groups approached in each country consisted of farmers, processors, retailers, consulting, control and certification professionals, academicians, public researchers.

The questionnaire of the first round of Delphi was sent to 15 experts from Italy, 14 experts from France, 14 experts from Croatia, 15 experts from Turkey and 16 experts from Tunisia.

Due to limited number of responses in the first launch, reminders have been sent several times during June and July 2023, along with supporting phone calls by the partner institutions involved. Finally, out of the total of 74 experts contacted, 48.65% returned the completed question form.

9 experts from Turkey, 6 experts from Croatia, 10 experts from Italy, 9 experts from Tunisia, 2 experts from France responded first round of the Delphi survey. A total of 36 experts were surveyed.

In the Delphi first round questionnaire:

Seven open-ended questions prepared to open the subject and discover as wide a range of perspectives as possible were asked to the experts.

Besides, demographic data (age, gender, education, experience in the sector, etc.) were collected.

These Delphi first round questions were sent to the experts, and they were asked to list their thoughts and answers to each question.

The data were collected via Qualtrics online survey website (Qualtrics software) which is used to collect and analyse data for market research, customer satisfaction and loyalty, product and concept testing, employee evaluations and website feedback using various distribution methods.

After the compilation of the first round, the study on the second round of the Delphi survey was initiated.

The purpose of the second round is to allow the experts to react to each other's assessments.

To this end, the answers of all country experts to the questions (except the question #5, since it was already a numeric question) posed to them in the first round were aggregated and listed one below the other.

Similar answers and expressions were grouped and combined.

Then statements were set up to be used in the second round. Each item was transformed into a structure that could be evaluated using a 5-point Likert-type scale. Statements were reviewed to be optimized and duplications were reduced to a single statement. Too specific ones were eliminated.

As well as the 1st round, the preparation of the second round Delphi questionnaire was carried out in close cooperation with the University of Ancona through e-mail correspondence and online meetings.

Currently, the second round Delphi expert question form is finalized and started to be translated into each country's native language.

The second round Delphi questionnaire will be sent to the same experts who responded to the first-round questionnaires.

WP8 Demonstration of environmental impacts and sustainability of the proposed innovations

OBJECTIVES

The data needed for the environmental sustainability assessment will be collected in close cooperation with all Partners, based on tasks 1.2 and 2.2. The main objective of this WP is the calculation of sustainability indices through the Life Cycle Assessment (LCA) method as defined by the ISO 14040 and ISO 14044 standards, using updated SimaPro software application and associated LCA database. Specific PEF-PCR documents will be considered if available. Different indices will be evaluated for the entire sea fennel supply chain including carbon footprint and water footprint.

TASKS AND STATUS

Task 8.1 (D) Sustainability assessment of sea fennel open field production (month 1-35). **ON-GOING**

Task 8.2 (D) Sustainability assessment of new sea fennel-based foods/food ingredients (month 1-35). **ON-GOING**

Task 8.3 (D) Sustainability assessment of functional extracts for food ingredients/nutraceuticals (month 1- 35). **ON-GOING**

DELIVERABLES DELIVERED IN THE REPORTING PERIOD

	Deliverable	Status	Comment
WP 8	D8.1 Report on sustainability assessment of fresh sea fennel carried out by LCA from data collected thanks to WP4 activities	In progress	
	D8.2 Report on sustainability assessment of processed sea fennel products carried out by LCA from data collected thanks to WP5 activities	In progress	
	D8.3 Report on sustainability assessment of sea fennel residues extracts from data collected thanks to WP6 activities	In progress	

BRIEF DESCRIPTION OF WORK DONE IN THE REPORTING PERIOD

Regarding the first task (T8.1), LCA analysis is at its final step, being interpretation. For the second task (T8.2), LCA is at the second step of LCA, being the inventory analysis.

Finally, regarding T8.3, LCA has just started with the definition of goal and scope.

The preliminary results of sustainability assessment of sea fennel open field production clearly suggest that:

- Organic open-field cultivation of sea fennel has a relatively low environmental impact.
- The main contributing input (material) was the plastic mulch.
- Increasing plastic recycling rate can substantially reduce environmental impacts.
- Substitution with alternative mulches like soil biodegradable mulch may improve environmental performance.
- Other emerging environmental concerns, such as microplastic pollution are currently not included in the impact assessment models.

2. Update of the plan for exploitation and dissemination of result

The plan for exploitation and dissemination of results as described in the proposal submitted was not updated.

3. Update of the Data Management Plan (DMP)

No updates

4. Follow-up of recommendations and comments from previous review(s)

Not applicable

5. Deviations from original proposal

A few deviations from the original proposal have been foreseen; they are described as follows:



- For **WP3**, a minimum number of 4 sites per country (Italy, Croatia, France, Tunisia, and Türkiye) was set for the sampling of wild sea fennel populations, thus leading to the sampling of at least 20 populations across the Mediterranean. In the original proposal selected by PRIMA for funding, a significantly lower number of Mediterranean sea fennel populations were set to be sampled (> 6).



- For **WP4**, bio-stimulant consisting of selected bacterial strains known to improve soil quality and health as well as promoting crop yields was assayed in place of blends of effective microorganisms. Moreover, in addition to the application of the biofertilizer at the demo field, the same bio-stimulant was also assayed for the bacterization of seeds, to evaluate the impact of the beneficial microorganisms inoculated on growth parameters of sea fennel roots.



- For **WP6**, in task T6.1 "Preparation and analysis of extracts from sea fennel crop by-products (month 12 – 18)" the extraction and analysis of essential oils (EOs) was included (this activity was not foreseen in the original proposal). Accordingly, the exploitation of EOs for manufacturing of innovative foods/food ingredients/nutraceuticals has been added in Task 6.2. This change, agreed by all the Consortium partners, was based on the great interest by the Scientific community and food/pharmaceutical industry toward essential oils and their potential applications for manufacturing of food ingredients/nutraceuticals/etc.

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