



General information	
PPP number	TKI-AF-16202
Title	MIP Seaweed for food and feed
Roadmap/Umbrella	
Executive knowledge institution(s)	WUR-Food & Biobased Research
Research project leader (name + e-mail address)	Willie van den Broek, willie.vandenbroek@wur.nl
Coordinator (on behalf of private parties)	Koen van Swam, Stichting NZB
Government contact person	Yvonne Korengevel, Cor Wever
Start date	1 juni 2017
End date	31 mei 2021

Approval coordinator/consortium	
The coordinator has assessed the annual report on behalf of the consortium:	X approved
Possible feedback on the annual report:	-

Short content description/aim PPS	
This program aims to develop knowledge to stimulate a growing seaweed sector in the Netherlands. Knowledge is required along the whole seaweed supply chain: from breeding to consumer behaviour.	Besides knowledge development, this program strives to bring together a coherent network of companies and specialists who together develop the seaweed sector towards a sustainable source for new food products, cultivated from a 2000 ha off-shore seaweed area.

Planning and progress	
Is the PPP going according to plan? ¹	No. 1) Expected delay of about 6 months. 2) Partners reduced their financial contribution. The reason for both deviations is described in the following paragraphs.
Have there been changes in the consortium/project partners?	Yes Although the program started in June 2017, the industrial partners all had to become formal partner in the program. This caused a delay in planning due to contract construction & IP discussions, specifically for this new MIP-instrument. A core-group (3 consortia) demanded more time to discuss this within their own companies. In the meanwhile, other candidate partners stepped out because of this delay. At February 15 th , 9 partners confirmed formally the participation of 3 consortia, initiating 8 projects. There are 3 new consortia seriously discussion participation: they agreed on content, but are internally discussing financial or contractual issues.

¹ If applicable, use the explanation from the financial project report

Is there a delay and/or deferred delivery date?	Yes, The expected delay is about 6 months.
Are there any substantive bottlenecks? Provide a brief description	Yes, Not all planned financial program contribution from industrial partners is yet allocated to the planned activities. Some consortia are still entering the program, but at present, this does not add up to the original planned budget. Discussions with governmental contact persons lead to the following time planning: in June 2018 a summary of the financial partner contribution will be made for the than contributing consortia. A discussion on re-planning and/or rescheduling will be started thereafter.
Are there any deviations from the projected budget?	Yes Due to a delay in partner commitment, some 2017 activities have been delayed actively (they needed partner input). In total, 92k€ in activities have been delayed to 2018 (NAPRO). In June 2018, discussions will be held about non-allocated activities and their budgets. No exceedance of project budget expected.
Do you expect a patent application to arise from this PPP?	Since the formal contracts have been arrived in January & February 2018, no IP-results have been discussed nor interchanged. This will be subject of discussion for the 2 nd half of 2018 and further.

Current summary of the project for the website Kennisonline
EN: ProSeaweed: safe, sustainable and commercial seaweed value chains Our food systems must become more sustainable and more circular in order to solve the global societal challenges (including decreasing biodiversity, land and fresh water scarcity). Using seaweeds as high-quality biomass from our own North Sea is a promising part of the (future) circular economy of the Netherlands. Over the past 5 years, more than 140 new seaweed food products have entered the Dutch market. There were also new seaweed products for animal feed, agriculture and horticulture. With a nutrient rich North Sea and strong Dutch Agrifood sector, it is important to stimulate this sector at an early stage in its development so that business economic opportunities can be explored and exploited in a sustainable manner. For this ProSeaweed works with a core group of 3 consortia, consisting of 9 active partners, to develop safe, sustainable and commercial seaweed value chains for food and feed. The residual streams of seaweed products can be added as a bio-stimulant to land crops. A special feature of this program is that it is focused on growth. On one side growth of the program, new initiatives can join the program. On the other side growth of the sector, with already 8 coherent seaweed projects. Among other things, the effects of seaweed as a feed supplement are being investigated, research is being executed in order to develop a basis (e.g. norms and standardization) for safe use of seaweed as food product, and the ecological adaptability of large-scale seaweed cultivation is investigated during seaweed pilots on the North Sea – 15 km from the coast of Scheveningen. Publishable results of these studies will be available later this year on the website of the program: www.proseaweed.eu .
NL: ProSeaweed: veilige, duurzame en commerciële zeewierwaardeketens Onze voedselsystemen moeten duurzamer en meer circulair worden om de globale maatschappelijke uitdagingen (o.a afnemende biodiversiteit, land- en zoetwaterschaarste) op te lossen. Het benutten van zeewieren als hoogwaardige biomassa uit onze eigen Noordzee is een veelbelovend onderdeel van de (toekomstige) circulaire Nederlandse economie. De afgelopen 5 jaar kwamen er meer dan 140 nieuwe zeewervoedselproducten de Nederlandse markt op. Ook kwamen er nieuwe zeewierproducten voor diervoeders, land- en tuinbouw. Met een rijke Noordzee en sterke Nederlandse Agrifoodsector is het van belang om in een vroeg stadium deze sector te stimuleren bij haar ontwikkeling zodat bedrijfseconomische kansen onderzocht en op duurzame wijze benut kunnen worden. Hiervoor werkt ProSeaweed met een kerngroep van 3 consortia, bestaande uit 9 actieve partners, aan het ontwikkelen van veilige, duurzame en commerciële zeewierwaardeketens voor voedsel voor mens en dier. De reststromen van zeewierproducten kunnen worden aangewend als

biostimulant voor landgewassen. Het bijzondere aan dit programma is dat het gericht is op groei. Enerzijds groei van het programma, nieuwe initiatieven kunnen zich aansluiten bij het programma. Anderzijds groei van de sector, met inmiddels al 8 samenhangende zeewierprojecten. Zo worden onder andere de effecten van zeewier als veevoersupplement onderzocht, wordt er gewerkt aan een basis (o.a. normering en standardisering) voor veilig gebruik van zeewier als voedselproduct, en wordt de ecologische inpasbaarheid van grootschalige zeewierteelt onderzocht tijdens zeewierpilots op de Noordzee – 15 kilometer uit de kust van Scheveningen. Publiceerbare resultaten van deze onderzoeken zullen later dit jaar te vinden zijn op de website van het programma: www.proseaweed.eu.

Highlights

WP 1: Seaweed, consumer and market

1.1: Seaweed Scan

An assessment has been made of which seaweed species are of interest to cultivate and/or to harvest for food, feed and bio-based products applications, based on predefined characteristics of the selected species for growth potential and likelihood of successful cultivation. A first set of commercial interesting seaweed varieties have been selected: *Ulva armoricana*, *Ulva* spp (green), *Soliera chordalis*, *Ceramium rubrum*, *Gracilaria* spp, *Porphyra* (*Pyropia*) spp. and *Grateloupia turuturu* (red), and *Himanthalia elongata* and *Undaria pinnatifida* (brown).

1.2 Site selection

Seaweeds can be cultivated in inshore, nearshore and offshore locations, where water quality and physical characteristics of the site will define the production potential for seaweed, both in terms of quantity and quality. Besides bio-physical constraints, site selection for cultivation is restricted by social aspects, regulation and use of sea space by other functions (e.g. shipping, gravel extraction, aquaculture, nature). The project envisions to identify the aspects defining the production potential in different areas/sites, with a strong focus on the nearshore areas (outside) Haringvlietdam for which interest for large scale seaweed production has already been expressed. A first work plan for site selection was established based on biotic and abiotic drivers. In 2018 finish this for all other drivers (commercial, logistics).

1.3 Consumer attitude study

Seaweed is still a relatively unknown product on the food market. Previous research by Wageningen Economic Research shows, among other things, that many people have no concrete picture of seaweed as food; it is an unknown product. The research also shows that consumers do not always make a conscious decision. More specifically, they are not always conscious attitudes towards seaweed that determine the choice to try seaweed. Emotions also show to be relevant. Therefore it remains unclear under which conditions consumers perceive a product as seaweed (hybrid versus fully seaweed) and how can seaweed be best positioned (emotional versus cognitive argumentation). A first consumer study was performed to open up understanding of consumer attitude:

What is the seaweed percentage that a food product should contain?

Most attractive communication message towards consumers (cognitive vs emotional)?

Can we identify certain consumer groups, based on percentage & com. Message?

Can we get an idea about the specific consumer profile?

Final results are expected early 2018 and will be used to attract new project partners.

WP 2: Innovation in seaweed cultivation

2.1 Development of reproduction & breeding techniques

The aim of this research is the development of reproduction & breeding techniques for the cultivation of seaweed species with high economic interest. The first main activity in this project was a literature search on life cycles and the relationship between environmental factors responsible for the induction of spores for *Ulva* spp, *Porphyra* spp, *Saccharina latissimi*. The gathered information allowed the construction of a growth cabinet in which temperature, light quality and quantity can be accurately controlled (see picture). The first experimental tests inducing sporulation in *Ulva* spp were successful.

- 2.3 Cultivation & chemical composition**
The aim of this project is to study productivity and chemical composition of the harvested biomass in relation to growing conditions/seasonality. Both productivity and chemical composition will strongly influence economic value whereas variation in chemical composition may influence the quality of the products (food/feed, biostimulant- and plant protective extracts). First, a land-based cultivation system was built and tested, consisting out of 40 tanks of 600 L (see picture below). Five populations of 1 *Ulva* species were grown from half of July until mid-November. During growth, large variations in productivity were observed between the strains. Every month, harvested biomass samples were collected stored frozen and freeze-dried In December all samples were analyzed on proteins, amino acids, fatty acids, fibers, starch, sugars vitamins, carotenoids, polyphenols, alkaloids. The analysis on these measurements will become available in the first Q of 2018. However, large differences in growth performance (and presumably chemical composition) were observed between populations sampled within only The Eastern Scheldt, thus offering unique opportunities for selection, preservation and breeding of high quality material. Finally, several presentation were given on these results, amongst others to a Saudi Arabia delegation interested in seaweed cultivation in combination with fish/shrimp cultivation.
- 2.4 Ecology**
This project aims to analyses whether seaweed cultivation-ecosystem interactions are positive (services) or negative (impacts) depending on location, scale, cultured species, season and system configuration. Eutrophication control has been identified as one of the ecosystem services provided by seaweeds, as seaweeds remove (excess) nutrients from the water. On the other hand, when seaweed densities exceed the carrying capacity of an ecosystem, nutrient extraction may result in nutrient limitations, changing the ecosystem service in an ecosystem impact. Therefore a good understanding of nutrient uptake rates of seaweeds is needed. To study nutrient uptake, monthly nutrient uptake rates (NH_4 , NO_3 , NO_2 and PO_4) were measured as a function of seaweed biomass in the cultivation system developed in project 2.3. Results showed that *Ulva* spp. populations differed in nitrogen (DIN) and phosphorus (DIP) uptake rates, and that differences between the strains correlated with seasonality. These results show that differences in nutrient uptake rates observed within a seaweed species, can be the result of differences between populations. This should be taken into account when quantifying seaweed-ecosystem interactions.
- 2.5 Food Safety**
The current concern regarding food safety of seaweed focuses mainly on the Arsenic and Iodine content. In this project we concentrate on all aspects of formal validation dossiers to be ready for application for certain new seaweed species as Novel Food, and on ingredients to be ready for certification of complete certain seaweed production chains by the end of this project.
First experimental set-up was built to analyses arsenic uptake (both organic non-toxic and inorganic toxic) by *Ulva* (see picture below). Preliminary results showed relatively low rates of uptake compared to that described in the literature. Despite literature indication that peak uptake would appear after a few days, the peak didn't appear in the 4 months experiment. Therefore, further R&D questions arose for the upcoming year. Furthermore, at relatively high concentrations in the seawater, toxic inorganic arsenic is converted into the non-toxic organic form. The test protocol for depletion and accumulation experiments with *Ulva* have led to a generic test protocol for other species. A test plan for other contaminants for the period of 2018 – 2020 has been initiated but will be ready in 2018.
RIKILT not only realized to participate in the European and Dutch standardization committee CEN 454, but also managed to become convener of the product test method (WG 6) of CEN committee 454 on Algae and Algae Products. Within this working group, standards for sample preparation, analysis techniques and product declaration will be developed. From this committee the international network will expand quickly, which enhances the possibilities of information and data exchange and increasing the business contacts for the WUR.

WP 3: Value Creation through processing

- 3.1 Seaweed processing
An inventory of pretreatment processes used worldwide has been realized. In particular on how to remove macroscopic contamination and how to clean and stabilize the seaweed (e.g. drying) after harvest. The inventory is based on desk study, including experiences from other fields. (Pre-)processing technologies are very much seaweed type dependent. More knowledge on up-scaling technologies is needed, esp. for North-sea seaweeds and in relation to economic feasibility.
- 3.2 Food products and taste
To understand the market of food products with seaweed as an ingredient a survey on market innovations has been realized. The Innova Database has been consulted for this. It is the biggest food industry database in the world where launches of new food products, brands, ingredients, claims, etc. are recorded. From 2013 to 2017, almost 8000 products in which seaweed and/or its functional components are listed in the ingredient list were launched worldwide. 61% of these products were launched in Asia and 22% were launched in West Europa. While there was a slight decrease in the number of products launched from 2013 to 2017 in Asia, there was an increase in the number of products launched in West Europa in the same period. In the Netherlands, in the last 5 years, 140 products containing either seaweed as a whole or functional ingredients derived from seaweed, have been launched. These products are ranged from ice cream containing stabilizers derived from seaweed to crackers containing 23% seaweed. Seaweed and its functional components are also found in supplements and pet food. These numbers have shown the growing migration of seaweed from Asian cuisine to the Western diet and its wide range of applications.
In term of functional ingredients, seaweed has been known to possess different types of polysaccharides that can be used as stabilizers, gelling agents, or flocculating agents in food products (such as carrageenan and agar) and proteins containing all the essential amino acids. It is also rich in some health-promoting molecules and materials such as, dietary fiber, ω-3 fatty acids, and vitamins A, B, C, and E. and antioxidants that can be widely applied in not only food applications but also in the pharmaceutical industry.
- 3.3 Holistic extraction for Food
The activities have been focusing on consortium formation. Different food companies had different interpretations on food extraction. Ultimately, only Givaudan agreed to step into this program. A project plan has been developed for this cooperation, whereas contract negotiations have almost finished. Expectations are to start Q1 2018. Learnings from discussions with the other partners are that they consider the seaweed sector as still in its early development stage which makes cash investment hard to justify internally. The ProSeaweed project is not seen as a consortium that can generate large seaweed volumes in the near future.
- 3.4 Holistic extraction for feed where proteins serves as main target
It was decided to start with the seaweed species being processed by partner Olmix: Ulva (green) and Soliera (red). These species serve as benchmark when switching to Dutch partner species later on in the program. Olmix has sent sample material to Wageningen to characterize the chemical composition of a range of seaweed species, to develop a suitable processing method for extracting in particular the protein fraction of some of these species, to quantify the functional components in these seaweed species, in particular in the protein fractions, and to assess the nutritional value and the health promoting effects of these protein fractions in monogastrics. This has led to a selection of target seaweed species, a detailed project plan for protein isolation from Olmix material and in vitro testing on monogastrics. Furthermore, a lecture called: 'Opportunities of seaweeds in animal nutrition' was presented during the Breizh Algae Tour in Bréhan, France, at September 12th 2017.
- 3.5 Impact seaweed extracts on plant nutrition & health
Little structured information is available regarding the possible modes of action of seaweed or seaweed components as source of plant nutrition, stimulant and health care. To gain more insight on the positive effects of seaweed (intact or as a whole) on plant care and health stimulating research is carried out whether positive effects are related to intact seaweeds, or specific components. Moreover, the fertilizing value of the remaining seaweed ash fraction after extraction of proteins and carbohydrates has to be assessed as well. A start was made with the literature search on available knowledge on plant care with

seaweed products with special attention to Ulva and Soliera. First measurements on chemical composition have been realized but will be finished in 2018.

WP 4: Animal Health

4.1 Health aspects for animals

Health aspects of several algae species in piglets, dairy cows, and dogs, as well as on the impact on methane emissions in dairy cows have been investigated. In 2017, one consortium meeting was organized to discuss the participation of the consortium to the MIP project and a second one to discuss the overall approach of the project. A first in vitro test was initiated to determine the effect of the algae species on gut enterocyte cells. This test will be finished in 2018 and provides information about the expression of genes in these cells because of their interaction with the algae. Genes expression will be related to the biological properties that are effected. Furthermore, a conference paper (Queenstown, October 16-19) was presented about novel proteins, a.o. seaweeds and micro algae. Because of the contract issues, the project started at a later stage than expected.

WP 5 Management & Impact

5.1 Impact

First activities have been initiated to improve impact, knowledge dissemination and the development of public understanding and a sound network in the value chain of seaweed:

1. Stakeholder meeting in November with the attendance of 30 people
2. Method Impact- and evaluation strategy
3. Communication materials such as a new project name, website and possibility for an academic book on seaweed.
4. Multiple events have been set up and used to communicate about ProSeaweed: Seaweed event in Flanders Belgium, Unilever Algae workshop, Brehan Algae Tour, Feasability of Seaweed in Province of North-Holland and an Information panel at Grüne Woche, Berlin.

5.2 Management

The management of this program has been focusing on structuring of activities, formalization of cooperation and positioning the program in the external environment.

- A legal framework for the whole Seaweed program (Program Agreement) and their separate projects (Project Agreement), including IP issues.
- Structuring activities
- Re-engagement of potential industrial partners; defining an industry core-group to initiate the first projects.
- Assign 4 Japanese students to do literature searches in Japanese language.
- Put Seaweed on the agenda of the Carbohydrate Competence Center as candidate CCC-programme.
- Arrangement and installation of a MsC student from Groningen to investigate the scientific potential of carbohydrates in Seaweed.

Revitalize TO2 cooperation on Seaweed with ECN.

Number of delivered products in 2017			
Academic articles	Reports	Articles in journals	Introductions/workshops
Does not apply for 2017			

Appendix: Names of the products or a link to the products on a public website

Does not apply for 2017. Publishable results of abovementioned studies will be available later this year via: www.proseaweed.eu.

<https://www.wur.nl/nl/project/AF-16202-MIP-Seaweed-for-food-and-feed-1.htm>

http://fabriekenvoordetoekomst.be/sites/default/files/Attachments/ZWP_2017_W3_6_Koplopers_MIP_Willie-van-den-Broek%2C-WUR.PDF

Akkoord: Hans van der Kolk (Topsectorsecretaris).