Sustainable Uses of
Baltic Marine Resources

SUBMARINER Report 3/2013:

Development plan for the potential resumption of agar production from red algae *Furcellaria* in the Latvian coastal region Kurzeme

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Abstract The use of macroalgae for agar production is an environmentally friendly exploitation way of Baltic Sea resources. Agar production from red algae *furcellaria* collected from the Baltic Sea cost of Kurzeme would have a positive impact on Kurzeme region, since the agar production would promote development and increase economic competitiveness of the region. *Furcellaria* is a very common algae species in Latvia, and the amount of the material which can be collected in the coastal territory seasonally is 52,366.67 m^3. The process of agar production includes different steps, of which some are highly energy-intensive processes, therefore in order to ensure successful production of agar there is a need to ensure sufficient availability of energy sources, for example biogas stations. Applying the most profitable production cycle, 1 kg of agar can be obtained from 8.5 kg furcellaria dry matter. Agar can be used for a wide range of applications; one of the most common uses is as a food additive.

URL The report is available for download at the SUBMARINER project's website at http://publications.submariner-project.eu

Cover Photos Jolanta Jansone

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Content

1. Agar production from algae *Furcellaria* collected from the seacoast of Kurzeme

At the moment the opportunities given by the Baltic Sea are mainly used for fishing and fish processing. However *furcellaria* is one of the most common species of algae in the seacoast of Latvia with the highest total amount of biomass, thus including the potential for the production of agar. Using algae for agar production is an environmentally friendly exploitation way of Baltic Sea resources in the future, which also would increase economic competitiveness of Kurzeme region and promote its well-balanced development.

Kurzeme region is located in the western part of Latvia along the Baltic Sea, but in the northwest is on the border of the Gulf of Riga. One of the special features of Kurzeme region is its uneven development. This is due to the asymmetry in the population, investment and economic concentration. Production of agar would reduce the region's dependence on certain sectors of the economy and a few large companies. Thus, it would increase the region’s economic activity and competitiveness, and consumers would have the possibility to choose locally produced products when the company for the production of agar would use algae from the seacoast of Kurzeme. Currently agar, which is available and used in Latvia, is imported from other producing countries.


Furcellaria lumbricalis

2. Agar – polysaccharide from algae

The American Society for Microbiology in the „Manual of the General Bacteriology Methods" (1981) according to Araki defined agar as: "extract, being obtained from appointed red algae, consisting of 2 polysaccharides, agarose and agaropectin, and is 70 % of the whole mixture''. Different types of red algae, called also agarophites, are being used as a raw material for agar production, from which the most common species today are:

1) Various *Gelidium* species, mostly being gathered in Spain, Portugal, Morocco, Japan, Korea, Mexico, France, USA, China, Chile and South Africa.

2) Various *Gracilaria* species from Chile, Argentina, South Africa, Japan, Brazil, Peru, Indonesia, Philippines, China, Taiwan, India and Sri Lanka.

3) *Pterocladiacapillace* from Azores (Portugal) and *Pterocladialucida* from New Zealand.

4) *Gelidiella* from Egypt, Madagascar, India, etc.

From *Gelidium* species the best quality agar is produced, but its cultivation is difficult and its resources in the environment are less than for *Gracilaria*, which is grown in many countries and regions on a commercial scale. *Gracilaria* is the richest and the most perspective resource for the production of agar. *Gracilaria* has more than approximately 150 species and it is distributed mainly in temperate and sub-tropical zone. Nowadays approximately 60 % of agarophites being gathered for agar production is *Gracilaria spp.* 35 % - *Gelidium sp.* and 3 % different other algae.

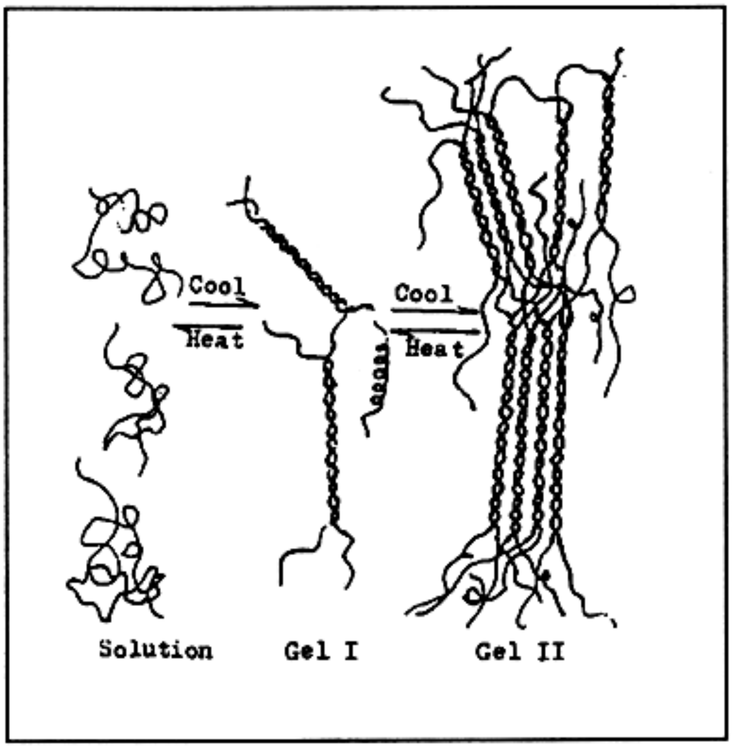
The world's largest producer of agar is Japan, followed by Spain and Chile. Recent estimates indicate that about 8,000 tonnes of agar each year has been produced in the world. Countries having abundant agarophite resources, such as Chile, Philippines, Brazil, Portugal and Indonesia export them to other regions. Yearly Japan imports from these countries a large amount of *Gracilaria*.

3. Properties of agar

Agar is colourless, odourless and flavourless. It is non-allergic and non-toxic, and contains no calories because the human body does not ingest it. Agar powder is in white or grey shaded colour. The main advantages which make it applicable on a widespread basis are:

- Gelation
- Mechanism of alkali modification of agar
- Gel strength
- Gelling and melting temperatures
- Viscosity and molecular weight
- Compatibility

Gelling mechanism of agar is given in the image. Agar has the ability to form gels upon cooling of a hot solution from 30 to 40 °C temperature and to melt, becoming a liquid, upon heating to 90–95 °C temperature.



Gelling mechanism of agar

At temperatures above the melting point of the gel, the influence of heat overcomes the tendency to form spirals and the polymer exists in solution as a random coil. When cooled down, three-dimensional network is formed in which double spirals form the junction points of the polymer chains (Gel 1). Further cooling leads to aggregation/accumulation of these junction points (Gel 2). In more general terms, the gel strength of agar depends on the content of agarose, the component having higher gelling ability. Agar with higher content of 3,6-AG and lower sulfate content gives higher gel strength. The idealized agarose does not contain sulfate group, but in reality there still exists a trace of it (0.1 to 0.5 %), because there are no pure agarose molecules present in nature. Moreover the yield, physical parameters and the content of chemical components in agar vary depending on the species and location of growth and collection.

4. Application types of agar

Agar has a wide range of application possibilities which are mainly relevant to its high gelling ability and the special gel structure, but most often it is used in food products, for example, in production of confectionery and bakeries as stabilizer, thickener, etc. Relatively small amount of agar is applied in meat and dairy product manufacturing. Safe usage of agar in manufacture of human food is guaranteed by long-term (about 300 years) experience of different countries. Food production constitutes for 80 % of its total use.

Followed by a recent research studies the demand for agar is growing in the retail business, when it is used as a gelatine substitute, because it is 100 % of plant origin.

It can be used in pharmaceutical manufacturing, for example, microbiology, as it is used as the culture medium for both pathogenic and non-pathogenic bacteria. Agar is not easy to metabolize, it has a good gel firmness, elasticity, clarity and stability. None of pathogenic bacteria is known to digest agar. It is also used in dentistry as a teeth impression material and in biomedicine and biotechnology, since agar's gel prevents convection in liquid, is biologically inert and has controlled ionic properties. There are continuously made new discoveries about agarose and its derivatives in biotechnology.

5. Previous years' experience in Latvia

Dobele district collective farm "Future" began producing agar in 1965. In 1966, in Latvia *furcellaria* algae were already systematically collected and dried in voluminous amounts as a raw material for the production of agar. Further dried algae were delivered to the fishing collective farm for production of agar. 200 tonnes of agar per year were produced and the manufactured production was sent to the fifty-seven cities of the USSR.

However, due to oil tanker accidents nearby Ventspils harbour in 1979 and near the port of Klaipeda in 1981, there was a dramatic decrease of red algae. It was due to the fact that water pollution by oil reduces *furcellaria* ability to cling to the natural substrate, resulting in a reduction of algae propagation capabilities. For example, according to the monitoring activities of the *furcellaria* distribution and occurrence made by the Latvian Fisheries Research Institute (since 2010 renamed: The Institute of Food Safety, Animal Health and Environment "BIOR") there was calculated that in the period since year 1978 until 1990 the number of red algae from 84,500 tonnes fell down to 15,000 tonnes in Klaipeda – Ventspils seacoast, disrupting the ecological balance of the coast. However, according to estimates, it was found out that in the next eight years *furcellaria* were able to regenerate after the drastic reduction of red algae in year 1990. Total production in Latvia stopped during the 90's according to the process of changes in the Soviet Union.

6. Distribution patterns of *furcellaria* algae in the seacoast of Kurzeme

Most of *furcellaria* algae are rinsed out on the coast in late July and in the beginning of August, then in October and November, also occurring in March and April. During the autumn and winter periods algal biomass can significantly reduce due to the storm, when the algae are fragmented or completely destroyed. *Furcellaria* are washed out by west or southwest wind.

At the moment more compact *furcellaria* stands are found in the seacoast stage Nida – Liepaja, where they form more than 80 % of the hard bottom substrate coverage. High distribution potential keeps up to Akmenrags, where is a suitable bottom substrate for algal growth. In the coastal zone from Akmenrags to Ventspils *furcellaria* distribution potential decreases.

One of the characteristics that determine *furcellaria* distribution is the depth of the particular site. In shallow depths (less than 5 meters) there are unsuitable conditions for *furcellaria* growth, because of the powerful effects of waves they can be fragmented or torn off from the substrate. Distribution into deeper regions is dependent on the available light amount.

The second indicator is the substrate type. For *furcellaria* growth it is necessary to have ground substrate, boulders. Usually in stone areas coverage of *furcellaria* is not more that 30–50 % of the hard rock surface.

7. Potential of agar production in Latvia

Furcellaria algae are one of the most common algae species in Latvia that is wash out in the seacoast of Kurzeme which could be used for agar production. The collection material is a mass of *furcellaria* algae being washed out in average 5 m of the seacoast width, as well as, 5 m in wide zone. Thus, it can be assumed that each meter of seacoast and seacoast waters contain on average 0.242 m^3 *furcellaria* and the amount of the material which can be collected in the coastal territory is 52,366.67 m^3. *Furcellaria* dry matter is 1/6 of the initial amount.

Agar production and marketing is a relatively small industry, however it is anticipated that demand of agar will continue to grow, since its application in food production continues to grow, which is also the main application of agar among wide variety of uses.

8. Collection of *furcellaria* algae and primary concentrating repositories in the seacoast of Kurzeme

Dividing the seacoast of Kurzeme in stages one can create a logistic foundation for *furcellaria* material collection, transportation and primary storage. Creation of such stages is related to the coastal geography features and natural formations, such as river flows into the sea, port basins and drives ways. After evaluation of the mentioned factors the coastal territory can be divided into the following stages:

No.	Starting point of the stage	Destination of the stage	Distance, km	Amount of the material, m^3
1.	Nida	Pape	6.2	2,066.67
2.	Pape	Jurmalciems	17.2	5,733.33
3.	Jurmalciems	Liepaja D.	14	4,666.67
4.	Liepaja D.	Liepaja Z.	0	1,833.33
5.	Liepaja Z.	Saraiki	16	5,333.33
6.	Saraiki	Akmenrags	15	5,000.00
7.	Akmenrags	Pavilosta D.	9.3	3,100.00
8.	Pavilosta D.	Pavilosta Z.	0	100.00
9.	Pavilosta Z.	Riva	15	5,000.00
10.	Riva	Zaki	10.5	1,750.00
11.	Zaki	Sarnate	1.8	300.00
12.	Sarnate	Uzava	18.3	3,050.00
13.	Uzava	Ventspils D.	18.7	3,116.67
14.	Ventspils D.	Ventspils Z.	0	850.00
15.	Ventspils Z.	Ovisi	16	2,666.67
16.	Ovisi	Mikeltornis	16.3	2,716.67
17.	Mikeltornis	Jaunciems	10.2	1,700.00
18.	Jaunciems	Kolka	20.3	3,383.33
			215.7	**52,366.67**

The table show that material outcome of the stages 4 and 8, and 14 is 0, because the given stages are port basins. Length of the coast stages is dependent on the factors mentioned above. The average stage length is 12 km of 2,909 m^3 *furcellaria* deposit.

Repositories locations in the seacoast of Kurzeme

Yellow dots are the possible repositories location places in the seacoast of Kurzeme. It is possible to establish *furcellaria* transportation and collection costs for each stage and for all 15 stages in total.

9. Production of agar

The major steps in the process of agar production includes: algae collection, drying, extraction, filtration, concentration and milling. As well as there is several agar production cycles that could be used, one of them are shown below.

Collection

In order to ensure the agar production, it is necessary to collect a sufficient amount of *furcellaria* algae rinsed out on the cost. Before drying the algae are washed to remove sand, salts, shells and other foreign matter.

Drying

Once collected, the algae must be dried. There can be used two methods – natural and compulsory drying. Natural drying in Latvia is possible only in summer months, since climatic conditions change frequently. During drying process algae must be sprinkled with clean water until they became discoloured.

There can be used heat, natural air flow or ventilation for the second type of algae drying. The picture shows drying of algae using equipment, which can be specially adapted for this purpose.

Drying of algae by using a drying equipment

Extraction

Algae are heated at 121°C for 1–1.5 hours. The quantity of water must be 15–20 times greater than the weight of the algae. If necessary, during algae extraction there can be added an appropriate amount of bleach to reduce the colour, such as sodium hypochlorite or calcium hypochlorite.

Filtration

Filtration removes the seaweed residue and separates the product from other waste such as rocks, shells, dirt, etc. This is accomplished by passing the water with the algae throughout different filtering tanks. The extract is thick and will gel if allowed to cool down, so it must be kept hot during the filtration process.

Concentration

The filtrate is cooled to form a gel, which is broken into pieces. This gel contains about 1 % agar and 99 % water that may contain salts, colouring matter and soluble carbohydrates. In order to remove the 99 % of water in the gel, two methods can be used.

One of the methods is the freeze-thaw process. The gel is slowly frozen so that large ice crystals form. The structure of the gel is broken down by the freezing and when the material is thawed most of the water drains away. The gel contains 10–12 % agar now (around 90 % of the original water content has been removed). Then the thawed material is drained and placed in a hot-air dryer. However there are high refrigeration costs which make freeze-thaw process relatively expensive.

The other method relies on synaeresis – separation of liquid from a gel. There is used pressure in order to force the separation of the liquid in this method. At the end of the process the gel contains around 20 % of agar. Advantage of this method is that there is no need of refrigeration, which means that there is much lower energy consumption compared to freeze-thaw method.

Milling

Agar can be divided into blocks, strips, or grind in necessary roughness fractions (powder) which is normally in size of 14–18 millimeters. Below in the picture is shown agar powder.

Agar powder

10. Production cycle

The raw material (8.5 kg of dry, shredded seaweed)
↓
Washing in clean water
↓
Maceration overnight in clean water
↓
Wet milling or mechanical pressing approx. 30 minutes
↓
Seaweed mass
↓
Boiling in 100 litres of water for approx. 2 hours in the steam boiler, maintaining pH 6 by adding 400–500 ml of sulphuric acid
↓
Liquid filtration in double hermetic vacuum filter
↓
Filtrate cooling to room temperature
↓
Obtained gel separation (using equipment) into the blocks or strips
↓
Freezing for 24 hours (refrigerators)
↓
Defrosting at room temperature
↓
Sun-drying or drying in the chamber with hot air circulation
↓
Agar (1 kg)

1 kg of agar can be obtained from 8,5 kg *furcellaria* dry matter by applying this production cycle. This is the most profitable production cycle compared to other agar production cycles that could be used. Production is with the approximate capacity of 1,000 tonnes finished products per year.

The biggest problem of agar production is large energy consumption. In order to ensure profitable production of agar there is need to ensure the heat source at first. Latest market analysis shows the growing interest in building biogas stations in Latvia. During the winter biogas station cheap heat could be used for households heating, but in summer and early autumn for the processes of agar production, as extraction and drying or freezing that are highly energy-intensive processes.

11. Calculation of agar production raw material

Assuming that production site is located near (<10 km) from the *furcellaria* algae mass primary-storage sites and according to the fact that algae collection is seasonal, there can be established the approximate actual cost of agar production.

	Basic expenditures	EUR	EUR/kg
1.	**Preparation of the material.**		
1.1.	Collection of furcellaria algae	43,825	0.044
1.2.	Transportation of furcellaria algae	52,077	0.053
1.3.	Purification of furcellaria algae	5,122	0.006
1.4.	Extrusion of furcellaria material	5,122	0.006
2.	**Processing.**		
2.1.	Washing of furcellaria material	12,240	0.013
2.2.	Rinsing of furcellaria material	57,871	0.058
2.3.	Wet milling	7,117	0.007
2.4.	Extraction	3,426,295	3.426
2.5.	Vacuum filtration	129,038	0.129
2.6.	Precipitation and cooling of the filtrate	22,015	0.021
2.7.	Primary processing of the gel	6,784	0.007
2.8.	Processing at low temperatures	3,334,092	3.334
2.9.	Drying	3,349,459	3.349
2.10.	Milling	12,904	0.013
2.11.	Packing	11,574	0.011
3.	General production costs	1,576,551	
	Total:	**12,052,086**	**10.477**

Indirect or general production costs – costs that are not used for the direct material application and labour. Examples for such type costs are material storage costs; indirect material costs (auxiliary materials, packing, etc.); indirect wage costs, including the social ones (wages for workshop and production managers); production department space costs; vehicle and inventory amortization; production equipment repair and inventory capital current percentage; electricity consumption costs.

In the calculation there are not included production costs of construction cranes and site infrastructure installation costs. Required area for the production site is 3,000 m^2, not including material storage facility. It is possible to use territories of the former factories in Kurzeme region. Production equipment purchase costs are around 425,000 EUR.

12. Lesgislation

Baltic Sea and Gulf of Riga waters and coastal zone is regulated and administrated by the Republic of Latvia, no private owners are allowed. Coast of Baltic Sea is 150–300 m wide protected area, where is restricted ownerships, construction and economic activity (Protection Zone Law). In the protected area and coastal zone is forbidden to drive a motor vehicle, except if it is for coast cleaning purposes. As well any economic activity can be allowed only with special permission from responsible authorities.

Legislative documents states that the foreshore is owned by the state, but in fact the coastal management is realized by local municipalities. There are five municipalities on the Kurzeme coast. And only Pavilosta municipality resolution determinates a fee for the collection of algae using motor vehicle. The fee for issuing permission for a single descent on the beach with the motor vehicles for seaweed collection is from 0.35 EUR – 2.13 EUR for one time. All collected funds are spent for coastal zone and beach improvements.

Other municipalities do not develop any regulations for collecting of algae on the coastal zone. But in future it is possible that analogical resolution will issue other municipalities to control entrance on coastal zone with motor vehicles.

13. Strategy output

Before starting production process, the attention should be paid to the following aspects:

- Legal party (licensing procedures)
- Economic and financial side
- Education and information
- Technical and organizational side
- Society/regional population support

Legal party

The main objective is to identify the necessary permits and its granting procedure. Contact with the appropriate state/local authorities.

Economic and financial side

The main objective is to improve conditions to attract funding and to ensure the company's competitiveness. Approximate agar production actual costs are the highest, followed by manufacturing equipment acquisition costs.

Education and information

The main objective is to deal with challenges being related to the lack of experience, local experts and consultants in the field of agar production.

In this case, the proposed measures are the following:

- Investigation visits to the existing agar production plants
- Acquaintance with other countries' production experience
- Educational programs for potential factory workers.

Technical and organizational side

The main objective is appropriate agar production plant management and organization. Necessity to have knowledge of algae *furcellaria* collection and transport from the coast to the production plant, as well as knowledge about production processes.

Society/regional population support

The main objective is to get the society/region population support by timely informing them about the plans and activities related to the collection of algae in Kurzeme seacoast and further processing for agar extraction.

The proposed measures for society/region population support are the following:

- Information distribution about the region benefits from the production of agar
- Open discussion with the local authorities and inhabitants about the planned agar production advantages and disadvantages

14. Conclusions

Red algae *furcellaria*, collected from the Baltic Sea cost of Kurzeme, is one of the most common species of algae in the seacoast of Latvia with the highest total amount of biomass, thus including the potential for the production of agar. Agar production would be beneficial for Kurzeme region, since it would improve the development of the region and increase its competitiveness.

Production process includes steps such as algae collection, drying, extraction, filtration, concentration and milling, of which some are highly energy-intensive processes. Therefore, in order to ensure successful production of agar, there is a need to ensure the energy source as, for example, biogas stations. Agar has a wide variety of uses, but mainly it is used in production of food products, which is due to its high gelling ability and the special gel structure.

Improving the Baltic Sea environment and economies: Innovative approaches to the sustainable use of marine resources

The Baltic Sea Region faces enormous challenges including new installations, fishery declines, excessive nutrient input, the effects of climate change as well as demographic change. But novel technologies and growing knowledge also provide opportunities for new uses of marine ecosystems, which can be both commercially appealing and environmentally friendly. Through increased understanding and promotion of innovative and sustainable new uses of the Baltic Sea, SUBMARINER provides the necessary basis for the region to take a proactive approach towards improving the future condition of its marine resources and the economies that depend on them.

Activities

Compendium

Describing current and potential future marine uses

- Comprehensive inventory of current and new uses
- Strengths, weaknesses, opportunities and threats to the BSR
- Environmental and socioeconomic impacts
- State and availability of technologies
- Market potential
- Gaps and obstacles in the legal framework

BSR Roadmap

Recommending necessary steps across all disciplines to promote beneficial uses and mitigate against negative impacts

- Research topics
- Institutional and network initiatives
- Legal changes (e.g. spatial plans)
- Environmental regulations
- Economic incentives

Regional Strategies

Testing new uses in real conditions

- Feasibility studies for new uses
- Technological and financial needs
- Impacts on environmental and socioeconomic conditions within the area
- Specific legal constraints

BSR Network

Bringing relevant players together

- Business cooperation events
- Network structure (incl. membership, mission, independent finances, business plan, etc.)
- Virtual information and exchange platform
- Regional, national and BSR-wide roundtables and seminars on new marine uses

Partners

Poland

- **Lead Partner:** The Maritime Institute in Gdańsk
- Gdańsk Science and Technology Park

Germany

- Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
- Norgenta North German Life Science Agency
- Kieler Wirkstoff-Zentrum am GEOMAR | Helmholtz Centre for Ocean Research Kiel
- University of Rostock
- BioCon Valley Mecklenburg-Vorpommern e.V.

Denmark

- ScanBalt
- Lolland Energy Holding

Sweden

- Royal Institute of Technology (KTH)
- The Royal Swedish Academy of Sciences
- Trelleborg Municipality

Estonia

- Tallinn University of Technology
- Entrepreneurship Development Centre for Biotechnology & Medicine

Lithuania

- Klaipeda University Coastal Research and Planning Institute
- Klaipeda Science and Technology Park

Latvia

- Ministry of Environmental Protection and Regional Development of the Republic of Latvia
- Environmental Development Association

Finland

- Finnish Environment Institute – SYKE

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- Partners' contribution: € 0.8 million
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