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Estonia: Algae valorisation through partnership of RDI institutions and enterprises

Case study

Tartu 2022

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Introduction

The subject of the case study are two Estonian companies whose main activity is valorisation of red algae *Furcellaria lumbricalis.* The case study focused on the history of the companies, studied resource efficiency and use of residual products, sustainability, product development and cooperation. In addition, the socio-economic impact of the sector was studied. The report is based on the analysis of the individual interviews of both companies and the socio-economic impact was described using the results of the study "Socio-Economic Analysis of Algae Storm Casts management" completed by Consultare OÜ in 2021.

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1. Red algae Furcellaria lumbricalis and possibilities for use and valorisation

There is a total of 80 macroalgal species and higher plants growing in water in Estonian sea area (Joller-Vahter, L. *et al.* 2021). Among them, red algae *Furcellaria lumbricalis* is not the most frequently occurring algal species but it is one of the most well-known and industrially used species (Kiiker, K. *et al.* 2021).

In the Baltic Sea, this algae species occurs in two forms - attached and floating, or drifting form. The attached form *Furcellaria lumbricalis f. lumbricalis (= F. fastigiata)* is very common in the Baltic Sea. The plant attaches itself to rocks, limestone slabs or slime chambers by means of rhizoids. The diameter of the thallus of the attached form is up to 1 mm and the height is up to 20 cm. The floating algae (only *Furcellaria lumbricalis f. aegagropila* in the Baltic Sea is discussed) has a radially symmetrical structure and springy thallus and thus the waves roll it along the open seabed (Trei 1991). Diameter of the floating form is 5-12 cm. *Furcellaria lumbricalis* is cartilaginous and cylindrical, has repeatedly dichotomous branches with straight, narrow, pointed stems. It is reddish brown by colour and turns black when dry. The red algae growing in Kassari Bay between Saaremaa and Hiiumaa (Figure 1) is an intermediate form of an attached *F. lumbricalis f. lumbricalis* and floating *F. lumbricalis f. aegagropila*. The plants lie loose on the seabed, forming an intertwined tangled mass (Nõmmela, K. et al. 2019). Kassari Bay is home to the world's largest, 150 km^2 growth area of red floating algae.

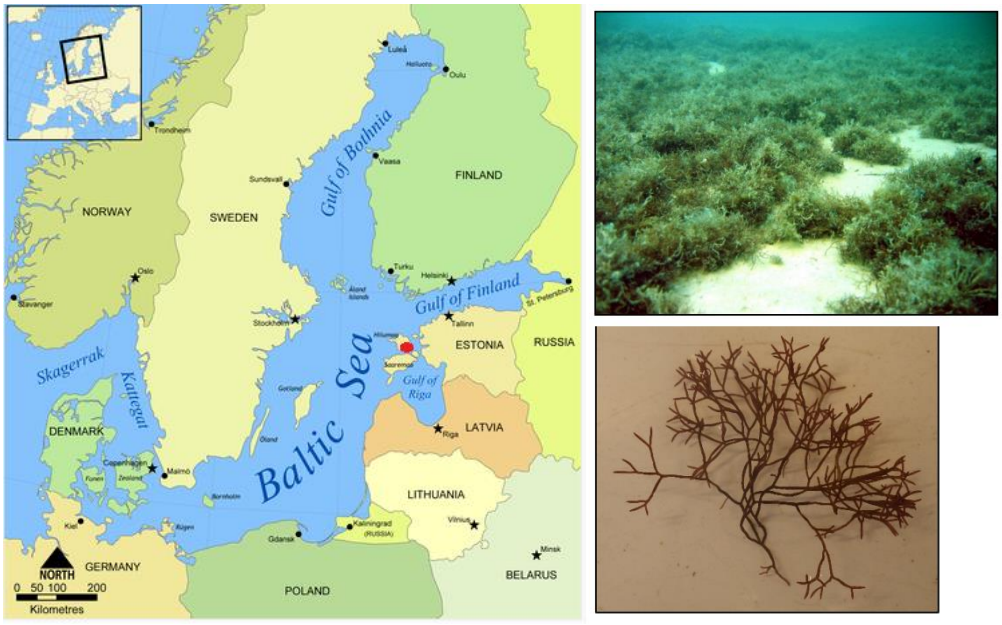

Figure 1. The growth area of red algae *Furcellaria lumbricalis* (red dot) and its floating form

Source: Wikipedia, Estonian Maritime Institute of the University of Tartu

The volume of biomass of red algae growing in Kassari Bay is estimated at 145,000 t (Joller-Vahter, L. *et al.* 2021). In Kassari Bay, red algae trawling for industrial purposes began in 1966 (Paalme, T. *et al.* 2017). As of today, two trawling licenses have been allocated for red algae trawling with a total volume of 2,000 t per year. In the years 2007–2021, red algae were not trawled to the maximum allowed amount (Figure 2). Year after year, red algae trawling volumes have decreased and there was no red algae trawling in 2018.

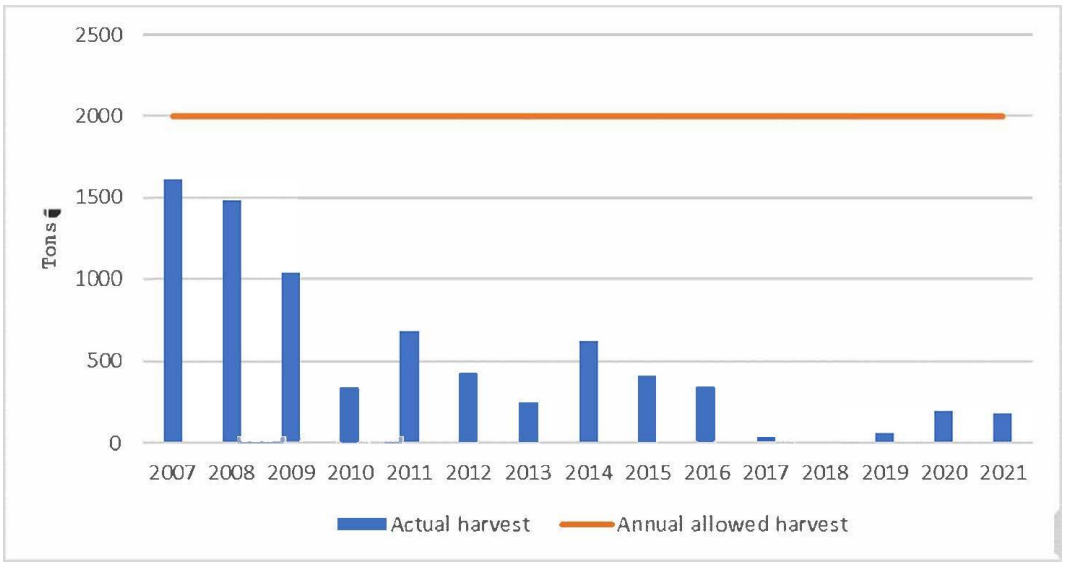

Figure 2. Allowed and actual trawling of red algae in 2007–2021
Source: Agriculture and Food Board

Red algae *Furcellaria lumbricalis* is known to be available in industrial quantities only in Kassari Bay. For industrial use, the floating form of red algae is trawled and the attached form washed ashore by storms is gathered from the shore.

Red algae biomass trawled or stocked-up from seashore has several possibilities for use and valorisation (Joller-Vahter, L. *et al.* 2021):

- organic fertiliser in agriculture and gardens;
- biostimulant in horticulture;
- texturising additive furcellaran (gelling polysaccharide) in food (marked E407 in marmalade, zefir and milk products), cosmetical and pharmaceutical products;
- pigment (red antioxidant colour pigment) in cosmetic and food industry products;
- proteins in food, feed, or similar industries;

- etc.

Sustainable blue economy is a rapidly developing field, which receives a significant share of research funding (research and innovation programme "European Horizon" 2021-2027, etc.). This provides an opportunity for better and more efficient use of the potential of algae.

2. A case study of two companies

The subject of the case study are two companies whose main activity is the industrial valorisation of *Furcellaria lumbricalis.* Both companies operate on Estonia's largest island, Saaremaa. One of them is a small company with a long history, Est-Agar AS, which is the only producer of furcellaran from the red algae *Furcellaria lumbricalis* in the world. Est-Agar's 2020 sales revenue was 0.75 million euros. The second company is a micro-enterprise Vetik OÜ that has been operating since 2017. Vetik has sold a small amount of phycoerythrin, a pigment produced from red algae as sample batches for testing in the cosmetic industry and dried algae for testing but the company has not yet achieved significant and consistent sales activity.

The production of both companies is an intermediate product or input for other production companies. Both companies predominantly use direct i.e. B2B marketing.

2.1. Case study methodology

The case study focused on the history of the companies, studied resource efficiency and use of residual products, sustainability, product development and cooperation. In addition, the socio-economic impact of the sector was studied. For this purpose we designed a questionnaire for an interview (Annex 1). The interviews with the entrepreneurs were carried out in Saaremaa at the companies on fifth of May 2022. The interviews were recorded, transcribed and a report was written.

2.2. History of the companies

Est-Agar

Est-Agar is an industry with a long history. The history of the industry dates to the 1960s when Estonian marine scientists found out that the red algae *Furcellaria lumbricalis* found in Estonian Väinameri could be used to produce a stabilising, thickening and gelling agent, furcellaran, which in chemical terms is a mixture of certain sulphur-containing polysaccharides (furcellatan). The finding was snatched up by Kalev, Estonia's largest confectionery that developed the technology for production of furcellaran and in 1966 built a furcellaran industry in Saaremaa. The output of the factory was primarily used as input for Kalev's own production

but furcellaran was also delivered to Russia, Ukraine, Latvia, and elsewhere. At the beginning of the newly independent Republic of Estonia, in 1996, Saare Kalur bought the furcellaran industry from the confectionery and in 2016, the industry was bought by its current owners. (Viira, A.-H. *et al.* 2021).

The current owners of Est-Agar came up with the idea to get engaged in the blue economy, more specifically farming and processing of algae on the Baltic Sea coast on the island of Vormsi. To start with, they researched the valorisation potential of the algae growing in the Estonian Baltic Sea's coastal waters and its possible uses. It was found out that by using various technologies a variety of useful substances can be extracted from the algae growing in Estonian coastal waters to be used mainly in the food and cosmetic industries. After thorough research and consideration, it was decided to buy the Est-Agar factory located in Kärla, Saaremaa, Estonia's largest island. The company was the world's only producer of furcellaran, a unique texturising additive produced from red algae *Furcellaria lumbricalis*. The deal was signed in 2016 when the friends bought all the factory's shares. Thus, they got a working factory to realize their ideas, access to the algae, i.e. the raw material quota and a market share in the carrageenan market. (Viira, A.-H. *et al.* 2021).

Figure 3. Logos of companies Est-Agar and Vetik

Vetik

There were several things that led to the founding of the Vetik company. One of the founders of the company was during his doctoral studies at the University of Tartu (UT) looking for opportunities in his hometown in Saaremaa to see what he could do in Saaremaa and what kind of business he could start. At the same time, in the mid-2010s, red algae trawling was at a low point due to lack of demand. Professional coastal fishermen were contacted as at that time they

had and still have the right to trawl for algae. In addition, the founders of the company saw red algae as a unique and potentially under-exploited biological resource. They came across research on pigments by a professor of chemistry at Tallinn University (TÜ) which inspired the start-up entrepreneurs to get involved in valorisation of red algae. The company was founded in autumn 2017 and currently has three shareholders.

2.3. Production and marketing

For both companies, the most important input is the local red algae *Furcellaria lumbricalis*. While Vetik plans to use the floating trawled red algae and farmed red algae in a five-year perspective, Est-Agar's production is using both trawled red algae and gathered red algae storm casts as well as farmed red algae in the five-year perspective.

Est-Agar

The volume of red algae purchased by Est-Agar varies from year to year. Today the production uses about 1000 tons wet weight of red algae which corresponds to about 200 tons of dry weight. Approximately half of this volume is trawled and half is red algae storm casts from the seashore. Production plans are primarily based on trawled algae because it is possible to better control the quality and volume of trawled algae than gathered red algae. The gathering of algae storm casts depends largely on the weather and the composition of species of algae storm casts varies. The mass of the red algae *Furcellaria lumbricalis* gathered from the shore contains about 20% of other algae (bladder algae or similar, Kiiker, K. *et al.* 2021).

The main activity of Est-Agar is the production of furcellaran from red algae (Figure 4). Both flaky and powdered furcellaran are being produced. The production technology of flaky furcellaran dates to 1974 and the product was meant for the confectionery industry. The production of powdered furcellaran has been added as a new direction. For this purpose and in cooperation with the French company SA Algaia, a pilot plant for producing powdered furcellaran was completed by the end of 2022.

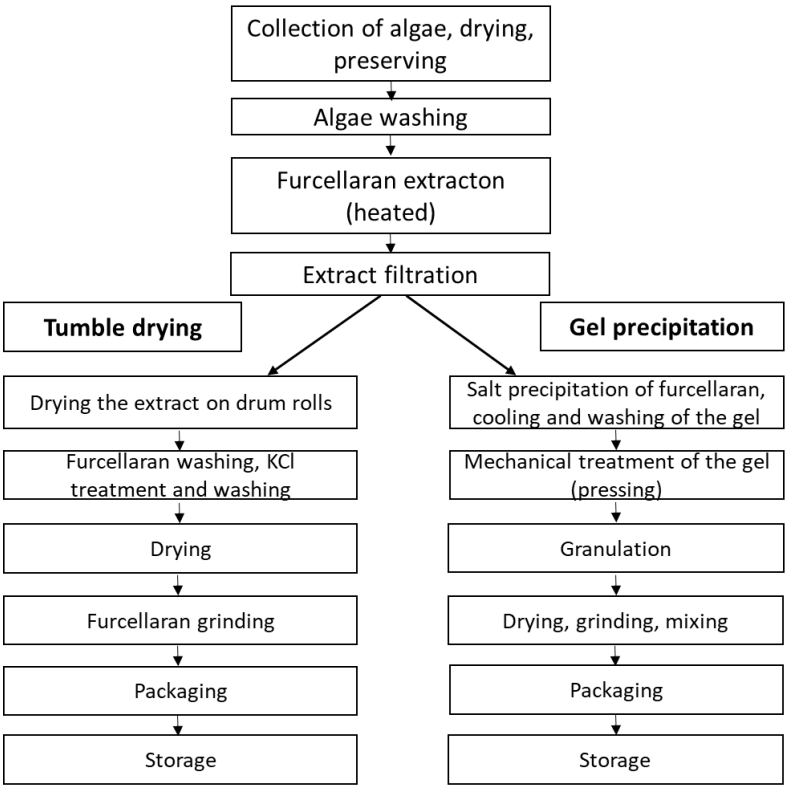

Figure 4. Stages in the production of flaky (left) and powdered (right) furcellaran
Source: https://estagar.ee/manufacturing/

The company's products are unique because the texturising additive furcellaran produced from said red algae is unique in the world. Although the company is the only manufacturer of furcellaran in the world they are competing in the total market of gelling agents, thickeners, and hydrocolloids. The company's competitors are manufacturers of gelatin, pectin, carrageenan, alginates, agar-agar, and other products. The company positions itself as exclusive and different and for different customers whose products also have an exclusive output. The company's selling point is that furcellaran gives products different properties compared to, for example, pectin. While pectin gives products stiff and strong texture, furcellaran gives a slightly softer texture.

Furcellaran is an anionic sulphated polysaccharide that was previously classified in Europe as a separate product E408. Today, due to the pressure of large manufacturers, furcellaran belongs to the E407 group of emulsifiers and stabilisers together with carrageenans. Since carrageenans are believed to be harmful to health and have carcinogenic properties, the additive label puts furcellaran in a bad light as well. Although furcellaran is relatively like carrageenan, the structure, properties and production processes of furcellaran are different. While many

carrageenan manufacturers extract carrageenan in solutions, Est-Agar uses pure water. Based on these arguments, the company is currently working on to exclude furcellaran from the E407 group. In the FDA classification of the US Food Administration, furcellaran is a separate product from carrageenans.

Most of Est-Agar's production is sold to confectioneries. An estimated 70-80% of production is exported all over the world. Mainly to European countries (Russia, Ukraine, Latvia, France, Poland, Romania, etc.) but the company also has clients in India, USA, Japan. The biggest customer in Estonia is the Kalev confectionery owned by Orkla Eesti AS. The company uses mainly B2B marketing.

Most of the residual products are given to local farmers free of charge and a lesser amount is sold for a small fee to households who use the residual products as organic fertiliser on their fields and in gardens.

2.4. Product development, obstacles, and possible solutions

Est-Agar

In a five-year perspective, Est-Agar has a plan to increase the company's production volume at least four times and start valorisation of residual products Est-Agar is constantly involved in product development in its laboratory and has been a partner in several product development projects in order to identify different production directions for valorisation of red algae components and residual products.

In 2018, a project to develop the production technology of r-phycoerythrin, a pigment from red algae, was started in cooperation with the Polli Competence Center for Knowledge-Based Health Goods and Natural Products of Estonian University of Life Sciences (EMÜ), Tallinn University and Vetik. The project completed a pilot production technology for production of natural red pigment by the end of 2019 based on existing laboratory tests. As a result of the project, it became clear that the technological process still needs to be improved and further research is needed for the results to be suitable for marketing. At the same time Est-Agar in cooperation with the French company SA Algaia got a development project of a new technological line for production of powdered furcellaran. The completed pilot plant will be an operational plant in the autumn of 2022, when larger quantities of powdered furcellaran can be

produced with more substantial equipment. When the new production line starts up, the company plans to start testing red pigment again and develop technology. The aim has been to finally develop the r-phycoerythrin line that requires research on multi-extraction possibilities of red algae at the production level in cooperation with scientists. This gives the company an opportunity to expand its markets because modern production technologies in food industry use powder mixtures where several different substances are already mixed (Viira, A.-H. *et al.* 2021). In addition, depending on the degree of purity uses of the red pigment are very wide from food industry to medical industry.

Est-Agar has had two product developments for valorisation of residual products. The development of recipes for organic fertilisers has started. Residual products were mixed with oil shale ash and wood ash and slurry to produce fertiliser pellet products. However, to produce natural fertiliser based on the developed recipes, the volumes of the company's residual products are too small and the company abandoned further developments in this direction. Next, it was found that the production residues could be used to make plant containers (for lettuce and similar). The idea is that since the residual products of the company contain enough furcellaran and 10–12% dry matter, furcellaran when cooling binds the production residue into a sufficiently hard and waterproof material and due to its properties it is suitable for use in gardening. Today, experiments in the company's laboratory are so far advanced that the company has a preliminary prototype of a plant container and has made a decision to start producing plant containers in the near future. In order to further develop the idea, it is planned to apply for support from the Applied Research Programme of the Enterprise Estonia (EAS) to test the recipes and pilot production of the plant containers.

Vetik

Vetik started its activities with the research of phycoerythrin and related product development from red algae targeted for the cosmetic industry. In a few years it appeared that (1) there are no methodologies for high-purifying the pigments from red algae, (2) it is difficult to make it to the cosmetic or food industry's final product with the pigment, and (3) pigment makes up about 0.5% of the dry matter and the rest are residual products. The company began to research what other components algae contains in addition to phycoerythrin and what else can be done with different components of algae. It was decided to give it a try and develop a biostimulant

product. Biostimulant is a plant growth-enhancing and strengthening preparation that can be produced among other feedstock of algae. Simply put, it means the liquefaction or hydrolysis of the algae, as a result of which the algae help to speed up the absorption of nutrients by plants. The company considers the product development of biostimulant based on local red algae important as it gives the company an advantage over other similar manufacturers. The advantage being:

1) the components of red algae are special. Red algae contain an unusually high amount of protein and pigment for algae with availability that appears to be good compared to alternatives.

2) there are not many uses yet to red algae and no knowledge of using it as an intermediate product within other products. The first corn field tests of the biostimulant outside of Estonia have been successful with good results.

3) it is a natural material and the production of the biostimulant will be environmentally friendly with a small ecological footprint. Today, biostimulants of algae are produced in Asia, Indonesia and Latin America and exported to Europe. Intra-European production from Europe-grown algae would mean a smaller ecological footprint and a more secure supply.

Since the production of biostimulant requires a rather large volume of raw materials, the company's red algae trawling quota is not sufficient and they have to start farming. But this is also the biggest disadvantage of red algae because according to Vetik's representative, it is difficult to farm.

Today, Vetik's goal is to find out application possibilities for red algae and map the most potential sectors. At the same time, Vetik is moving towards a so-called potential and available solution. Some equipment units in the production building have been acquired, but there is still a lot of testing to be done (optimal washing solution for red algae, etc.) and there is significantly more equipment needed. Since the company essentially has no sales activity, the biggest factor hindering the company's development is the lack of money. At the same time, they are looking for biostimulant experts who can advise the company in taking the biostimulant to the market. They are also looking for industrial partners outside of Estonia who would be interested in the intermediate product produced by Vetik to use in their own final products.

Both companies

Both Est-Agar and Vetik representatives stated that the companies' biggest development problem is that there are no pilot production units or complexes in Estonia where it would be possible to test the production of trial batches. The representative of Est-Agar added that the company's own laboratory is not sufficient for product development and the representative of Vetik noted that due to the small size of the sector, there are very few experts in the field in Estonia and it is difficult to find them outside of Estonia. It is a rare field which also makes the product development process challenging and time-consuming. One solution to the problem could be greater support for cross-border grants. If the company needs to test a specific production process (separation of components from algae, etc.), then if the service is available, it makes sense to purchase this service. Such an approach would probably be faster, cheaper and provide better quality than to offer the same task to an Estonian researcher. It may take them more time to achieve a result and it may happen that the result is not reached at all because Estonian researchers are specialised in other topics and do not have access to specific equipment or do not know how to use it.

Since Est-Agar wants to increase the production volume up to four times in their five-year plan and Vetik wants to start producing a biostimulant from algae, the red algae trawling quota of 2000t and the poor supply of algae storm casts may prove to be insufficient for increasing Est-Agar's production and starting Vetik's production. It means that it is necessary to start farming algae. In Estonia, the possibilities of algae farming are being investigated but according to the entrepreneurs the development of algae cultivation is at the beginning and there is an urgent need for more expert knowledge in this field (farming algae in ponds, etc.).

2.5. Corporate sustainability

The key to the success of Est-Agar's activities lies in the valorisation of biomass of local origin, unique in the world and well suited into the context of today's bioeconomy. Est-Agar is the only blue biotechnology company at the Baltic Sea that uses local resources. All other similar companies have built their business on imported resources of Asian origin. In addition, a lot of attention has recently been paid and support opportunities have been offered to companies for development of blue economy and blue biotechnology. According to the entrepreneur, it is also

positive that the representatives of fisheries and aquaculture are sufficiently involved in law-making and in the preparation of national sectoral development documents.

In addition to product development, there are various issues that a company must deal with in order to stay competitive.

1) Energy costs. From the autumn of 2020, the company's steam boiler began using new energy carrier. The company joined the gas network and instead of shale oil, are now using liquefied natural gas (LNG). Heat production thus became significantly more environmentally friendly but the savings in energy consumption thanks to the change of energy carrier were short-lived. If at the end of 2020, LNG price was 25–30eur per megawatt-hour, in September 2021 it was 60eur and at the beginning of 2022 already 100eur per megawatt-hour. The company has no alternatives. The use of biogas LNG would probably be even more expensive.
2) Sustainable use of water. In the context of the transition to green economy, all companies have to change their operations to a greater or lesser extent in such a way that natural resources are used sustainably. Est-Agar is using clean well water for the valorisation of red algae. Wastewater from production is directed through the company's water treatment machinery and hereafter to nature. Est-Agar's cosmetic industry partners though are increasingly interested in sustainability of the production process, including reusing water. Today, reusing water in the company is not economically justified, i.e. it is very expensive. However, against the background of the green economy, the company will most likely start dealing with it at some point.
3) Wage pressure.
4) In Estonia, obtaining permits for development of aquaculture is too long a process and communication with the authorities is too slow. In June 2018, Est-Agar applied for a construction permit to establish algae and shellfish farming in the Baltic Sea. In April 2022, the company received the decision to start the procedure. According to the entrepreneur, the process of establishing shellfish farming may take several more years. Due to the public sector's practice of such lengthy processes it is difficult for entrepreneurs to stay competitive and make investment decisions.

2.6. Cooperation and forms of cooperation

Since the development and product development of Est-Agar and Vetik companies is mainly research-based, both companies cooperate closely with **universities**. The cooperation has been very important and rather positive for both companies. For both companies, consultations based on direct contacts with researchers are very important. Both companies have long-term and trusting cooperating relations with researchers from Estonian University of Life Sciences (EMÜ), Tallinn University (TLÜ), the University of Tartu (TÜ) and Tallinn University of Applied Sciences (TTK). In case of specific questions regarding the valorisation of red algae, researchers from EMÜ, TLÜ and TÜ are often consulted. Est-Agar is also consulting the TTK professor in circular economy on the topic of wastewater solutions. **Small-scale projects between entrepreneurs and researchers** have usually grown out of these consultations, the purpose of which is to analyse, test, design, etc. Est-Agar has cultivated such small-scale but operational activities the most. Since one of Vetik's representatives is currently studying at the University of Tartu's molecular and cell biology doctoral programme, he has the opportunity to perform specific experiments himself in the UT laboratory for a fee. Based on the experience of Est-Agar, the pitfall of Estonian science is the fundamental principle of research funding which has been unchanged for decades and considers researchers to be the primary beneficiaries. This means that researchers offer entrepreneurs projects with a long implementation period by which they secure stable income and the required scientific articles based on the results of the project but the real benefits for the entrepreneurs which are scientific results completed in a short period of time and applicability in business may be considered less important.

Kuressaare College of Tallinn University of Technology is in Saaremaa where a **product development laboratory** for valorisation marine resources is being established. Est-Agar has actively participated in the establishment of the laboratory and the preparations of the laboratory plan. Both Est-Agar and Vetik hope to soon start effective cooperation with the product development laboratory because the companies themselves do not have such a laboratory neither do they have the ability to build a laboratory of this level. The existence of such a well-equipped laboratory is very important for Saaremaa companies because in addition to the laboratory's capacity it is in their immediate vicinity. In the future, experiments are expected to be carried out in this laboratory, recipes will be developed, etc.

Both companies actively participate in national and international joint projects. In 2018–2019, both companies participated in a project together with EMÜ and TÜ researchers, the aim of which was to develop an effective technological solution for the separation of phycobiliproteins (especially r-phycoerythrin) from red algae which can also be applied in industrial volumes. The project was supported by the European Regional Development Fund (ERDF). Most difficult about the joint project was that the activity of entrepreneurs participating in project activities was irregular and they did not meet each other's expectations. In Est-Agar, a technological pilot production line development project for powdered furcellaran was launched in 2018 with the opportunity for support for designing it into a full-scale production line in 2020–2021. The partner of both projects was Algaia SA from France and the projects were supported by ERDF. In several international projects, Est-Agar is involved as a partner representing the sector. Vetik has participated in many national and international projects supported by ERDF, Horizon 2020, ERA-NET, BlueBio Cofund, etc., all of which have been aimed to find out the possibilities of valorisation of red algae (especially red pigment). The weak point of international joint projects is the ownership issue of project results. Ownership rights are costly for a small business.

Est-Agar has cooperated with **research institutions** such as the center of excellence for biotechnology and food science - Center of Food and Fermentation Technologies (TFTAK). The zefir recipe was ordered from them. Vetik has used the opportunity to conduct experiments at the Estonian Crop Research Institute (the institute carries out research in crop breeding, agrotechnology, plant biotechnology and plant protection) by renting their equipment.

Both companies participate in different **networks**. Vetik is a more active participant in networks. In the beginning, the company was a member of the blue biotechnology network which unfortunately has ceased to exist. Vetik was invited to the Submariner Network following a long cooperation. Submariner Network connects companies and research institutions related to the sea and it also includes relevant universities in Estonia. Today, Vetik also belongs to the Blue Bio Alliance network.

In addition, both companies use **support measures** provided by the public sector. Many research and design support measures are targeted at the sector. Est-Agar has used the Enterprise Estonia product development measure that helped the company to design a production line for powdered furcellaran. At the same time, there are few investment measures supporting the blue economy.

As a start-up company, Vetik participates in various **accelerators**. It has participated in accelerators such as the Baltic Blue Biotechnology Alliance, Est-Lat Bioboost, Blue Bio Value (Portugal), Climate-KIC Accelerator and Beamline Accelerator. Today they are also members of the Saaremaa Green Accelerator meant for Saaremaa companies. The company plans to continue participation in various accelerators. With the help of accelerators the company receives mentoring support from various experts in the field to gain knowledge and experience, make its business model more resource-efficient, sustainable, etc.

Est-Agar cooperates with both **sectoral and external companies**. Cooperation with other companies is primarily commercial. For example, a local metal company manufactures constructions and spare parts for Est-Agar's production by special order, a transport company offers transport and logistics services, a design company draws up blueprints for constructions and similar, etc. Within the sector there is cooperation with red algae trawlers.

Neither of the companies have direct points of contact with the **local municipalities** but Est-Agar is represented in such **associations** as the Saaremaa Entrepreneurs' Association and the Estonian Chamber of Commerce and Industry. Participation in such associations gives an entrepreneur an opportunity to influence the development of business in the region, develop regional, national and international cooperation and participate in networks.

2.7. Socio-economic impact

The activities of both companies have a significant socio-economic impact on the local community. All 25 employees of Est-Agar are local residents. Employees who commute to work from a distance of more than 10 km are being compensated transportation costs. The average age of the employees is 53 years and most of the employees have worked in the company for an average of 20–30 years. The production is carried out periodically according to the demand for the company's production. They work for a month or two then there is a break and then they work again for a month or two, etc. During production breaks, workers are offered other jobs in the production building and those who cannot get jobs are maintained at the minimum wage. When the powdered furcellaran production line is launched, the production becomes continuous which in turn means that periodic production turns to continuous production and employees can work continuously in the company. The representative of Est-

Agar does not foresee an increase in the number of employees when the powdered furcellaran production line is launched. A separate company was created for the production line of plant containers where additional local workers are needed. To start a phycoerythrin production line they need a specialist with technological knowledge and production workers. While production workers can be recruited from the local community, a technology specialist must be recruited from further afield.

Vetik has a part-time CEO who is local and a part-time researcher.

If resources are needed, Est-Agar and Vetik employ the Tinurek company fishermen who will be trawling the floating red algae from the Kassari Bay. Tinurek is trawling algae with a boat of two to three men. Since trawled red algae is dried like hay, the algae are trawled in the summer. Red algae trawling is popular with fishermen because it offers additional income in the period between fishing (Kiiker, K. *et al.* 2021).

In addition to the trawlers, Est-Agar provides jobs and earning opportunities to an estimated 30 families who the company buys red algae storm casts from. Algae storm casts are gathered by the residents who are self-employed or legal entities (private limited company). Gathering algae storm casts is an inherited skill practiced by three generations at the same time in some families but there are also individual gatherers. The gatherers of algae storm casts that operate in protected areas, have a special licence for gathering the algae storm casts issued by the Environmental Board (Kiiker, K. *et al.* 2021).

Gathering and subsequent handling of algae storm casts requires experience and knowledge. It is necessary to know when it is the right time to gather algae and when to dry it. Usually, the algae are washed ashore during autumn storms and is dried in the spring. In snowless and dry winters, drying can be done earlier. If the weather is very wet and the algae storm casts cannot be gathered quickly, the algae piled on the seashore can spoil. Also, the algae gathered from the shore must be spread on the field within a few days. Some of the algae always goes to waste. Algae is gathered from the shore and dried in the fields by hand which results in better quality of dried algae storm casts (Figure 5). Because handling of algae storm casts is physically demanding, often agricultural machinery is used for this but it carries the risk of damaging coastal soil and roads. Before the gathering of algae, algae storm cast gatherers must obtain agreements with landowners for both gathering and drying of algae. All in all, the gathering of algae storm casts depends to a large extent on the weather. It depends on the storms whether

and how much algae are washed onto the shore by the sea, and it depends on the rainfall whether the algae can be dried and transported. (Kiiker, K. *et al*. 2021).

For the sake of maintaining good cooperation and gathering high-quality algae storm casts, Est-Agar has introduced a tradition whereby up to a few times a year the company invites all algae storm casts gatherers to visit the company to discuss together the joys and worries of the previous season and to introduce to the algae storm casts gatherers the plans for gathering red algae for the new season. The company has established quality criteria (proportion of additional substance from the sea in algae, etc.) for the gatherers of algae storm casts as well as conditional algae storm casts volume quotas. Since the gathering of algae storm casts is largely dependent on the weather which influences the volume and quality of gathering, an agreement is always reached regarding the payment of the fee and the volume exceeding the quota. During the year, algae storm casts gatherers gather between 500–80,000 tons of algae storm casts in wet weight (Kiiker, K. *et al.* 2021).

Figure 5. The gatherer of algae storm casts is heading to Est-Agar to sell the dried and pressed red algae. Author K. Kepp.

Although algae storm casts gatherers gather more or less pure algae and a small amount of mix of red and brown seaweed for their own use as fertiliser for their garden or fields, the socio-economic impact of algae storm casts gathering can be estimated as rather extensive. In general, the gathering of algae storm casts is considered important in maintaining or increasing the recreational value of the area as gathering algae from the shore before it decomposes alleviates the odour problem and ensures the aesthetic image of the shore. In addition, the removal of algae mass reduces the amount of recirculated nutrients. Purchasing of algae gives a reason to gather it. (Kiiker, K. *et al*. 2021)

Summary

The subject of the case study are two Estonian companies whose main activity is the valorisation of red algae *Furcellaria lumbricalis.* The red algae *Furcellaria lumbricalis* grows in Kassari Bay between Saaremaa and Hiiumaa and is one of the best-known and industrially used algae species in Estonia. Today, up to 2000t of red algae can be trawled from Kassari Bay per year.

Both companies operate on Estonia's largest island, Saaremaa. The history of the small company Est-Agar goes back to 1960 and it is the only producer of furcellaran, a texture-giving additive from the red algae *Furcellaria lumbricalis in the world.* Micro-enterprise Vetik OÜ has been operating since 2017. Vetik has sold a small amount of phycoerythrin, a pigment produced from red algae as sample batches for testing in the cosmetic industry and dried algae for testing but the company has not yet achieved significant and consistent sales activity. The output of both companies is an input to other production companies.

The most important production input for both companies is the local red algae *Furcellaria lumbricalis*. Est-Agar produces flaky furcellaran for the confectionery industry and small quantities of powdered furcellaran for the cosmetic industry. The red algae being used is trawled and gathered as algae storm casts. It is estimated that 70-80% of the production is exported. In a five-year perspective, Est-Agar's goal is to increase the company's production volume at least four times and to begin valorisation of residual products. The plan is to start producing larger quantities of powdered furcellaran, to develop a line of red pigment in cooperation with researchers and to start producing plant containers from residual products. Vetik has set itself the goal of producing a biostimulant from trawled red algae for horticulture. In order to meet their goals, both companies need farmed algae as production input in addition to naturally growing red algae.

The representatives of Est-Agar and Vetik stated that the company's biggest development problem is that there are no pilot production units or complexes in Estonia where it would be possible to test the production of test batches. The representative of Est-Agar added that the company's own laboratory is not sufficient for product development and the representative of Vetik noted that due to the small size of the sector, there are very few experts in the field in Estonia and it is difficult to find them outside of Estonia. It is a rare field which also makes the product development process challenging and time-consuming. One solution to the problem could be greater support for cross-border grants.

Since the development and product development of Est-Agar and Vetik is mainly research-based, both companies cooperate closely with universities and research institutions. The cooperation has been very important and rather positive for both companies. Consultations based on direct contacts with researchers as well as small-scale projects between entrepreneurs and researchers and the possibility of using laboratories are very important for both companies. Both companies actively participate in national and international joint projects and networks and use support measures provided by the public sector. As a start-up company, Vetik participates in various accelerators, while an already established company Est-Agar cooperates with both sectoral and external companies and is a member of various associations.

The activities of both companies have a significant socio-economic impact on the local community. All 25 employees of Est-Agar are local. In the five-year perspective, in case the production volume increases, Est-Agar will need an additional technologically literate specialist and production workers. While production workers can be recruited from the local community, a technology specialist must be recruited from further afield. Vetik employs two part-time employees, one of whom is local.

When raw materials are needed, Est-Agar and Vetik employ up to three fishermen who trawl the floating red algae from Kassari Bay. Red algae trawling is popular with fishermen because it provides additional income between fishing periods.

In addition to the trawlers, Est-Agar provides jobs and earning opportunities to an estimated 30 families who the company purchases red algae storm casts from. Algae storm casts gatherers are local residents. Gathering algae storm casts is an inherited skill practiced by three generations at the same time in some families but there are also individual gatherers.

Although algae storm casts gatherers gather more or less pure algae and very little of mix of red and brown seaweed for their own use as fertiliser for their garden or fields, the socio-economic impact of algae storm casts gathering can be estimated as rather extensive. In general, the gathering of algae storm casts is considered important in maintaining or increasing the recreational value of the area as gathering algae from the shore before it decomposes alleviates the odour problem and ensures the aesthetic image of the shore. In addition, the removal of algae mass reduces the amount of recirculated nutrients. Purchasing of algae gives a reason to gather it.

References

Est-Agar, estagar.ee (27.05.2022)

Joller-Vahter, L. *et al.* 2021. Uudsed võimalused Eesti biomajanduse väärtusahelate mitmekesistamiseks ja lisandväärtuse tõstmiseks. ADDVAL-BIOEC uuringu tööpaketi 3 raport, Tallinn & Tartu.

Nõmmela, K., Kotta, J., Piirimäe, K. 2019. Merekeskkonna ressursside kasutamisest saadava majandusliku kasu mudeli täiendamine ökosüsteemiteenustega. Tartu Ülikool, OÜ Hobikoda ja OÜ Roheline Rada. http://mereala.hendrikson.ee/dokumendid/Uuringud/mudeli_taiendamine_okosusteemiteenustega_aruanne.pdf

Paalme, T., Teeveer, M., Kaljuand, K., Püss, T., Reisalu, G., Esko, I., Pärle, R., Taevere., T., Luts, H.-L., Yarmola, N. 2017. Kassari lahe tööndusliku punavetikavaru uuringud. TÜ Eesti Mereinstituut. https://www.envir.ee/sites/default/files/kassari_lahe_punavetikavaru_uuringud_aruanne_2017.pdf

Põllumajandus- ja Toiduamet, pta.agri.ee (23.05.2022)

Trei, T. 1991. Taimed Läänemere põhjal. Tallinn: Valgus.

Vetik, vetik.eu (27.05.2022)

Viira, A.-H., Lillemets, J., Põder, A., Ariva, J., Aro, K., Lehtsaar, J., Kogabayev, T., Barth, H., Ulvenblad, P., Ulvenblad, P.-O., Hermus, S., Durchgraf, J. 2021. Report on Good Practice Business Models and Example Small and Medium Scale Pilot Business Projects for Sustainable Bioenergy and Side Bio-products Production in the BSR. Tartu: Estonian University of Life Sciences.

Äriregister, www.rik.ee (25.05.2022)