The algae and seaweed opportunity: An Australian prospect

Sourcing omega-3 and other active ingredients from algae

by Adrian Spencer
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AgriFutures® Emerging Industries

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Cover: Algal growth columns. Photo courtesy of Pacific Bio.

The algae and seaweed opportunity: An Australian prospect

Australia is already home to the two largest commercial algae production plants in the world, owned by BASF – the *Dunaliella salina* beta-carotene production plants at Hutt Lagoon in Western Australia (pictured) and Whyalla in South Australia. Beta-carotene is used for food colouring and as a nutraceutical in vitamin supplements.

Algae is making strong inroads into the global $620 million beta-carotene market, dominating the natural beta-carotene segment and providing an attractive alternative to synthetic algae.

Seaweed. Photo courtesy of Marinova.

Foreword

The global market for vitamins, minerals, supplements and functional foods is growing at a rapid rate. From 2013 through to 2021, it grew from $100 billion to $180 billion. Independent economic modelling has shown that Australia's nutraceutical industry generates annual revenue of $5.2 billion and has a total impact of $8.33 billion on the Australian economy. It directly employs 12,701 people and, including indirect jobs, supports more than 28,000 Australians. Within this context, there is potential for Australian algae and seaweed producers to supply locally sourced or grown ingredients into the product manufacture process.

The Australian nutraceutical industry relies on $1 billion worth of imported ingredients annually, for use in vitamins, minerals and supplements manufacture. The opportunity exists for companies to source Australian ingredients as replacements for those imports, and to identify emerging local and export markets that can be supplied with innovative local products with proven health benefits.

Australia is well positioned to benefit from this growth as a trusted supplier of 'clean, green, safe and secure' products, both in local and export markets. The climate and enormous variety of native algae and seaweed species in Australia enhance this opportunity. It is estimated that the Australian seaweed industry has a gross value of production of $3 million, with potential to grow significantly.

Participation in this industry requires investment in infrastructure and research. State governments are still refining their approval processes for growers to commercialise novel Australian strains. As such, the lead time to commercial production can be 2-3 years.

The rapidly emerging industries for algae and seaweed provide a clear opportunity for Australia to engage. Research as part of this project has shown that Australia has a wealth of native species that have highly sought-after nutraceutical benefits, such as omega-3 oils and inhibitors for collagen degradation.

Of note, this emerging opportunity offers unique advantages, including:

- Direct consumer health benefits
- Growth industries that are beneficial to the local economy
- Environmentally sustainable industries

CSIRO has analysed 680 strains of algae and created a shortlist of candidates that could be viably used to produce commercial levels of EPA and DHA content, as omega-3 supplements.

Separately, several compounds have been shown to have a role in stimulating collagen formation or as blockers to collagen-degrading enzymes. Given the size of the collagen market and its rapid growth, this could be a very significant opportunity. We invite you to explore this opportunity and consider the benefits of participating.

This report is an addition to AgriFutures Australia's diverse range of research publications. It forms part of our Emerging Industries Program, which aims to accelerate the development of viable animal and plant industries. Most of AgriFutures Australia's publications are available for viewing, free download or purchase online at www.agrifutures.com.au

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About the author

Adrian Spencer founded Sampano in late 2016 with the goal of building an Australian value chain for the burgeoning vitamins, minerals and supplements industry. While this industry relies on $1.1 billion worth of imported ingredients, the aim is to connect local growers into the value chain to replace imports. Sampano is working towards creating a fully Australian sourced, integrated and sustainable value chain for the complementary medicines and health industry.

Formal partnerships with Swisse Wellness and CSIRO have led to research projects that investigate the opportunity to bring new or emerging products to market.

Acknowledgments

Sampano has relied heavily on the knowledge, research and support provided by CSIRO. In particular, we thank the team from the Australian National Algae Culture Collection (ANACC), at CSIRO in Hobart, Tasmania. ANACC has contributed significantly to the research presented here and the drafting of this report.

Sampano also wishes to thank all the industry participants for their time and contribution.

In particular, we acknowledge the support, industry facilitation and funding provided by Swisse Wellness Pty Ltd and the guidance provided by Marinova Pty Ltd. Thank you to Pacific Bio for providing their images for use.

This project would not have been possible without the funding and support provided by AgriFutures Australia.

Thank you.

Acronyms and definitions

CSIRO	Commonwealth Scientific and Industrial Research Organisation
ANACC	Australian National Algae Culture Collection
EPA	Eicosapentaenoic acid
DHA	Docosahexaenoic acid
NCMA	National Collection of Algae and Microbiota
HAB	Harmful algal bloom
GMO	Genetically modified organism
PBR	Photobioreactor
CRC-P	Cooperative Research Centres projects
R&D	Research and development
TGA	Therapeutic Goods Administration

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Aerial shot of Pacific Reef Fisheries.
Photo courtesy of Pacific Bio.

Executive summary

What the report is about

Health food and vitamin companies wish to access quality local produce to ensure they continue to supply the highest-quality products with known provenance, and to capitalise on Australia's 'clean and green' reputation. Given the climate and enormous variety of native species, algae and seaweed could provide an opportunity for Australia to produce local ingredients for the nutraceutical market. It is estimated that the Australian seaweed industry has a gross value of production of $3 million, with the potential to grow significantly (Kelly, 2020).

The global market for vitamins, minerals, supplements and functional foods is growing at a rapid rate. From 2013 through to 2021, it grew from $100 billion to $180 billion. Independent economic modelling shows that Australia's nutraceutical industry generates annual revenue of $5.2 billion and has a total impact of $8.33 billion on the Australian economy. It directly employs 12,701 people and, including indirect jobs, supports more than 28,000 Australians (REMPLAN, 2016).

For decades, omega-3 oil supplements have been sourced from fish and krill. However, with the increasing ecological impact of large-scale fishing and consumer demand for plant-based products, there is pressure to find alternative sources. Global sales for fish oils and omega-3 fatty acids exceeded $3.2 billion in 2020. This market continues to grow and consumers of these products are rapidly demanding vegan alternatives.

With the support of AgriFutures Australia and our industry partners Swisse Wellness and Marinova, Sampano engaged CSIRO to answer the question: "Is there an algae that can be grown locally as a viable omega-3 source?"

As well as discovering the answer to this, we also discovered more about the algae opportunity. This report summarises our findings and provides background to the opportunity and the market context, plus information on how to participate.

Who is the report targeted at?

While the primary opportunity exists for farmers and growers of algae and seaweed, there is a need for all value chain participants to be involved at each step of the process – from growing, harvesting, processing and extraction, manufacturing, packaging, marketing, and export. For marketing companies and buyers wishing to access, promote and sell algae-based products, this report provides an introduction on what is available and their benefits, and identifies local providers.

Where are the relevant industries located in Australia?

The largest algae producers are currently in Western Australia and South Australia, followed by Queensland, Tasmania and New South Wales, with smaller operations in Victoria. These companies comprise a mix of inland algae operations and ocean-sourced or beachcombing seaweed harvesters. Many new players are entering the market and it is expected that the number of industry participants will rapidly increase over the next few years.

Background

Marine bioproducts are emerging as a global boom market. With algae as a frontrunner, Australia is well positioned to capitalise on this new and emerging sustainable market. What's more, algae isn't a one-trick pony – many other extracts can be derived from algae, including beta-carotene, chlorophyl, protein and a wide range of minerals and nutrients. The consumer appetite for algae-based products is rapidly growing, especially those used for health, skincare and consumption. Potential new products and extracts are being discovered and patented at a rapid rate.

Australia is already the world's largest producer of algal beta-carotene. While other countries may have a head start with other algae products, we are well positioned to grasp this opportunity. Our reputation for quality sets us apart. Our 'clean and green' reputation precedes us and allows us to access global markets and charge a premium for Australian products.

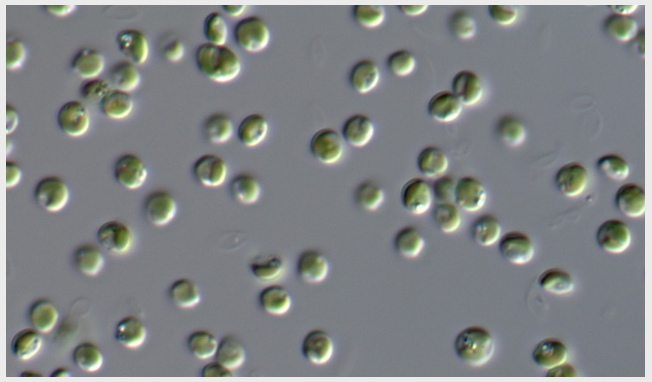
Results and key findings

Given the investment into the biofuels market over the past 20 years, there is a wealth of Australian experience and infrastructure available that can be adapted and repositioned for use in algae farming for the health industry. Algae farming is well suited to the Australian environment, with readily available sunshine and large areas of non-arable land, as well as an abundance of seaweed on the Australian coastline.

There are several existing producers of algae and seaweed already in position in the market, with new participants scheduled to come online in the next 12-18 months.

CSIRO has analysed 680 strains of algae and created a shortlist of candidates that could be viably used to produce commercial levels of EPA and DHA content, as omega-3 supplements. None of the Australian strains are currently available from a commercial supplier, but could be secured through bioprospecting, subject to approvals (Jameson, 2021). Alternatively, *Diacronema lutheri* and *Tisochrysis lutea* can be sourced from the National Collection of Marine Algae and Microbiota (NCMA) in Maine, USA for local production (Jameson, 2021).

Separately, several compounds have been shown to have a role in stimulating collagen formation or as blockers to collagen-degrading enzymes. Given the size of the collagen market and its rapid growth, this could be a very significant opportunity. The Australian-based company Marinova Pty Ltd has undertaken significant research and already produces two products with proven claims to anti-collagen-degrading efficacy (Marinova, n.d.).



Nannochloris. Photo courtesy of CSIRO.

Implications for relevant stakeholders

With rapidly increasing demand for algae extracts from around the world, this market appears to be growing. It is difficult to determine where the peak might be as there is continued growth, especially for Australian-sourced products. Given the trend towards environmentally sourced products, the continuing vegan movement and the science behind the many benefits of algae, this trend does not appear to be a fad. Essentially, there is an opportunity for Australian-based companies to secure a larger share of this market, but also potential for the market to continue to grow in size.

Entering the market requires a strong commitment to infrastructure and know-how, as well as the selection of suitable strains – which may take time if new strains wish to be brought to market. Fortunately, most states and territories in Australia seem favourably suited to commercial operations.

Recommendations

For growers and investors, starting due diligence as soon as possible is recommended, given the lead time required to achieve a full commercial operation. Right now, there is something of a footrace to identify the best strains and to secure their use. However, given the many uses of algae, the commercial focus has been quite narrow (food colouring, omega-3 and collagen-related products). There are many active ingredients in algae that can be exploited for human health. In addition, given the vast variety of strains, there are many opportunities to take advantage of our native strains.

Introduction

Algae, seaweed – what's the difference?

Scientifically, algae represent a very broad and diverse range of organisms. In some ways it is easier to say what they are not. Algae are not land plants, animal or fungi. They lack true stems, roots, leaves and vascular tissue, and are non-flowering. However, the category is so diverse that there are exceptions, which creates some confusion, especially when common naming systems are used.

What we can say is that most algae have the ability to conduct photosynthesis and most contain chlorophyll. They are very diverse and predominantly aquatic.

The more familiar types of algae are marine seaweeds (macroalgae) and microalgae from open oceans, coastal areas, lakes, ponds and wastewater. Algae can be freshwater or marine and are commonly classed as green, brown, red, and blue-green (cyanobacteria), but they do not include the seagrasses, which are vascular plants. Sometimes, algae are referred to as aquatic plants, and while elements of the scientific community may debate the terminology, it remains a useful definition.

In this report, seaweed and all other types of algae are simply referred to as algae. However, the focus of this report is mostly on microalgae. Much has been written on seaweed, and even though we include it in this research, we refer you to the most recent comprehensive report released by AgriFutures Australia, *The Australian Seaweed Industry Blueprint*, by Jo Kelly (Kelly, 2020).

Does Australia have many of its own species?

Yes, there is an enormous array of species native to Australia. Thousands, in fact, with algae growing in both marine and inland freshwater environments.

CSIRO houses the largest living collection of algae in Hobart, the Australian National Algae Culture Collection. ANACC has database records for 1877 algal strains, of which 1022 are currently viable (934 microalgae, 88 macroalgae). Beyond ANACC, each state and territory has hundreds of endemic species, the majority of which have yet to be cultured, with at least 12,000 marine, freshwater and terrestrial species thought to occur in Australia (Jameson, 2021).

Aren't some algae blooms toxic?

Yes. For that reason, any algae that exhibits toxicity, noxious species and harmful algal blooms (HABs) have not been considered in our research. That's not to say they don't have other beneficial properties. But with so many options to choose from, it is just easier to avoid the risk and regulatory hurdles.

What are the uses for algae?

Well, that's almost like asking what plants are used for. There are so many. So, let's break it down into some common categories.

1. Food

Algae is most commonly used for its beta-carotene content (used in food colouring and for its health benefits) and to produce blue and green natural food colouring, thickeners, and gelling and bulking agents. Algae has a natural salty taste and is abundant in minerals like potassium and magnesium, providing an opportunity to use it as a low-sodium salt substitute (Srivastava, 2020b).

Seaweed is a great source of umami flavour due to its high glutamate content, and is typically used as a seasoning agent to improve the flavour of food. It's popular in miso soup and sushi rolls, as well as many other Asia-derived meals.

An increase in awareness of the health benefits of algae-based ingredients is the main driver for new and emerging algae-based food and drinks. Algae is a promising and sustainable protein source. The presence of essential amino acids makes algae protein superior to some other plant proteins. (Srivastava, 2020b).

2. Vitamins, minerals and supplements

Primarily, our focus is sourcing the two main omega-3 acids: docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA). These are the most common active ingredients in fish oil products that have proven health benefits currently on the market.

Beyond omega-3, there are unique vitamins and minerals present in algae. In addition to the presence of protein, algae is high in dietary fibre, polyunsaturated fatty acids, beta-carotene, antioxidants, sulphated polysaccharides, sterols, vitamins and minerals, such as iodine, zinc, calcium and magnesium. Algae is an exceptional nutritional source and is especially suitable for vegan or vegetarian diets.

In recent years, controlled mass cultivation of spirulina has become increasingly popular, with producers using it to develop a health powder known for its particularly high protein and vitamin content (Habib, 2008). Spirulina is the common marketed name for the cyanobacterium *Limnospira*, formerly *Arthrospira maxima*, naturally harvested in certain parts of Africa and central America.

3. Skincare

Algae extracts from the red macroalga *Ahnfeltia concinna* are commonly used to moisturise dry skin. Spirulina is a source of chlorophyll, which has cleansing properties and helps skin retain moisture. Algae is used in the treatment of certain dermatitis and eczema. In terms of UV protection, the red macroalga *Gelidiella* has natural UV-blockers (Fisher, 2019).

One of algae's biggest cosmetic claims to fame is its ability to lift hyperpigmentation, including acne scars and dark circles. Some marine algae contain the red pigment beta carotene, a precursor of vitamin A and the basis of many anti-acne treatments (Fisher, 2019).

Current research for haircare products is focused on functional features of algae-based ingredients, including anti-dandruff, moisturising, hair nourishment and prevention of hair greying (Srivastava, 2020a).

Figure 1. Commercial products with algae extracts. Source: Swisse Wellness.

Figure 2. Skincare product containing red algae extract from *Corallina officinalis thallus*. Source: Swisse Wellness.

Introduction

Does collagen come from algae?

Collagen is one of the fastest-growing skincare and food ingredients in the market. Typically, it comes from bovine sources (cows) and more recently marine sources, which is a pleasant way of saying fish scales or fish waste. There is emerging demand for a non-animal-derived collagen source. Recently, some new brands are claiming to source collagen from seaweed and algae, but that may be misleading.

Collagen contains a specific set of amino acids, the building blocks of protein. Algae are a source of amino acids and protein, but algae are not particularly rich in the specific collagen amino acids, and it would be incorrect to say so. The holy grail of finding a rich collagen algae source is still elusive. However, our research showed something interesting. Several compounds have been shown to, or are suggested to, have a role in stimulating collagen formation or in blocking collagen-degrading enzymes. These compounds, such as the fucoidans, ulvans, and laminarins, are all sourced from macroalgae (Jameson, 2021)

Marinova is an Australian biotechnology company dedicated to the development and production of high-purity seaweed extracts for health. Based in Hobart, Marinova specialises in the manufacture of fucoidan compounds – highly bioactive polysaccharides derived from select species of brown seaweed. Marinova produces a range of products under its Maritech® brand, for use in nutritional, cosmetic and animal health applications. Included in this portfolio are two cosmetic extracts with proven claims – Maritech® Bright and Maritech® Reverse. Marinova extracts these compounds from a mix of imported and locally sourced wild-harvested seaweeds (Marinova, n.d.).

“Australia is already the world’s largest producer of algal beta-carotene. While other countries may have a head start with other algae products, we are well positioned to grasp this opportunity.”

A high-rate algal pond. Photo courtesy of Pacific Bio.

The market potential

The range of algae extracts is very diverse, and each has its own established or emerging market. Adding to this, algae use is on the rise amid the growth of vegan products. In Europe, the number of vegan products launched into the vitamins, minerals and supplements space doubled from 2015 to 2019. In 2019, 2.5 million Australians followed non-animal-product-based diets (Roy Morgan, 2019). Adding to their popularity and demand, algae are gluten-free and soy-free, produced sustainably, and a non-GMO protein, which dovetails into other growth areas.

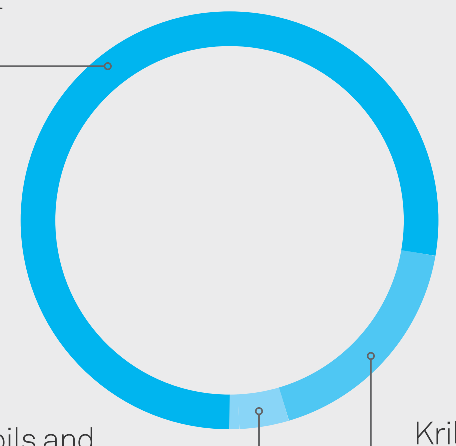


Figure 3. Australian retail sales of omega-3 products. Source: IRI MarketEdge Scan, moving annual tool (MAT) to 4 October 2020.

Figure 4. The Olay product 'Deep sea algae' contains extract from the brown algae seaweed *Fucus serratus* and microalgae extract from *Phaeodactylum tricornutum*. Source: Procter & Gamble.

Global retail sales of omega-3

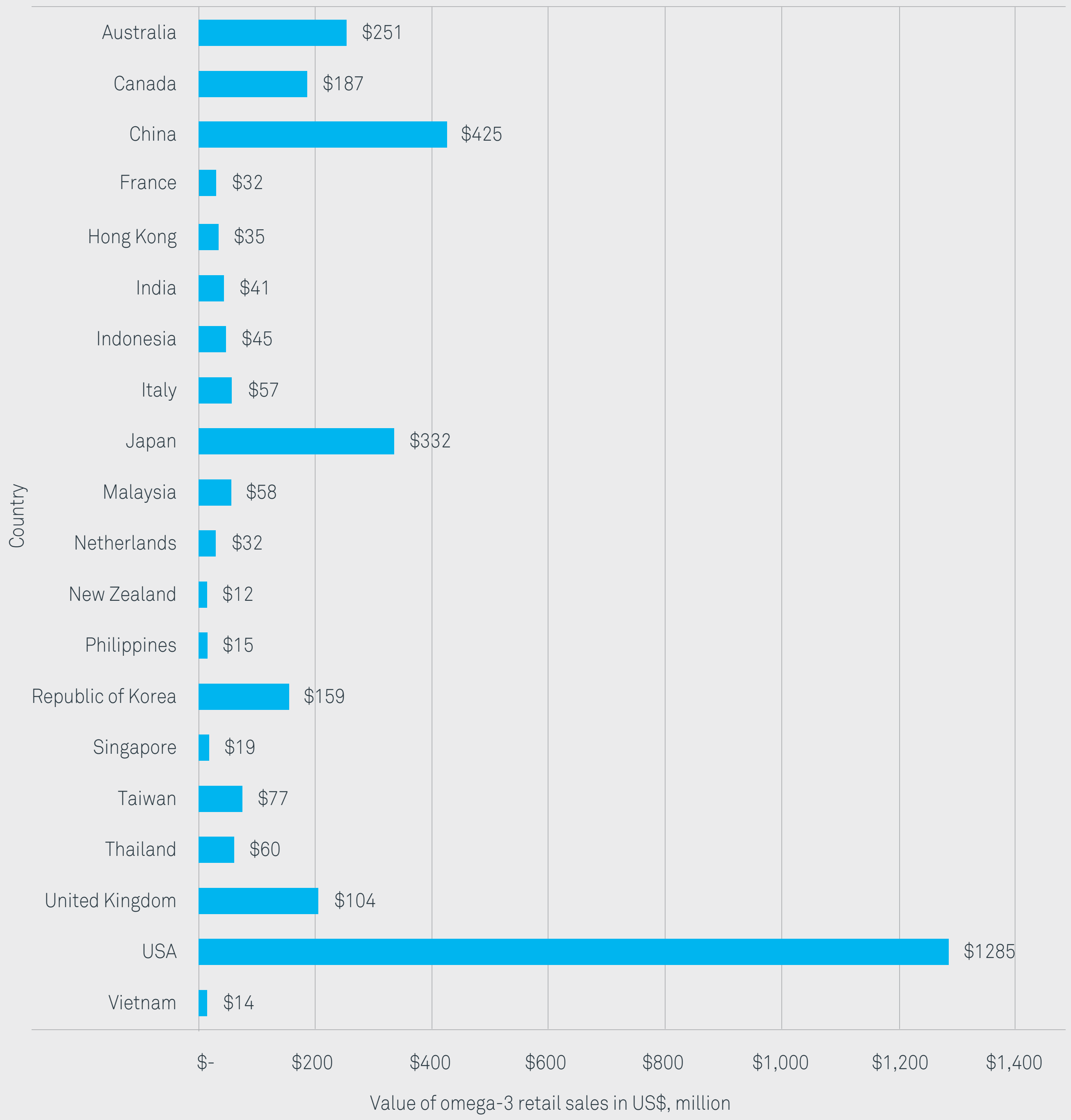


Figure 5. Global retail sales of omega-3 by country. This is an umbrella category that includes supplements sold or marketed as either fish oils or omega supplements. It includes three variants: cod liver oil, other marine-based oils and plant-based oils. Plant-based oils include those made from grains, flaxseed or algae. Source: IRI MarketEdge Scan, moving annual tool (MAT) to 4 October 2020.


Aerial shots of algal ponds.
Photo courtesy of Pacific Bio.

The value chain

Growing, harvesting and processing

For the past 20 years, the Australian seaweed industry has been developing algae farms for the purpose of producing biomass for biofuels. However, mainly due to commercial reasons, this industry has largely not been viable. This has the upside of leaving us with algae-growing experience and potential infrastructure, which in some cases may be adapted and repositioned to farm algae for the health industry.

Algae farming is suited to the Australian environment, with readily available sunshine and large areas of non-arable land. But success is not guaranteed. Selecting a strain that has an ideal growth rate, temperature requirement that matches the local climate, and ideal oil composition is critical to ensuring commercial viability. In terms of infrastructure, it is imperative to select an optimal production platform, such as open raceway pond, photobioreactor (PBR), a hybrid set-up (raceway pond with a PBR) or a fermenter (Jameson, 2021).

Viability also requires the right alignment of engineering capital expenditure, operating expenses and energy expenses relating to harvesting biomass and extracting lipid, contamination control, feedstock supply to site (nutrients such as CO_2), climate suitability, labour cost, insurance and affordable product delivery to market (Jameson, 2021).

Cradle to grave

Most producers of algae extracts grow, harvest and extract or process the algae. They then either sell a final product to the market or sell the extract to contract manufacturers for use as an active ingredient in a final product, which is on-sold by a marketing company.

For those without the time, knowledge, research, finance or inclination to develop their own production farm, we highly recommend working with existing producers.

Key producers

Microalgae

BASF is an international chemical producer and the world's largest producer of algal beta-carotene, grown and harvested from pink lakes at Hutt Lagoon in Western Australia and Whyalla in South Australia. The carotenoids are derived from an algae, *Dunaliella salina*, that is grown in naturally occurring open-air seawater lagoons. This natural colourant has been increasingly used in the food and dietary supplements industries across the world as a healthy replacement for azo-dyes (BASF Australia and New Zealand, n.d).

Algae Pharm is an Australian company (a subsidiary of Woods Group) based in Goondiwindi, Queensland. Following several years of research in collaboration with Australian universities, it has transitioned from pilot-scale to pre-commercial production of locally acquired *Nannochloropsis oculata*, delivering dried *Nannochloropsis* whole cell powder. EPA oil extraction remains at a pilot scale, with investment into larger extraction technology currently underway (Algae Pharm, 2021).

Qponics is a startup company that was originally financed out of a CRC project with The University of Queensland and Melbourne-based Nutrition Care. Qponics is aiming to soon scale up to having a 100 ha *Nannochloropsis* production farm in northern New South Wales that produces 20,000 kg/ha/year. While concentrating on EPA, Qponics has also identified a 50,000 kg high-protein by-product as a part of its multiproduct strategy (QPonics, 2021).

Seaweed

As well as the established companies, there are emerging companies, especially bespoke brands, that are either growing or harvesting seaweed for food and health products. Some key industry players are:

Marinova is an Australian biotechnology company dedicated to the development and production of high-purity seaweed extracts for human health and that specialises in the manufacture of fucoidan compounds – highly bioactive polysaccharides derived from select species of brown seaweed (Marinova, n.d.).

Pacific Bio, based in Melbourne with operations throughout North Queensland, uses macroalgae to sustainably and cost-effectively strip wastewater of environmentally harmful pollutants before they enter the ecosystem. This creates nutrient-rich products for plants and animals. Pacific Bio also supplies ReefAsta™, an Australian-made, naturally derived astaxanthin supplement extracted from *Haematococcus pluvialis*. Astaxanthin is an antioxidant with proven health benefits (Pacific Bio, n.d.).

Kelp Industries on Kind Island receives, dries and mills storm-cast bull kelp (*Durvillea pototorum*) for local use and export. The kelp is provided by suppliers that hand-select plants from beaches. Kelp Industries transforms the kelp into a granular product for sale. Buyers use a chemical extraction process to produce purified salts of alginic acid, most often sodium alginate (Kelp Industries, n.d.).

Venus Shell Systems, based in the Shoalhaven region, is developing a variety of formulations and supplements, as well as food-grade seaweed extracts, with high nutritional and bio-functional properties (Venus Shell Systems, n.d.).

SeaHealth Products hand-harvests golden kelp (*Ecklonia radiata*) from beaches on the far south coast of New South Wales for use in a range of specialist health products. These products are used in cooking and for self-care (Sea Health Products, n.d.).

Kai Ho 'Oceans Treasure', also known as Sea Vegetables Tasmania, harvests, processes and markets seaweeds for the edible market. Primarily using Tasmanian-sourced products, Kai Ho plans to be Australia's premier supplier of edible seaweed products. The principle product, *Undaria pinnatifida*, also known as Wakame, is an introduced invasive seaweed to Tasmania (Kai Ho, n.d.).

Ulva from a high-rate algal pond.
Photo courtesy of Pacific Bio.

Algae strains

Which algae is best?

For omega-3 product development, we have many options to choose from. In conducting research, CSIRO analysed 680 strains and created a shortlist based on their EPA and DHA content and their ratio.

There is no simple formula required in the marketplace. Some products focus on high EPA to aid certain types of inflammation and heart disease (WebMD, n.d., b). Alternatively, DHA is sought as it is an important structural component in the brain and it may benefit early childhood development and cognition later in life (WebMD, n.d., a). Some products have a balance of both EPA and DHA. (Zhang, 2019)

CSIRO reviewed single algal strains from species that produce both EPA and DHA in ratios similar to fish oil. Presented below are the standout strains that have EPA and DHA, elevated EPA, and elevated DHA.

Where do I buy these strains?

Obtaining access to strains for commercial purposes is not simple and varies by jurisdiction. Here is a quick summary of sources. Further information is available in the regulatory requirements section further on.

Australian strains

None of the following can be obtained from a commercial supplier:

- *Pavlova pinguis* and *Rhodomonas duplex* are all Tasmanian strains and bioprospecting approval is needed.
- The two Tasmanian *Nannochloropsis australis* strains with elevated EPA could be sourced from CSIRO but require state government approval for commercial use.
- *Nannochloropsis oceanica* from Queensland is an alternative option, but retrospective approval is required to commercially grow this strain.
- *Asterionellopsis* and *Helicotheca* require further research to confirm their suitability in high-biomass growth systems.

AlgaePharm is entering negotiations to secure bioprospecting approval of its own Queensland *Nannochloropsis* isolate.

It is worth talking with existing operators about their experiences or to collaborate or source strains from them directly.

Overseas strains

Diacronema lutheri and *Tisochrysis lutea* can be sourced from the National Collection of Algae and Microbiota (NCMA) in Maine, USA. NCMA offers commercial licenses.

Are these strains guaranteed to work?

No. Growing algae successfully is complicated, as is extracting its value. Choosing a strain and determining its potential success is being made easier thanks to the likes of Provectus Algae, in Queensland. Its technology offers a scalable platform to optimise growth of targeted strains. The platform can be upscaled from a high-throughput experimental phase to a 20,000-litre pilot facility (Provectus Algae, n.d.). Provectus Algae has used several ANACC strains for enhanced growth characterisation and technology proof of concept.

There is more that can be achieved. The algae cell is an extraordinarily efficient biofactory for the production of a range of useful compounds relevant to a wide spectrum of industries. Currently, just a handful of microalgae species are used commercially, for a variety of natural products. Thousands of microalgae strains with a vast array of industry-relevant product profiles have been characterised but remain untapped due to a previous lack of genetic tools and viable methods of commercial production (Provectus Algae, n.d.).

Provectus Algae's approach leverages recent advancements in synthetic biology, automation and artificial intelligence to bring a platform to market that enables new commercial opportunities for microalgae production, from product development through to commercial production.

Table 1: Summary of algae analysis for DHA and EPA content (Jameson, 2021).

Species	Origin	% EPA	% DHA	Ratio of EPA:DHA
Strains with an EPA and DHA ratio of 1.5:1				
Diacronema lutheri	Finland, 1956	17.7	11.1	1.6
Pavlova sp.	Woods Hole, Massachusetts, USA, 1959	25.0	9.2	2.7
Pavlova pinguis	Pipeclay Lagoon, Tasmania, 1992	25.7	11.1	2.3
Proteomonas sulcata	Fitzroy Island, Queensland, 1990	12.6	7.8	1.6
Rebecca salina	Woods Hole, Massachusetts, USA, 1959	25.8	10.2	2.5
Rhodomonas duplex	Derwent River, Tasmania, 1993	13.6	7.6	1.8
Strains with elevated EPA				
Asterionellopsis glacialis	Port Hacking, NSW, 1982	39.0	0.8	49.0
Helicotheca tamesis	Port Hacking, NSW, 1978	48.2	0.6	82.0
Nannochloropsis australis	St Helens, Tasmania, 1995	34.8	-	-
Nannochloropsis australis	Orford, Tasmania, 1995	32.6	-	-
Nannochloropsis oceanica	Deception Bay, Queensland, 1989	41.1	-	-
Strains with elevated DHA				
Tisochrysis lutea	Tahiti, 1977	0.33	15.8	0.02
Strains not available for commercial development due to current R&D activities with Pharmamark until January 2022				
Aurantiochytrium	Queensland, 2010	0.45	45.6	0.01
Schizochytrium	Tasmania, 2010	1.5	68.7	0.02
Ulkenia	Tasmania, 2010	7.5	27.8	0.3

Collagen

Based on a limited assessment of seaweed and microalgae species, the amino acid compositions of their protein appear to be similar, and they may contain collagen precursors. However, the collagen amino acids were found to be present in relatively low quantities, insufficient for commercial production (Jameson, 2021).

Of greater potential, several compounds of seaweed and microalgae have been shown to, or are suggested to, have a role in stimulating collagen formation or as blockers to collagen-degrading enzymes.

The Australian-based company Marinova has undertaken significant research and produces two products with proven claims to anti-collagen-degrading efficacy.

Marinova does not currently farm macroalgae, relying instead on wild harvest. A few relatively new Australian companies, such as Venus Shell Systems in Shoalhaven, NSW, are scaling up farmed production of macroalgae for multiple nutritional and health-related end uses.

"Several compounds of seaweed and microalgae have been shown to, or are suggested to, have a role in stimulating collagen formation or as blockers to collagen-degrading enzymes."

Seaweed in Tasmanian waters. Photo courtesy of Marinova.

Implications

Who owns the rights to grow and harvest?

In Australia, there is no single commercial licenser for algae. If you wish to obtain algae to grow, it has to be sourced from the wild (bioprospected) and then approved for use. Alternatively, it could be obtained from an existing grower that has the required licenses.

There are significant compliance issues surrounding the rights for commercial exploitation of genetic resources. The Australian Government and the state and territory governments all have different bioprospecting legislation that detail the pathway for commercialising any products derived from species collected within their jurisdictions.

Some of the complexities involve integrating with international policies, such as the *Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization* (Convention on Biological Diversity, 2011). Growers wanting to transition from research to commercial production have already encountered some of these regulatory issues.

Securing rights for use is clearly time-consuming and highly variable by state or territory. It seems best to undertake this approach in conjunction with an algae producer or researcher familiar with the process. If a researcher wishes to provide algae for commercial exploitation, retrospective bioprospecting must be undertaken, which is not preferred by state and territories.

The alternative is to initiate new sampling permits with a stipulated benefit-sharing agareement. For example, CSIRO is currently negotiating such an arrangement with the Commonwealth and Queensland jurisdictions for marine thraustochytrids, and progress suggests that having an end user participate in the negotiation is a key driver to progress.

Regulatory issues

Where a seller wishes to make health claims or benefits, the product must be approved by the Therapeutic Goods Administration (TGA). At the time of writing, the TGA website listed 126 products that contain DHA. Of these, 73 note the active ingredient is DHA sourced from *Schizochytrium*, a non-photosynthesising coastal marine microalgae-like species grown in fermenters. For EPA, the TGA listed 28 products where all of the 12 algal sources are again linked solely to *Schizochytrium*.

It is probable that all these strains originate from overseas, which means a locally sourced strain may require TGA approval for commercialisation as a complementary medicine. However, it might be possible to source an equivalent, which could make TGA approval simpler. *Schizochytrium*, for example, can be sourced locally.

Synechococcus sp. Photo courtesy of CSIRO.

Sea kelp

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