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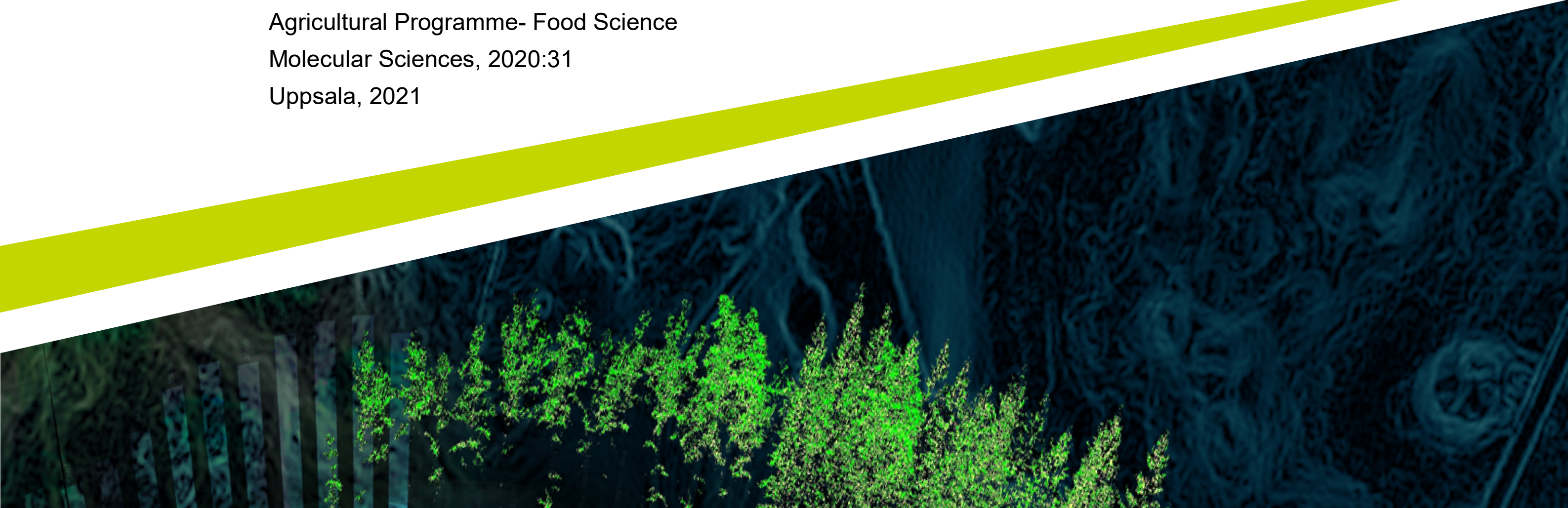

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Abstract

Macroalgae are an important energy source in several parts of the world and the popularity of algae has increased because of the specific properties. Due to the good gelling properties of macroalgae, algae derived products such as alginates can be used as additives commonly used as stabilizers in several food items. With a changing climate, the interest in algae has increased, both because algae can easily be grown without any major impacts on the climate, as well as their versatile applicability in the food industry. In Sweden, algae is an unutilized source even though the sea is a treasure box full of eatable and usable macroalgae. This may be because of the lack of cultural connection to algae as food. This thesis is a review of current literature and thoroughly investigates Swedish grown macro algae with a focus on three specific species and their potential of uses, mainly focusing on the possibilities involving food. Information has been collected through databases, scientific articles and book chapters. The review concluded that *Ulva lactuca, Saccharina latissima, Palmaria palmata* have the potential of being incorporated in to different existing industries such as the food industry, pharmaceuticals, future bioplastic production, energy production and as feed and fertilizer in agriculture. Furthermore, a regulated incorporation of algae in diets and food products may result in texture improvement and show health benefits. However, rather than incorporating the algae as a whole into a diet, the algae will most likely be processed and refined into certain desired substances. Even though there is a market for algae derived substances, one may argue that macroalgae should also be incorporated in food due to its nutritional properties. *U. lactuca* is one of few species from the non-animal source that is rich in Vitamin B_{12}, *S. latissima* is rich in dietary fibre and may be useful against obesity and *P.palmata* is rich in iodine and protein, and has an amino acid profile that can be better than chicken.

Keywords: Makroalgae, Ulva lactuca, Saccharina latissima, Palmaria palmata

Sammanfattning

Makroalger, även kallat tång på svenska, är en viktig energikälla i flera delar av världen och dess specifika egenskaper har ökat dess popularitet. Tack vare dess goda gel egenskaper, har derivat från alger, så som alginater, ett användningsområde som tillsats och används i flera livsmedelsprodukter idag. Med klimatförändringar har intresset med alger ökat, både för att alger enkelt kan produceras utan större åverkan på klimatet samt att alger har ett brett användningsområde. I Sverige är tång en outnyttjad källa, trots att det omgärdande havet är en skattkista med ätbara och användbara alger. Detta beror troligtvis på brist i kulturella kopplingar mellan alger och det svenska kulinariska köket. Denna essä är en litteratgenomgång innefattande nutida vetenskaper och kunskaper inom svenskt växande makroalger med fokus på tre specifika arter och dess potential, främst inriktat på användningsområden inom livsmedelsindustrin. Denna essä visar på att *Ulva lactuca, Saccharina latissima, Palmaria palmata* har en möjlighet att bli inkorporerat i flera befintliga industrier och användningsområden så som livsmedelsindustrin, läkemedelsindustrin, framtidens plasttillverkning, energi framställning och som foder och gödning inom jordbruksnäringen. Utöver detta, kan en reglerad integrering av makroalger i livsmedel resultera i förbättrad textur i kombination med hälsofördelar. Dock, är troligtvis en integrering av hela makroalger i dieten inte ett alternativ, utan makroalger behöver troligtvis bli processad efter önskade egenskaper för att bli accepterad av konsumenten. Även om det idag finns en marknad för derivat från makroalger, bör man fundera på om makroalger även bör finnas med i den svenska diet på grund av dess näringsämnen. *U. lactuca* är en av få arter, bortsätt från djurriket, som innehåller vitamin B_{12}, *S. latissima* är rik i kostfiber vilket kan vara användbart i kampen mot ökat övervikt och *P.palmata* har en hög nivå av jod och proteininnehåll, med en aminosyra profil som kan vara bättre än i kyckling.

Nyckelord: Makroalger, Ulva lactuca, Saccharina latissima, Palmaria palmata.

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Abbreviations

PUFA	Polyunsaturated fatty acids
Mariculture	Aquaculture in the open ocean or enclosed sectors filled with seawater involving cultivation of marine organisms for food or other products.
dw	Dry weight
ww	Wet weight
tc	Total content

1. Introduction

Throughout Asia, seaweed has been a staple food for both human and animal consumption for many years. But it is not just the Asian countries that have a tradition of seaweed consumption. Several parts of the worlds coastal regions, has historically had seaweed as an important source of energy. Archaeological evidence found in Chile dates seaweed as part of staple food back to 14,000 years BC (Dillehay et al. 2008; G. Mouritsen et al. 2013). It has also been found that the red seaweed Dulse have has a historical significance in both America and Europe as staple food. Despite its previous significance as a staple food, seaweed consumption has decreased in most parts of the world. It is believed that an easier access to other sources of energy along with a cultural development have caused the decrease. However, in the case of Dulse, it has remained as local snacks or food supplements in modern times in some parts of the world. In recent years, the public interest of more healthy and environmentally sustainable foods has grown with a trend with more seaweed incorporated as a part of the diet. The numerous properties of seaweed, also makes it a valuable component already used in several products unknown for most people. To mention some alginates can work as gelling agent, stabilizers and in drugs reducing acid refluxes (G. Mouritsen et al. 2013).

Today, China and Indonesia are the main exporters of seaweed and stand for 87%, of the total seaweed production. Nevertheless, smaller production can be seen all over the world as in the republic of Korea, Chile, Japan, Ireland, Malaysia, United Republic of Tanzania, Norway among others (Food and Agricultural Organisation of the United Nation (FAO) 2017).

Sweden is one among the countries whose interest in seaweed consumption has increased. Due to the increased demand, smaller companies across Europe have started to harvest wild grown seaweed. This has triggered researching initiatives for cultivation and processing methods for seaweed. However, despite an increased popularity the general public opinion of seaweed in Europe is still rather poor. Seaweed is often associated with an unpleasant odour coming from "weeds" washed up ashore. Despite this opinion, seaweed is still consumed throughout Sweden and is often incorporated in Asian cuisine.

Even though parts of the Swedish seaside are habitats of edible seaweed with a potential centre of cultivation in Skagerrak, seaweed is mainly imported from larger producers mostly situated in Asia (Mouritsen 2017; Thomas et al. 2018).

An incorporation of seaweed in the diet could not only benefit domestic food production but comes with health beneficial properties. Several studies have indicated that many of the compounds found in seaweed have health promoting effects, and incorporation seaweed in the diet may contribute to a healthier life (Kim et al. 2011).

The global consumption of both macro- and microalgae is increasing not only for its nutritional benefits but also due to its functional biochemical properties as additives. Therefore it can, and is, important for incorporation in several products and foodstuff. (Wells et al. 2017).

Furthermore, the increasing global demand of seaweed aside from food, seaweed have a range of potential future uses such as, fertilizer, feed, clothes, biodegradable plastic, supplement for fossil based raw material which makes seaweed a good potential resource in the future. (Hasselström et al. 2020; SeaFarm 2020).

Little is known about the possibilities of the seaweed naturally grown in Sweden. Furthermore, this review provides a brief summary on current information regarding the potentials of seaweed native to Swedish shores. The review in mainly focused on the *Ulva lactuca, Saccharina latissima* and *Palmaria palmata* species. However, despite the lack of research conducted on Swedish grown algae, this review use information based in other countries but with the accurate species when referring to the contents of specific algae.

1.1. Method

There are numerous articles in the topic of macroalgae. However, this review has collected the most significant information regarding the selected approach of Swedish wild grown macroalgae. The collection of information for this review has been implemented through searching at reliable sources for scientific articles on *NCBI, PubMed* and *Primo*. Further have relevant articles been found through references in found articles. Websites for specific research and an online database for algae as Sealifebase.ca, www. algaebase.org and www.marbipp.se have also been used. The words used for search in different combinations were as follow: *seaweed, food, feed, Svensk tång, nutritional value, Iodin, Saccharina latissimi, sweet kombu, sugar kelp, Laminaria saccharina, havsallat, Sea lettuce, Ulva lactuca, Palmaria palmata, Rhodymenia palmata, söl, Dulse.*

2. Seaweed

Algae are photosynthetic organisms divided into two different groups, Macroalgae (multicellular) and Microalgae (unicellular). This thesis will focus on macroalgae or “seaweed” “Tång (Swe)”, which are divided into three different phyla. Brown algae (*Phaeophyta*), red algae (*Rhodophyta*) and green algae (*Chlorophyta*) (Johansson 2002; Plaza et al. 2008). Seaweeds have an ability to grow without arable land and freshwater resources. Consequently seaweed does not compete with traditional terrestrial crop farming and has therefore been considered to be the food of the future (Neto et al. 2018). Currently, both wild and cultivated seaweed, are utilized around the world for a range of different purposes. The main application however, is for human and animal consumption (van Oirschot et al. 2017).

Due to its biodiversity, the marine world of algae is a rich source of natural biologically active compounds and essential nutrients such as proteins, polysaccharides, antioxidants, pigments, polyunsaturated fatty acids (PUFA), and sterols. It is also a good source of minerals, vitamins, antioxidants and important trace elements as iodine. However, regarding how we consider food and seaweed based food, and through which methods used to drive specific components, the current legislation is in a continuous change with little transparency and may be a problem regarding potential uses (Holdt & Kraan 2011; Lordan et al. 2011).

Macroalgae, are water grown organisms and consist of 94% water. Due to the high water content, algae require a high content of carbohydrates to absorb all the water, where up to 76% dry weight (dw) of macroalgae consist of gelling algal polysaccharides. There are however, algal species where the polysaccharide concentrations is as low as 4% (dw) (Holdt & Kraan 2011). Together with phycocolloids, gelling algal polysaccharides has become a huge industry due to its range of possible uses. Agars, alginic acids and carrageenans, just to mention a few, are used in food, cosmetic and pharmaceutical industries. However, different phyla have different polysaccharide compositions which in turn have different properties and can therefore be used for different products. Additionally, research has investigated several of the general unique properties of the structural polysaccharides in the algae for other purposes, such as potential biological compounds of eg. stabilisers or thickeners in functional foods potentially reducing diseases. In correlation to different properties there are differences between species.

This is probably due the different sequences of the monomer units in the polysaccharides. However, all polysaccharides in algae are sulphated and have a complex structure with several unusual monosaccharides of galactose derivatives and rare uronic acids. The galactans of red algae and ulvans of green algae consist of a linear backbone with strictly repeated disaccharide units. The alginic acid has a linear backbone with different blocks of two monomeric units (Holdt & Kraan 2011; Usov & Zelinsky 2013; Neto et al. 2018).

The protein content of algae can vary between 10-47% amongst different species. However, red and green algae *Poryporia spp*. (nori), *Porhyra spp.* ("laver"), *Ulva spp.* ("sea lettuce") as well as *Palmaria palmata* ("dulse") often have a higher protein content compared to most brown algae. The protein content in algae sometimes varies dependent of the season. Some species can, depending on season, have levels of protein higher than other known meat substitutes such as soybean. (G. Mouritsen et al. 2013; Kraan & Dominguez 2013). Macroalgae normally consists of all the essential amino acids. However, a seasonal variation, different environmental settings, temperature fluctuation and different species can create a variation in amino acid composition (Kazir et al. 2019). Glutamic acid, which is one of the major components contributing to the taste of Umami, is together with aspartic acid one of the two main amino acids in algae. Glutamic acid and aspartic acid can either occur as protein constituents, free amino acids or as salts. Taurine is abundant in red algae. Taurine is a non-proteinaceous amino acid and functions as a component of bile acids. Even though it is not considered essential, taurine has a positive cholesterol lowering effect (Wells *et al.,* 2017).

Similar to the protein content, the nutritional value of algae varies between species. The variation of minerals, can be seen in the mineral ash content and usually ranges between 7-36% (Lordan et al. 2011). The fluctuation in lipid content is not as large as in other nutrients but normally ranges between 1-3%. Even though macroalgae have a relatively low lipid content, they are still considered to be a potential good source of lipids due to the high ratio of PUFA such as omega-3 acids (Kraan & Dominguez 2013). Furthermore, the nutritional value of the proteins in macroalgae is higher due to the good amino acid composition. The marine algae have a protein value higher than proteins in cereals and vegetables. However, different species may show differences in digestibility, but the mechanism behind the degradation is not completely understood and further research need to be conducted before any complete statement can be established. However, the phenolic compounds of brown algae may limit the availability of protein in vivo which may not be the case in green and red seaweed due higher protein levels and lower levels phenolic compounds (Fleurence 1999; Holdt & Kraan 2011).

2.1. Seasonal variation

The nutritional contents in seaweed does not just vary in between species but also changes depending on the season. Different seasons have periods of nutrient limitations or excess in correlation where changes of temperature and sun radiation creates different possibilities for seaweed to grow. The seasonal difference affects the protein content and its amino acid composition where the protein content is at its highest in the winter and the lowest in late summer. On the contrary, the polysaccharide content is at its highest in the summer (Wells et al. 2017). The same pattern can be seen when observing the dry weight and ash content where the dry weight is at its highest during late summer or autumn and its lowest during winter. Regarding ash content, some values show opposite trends similar to the patterns of protein (Usov & Zelinsky 2013).

2.2. Swedish habitat

The Swedish coast provides a habitat for macroalgae which varies in richness of species depending on the salinity gradient. Approximately 300 species are found in outer Skagerrak whereas less than 30 species of upright thalli occur in the northern bay of Bothnia. This decrease of species correlates with shift of dominating species between algae. On the west coast, brown and red algae dominate whereas green algae dominate in the Baltic Sea due to the majority of freshwater algae belonging to Chlorophyta (Johansson 2002).

The Baltic Sea has a drainage area of 355 000 km^2 which is approximately 4.5 times larger than the water surface area. With a population of more than 85 million people living in the area in combination with a limited water exchange with the ocean, the Baltic Sea is exposed to many anthropogenic stressors (Johansson 2002). The eutrophication of fields has also led to discharges of nutrients resulting in an increased pelagic primary production or changes in different growth of species due to increased sedimentation (Elmgren 1989; Johansson 2002).

Swedish temperate water and especially the Baltic Sea have changed from being a fresh water ecosystem to brackish due to an increased salinity over the last 8000 years. The Baltic Sea has then changed from first having a wider connection to the North Sea to a more narrowed to present condition with less salinity which has been present for approximately 3000 years (Andersen & Borns 1997; Bergström 2005). Macroalgae that are most conspicuous of rocky seashores and occur in many shapes and sizes, from highly differentiated large thalli to delicate filaments with a shift from larger thallus to reduced size from the North Sea to the Baltic Sea (Johansson 2002).

The current distribution of algae in Sweden is probably a result of a strong selection due to the change in salinity. This can be described through the significant difference of species numbers of macroalgae dependent on salinity with around 225 species in inner Kattegatt compared with around 25 species in the Bothnian Bay (Bergström 2005). The Swedish coast is dominated by seven different species. "Bladderwrack" *Fucus vesiculosus* (blåstång) predominate and can be found along the entire west coast, the Baltic Sea and up to the High Coast of the Bothnian Bay. Further north in the Bothnian Bay the predominate specie is *Fucus radicans* (smaltång), where Bladderwrack is still growing but in smaller quantities. Along the west coast and around the Swedish headland, in through the Baltic Sea to Öland are also the habitat of *Fucus serratus* (sågtång). The other four species of *Ascophyllum nodosum* (knöltång), *Sargassum muticum* (sargassosnöre), *Fucus evanescens* (ishavstång) and *Fucus spiralis* (spiraltång) are more sensitive to brackish water and are mostly limited along the coast between Bjärehalvön and Öresund depending of depth or local deviations of structure and functions (Nielsen et al. 1995). However, changes in communities of kelp forests, *Saccharina latissima* among others, have lately been through changes. The kelp forests along the inner parts of coasts of Skagerrak have been replaced by opportunistic filamentous algae due warmer climate in a combination of more available nutrition (Moy et al. 2008; Visch et al. 2019).

2.2.1. *Ulva lactuca*

Ulva lactuca is a marine species of the phylum Chlorophyta (green algae). It has the ability to grow free floating, attached or sessile to other macro algae (Dominguez & Loret 2019; Guiry et al. 2020). Due to its ability to reproduce both sexually and asexually through fragments of the thallus it has the capacity to proliferate rapidly. The rapid growth has probably together with its ability to resist fluctuations of chemical and physical conditions in tidal zones across the world led to a decrease in biodiversity. "Green tides", big formations of *Ulva spp* in tidal zones, has due favourable conditions prevented anything else to grow there (Guidone & Thornber 2013; Perrot et al. 2014). However, experiments with specific natural viruses might be a way to control these unwanted blooms due to the algal enzyme activity (Dominguez & Loret 2019).

Since, *U. lactuca* is a polymorphic specie, this thesis has chosen the subgroup of leaf-like thallus named *Ulva Linnaeus 1753* in the family of *Ulva spp.(Chlorophyta, Ulvaceae).* This form of *Ulva spp*. has the ability to grow in less saline conditions but tends to prefer a salinity between 30-40 PSU in tidal waters and 18-30 PSU in polyhaline waters. However, in less saline conditions, a change in shape will occur and *Ulva spp* will take on string like shapes of the thallus even though being of the same specie (Hayden et al. 2003; Rybak 2018). This polymorphism of *U. lactuca* and the different appearance depending on environment has led to a confusion of existing different species and has led to several names and difficulties in the world of research (Dominguez & Loret 2019).

U. lactuca, also known as “Sea Lettuce”, probably due the leaf-like thallus, has for a long time been consumed as food by humans but is still identified as an underexploited resource for food purposes. *U. lactuca* is eaten as a whole but have the potential to be further developed into different food products and possible be used for pharmaceutical purposes. Research have also indicated that this species may be a potential source of non-synthetic antioxidants. Non-synthetic antioxidants have lately been more requested in especially food industry due to the side effects of synthetic substances (Kim et al. 2011). Research has also found antibacterial agents in *Ulva spp*. Farming/ cultivation of *Ulva spp*. may therefore pose a significance to the pharmaceutical industry or functional food.

Ulva spp. have a low starch content of 1-4% wet weight (ww). However, *U. lactuca* mainly consist of a mixture of water soluble and insoluble polysaccharides with components consisting of sulphuric acid polysaccharides, sulphated galactans and xylans (Holdt & Kraan 2011). The major part of these sulphated polysaccharides are called Ulvans with a content up to 30% dw. It works as the main constituent of the cell wall and mainly consists of sulfonic acids, xylose sulphated L-rhamnose and glucose which gives the green algae its flexibility. These polysaccharides and oligosaccharides have proven to have medicinal effects such as anti-tumour, anti-viral, anti-bacterial, coagulant and anti-depressants (Holdt & Kraan 2011). The anti-bacterial effects have been shown to be effective against *E, coli, K. pneumonia and S. typhi* as well as against the methicillin-resistant *Staphylococcus aureus* (MRSA) (Deveau et al. 2016; Anjali et al. 2019). Furthermore, ulvans have indicated a potential to be used in medicinal treatments for burn victims, as ulvans are thermo reversible gels. Ulvan starch can also be a potential carbon source for microbial production of a range of biomaterials, chemicals and intermediates (Dominguez & Loret 2019). Furthermore, *Ulva spp*. also contain sterols, mainly cholesterol and isofucosterol, which have in clinical studies demonstrated the ability to reduce the total amount of LDL cholesterol in blood. These sterols have also demonstrated anti-inflammatory and anti-tumoral activity to mention a few and may have further the potential to be used as functional food. (Plaza et al. 2008).

The genus of *Ulva spp.* has a protein content ranging from 10 to 26% in dw (Fleurence 1999). Macroalgae are known to have all essential amino acids, however as mentioned above, the concentration varies between species, season and settings. Studies have shown different amino acid compositions between different specimens of *U. lactuca,* where the major essential amino acids in *U. lactuca* are leucine, phenylalanine and valine (Kazir et al. 2019). Moreover, Histidine which is another important amino acid as it is essential especially for children, have been found in greater levels in *Ulva spp*. Compared to eggs and legumes (Lordan et al. 2011).

Through the biorefinery processes and utilization of single fractions of the biomass, proteins, free amino acids, and Ulvans of *U. lactuca,* raw materials to multiple products can be refined. For example, a provision of a non-synthetic source of antioxidants where acidic Ulva extracts could replace the synthetic antioxidants as additives in production preventing oxidation (Dominguez & Loret 2019).

U. lactuca is due its high protein content, high Fe, high mineral level, low-fat content with good ratio between saturated and unsaturated lipids, acids and its presence on essential amino acid considered a valuable nutriment (Plaza et al., 2008; Li *et al.* 2018). However, *U. lactuca* have the ability to accumulate high levels of trace elements (Cd, Cr, Cu, Ni, Pb, Zn) which can be harmful in larger quantities (Bonanno et al. 2020). *U. lactuca* also has the potential to become a possible source of vitamin B_{12} for vegans, considered that this algae is one of the few non-animal sources where this vitamin is normally found. At a estimated normal consumption of 8g dw /day seaweed regularly incorporated in daily intake, the level of vitamin B_{12} is 5µg. This is an excess when referring to the recommendation of 2 µg made by the Swedish food agency (MacArtain et al. 2008; *Livsmedelsverket* 2020). Another aspect to take into consideration is the nutritional value of the proteins, where *U. lactuca* have shown a high digestibility of 86% in vitro. However, the digestibility of algae protein is still not well documented (Holdt & Kraan 2011)

Other applications of *Ulva spp*. have also been tested. Shrimps fed with Ulva extracts have indicated a higher growth rate, higher carotenoid content and a lower lipid content. When used in agriculture, indications of enhanced vegetative growth under drought stress, limited lipid peroxidation and increased phenolic content probably to enhanced antioxidant activity have been seen (Dominguez & Loret 2019).

2.2.2. *S. latissima*

Saccharina latissima (Linnaeus), previous known as *Laminaria saccharina,* also known as sugar kelp (eng), sockertare (swe), broadleaf kelp (eng), sugarwrack (eng) , Karafuto kombu, Sweet kombu (Japanese) just to mention a few (Mayes et al. 2006). *S. latissimi* is a brown macroalgae in the *Laminariaceae* family, abundantly found along the Norwegian coast down to the Swedish west coast (Moy et al. 2008; Sharma et al. 2018). As the water becomes more brackish closer to the Baltic Sea, *S. latissimi* becomes more infrequent, but still has important ecological functions such as serving as a habitat to several fish species. However, a reduction in *S. latissima* has been seen in Sweden, Norway and Denmark probably due other opportunistic species (Moy et al. 2008). These algae has an alternating life cycle where microscopic gametophytes alternate with large multicellular gametophytes.

This makes S. latissimi advantageous over several other species due the possibilities to have a full controlled breeding if desired (Visch et al. 2019).

Saccharina latissimi is a close relative to *Saccharina japonica* “Royal kombu” which is distributed off the coast of Japan, China and parts of the Russian pacific coast, has a commercially importance and said to be the species where the fifth basic taste, umami was detected after large amounts of monosodium glutamate (MSG) were found. (Holdt & Kraan 2011; Mouritsen 2017; Guiry & Guiry 2020). *S. japonica* have indicated a good ability to absorb water and oil when added as powder and have shown to improve characteristics in meat products resulting in an increase in product fibre and mineral content. The same ability of water holding capacity has been seen for *S. latissima,* making it a possible source for similar additives. (Neto et al. 2018; Visch et al. 2019).

Alginates are the major part (over 50% of tc) of the polysaccharides in the cell wall and the intracellular matrix of brown algae and can be available in both salt (Sodium alginate) and anionic acid form (Alginic acid) (Usov & Zelinsky 2013; Pérez et al. 2016; Stévant et al. 2018a). These polysaccharides have been known since the 1880s and have become a growing flourishing industry together with other phycocolloids carrageenans and agar, having applications in various industries due to their properties such as thickening agents, water soluble films, gorming gels, stabilising agents for cream, toothpaste etc. Additionally alginates commonly from *Saccharina* and *Undaria* have a vast varietal use in various industries such as food, pharmaceuticals, cosmetics and feed. These alginates are uncommon polysaccharides and are not found in higher plants. *Undaria* are considered to decrease cholesterol levels, have anti-hypertension effects and prevent absorption of toxic chemical substances in acidic form. The ability of being dietary fibres are also to be in consideration when seen as a health maintainer for animals and human consumption. Added alginates have shown significantly reduction in body weight, decreased glucose absorption and a prevention of diabetes, obesity and hypocholesterolaemia. The ability to absorb possible dangerous substances together with the gel forming ability and may protect the intestine membranes, clear digestive systems and support protect against potential carcinogens. Other polysaccharides of brown algae such as fucoidans and laminarins have together with alginates shown to have antibacterial properties against *E.coli* and *Staphylococcus*. A good example of the uses of these alginate properties are the uses in drugs such as “Gaviscon” suppressing postprandial (after eating) and acidic refluxes, where the bile acids binds to alginate (Holdt & Kraan 2011). The polysaccharides, fucoidans or fucans, can be found in brown seaweed in large concentrations and includes galactose, mannose and glucuronic acid (Stévant et al. 2018a). Fucans are easy to isolate and have the potential to be a valuable bioactive compound due to its numerous health benefits. Usually 5-10% dw of brown seaweed consist of fucans. This compound is yet not fully understood but has shown evidence of being a potential new drug involving its ability as antiviral, anti-inflammatory anti-tumour among others (Holdt & Kraan 2011; Usov & Zelinsky 2013). Even though several of these polysaccharides can be effective as dietary fibres, *S.latissima* only contains 29% of dietary fibres (Holdt & Kraan 2011). Another interesting carbohydrate is mannitol which stands for around 25% of total content in *S.latissima*. This noticeably high content does however change depending on season with the highest amount during summer and fall (June – November). Mannitol is used as sweeteners in the food industry and is considered very interesting since it is not metabolised in the human body and its glycaemic and insulinemic indexes are 0. The very low hygroscopicity also makes it very interesting in products with high humidity due to its stability. The stability together with the cooling taste of mannitol are also being used in masking and maintain drugs of pharmaceutics. The main production of mannitol is today produced of the by-products from iodine and alginate production (Song & Vieille 2009; Holdt & Kraan 2011).

Seaweed have an enormous capability to absorb inorganic substances, both essential elements and toxic elements, where brown algae have a higher capability possibly because of their structure of more anions. At the same time, research has shown that the red algae *Palmaria palmata* also has a high affinity to accumulate heavy metals such as Cd and Cr similar to brown algae. Studies have shown that high levels of arsenic, cadmium and iodine can be found. There is however large variations in absorbed content and levels of arsenic and cadmium being below unsafe to humans when compared to health based guidance made by the European Food Safety Authority (EFSA)(Stévant et al. 2018). These binding properties are due to the alginic acid which cannot be digested in the intestines due to the lack of enzyme ability to degrade them. Therefore, heavy metals become gelated and insoluble for the body to absorb if consumed. However, the linking between consumption of seaweed and clinical pathology of heavy metals is scarce and more evidence is needed in decision if it may be harmful as consumption (Holdt & Kraan 2011; Mišurcová et al. 2011; Stévant et al. 2018).

When it comes to mineral content, *S.latissima* has high levels of potassium compared to sodium salts. This makes it a potential salt replacing ingredient in the food industry. However, high levels (up to 6568 mg / 7kg dw) of iodine are present in *S.latissima*, which may be harmful to humans if large amounts are consumed for an extended period of time. Nevertheless, these levels can be reduced through specific processing where simple soaking in fresh warm water reduces the amount of iodine. Another solution may be freeze drying, as this process has shown similar decrease pattern of iodine when treated for industrial purpose (Stévant et al. 2018, 2018a).

S.latissima has shown high levels of alanine, glutamate and aspartate as free amino acids. Alanine are perceived as sweet, whereas glutamate is a major component in the umami taste. Depending on treatment different components can be obtained. For example, freeze dried and airdried specimens showed a higher content of free glutamate than application of other drying treatments. However, *S.latissima* seems to have substantially lower free alanine, glutamate, aspartate than its close relative Japanese Kombu. It is worth taking in consideration that Kombu typically matures for several years to ensure development of characteristic flavours and may be the reason why such high levels of free glutamate are found in aged Kombu (Stévant et al. 2018a). Taurine, which is not a true amino acid due to its lack of carboxyl group, but still important and found in seaweed, fish and shellfish can be found in *S.latissima* in quantities of 400mg/g dw similar to levels of shellfish. Because of its ability to work as emulsifier, it is important for the bile function as it binds lipids and potential create an reduction of cholesterol in the blood. Taurine has also shown indications to possess antioxidative properties (Holdt & Kraan 2011)

One of the most noticeable phenolic compounds of seaweed are phlorotannins and can be found in quantities of up to 25%. This compound shows high antioxidant activity in both pure and crude extracts with successful results similar to additives. Furthermore, this compound has together with other phenolic compounds the ability to inhibit important enzymes such as alfa-amylase, alfa-galactosidase and lipase. This limits the degradation but may be important due to the fact that these enzymes are key-enzymes for diabetes control and obesity. However, little investigation of *S.latissima* and potential enzyme inhibitory activity has been performed even though well characterized composition (Neto et al. 2018).

2.2.3. *P. palmata*

Palmaria palmata, also known as "Dulse" or "Söl" is one of few historically documented algae used for consumption in Europe and around North Atlantic where it has been used for centuries and possible even longer. In sagas and legal documents from the tenth century in Iceland, seaweed, presumably red seaweed, has been mentioned as food. There are even suggestions of the Norwegian Vikings using dried seaweed as prevention method of scurvy (G. Mouritsen et al. 2013). *Palmaria palmata* are a species of red algae (Rhodophyta), in the order of *Palmariales*, and has formerly been called *Rhydomenia palmata* along with several other names through the years. It is a reddish brown marine species, common in the North- and North-East Atlantic Ocean, growing intertidal or shallow subtidal on rocks, mussels and epiphytic on several other algae. It grows in cold, turbulent water as membranous or leathery upright, it has an elongated thallus ending in the shape of a fork or palm and can vary in size from 5cm to 50cm. and can be found along the northern west coast of Sweden (G. Mouritsen et al. 2013; Sverige &

Naturvårdsverket 2013; Usov & Zelinsky 2013; Guiry & Guiry 2020; The Marine Biological Asssociation of the UK).

P. palmata is considered to be one of the more delectable seaweeds for consumption but is still a fairly unexplored product for gastronomical use. Normally consumed dried algae are considered most palatable in contrast to freshly harvested algae. When dried it has notes of smoke and liquorice aromas and if toasted it develops more nutty flavours. When fresh, very young *P.palmata* are used but due to its hard texture, a ripening procedure is needed after drying for larger specimens. *P.palmata* has the potential to be incorporated in bread, soups, fish dishes, toasted or just to be eaten as dried snacks. The latter, eaten as snacks has shown to be a good combination with dark beer. Another possible use may be to addition in bread. Evidence has shown that an addition results in further dough stretching. Seaweeds can have a range of flavours where *P. palmata* has a more distinct flavour, close to floral and liquorice. A somewhat sweet taste according Mouritsen (2013) makes this algae a possible supplement to root vegetables and corn. Differences in palatability have also been seen in differences of locus. Specimens from the Irish coast have shown that plants growing on exposed shores are considered to be more palatable than the lower intertidal grown leathery plants (G. Mouritsen et al. 2013; Guiry & Guiry 2020).

P. Palmata is a good source of minerals and proteins and are even known to have protein levels exceeding those of soybean which is, known to be a protein rich source outside the animal kingdom. Dulse have a typical protein content of 20% dw, but can vary between 8-35% depending on the seasonal period. In late winter and early spring, the protein content has a tendency to be higher, probably correlating with changes of available nitrogenous nutrients in the water. There is also a fluctuation in amino acid composition varying depending on season. Aspartic acid, glycine, alanine and glutamic acid are the most abundant amino acids, characterizing *P. Palmata*. However, different extraction methods have shown different values with larger amounts of proline and serine and lesser amounts of glutamic acid, leucine, valine. Due to the seasonal fluctuation, a definite composition of essential amino acids is hard to define. The essential amino acids have a variation between 26.1 to 50.0% but with an average of 35.8% of total amino acids. Because of the high protein levels and the amino acid composition, *P.palmata* is considered to be a potential good source of protein for both food and feed where *P.palmata* has historically already been used as feed for livestock in England and Norway and is still used in some parts of Great Britain there is evidence that when extracts of several algae are added to animal feed, there are almost only positive effects such as increased growth rate in lamb and higher milk yield (Holdt & Kraan 2011). Kainic acid, an analogue of glutamic acid, is a bioactive compound found in some species of red seaweeds, one of them being *P.palmata*. This is a neurotoxin acting similar to domoic acid causing amnesic shellfish poisoning and can in large doses lead to brain damage. (Holdt & Kraan 2011; G. Mouritsen et al. 2013). *P. palmata* has also shown signs of having high affinity to accumulate heavy metals as Cd and Cr which can be potentially harmful. Location and time of harvest can have a significant impact in the content of mineral content (Mišurcová et al. 2011). In a review of Mouritsen et al (2013) some differences in mineral content has been detected. The heavy metal content was however below the detection limit of 1µg g^{-1} which is often the low levels found in *P.palmata*. The Iodine content in *P.palmata* can range quite wide. In Denmark a content of 5-7µg $g^{-1}$was measured. However, in Iceland and Maine <5 µg was detected but studies have shown a content range up to 100µg g^{-1} (G. Mouritsen et al. 2013).

Algae are also considered to be a good source of polyunsaturated fatty acid because of the high amounts of eicosapentaenoic acid (EPA). However, due to a significant fluctuation depending of age, treatment and location of growth for *P. Palmata*, the content of EPA can vary significantly in the total lipid content of 0,4-1.8%. This is not considered to be a high level, however there are other species with a higher content. (Fleurence 1999; G. Mouritsen et al. 2013).

Red algae have a storage polysaccharide known as floridean starch that is structurally similar to glycogen and amylopectin. It does not have a linear Backbone like amylopectin, as in the green algae, but is instead a branched intermediate of glycogen and amylopectin. Floridean is a water soluble starch that can take up to 35% of dry content in red algae, but can vary dependent on growth condition and species. In the majority of red algae, 2-10% of the cell wall are constructed of cellulose (linear 1→ 4linked β-D-glucan) but seams to show microfibril differences when compared with land plants. However, the main polysaccharide component of *Palmaria palmata* are xylans. Xylans are water soluble polysaccharide consisting of a 4-linked β-D-xylopyranose interspersed with single 3-linked β-D-xylopyranose residues in linear chains. However, if the former residue has a higher proportion than 1:4 its water solubility decreases and the elimination of xylans through fermentation or physical processes may be needed to improve digestibility of the algal proteins. Another main component of the polysaccharides in red algae are sulphated galactans with four repeating units of disaccharides (Agaran, Agarose, Carrageenan, Carrageenose) as precursors to different structures (Usov & Zelinsky 2013). In the cell wall of red seaweed, carrageenans are usually the major component and is composed of linear polysaccharide chains with attached sulphate half-esters to the sugar units where the sulfation can vary between one to three groups attached (Vera et al. 2011; Pérez et al. 2016). The water soluble galactans-are usually isolated through alkaline treatment which also often leads to an enhanced anility of gel-formation. If a total acid hydrolysis on galactans would be performed, the result would be a liberation of galactose and a degradation of residues (Usov & Zelinsky 2013).

2.3. Farming

Traditionally, wild grown seaweed have been harvested and sundried on top of warm cliffs. This method is still being used today in small scales, but has been supplemented and almost replaced by specific cultivation called mariculture. In 2013, 95% of the global production of seaweed was estimated to be cultivated in mariculture with the value of US $6,7billion. Cultivation of some microalgae are also a large industry because of the possibility to use it as both food and food additives. Even though seaweed have the ability to grow in several parts over the globe, the major producers of seaweed are located in China and Indonesia (Wells et al. 2017).

However, due to environmental changes, the natural population of algae may be vulnerable, and farming may be a possible solution for a secured production and to maintain diversity. Moreover, a cultivation of seaweed also has the possibility to be used as a conservation of important species and can be an important part in securing the future of important species (Visch et al. 2019).

The cultivation of seaweed is a large global industry, yet smaller quantities find their way in to Europe and a largescale production of macroalgae, as *Saccharina latissima*, in Sweden has through research shown a potential to be a successful industry. However, beyond several technical issues there are two different foci to take in to consideration when it comes to a potential cultivation in Swedish waters. First the potential environmental benefits. Eutrophication are seen as a problem and one of the causes for environmental changes. Seaweed can recover the abundance of phosphorous and nitrogen (60% P and 8% N) by converting them to biomass matter and may therefore have a potential to have positive environmental impacts if cultivated. The biomass can then be used as food, feed or in other industries as substitute for fossil based raw materials. However, these socioeconomic values of removing of abundant nutrients are not considered to be economically sustainable, giving rise to an economical focus in order to create a successful cultivation of macroalgae. A larger industry development is still unsecure because of risks such as variation in the yearly yield, allowed space to growth, high labour costs and lack of reliable mature commodity chains (Hasselström et al. 2020). The majority of Swedish aquaculture are in general open systems but research is trying to find new strategies as climate changes forces more climate friendly technologies to evolve. Macroalgae are extensive, meaning that without adding any nutrition, it may grow in open systems in the sea. However, the production in Sweden is considered to be nascent with *S. latissima* being in forefront in development. Today, this algae is the first to be cultivated in land based systems with added nutrients to become inoculated on to ropes and later brought out to a test facility in the sea of Koster

(Kosterhavet). This test facility obtained a yield similar to Scottish and American cultivation of 30 tonnes (horizontal grown) respectively 65tonnes wet weight per hectare (ha) depending on the cultivation system. *U. lactuca* can potentially be a good candidate for growing macroalgae in the brackish water of the Baltic Sea. However, in this case cultivation on ropes is not favourable, but research of potential Asian techniques of growing on big sheets are under progress in the Netherlands. However, because algae is a new production in Sweden, this trade and its system is still under progress. Moreover, an algae cultivation system may have a potential positive vector in the prevention of eutrophication, as has been becoming a major problem, and have achieve a good environmental status according to the Swedish Agency of Marine and Water Management. (Eriksson et al. 2017; Hasselström et al. 2020).

3. Diet and nutritional values

If foodstuff is not considered to be tasty, it will not be eaten no matter the nutritional status. Depending on culture, social environment and previous experiences in combination with actual personal taste, the same product can be perceived as completely different. Taste is important and if one would pose a question if algae is being tasty to person raised with Asian cuisine, it will probably be a positive answer due to the cultural acceptance. The same answer would probably not occur in Scandinavia where algae is not as incorporated in to the gastronomical culture. However, seaweed is used in food for more than its taste. Because of its immense variety in texture and color, seaweed can both give rise to different mouthfeel and contribute to the overall organoleptic properties (Mouritsen 2017).

Due to the societal development, the dietary preferences and lifestyles have undergone major changes. The diets in developed countries have become to consist of high calorie, sugary diets often rich in saturated fats and low in dietary fibres (Simopoulos 2004; Geslain-Lanéelle 2006). The correlation between diet and health has been known for a long time. This has led to a great interest in seeking new healthier food products, also known as functional foods where algae has become more interesting (Sloan 1999; Plaza et al. 2008). When comparing Western and Japanese diets, a consumption of seaweed has been correlated to good health where Japan has fewer occurrences of chronic diseases such as certain types of cancer, coronary heart disease and hyperlipidaemia. (Kim et al. 2009; Iso 2011). However, the understanding of how benefits of algae can be quantified, understood and made bioavailable to humans is still somewhat limited (Wells et al. 2017).

Algae mainly consists of fibre with a soluble fraction of sulphated galactans. Agar and carrageenates are the main constituents in red algae and laminarin, fucans and alginates in brown algae. These dietary fibres have shown to have positive influence on health and may reduce the risk of colon cancer, diabetes, hypercholesterolemia and obesity among others (Ikeda et al. 2003; Suzuki et al. 2004). The sulphated polysaccharides of some brown algae, especially fucans, have shown a potential of antiviral activity against herpes type 1 and 2 virus (HSV-1, HSV-2) (Lee et al. 2004). *In vivo* studies on rats have also shown the potential of these polysaccharides to be antitumoral with mammary carcinogenesis (Maruyama et al. 2003). Similar results have transpired with the sulphated saccharides of red algae called porphyrans which may have an apoptotic activity of carcinogenic cells (Kwon & Nam 2006). Even though the carbohydrate content is high in algae, most are dietary fibres and not absorbed by the human body. Instead, the dietary fibres are considered to be good for the human health and a perfect substrate to create a good intestinal environment and a are good energy source for the gut microbiota (Holdt & Kraan 2011).

Algae have the potential to be a source of polyunsaturated fatty acids, particularly the ω-3 acid eicosapentaenoic acid (EPA). The contemporary western diets are deficient in omega-3 fatty acids in ratio to the excessive intake of omega-6 fatty acids (PUFA) making finding more relevant sources a hot topic (Simopoulos 2004; Holdt & Kraan 2011). Sterols which can be found in most algae have through several studies proven to help reducing cholesterol levels, making them a possible functional ingredient in fortified margarines among other products (Plaza et al. 2008).

Lately there has been an increased concern regarding the safety of commonly used synthetic food additives such as antioxidants where a drive towards a search for non-synthetic alternatives has developed, where the balance of nutrients and bioactive phytochemicals in algae might be a possible alternative source (Chen et al. 1992; Brown et al. 2014). Studies have indicated that the presence of a range of different bioactive compounds might have antibacterial, antiviral, anticancerogenic and antioxidant properties (Plaza et al. 2008). However, in western countries, the main use of algae has lately been as raw material for extraction of alginates, agar and carrageenans from brown and red algae respectively (Plaza et al. 2008). Phlorotannin is a phenolic compound found in high concentrations in brown algae. This compound may be of noticeable importance since it has a high antioxidant activity, both as pure and crude extracts. Macroalgae have more potent polyphenols than their analogues in terrestrial plant and hence can be relevant as part of food products since the antioxidant effect can be used to prolong shelf life of products. (Kirke et al. 2017; Tenorio-Rodriguez et al. 2017). Phlorotannins have shown to inhibit α-amylase, α-glucosidase and lipase which are important key enzymes for diabetes control and for obesity (Kellogg et al. 2014).

Another important nutrient is vitamin K. Vitamin K found as K_1 in plants and algae and K_2 from bacteria in human colon, are fat soluble compounds required in small quantities. Although there are no records of hypervitaminosis, high doses of vitamin K may interfere with other active substances such as medication. An inadequate intake is however not common with an estimated intake between 72-196µg/day for adults, when an intake above 90µg are considered accurate. K-vitamins are coenzymes, required in formation of blood coagulation and hence interfere in treatments regarding blood thinning e.g. warfarin. However, studies have shown that small quantitative changes do not interfere with medication. Vitamin K is mostly found in larger quantities in green leafy vegetables such as spinach (480µg /100g). The algae mentioned in this thesis have different quantities of vitamin K and earlier research have indicated that *P.palmata* had a content of 17µg g^{-1} and in *U. lactuca* a content of 13µg g^{-1}. However, these results are relatively outdated and recent studies shows a content of 2-7µg g^{-1} for *P.palmata* which could be a result of different techniques or differences in specimens. This other method also showed a content of 1-6µg g^{-1} when analysing S.*latissima*. With a daily intake of *P.palmata* of approximately 5g, dw, the levels do not cause any harm. Nevertheless, caution may be in consideration by not mixing with other products rich in Vitamin K(Becker et al. 1996; G. Mouritsen et al. 2013; Turck et al. 2017).

Different processing methods of algae for industrial purposes have different effect on the specimens. Freeze drying has trough several studies shown to be the most efficient when it comes to keeping the nutritional value but at the same time it decreases the content of iodine. Dietary iodine is essential for the production of thyroid hormones that regulates many of the important physiological processes of the human body. A deficiency of iodine may have effects on growth and development (Mišurcová et al. 2011) and can be the cause of miscarriage and stillbirth. However, an excess of iodine can also be harmful and result in eg. autoimmune thyroid disease even though the thyroid has the ability to adaptation (Laurberg et al. 2010). However, a daily consumption of *S. latissima* may lead to an excess intake of iodine whereas a moderate intake can create an improvement in iodine-deficient populations (Stévant et al. 2018). Iodine deficiency is a global prevalence with 1.9 billion individuals, 285 million out of these school children, that suffer from an inadequate intake of iodine. When it comes to Europe, the prevalence of inadequate iodine intake of school children is 59.9% compared to 10,1% in America. For now, the recommended strategy to prevent iodine deficiency is through salt iodisation and the most common regions of this occurrence is also the regions where the lowest prevalence of iodine deficiency occurs (de Benoist et al. 2003).

4. Summary and Conclusion

Algae are already a part of a large industry which keeps on growing. The major hurdles for a Swedish production are the practical development and creating profitable and reliable commodity chains. In this industry branch, like many others, dealing with climate change and finding new climate friendly methods are imperative and seaweed is considered to be a good nutritional resource for the future. Since a few years, a dialogue on a decreased meat consumption has been topical due to its impact on the climate. However, this topic and possible changes are complex and rarely does an extreme change come without side effects and should therefore be modified with care. Alternative sources of protein can be found in a variety of different sources, however some sources of protein such as algae may have been forgotten due to a loss of cultural significance. *P. palmata* has 20% protein content if it is harvested during winter and can be used as a potential substitute for animal proteins. This makes it a protein source which has a higher total protein content compared to that of chicken as well as an amino acid composition better than many other meat substitutes, for example soybean-based products. However, the protein composition is very seasonal dependent and follows the seasonal fluctuations in the water, sometimes showing low in tryptophan and cystine. For this reason, *P. palmata* as a protein source may be seen as a seasonal food product (G. Mouritsen et al. 2013). In addition, *P. palmata* lack the amino acid cystine which is not essential except for infants, elderly or people with underlying metabolic diseases since the human body has the ability to produce it.

P. palmata contains iodine but not in the same levels as *S.latissima.* Nevertheless, larger consumption may still be harmful due an excess of intake of iodine. Henceforth, *P. palmata* should probably be a substitute interspersed with other substitutes to ensure a good and safe level of iodine intake. However, it could still be good source for not only iodine and protein, but minerals such as iron for people choosing plantbased food. *U. lactuca* is also a good source of protein considering its amino acid composition, where all of the essential amino acids are present, and the non-essential histidine can be found in higher levels compared to those of legumes and eggs. However, the amino acid content has shown large variation depending on different seasonal water fluctuations. *U. lactuca* is one of few plants containing vitamin B_{12} and together with the high mineral content, especially that of iron, it could be used as a potential source of vitamin B_{12} and minerals for people on plant based diets. The polysaccharides of *Ulva spp*. have the property of being very flexible and may be used in several products in need of this quality. In popular press there have been reports of new applications of algae as the incorporation of seaweed in textile creates elastic clothes (Satria Akbar 2020). *Ulva spp.* also has a high content of antioxidants which may be used as a preservative for both food and pharmaceutical purposes. Considering that *Ulva spp.* has a fast growing rate, these substances could be produced relatively fast.

The seasonal fluctuations of nutrients and mineral content may pose a problem because the production needs to be adapted depending on season. Algae harvested in the late winter to early spring are better to use for direct consumption compared to algae harvested during summer to fall which is better for the production of bioactive compounds and specific polysaccharides. Furthermore, algae have a range of other application possibilities as for example, biofuel- bioplastic supplements, biofilm, gelling forming agent, pharmaceuticals among many others. The richness of nutrients of Swedish water makes it a suitable implementation to the Swedish economy as it is in many other countries. The main potential industry are the polysaccharides extracted from *S. latissimi* which can be used to improve food products, resulting in additional enhancement of fibers and minerals to the food. The alginates are used as stabilizer in several food products but do also have an important role in pharmaceuticals against acidic refluxes as they have the ability to absorb and bind to several components as bile acids or cholesterol. Including *S.latissima* in the regular diet may alleviate these problems which may in turn reduce the excessive use of postprandial acid reflux drugs. Furthermore, the high inhibition of enzyme activity, prevents degradation within intestine during consumption. Therefore *S.latissima* may be useful in the control of the obesity epidemic, which is becoming an increasingly severe problem in society. Together with the high amount of phlorotannins and alanine, it may serve as a good source of antioxidants. Furthermore, the sweetness perceived by mannitol may be appealing for the consumer for consumption. However, *S.latissima* does not contain the compounds contributing to the umami flavor. These compounds can on the other hand be found in *P.palmata* and with its flowery aroma it is said to be one of the more delectable algae. However, kainic acid which may be toxic in higher doses, can be present in *P.palmata*. The concentration can vary from trace levels to up to 130 $\mu g\ g^{-1}$ and the safe intake levels of kainic acid is yet to be established (G. Mouritsen et al. 2013; Jørgensen & Olesen 2018).

Taste is the most important attribute of food and is the way we determine food quality. However, the taste of "sea" in seaweed is a taste not commonly found in the Swedish cuisine, therefore creating difficulties when incorporating plain seaweed as a nutritious source. However, this is still a very unexplored field where interest has flourished lately. Seaweed in general contain plenty of important minerals, vitamins, trace elements, PUFA, soluble and insoluble dietary fibers and proteins. Additionally, it is low on calories and certain types of seaweed are high of essential amino acids and are considered safe to eat as long as the consumption does not exceed the normal consumption of 8g day^{-1} dw. Beyond this amount, possible harmful substances, as iodine, can reach an unsafe level in different levels dependent on the specie.

In conclusion, macroalgae have a range of possible uses, but must probably be specialized depending of the different qualities of the specific algae in order to be incorporated into the Swedish economy. Once algae is incorporated into the Swedish economy as a sustainable commodity in the food vale chain, finding uses and applications of algae and algae derived products will be elementary, since such products and applications already exist in many other parts of the world.

The three different species mentioned in this review, *U. lactuca, S.latissima* and *P. palmata,* have all shown several potential uses, both in food production as well as many other useful applications in other industries previously mentioned.

Algae are a very versatile product and there is a profusion of research exploring further what it has to offer. Much of this research involves finding new environmentally sustainable applications and substitutions for existing products. One may therefore speculate that algae will be an important commodity in the future and is in Sweden an unutilized resource of great economic significance, that would be a waste not to benefit from both ecologically and economically.

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