International Society for

Applied Phycology

NEWSLETTER

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Message from the President, Dr. Roberto De Philippis

Dear ISAP Members,

I am happy to introduce this Newsletter as the first of my term as President of ISAP.

First of all, I would like to thank our outgoing President, Susan Blackburn, for all the activities she made during the triennium 2011-2014 for increasing the influence of ISAP and for her excellent guidance of our Society. I would also like to thank the Members of the outgoing Executive Committee for their contribution to ISAP life. A special thanks to Amha Belay, Editor of the Newsletter, for the efforts he made for the preparation of the issues published until now, and also thanks to the contributors to this issue.

In the last few months we had a number of important events for our Society: **5th ISAP Congress**

Last June, the 5th ISAP Congress took place in Sydney, gathering a large number of applied phycologists and giving them the opportunity to present and discuss their recent achievements in the field. You can find some information and pictures of the Congress on ISAP Website, but I take the occasion of this message for thanking again all the Members of the Local Organizing Committee, with a particular mention to the Chairs Pia Winberg and Susan Blackburn, for the excellent work they did in organizing such a successful Congress.

During the Congress, the ISAP General Assembly took place (you will find on ISAP website the report of the Assembly and the balance for the triennium 2011-2014), followed by the election of the new Executive Committee. At the end of the elections, the EC 2014-2017 resulted composed by the following Members:

Name	Country
Amha Belay	USA
John Benemann	USA
Sammy Boussiba	Israel
Rupert Craggs	New Zealand
Claudia Grewe	Germany
EonSeon Jin	Korea
Yannick Lerat	France
David Lewis	Australia
Emilio Molina-Grima	Spain
Sasi Nayar	Australia
Stephen O'Leary	Canada
Céline Rebours	Norway
Jean Francois Sassi	France
Mario Tredici	Italy
Ioannis Tzovenis	Greece
Vitor Verdelho	Portugal
Avigad Vonshak	Israel

I remind you that, in addition to the elected Members, the EC also includes the President, **Roberto De Philippis**, the Outgoing President, **Susan Blackburn**, the President Elect (the was voted by the EC Members by mid September). The President also appointed as Secretary/Treasurer for the triennium 2014-2017 **Pia Winberg**, who accepted this role.

Elections of President Elect of ISAP for the triennium 2014-2017

The EC received two nominations in the due time:

(1) Prof Kirsten Heimann, James Cook University, Townsville, Australia;

(2) Dr Celine Rebours, Bioforsk Nord, Bodø, Norway.

The elections took place in September and Celine Rebours received the majority of the votes and thus she is the President Elect of ISAP for the triennium 2014-2017.

Venue of the 6th ISAP Congress in 2017

The EC received two bids in the due time:

(1) Nantes, France, sent by the Local Organizing Committee co- chaired by Dr Jean Paul Cadoret, IFREMER, and Prof. Pascal JAOUEN, University of Nantes, France.

(2) Changwon, Korea, sent by the Local Organizing Committee chaired by Prof Ji-Won Yang, Korea Advanced Institute of Science and Technology, Korea.

The two bids were both excellent, but at the end the EC decided for France mostly because some years ago ISAP took the decision to have a rotation in the geographical areas of the Congresses in the presence of bids of comparable level of quality. Considering that the last ISAP Congresses were organized in Galway, Ireland (2008), Halifax, Canada (2011) and Sydney, Australia (2014), the EC decided that in 2017 the location of the Congress has to be in Europe.

Brainstorming 2014

In August and September, I launched a brainstorming among the EC Members in order to find new ways and to consolidate old ones for enlarging the influence of ISAP and for having a frequent contact with ISAP Members. We are now at the stage of finalizing the ideas exchanged and within few weeks. I will inform you of the final decisions taken by the EC.

Journal of Applied Phycology

During the Congress, Springer gave us the important information that all the Members of ISAP will have free access to the electronic version of the Journal of Applied Phycology. You only have to register yourself to ISAP website and you will find the link to the Journal. I would like to thank very much Springer for this recognition to our Society and for this useful service given to ISAP Members. It could be a good opportunity for enlarging the number of ISAP Members. Please, publicize this opportunity among your Colleagues, suggesting them to become Members of ISAP.

Payment of ISAP dues by credit cards

Membership to ISAP is now available online and with credit card payment. Membership is will provide you with free access to the Journal of Applied Phycology. You can become a member by clicking here.

Please, contribute to this Newsletter by sending your ideas, feedback on ISAP, news and announcements of interest for ISAP Members. Please contact either the Editor of the Newsletter Amha Belay, myself or the ISAP Secretary/Treasurer Pia Winberg.

I wish to all the ISAP Members a successful year in their researches and/or business in applied phycology.

With my warm regards
Roberto De Philippis
President, International Society for Applied Phycology

Message from the Editor – Amha Belay

I am happy to introduce the third issue of our ISAP Newsletter. As in previous issues, we present two interesting articles, one on macroalgae and the other on microalgae.

Realizing that bringing down the cost of algae biofuels to that of conventional fuels is challenging and takes time, many companies are targeting high value products from algae as a first step to develop technologies that will enable them to achieve their biofuel cost targets while making revenues at the same time. One such high value product that has become the focus of attention is astaxanthin from *Haematococcus pluvialis*. We have invited Sammy Boussiba to give us insight into his journey as a pioneer in this area.

While seaweeds have played a significant role in the economics of many nations, they have not been given the attention they deserve. An interesting article by Pia Winberg on macroalgae highlights the historical development of macroalgae and the contradictions that abound surrounding its production, application and economic contribution. The historical account that dates back to 35,000 BC is fascinating.

Any societal activity is as good as its members. The Newsletter is not an exception. Please provide us feedback as to how to improve the content of the newsletter. We would also be happy to get any news and views that you may have relevant to Applied Phycology. With your help, we will strive to make the newsletter educational and informative.

Astaxanthin from *Haematococcus* “The long way to glory”

SAMMY BOUSSIBA

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It all started for me in when I was listening to a lecture of Paul Bubrick from Microbio Resources, California, USA about a wonderful green alga which produces the lucrative red ketocarotenoid, Astaxanthin

The work was presented at the 5th International Conference of the Society of Applied Algology: Recent Advances in Algal Biotechnology, 1990, Tiberias Israel.

Scientific Background

A major endeavour of modern society is to produce essential goods to mankind in a sustainable manner. Microalgae are recognised as proficient natural sources for various valuable products. Their mass cultivation is in good measure a function of available solar radiation, and hence is sustainable at almost no environmental cost. This is especially suited to semiarid and arid regions, where very limited other opportunities exist. Despite its enormous potential, microalgal production is centered today on biomass production of natural strains and still relies on traditional technologies. Many valuable algal products are stress-induced secondary metabolites accumulated by organisms in stationary phase or slow growing cultures. In this situation, the commercial productivity is significantly reduced by competition or grazing, in addition to their slow rate of proliferation.

The intensive exploitation of bio-compounds production by microalgae, founded on solid basic science represents an important development goal of the Microalgal Biotechnology Laboratory (MBL). The application-oriented research spans various fields such as physiology, biochemistry and basic molecular biology, although it relies primarily on robust, but classical methodology. The MBL has promoted commercial-scale growth of microalgae and exhaustively developed conditions for mass production of bioactive pigments such as carotenoids and lipids at relatively high cellular yields. However, improving resistance to contamination and promoting more efficient utilisation of resources for both general growth and specific productivity remain high priority aims to significantly enhance algal natural productivity.

Carotenoids production

Carotenoids are accessory pigments in the photosynthetic apparatus with a primary role of light harvesting. As evident in *H. pluvialis*, they may also accumulate as secondary metabolites under stress to play a photoprotective role. Carotenoids are potent antioxidants and free radical quenchers, with demonstrated biomedical applications; they may also play a role in regulating gene expression. Due to their intensive color and antioxidant properties, several carotenoids are in high demand for various applications in animal feed and aquaculture, cosmetics, food coloring, and nutraceuticals.

Carotenoids were the first commercially successful industrial high-value products from microalgae. β-carotene from *D. salina* is produced in several countries, including Israel and Australia. Recent research indicates that only the natural *Dunaliella* isomeric composition displays the required health benefits, in contrast to the isomerically pure synthetic product. Astaxanthin from *H. pluvialis* is today a popular, high-price nutraceutical antioxidant ($15,000/kg pigment) that has been intensively studied. It is being successfully produced by various companies worldwide (e.g., in USA, Chile and China), among others also in Israel at Kibbutz Qetura by Alga Technologies using BGU’s proprietary technology. The unicellular green alga *H. pluvialis* is regarded as the best natural source of this high-value red pigment, accumulating up to 5% on a dry weight basis in cytoplasmic oil globules under various stress conditions.

The organism - *Haematococcus pluvialis*

Algae are a very heterogeneous group of photoautotrophic organisms, which, unlike higher plants (Streptophyta), do not develop an embryo. This definition allows several very heterogenic organisms to be grouped together, namely prokaryotes and eukaryotes, as well as microalgae and seaweeds. *Haematococcus pluvialis* is a green unicellular microalga (class Chlorophyceae, order Volvocales). It is common in small transient freshwater bodies. Four major cell types are distinct, according to their maturity and the environmental conditions: motile zoospores, immotile aplanospores and mother cells, and resting cysts. Except for the latter, these cell types can occur either in a green (chlorophyll-rich) or a red (carotenoid-rich) form under unstressed or stressed conditions, respectively. Stress conditions such as nutrient deficiency, high light or desiccation trigger the transformation of green zoospores into red aplanospores. Under enduring stress these red aplanospores develop further into thick-walled red resting spores. The red pigment astaxanthin, synthesized by these stressed aplanospores, is accumulating in algae-grazers and their predators such as shrimps, salmon and flamingos, giving them their pink coloration. In human nutrition astaxanthin is biotechnologically utilized for the nutraceutical market.

The Biology

I - Astaxanthin synthesis and cell division

- The duration of motility in the cell cycle is strain characteristic
- Loss of motility generally precedes astaxanthin accumulation, but this does not represent a necessary condition.
- The portion of the cells which will undergo one event of division under stress conditions is determined by three parameters:
  1. severity of the stress
  2. position at the cell cycle
  3. physiological status of every single cell
- In asynchronous cultures, the degree of cell division under stress which leads to astaxanthin accumulation is marginal in all cases reported.

II - Astaxanthin biosynthesis pathway

Using the carotenoid inhibitor DPA we were able to demonstrate that astaxanthin synthesis proceeds via cantaxanthin and that the hydroxylation of β-carotene is prior to the ketolase activity, suggesting that both of these enzymes are present in the cytoplasm.

IV - Role and function of astaxanthin in *Haematococcus* cells

In response to exposure to environmental stresses, *Haematococccus* cells accumulate large amounts of carbohydrates and lipids and few percent of pigment.

The production of astaxanthin in *Haematococcus* is a typical example for the production of secondary metabolites when cells encounter unbalanced growth conditions upon exposure to environmental stresses. We have demonstrated that under high light irradiance the pigment synthesized is acting as a screen to protect the photosynthetic machinery from light damages.

V - Product characteristic

- High content in cell - not enough
- Easy to extract - no, but cell wall is important in the biotechnology
- Difficult to synthesize - no
- High rate of production - not enough
- High price - yes
- High demand - yes

VI - An insight into the future of astaxanthin from *Haematococcus*

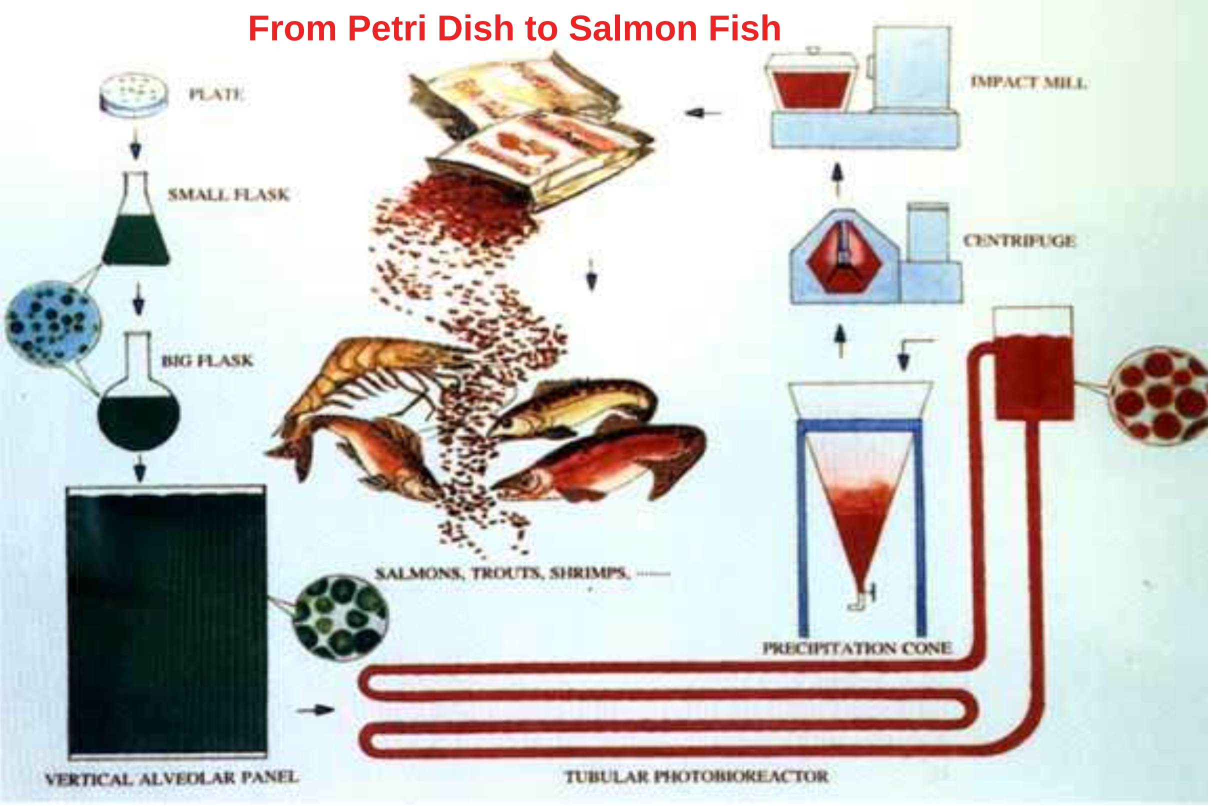
- Further study on cell physiology

- Genetic engineering studies to facilitate production
- Utilization of efficient and low cost photobioreactors

The Technology

The commercial production process is based on two distinct cultivation stages. The first is called the “Green Stage”, which starts indoors with a single colony of the microalga, and continues outdoors in solar-powered photobioreactors. The aim of this stage is to produce plenty of viable, unstressed “green” algal cells by the normal cell-division process. The “Green Stage” provides optimal growth conditions in order to achieve maximal biomass production rate. The second cultivation stage is the “Red Stage”, in which the algal cells synthesize and accumulate the pigment astaxanthin under stress conditions. Cultivating the algal culture in closed systems allows an environmentally controlled process with less biological and chemical contamination. The level of astaxanthin in the “red cells” may reach up to ~4% of their dry weight. In due time, the “red culture” is pumped to the down-processing area, where the cells are cracked (to render the pigment bioavailable), dried and vacuum-packed.

Two-stage production system (Patent 1996)



Scheme by Hu Qiang, 1995 Sede Boker Israel

Courtesy of Algatech, 2012 Ketura Israel

Take home message:

Biological aspects are the most critical issues when developing large-scale production systems for algal products or biomass. Reactor design and down-stream processing are important but not critical. They are tailor-made to the specific characteristics of the desired algal strains and products.

Today Algatech runs one of the biggest tubular photobioreactors and is one of the main producers of astaxanthin from *Haematococcus*.

“It was worthwhile”

Sammy Boussiba, July 2014

The contradictions of macroalgal applications; age, scale and sophistication

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Introduction

Compared to terrestrial crops, the contradictions of macroalgae abound; it is a crop that is both old and new, small and large, crude and high tech at the same time. Macroalgal cultivation and domestication is in its infancy, compared to terrestrial crops, at less than a century old; while in contrast humans have used macroalgal crops for 1000s of years. The production of macroalgae is barely perceived as a global primary product in the financial world markets, yet its scale of biomass far exceeds that of other categories of aquaculture. The applications of macroalgae extend from organic matter in the form of compost to 3D medical biomaterials. Thus, contradictions regarding the age of industry, economic opportunity and levels of sophistication in applications are stark.

The objective of this brief review is to highlight the rapid emergence of many forms of macroalgae being grown as crops; from primary production commodities to futuristic niche applications; while at the same time reflecting upon the history and legacy of macroalgae and its important roles in human society through the ages. As phycologists we are contributing to this journey in a collective, and it is sometimes good to reflect on what isn't, and what really is new.

A time line of production and getting to scale

Here I will use the simplified categories of brown, red and green macroalgae, the first of which was historically the most accessible and abundant to humans. Thus, brown macroalgae have historically been the dominant biomass in harvest operations for food and materials. Some of the oldest records of macroalgal applications are from harvested brown macroalgae and can be found in my adopted stomping grounds, Australia, where there are records as far back as 35,000BC of Aboriginal Australians using *Durvillea potatorum* (bull kelp) as water carriers (Figure 1). This domination of brown seaweeds continued during the onset of cultivation in the early 1900's which provided for increased production and reduced pressure on coastal populations of seaweeds. China led the pace of cultivation with the rapid expansion of *Saccharina* cultivation.

Figure 1. Traditional water carrier created from bull kelp in Tasmania (*Durvilleae potatorum*). (Richardson 1937).

In contrast, Japan was commercialising a very distant taxa in the red macroalgae, after the control of the life cycle of nori species was achieved. Japan established what is now extensive food production from *Pyropia* (prev. *Porphyra*), but this was dwarfed by the production of brown species in China. However in the last decade global production has experienced a significant shift; the rise of the reds. Carrageenan-producing seaweeds, primarily from the Philippines and Indonesia, are currently today's most dominant seaweeds in production (FAO data (2012)). *Kappaphycus* and *Eucheuma* production accelerated during the last decade overtaking the production of nori species by nearly 200% and brown seaweeds collectively by 50% in that time (Figure 2). Thus at over 5 million metric wet tonnes per annum this category of macroalgal production must be considered the largest on earth. Much current research talks about the potential for seaweed biomass to contribute to food, technology and economic development; but this has actually been realised in the case of the source of kappa carrageenan (Valderrama, Cai et al. 2013). Now at such a scale of application in food and other manufacturing, carrageenan (or food additive E-407), is gaining a notoriety that goes hand in hand with modern food processing and multi-national companies that market refined commodity products (Watanabe, Reddy et al. 1978; Cohen and Ito 2002). No doubt a sign that seaweed is indeed "big business". However, regardless of where this debate ends, the actual impact of algae on the modern world is poorly appreciated outside the producer countries and particularly by the west.

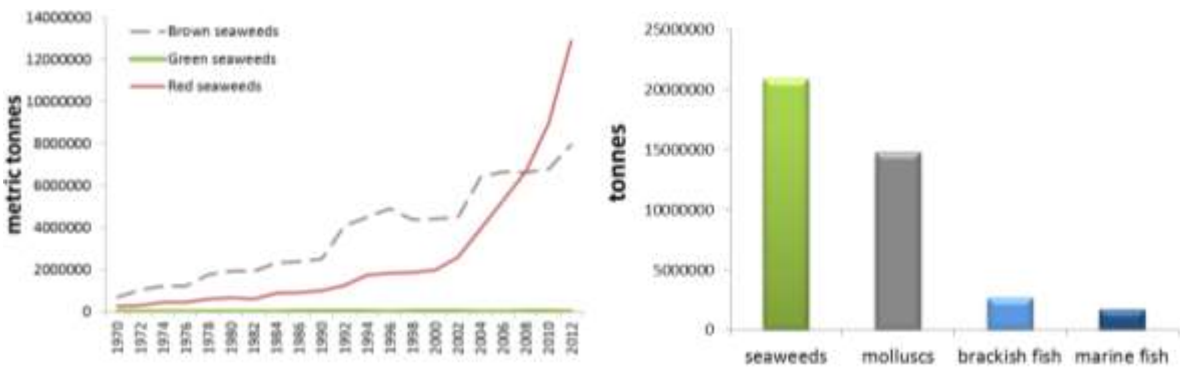

Figure 2. The global production of red, brown and green seaweeds in the past 4 decades, and the biomass production of macroalgae (seaweeds) compared to other categories of aquaculture.

Food & Health

Macroalgae industries cultivate approximately 20 species (data from FAO (2012)); from arctic water kelps such as *Laminaria spp*., to tropical red species such as *Kappaphycus*. This is produced mostly for foods including the highly valued nori (*Porphyra* or *Pyropia spp*.). Seaweeds are arguably more diverse in our oceans than land plants are on land, and this implies huge potential for nutritional diversity.

Archaeological findings in central Chile suggested that macroalgae were an important nutritional supplement that was traded between coastal and inland people as long ago as 13,000 BC (Dillehay, Ramirex et al. 2008). More recently, but still for over 100's of years, the processing of *Chondrus crispus* for carrageenan in food and for the common cold was well established in Europe, while in Asia the tradition of using kelp for iodine supplementation was well established (Aquaron, Delange et al. 2002). Although we can make some broad and confident statements about the role of seaweed in nutrition; we are really on the cusp of truly appreciating the role of seaweed in our food today and into the future. This includes addressing the issues of current global malnutrition (esp. vitamins, minerals and other trace elements) (Traka and Mithen 2011) and the future challenge of feeding nine billion people (Godfray, Beddington et al. 2010).

There are some common features of all seaweeds which make them standout from a nutritional point of view. The first is that because they grow in seawater, they have access to abundant and many types of minerals and essential trace elements. Today we should consider that seaweeds could be our natural source of multi-vitamin and mineral supplements if we are not getting enough from our modern diet.

One particular application of macroalgae in food and health is related to the improvement of sub-optimal gut health condition from modern western diets. Since seaweeds have already been applied as supplements in a wide range of livestock and animal studies in order to improve gut conditions and reduce the use of antibiotics (Craigie 2010), gut health is a very promising area of application for macroalgae and extracts thereof; a condition now linked to a range of common and chronic health disorders (Gravitz 2012).

However it is still not clear which metabolites, or if a collective of metabolites, are responsible for specific or a chain of events that can contribute to improved gut condition. Macroalgal sulphated polysaccharides (SPS) are one of the defence interfaces of seaweeds that could improve gut condition. In the marine environment, SPSs are involved in the defence from a constant barrage of microbes, as well as signalling and supporting the right kinds of microbes. In addition and in combination with other metabolites such as phenolic compounds, there are also many synergistic metabolites. Thus the effects we see from seaweeds and extracts thereof on soil and plant health, as well as the gut microbiome, makes a lot of sense; we just have a long way to go before we understand it well. These are, after all, the major biomes of each organism directly affecting the host condition.

Some examples of gut improvement from macroalgal applications include the prevention of gut ulceration by stressors on the mucosal linings (Choi, Raghavendran et al. 2010), improved microfloral profiles and activity (pre-biotic or antibiotic effects) (Dierick, Ovyn et al. 2010), anti-inflammatory properties, and regulation of glucosidase and other enzymes and thus sugar metabolism (Andrieux, Hibert et al. 1998; Charles, Chang et al. 2007). Indirect effects include reduced insulin stress, improved digestion, increased production of metabolic signals from the gut, reduced inflammatory progression among others. Thus, there is huge potential, but equally huge challenge, in pursuing the applications of macroalgae and their extracts for human health. This can only be overcome by an increased interest and investment by medical research funding into clinical trials in humans, and one aspect in favour of macroalgae is that many seaweeds and their extracts have good evidence for low-toxicity (Song, Ku et al. 2012; Abe, Hiramatsu et al. 2013; Alves, Sousa et al. 2013).

Biotech

Medical applications of the hygroscopic and gelling properties of seaweeds existed in the 1700’s as dilating devices in the treatment of abysses or during cervical procedures (Johnson 1990). In 1882, Koch announced that agar was the medium used for the culture of tuberculosis bacteria; an essential tool in the research, which would deliver progress in the fight against microbial diseases. So pharmaceutical applications are not new; from bacterial culture media, to modern DNA gel electrophoresis and dental impressions, seaweed polymers are an integral part of our biotech world.

However, it was not until the 1960s that biologically functional gels like fucoidan started to emerge in the literature. These types of molecules have analogues represented in animals such as mammalian glycosaminoglycans, heparin, chondroitin sulphate, hyaluronic acid and arabinoglycans or other dietary fibres (Fitton 2011; Winberg, Fitton et al. 2014). All of these molecules have high level biotechnology applications that potentially could be replaced or complemented by sources from macroalgae. However the challenge is to produce consistent molecular structures that are responsible for functional applications. This includes increasing the consistency and identifying the areas of efficacy for different molecular weights, degrees of sulphation and the composition of rare sugar groups.

With improved consistency, applications across disease prevention, management and even new medical tissue engineering will become a reality. The treatment of cancer has been improved with the intake of seaweed extracts (Ikeguchi 2011) although the precise molecular modes of action are poorly understood. For example, very specific matching between sulphated polysaccharide structure and blocking certain cancer cell lines has been identified (Atashrazm, Dickinson et al. 2014; January, Naidoo et al. 2014). Some of the research presented at ISAP 2014 included leading oncologists that have had success in the use of seaweeds in improving the recovery, or reducing the progression, of cancer in animal studies (Lowenthal and Atashrazm 2014). Similarly, antiviral effects have been shown for a number of sulphated polysaccharides from seaweeds by blocking the progression of viral infection (Damonte, Matulewicz et al. 2004); an effect that seems to increase with the molecular weight and high levels of sulphation by binding to the positively charged glycoprotein of the viral envelope. This interferes with viral attachment to heparin-type mammalian host cell-wall antigens (Witvrouw and De Clerck 1997), but there is still more to understand in terms of the function, efficacy and application of this health opportunity.

Summary

In a historical perspective, macroalgal cultivation was only established on an industrial scale in the early 1900's and a rapid development folowed in many nations, but in diverse contexts. From highly industrialised nations such as Japan, for traditional foods, to lower income nations in Africa as industrial commodity ingredients. From large nations such as China and to small ones like Fiji macroalgae have been vital to the employment of 100,000s of families, socio-economic progress and the sustainable development, particularly in South East Asia (Valderrama, Cai et al. 2013). It is truly a global industry, and the use of macroalgae has a long heritage across many peoples of the world for food and health, biotechnology and other industries. Yet these applications still offer new frontiers of research and industrial opportunities with our increasing knowledge, especially at the molecular and microbial levels of research. Although we need to maintain respect for what is an impressive legacy of phycological research and industrial development, "macro"phycologists can still be pioneers in a new frontier aligned with developments in other fields of research. It is therefore not surprising that the medical literature on applications of macroalgae (and their extracts) currently has a faster publication rate than all of the other macroalgal disciplines combined (Winberg, Fitton et al. 2014). So although the role of macroalgae in the industrialised world has a long history, it is also young; and more importantly its story and value is under-estimated (Table 1).

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Table 1. A timeline of applications of macroalgae. Adapted from (Winberg, Fitton et al. 2014)

Period	Status or stage of development in applied seaweed research and industry
up to 35,000BC	Tasmanian aboriginal cultures utilise the hygroscopic properties of kelp to make water carriers[1]
13,000BC	Seaweed used and traded in nutrition and health of ancient civilisations in Chile[2]
0-300	Seaweeds used as medicines in Greece[3]
	Roman Columella and Paldeus recommend the application of marine algae to the roots of agricultural crops[4]
	Documented nutritional use of seaweeds in China for iodine supplmentation[5]
	Seaweed ranching for food production in Japan6
1700s	Seaweed hygroscopic properties utilised in medical dilating devices[7]
1940s	Industrial development of hydrocolloids from seaweeds; seaweed biology; research on seaweed as food[8,9]
	Reproduction breakthrough on *Porphyra* lifehistory and intensification of *Porphyra* industry in Japan[10]
	Technology to liquefy brown seaweeds for agricultural crop application developed[11]
1950s	First International Seaweed Symposium in Scotland[11,12]
	Peoples republic of China establishes large-scale, *Laminaria* raft cultivation[12]
1960s	Taxonomic classification; biogeography and ecophysiology of seaweeds continues and industry grows[11]
	Early publications on bioactive fucoidan polysaccharides emerge
1970s	Tank based cultivation developed in Canada to secure source of carageenan from *Chondrus crispus*[13]
	Micropropagation techniques developed[14]
	Establishment of commercial phycocultivation of carageen seaweeds in the Philippines[15]
1980s	Mutant studies; seaweed cultivation and biotechnology growth; properties of hydrocolloids in industries; drug discovery and bioactive compounds; classical genetics.[11]
	Phycoculture in China reaches over 1million tons per annum[12]
	Seaweed carageen cultivation introduced to Indonesia and Africa[14,15]
1990	Genetic transformation and tissue culture; molecular phylogenetics; small-scale gene cloning and characterisation[11]
2000	Introduction of Expressed Sequence Tags approach in large-scale study on molecular genetics[16]
	Barcode of Life established and first seaweed barcodes published
	Micropropagation technology expands[14]
	Evidence for the bioactivity of seaweed sulfated polysaccharides[11]
	Search of a model plant for large-scale genomic study; shift to multi-disciplinary research[11]
	Increased interest in biorefinery and chemical engineering for high value products or biofuels
	Porphyra as proposed candidate for genome sequence[11]
2010	First model seaweed genome sequenced - brown, *Ectocarpus*[18]
	Genetic tools applied to reclassify taxonomy of some of the biggest commercial species[19]
	Seaweed, molecular techniques and glycobiology meet
2013	*Chondrus crispus* (red) genome sequenced[20]

News and Views

Algae Production and Networking Workshop
22-23 January 2015, Lafayette, Louisiana, USA

www.nationalalgaeassociation.com

European Algae Biomass
22-23 April, Amsterdam, The Netherlands

http://www.wplgroup.com/aci/_crosslink/register.asp?intSitePageId=12461

15th International Symposium on Phototrophic Prokaryotes
2-6 August 2015, Tübingen, Germany.

http://www.ispp2015-freiburg.org/

EPC6 - 6th European Phycological Congress
23-28 August 2015, London, UK.

http://www.epc6.org

ISS2016 - 22nd International Seaweed Symposium

19-24 June 2016, Copenhagen, Denmark

http://www.iss-2016.org

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