FutureFeed Report to Industry 2023

A Seaweed Solution to Address Climate Change

FutureFeed®

Contents

About this report

This report provides a comprehensive snapshot of how FutureFeed and our nine licensee partners are progressing the production and adoption of *Asparagopsis* as a proven livestock feed ingredient for reducing methane globally.

It tracks progress since FutureFeed was founded in 2020 through to December 2023.

The report provides a summary of the challenges and achievements, the significant investments in capital and grant funds, the policy and regulatory environment and a summary of 15 significant research programs that are supporting the development of the technology.

Asparagopsis promises significant environmental benefit to combat climate change and reduce greenhouse gas (GHG) inventories.

It is not only beneficial to the livestock and dairy industries, but also to our licensees who are growing and processing the seaweed and in the regions in which they operate, creating new economies using local labour.

FutureFeed, together with our licensees, is creating a new, sustainable, nature-based industry.

As this report shows, investors, governments and organisations globally recognise the potential and need to continue to invest and build this exciting industry to address climate change and build sustainability in the agricultural sector.

Key Achievements

- *Asparagopsis* scientifically proven to be capable of reducing methane emissions in cattle by 80% or more[1], while also improving feed efficiency.
- Multiple research studies have shown *Asparagopsis* as a feed material is safe for animal consumption, and the resulting meat and dairy products are safe for consumers.
- *Asparagopsis* is an approved feed material allowing for its commercialisation in a number of markets.
- Scientific trials are underway in a number of global markets, taking into consideration local variations in agricultural processes to gain regulatory approvals in those locations.
- FutureFeed is actively developing an Australian enteric methane methodology with government to ensure livestock producers will be able to verify methane reductions from their animals using *Asparagopsis*.
- FutureFeed has been instrumental in co-funding and establishing an industry working group to progress the development of a methodology under the ACCU Scheme – the Livestock Emissions Carbon Farming Working Group.
- Commercial supply of *Asparagopsis* to livestock producers from licensees has commenced at a small scale.

Key Challenges

- Scaling-up *Asparagopsis* production to meet global demand and reduce costs. Although *Asparagopsis* generates a very good result when measured per unit of methane suppression, the cost of production can be high and challenging for wide-scale adoption.
- Further stabilising the bioactives in *Asparagopsis* through processing techniques to generate best results as product moves through the value-chain.
- Carbon credits for enteric methane remain nascent and not yet delivering value to those using *Asparagopsis*.

1. Kinley et al. 2020. Journal of Cleaner Production. Mitigating the carbon footprint and improving productivity of ruminant agriculture using a red seaweed
Roque et al. 2021. Plos One. Red seaweed (Asparagopsis taxiformis) supplementation reduces enteric methane by over 80 percent in beef steers

About FutureFeed

FutureFeed was born out of Australian innovation aimed at helping to solve the global climate crisis.

Enteric methane – predominantly burping by cattle – accounts for 5.5% to 5.7%[2] of all human-caused greenhouse gas (GHG) emissions globally.

When a team of scientists from CSIRO and James Cook University, supported by Meat & Livestock Australia (MLA), came together more than a decade ago to investigate the methane reduction potential of native Australian seaweeds, they made a world-changing discovery.

They found red seaweed species *Asparagopis taxiformis* and *Asparagopsis armata*, which are endemic to Australia and NZ and found in many parts of the world, are the most efficient natural supplement available for livestock, capable of reducing emissions by 80% or more while also improving feed efficiency.

This result can be achieved by the addition of a small amount of the seaweed into the daily diet of livestock.

CSIRO established FutureFeed in 2020 with support from Woolworths Group, GrainCorp, Harvest Road and AGP Sustainable Real Assets, to drive the commercialisation of this technology.

FutureFeed holds the global intellectual property (IP) for the use of *Asparagopsis* as a livestock feed ingredient for reducing methane and holds granted patents and patent applications for a method of use for methane reduction, a method of use for productivity gains, and the process of manufacturing vegetable oil-based *Asparagopsis* products.

To date, FutureFeed has licensed nine partners across Australia, New Zealand, United States, Europe and Canada to drive the development and commercialisation of the technology.

FutureFeed does not sell seaweed – the livestock industry and livestock feed industry source quality *Asparagopsis* seaweed from our licensees.

This feed ingredient is currently applicable in the beef feedlot and dairy markets, with research into its application for grazing systems underway.

On the back of years of research into growing and processing *Asparagopsis*, FutureFeed is starting to see some of our licensees approach commercial production at scale.

The production costs of the commercial product are expected to come down as efficiencies are operationalised by licensee partners and supply is scaled up to meet the growing demand in Australian and overseas markets.

If just 10% of global ruminant producers adopted *Asparagopsis* as an ingredient to feed their livestock, it would have the same impact for the climate as removing 100 million cars from the world's roads, and potential increases in livestock productivity could create enough food to feed an additional 23 million people[3].

FutureFeed plays a leading role in a range of areas that support our licensees and ultimately the livestock industry and livestock feed industry by:

- Licensing new *Asparagopsis* partners
- Extending research and development (R&D)
- Supporting market access
- Setting minimum standards to industry
- Building carbon markets for enteric methane
- Building tools to support transparency across the value chain
- Extending and protecting IP for use by licensee partners.

Image courtesy of CH4 Global

2. IPCC. 2019. Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems
3. CSIRO: https://www.csiro.au/en/research/animals/livestock/futurefeed

Global support for methane reducing feed material

Governments and society largely accept that we face planetary climate change that could change the face of the earth and our existence without significant interventions.

Given the responsibility that greenhouse gasses (GHGs) play in our rising global temperatures, there is a focus on the sustainability of our global food production systems, and particularly those of animal-derived protein.

Over 150 countries including Australia have signed the Global Methane Pledge to decrease anthropogenic (human-caused) methane emissions by 30% from 2020 levels by 2030.

Asparagopsis has been recognised by a number of governments and organisations as among the key tools that can help reduce methane emissions from the livestock sector.

In Australia, the federal government is funding the three-stage $29 million Methane Emissions Reduction in Livestock (MERiL) program to support research and development (R&D) of methane-reducing livestock feed technologies including *Asparagopsis*.

As part of the MERiL program, the livestock emissions framework for feed technologies (LEF) is being developed to provide a consistent approach for estimating emission reductions from the use of feed technologies without having to directly measure methane at the farm, industry, state, and national scales.

It will inform updates to the National Greenhouse Gas Inventory (NGGI) and development of potential new Australian carbon crediting methods and carbon neutral certifications.

In 2022, enteric methane accounted for 70% of agricultural emissions, 11% of national emissions and 44% of national methane emissions in Australia.[4]

MLA, as the Australian red meat and livestock industry's Rural Research and Development Corporation (RDC), supports investment in R&D into *Asparagopsis* as one of the tools available to potentially help the Australian red meat and livestock industry achieve the ambitious target of being carbon neutral by 2030 (CN30).

Globally, support for *Asparagopsis* is also growing.

In Sweden, a new report from Naturvårdsverket,[5] Sweden's Environmental Protection Agency, proposes urgent government support to incentivise the uptake of feed additives such as *Asparagopsis*. Naturvårdsverket's report highlights that methane-reducing feed additives are one of the few fixes available to cut emissions from livestock, which account for approximately 70% of Sweden's methane emissions.

In the United Kingdom, the Department for Environment, Food and Rural Affairs (DEFRA) considers methane suppressing feed products are an essential tool to decarbonise the agricultural sector. It has stated it is committed to working with industry to stimulate the market and encourage uptake of these products. In England, it plans to incentivise the uptake of high efficacy products with proven safety once suitable products enter the market. The agricultural sector in the UK accounted for 10% of the total GHG emissions in 2019,[6] with methane emissions contributing substantially to this figure.

4. Australian Government, DCCEEW https://www.dcceew.gov.au/sites/default/files/documents/livestock-emissions-framework-feed-technologies-factsheet.pdf
5. Naturvårdsverket https://www.naturvardsverket.se/om-oss/regeringsuppdrag/slutredovisade-regeringsuppdrag/minskade-utslapp-av-metan/; https://medium.com/@VGreentech/swedish-government-advised-to-feed-cows-methane-reducing-additives-to-meet-climate-targets-8b84a0e87f21
6. UK DEFRA https://www.gov.uk/government/news/further-action-to-cut-methane-emissions-from-livestock#:~:text=The%20agricultural%20sector%20in%20the,emissions%20in%20the%20agricultural%20sector

Awards

The efforts of FutureFeed and its nine licensee partners have been widely recognised via various environmental, business and innovation awards.

FutureFeed Awards

- Food Planet Prize winner 2020
- Eureka Prize finalist 2021
- Australian Financial Review Sustainability Leaders 2022
- BloombergNEF Pioneers Award 2023
- Banksia Sustainability Awards finalist 2023

Licensee Partner Awards

Blue Ocean Barns

- 2023 Hawaii Venture Capital Association Deal of the Year Award
- CEO Joan Salwen named 2021 Ag/Clean Tech Entrepreneur of the Year

CH4 Global

- Global CleanTech Top 100 list in 2022 and 2023
- Norrsken top 100 Impact Award 2023
- Eco Innovation Award 2023
- SA Climate Leaders Award 2023

CleanEyre Global

- Member of the 2023 Sparklabs Cultiv8 Cohort start-up accelerator program.

Sea Forest

- Finalist in the 2023 Earthshot Prize
- Telstra business awards in Australia and Tasmania
- Numerous agritech innovation awards in Australia and Tasmania

SeaStock

- MassChallenge 2023 Louis Dreyfus Climate Resilience Prize

Symbrosia

- Numerous high-profile awards including Forbes 30 Under 30 for Social Impact, the Blue Climate Initiatives Ocean Innovation Prize, and Global Warming Mitigation Project's Keeling Curve Prize

Synergraze

- Emissions Reduction Alberta - Food, Farming and Forests Challenge Award
- Sustainable Technology Canada Award
- CEO Recipient of a Queen's Platinum Jubilee Medal 2022

Image courtesy of FutureFeed

Growing *Asparagopsis*

Overview

While *Asparagopsis taxiformis* is a tropical species and *Asparagopsis armata* is a temperate species, both have a highly complex life cycle.

Reliance on wild harvest of *Asparagopsis* is neither consistent nor sustainable and commercial-scale *Asparagopsis* cultivation production growth will depend on aquaculture.

FutureFeed's licensee partners are using both land-based and marine-based farming techniques to cultivate *Asparagopsis*.

A seaweed cultivation system is made up of two main components – a hatchery and a growing site.

Land-based farming generally takes place in closed systems comprising tanks, raceways, ponds, or lagoons in which water is retained under agitation to keep seaweeds suspended and exposed to the light.

Marine-based farming typically involves seaweed species being seeded on long lines and hung in the ocean until the harvest season. It also involves tidal ponds, which are open systems that use seawater for growing *Asparagopsis*.

In nature, is takes approximately 3 months to establish a mature *Asparagopsis* plant, however, the various cultivation methods being developed by our licensee partners mean the growing process is measured in weeks.

Once harvested, the seaweed is processed into a dried powder or into an oil-infused product, while preserving the bioactivity.

Asparagopsis produces a number of bioactives including bromoform, which prevent the formation of methane in ruminant livestock by inhibiting specific enzyme in the bacteria of the rumen during the digestion of feed.

The key challenges and opportunities are now in scaling-up production to meet global demand and producing a product at a lower cost.

Factoring in primary production margins, FutureFeed and its licensee partners are working hard to reduce the cost per animal per day of adding *Asparagopsis* to feeding regimes.

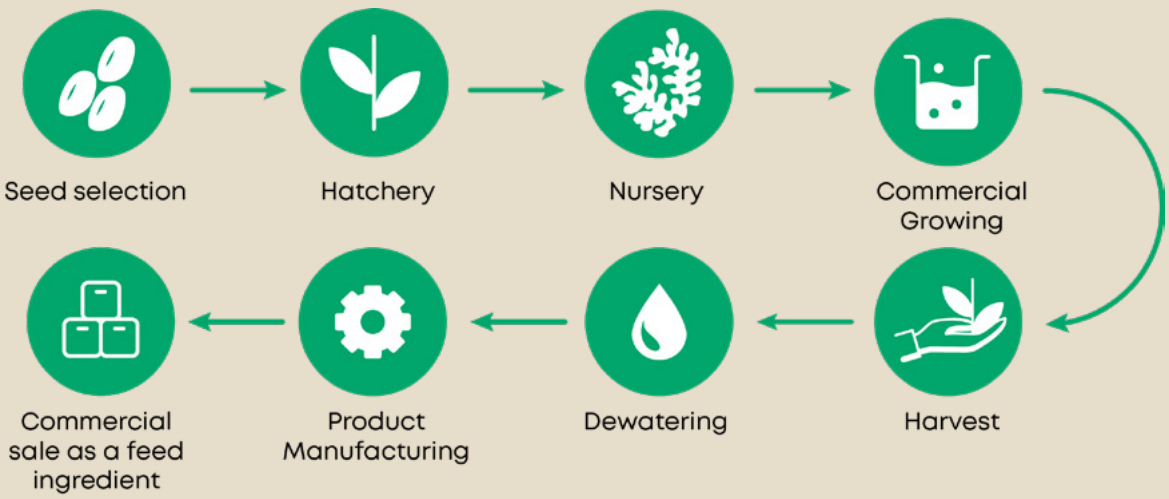
Current production is in trial stage and needs to be scaled from hundreds of tonnes per year to hundreds of thousands of tonnes per year to meet demand.The Commonwealth Government has committed $8.1 million to progress seaweed research and support the establishment of a National Hatchery Network for the commercialisation of seaweed production as a key input into feedstock to help reduce methane emissions.

Fisheries Research and Development Corporation (FRDC) will administer the $8.1 million investment on behalf of the departments of Climate Change and Energy (CCE) and Agriculture Fisheries and Forestry (DAFF) and it will be undertaken as a partnership between the Australian Sustainable Seaweed Alliance (ASSA), FRDC and DAFF.

ASSA is the peak body for commercial seaweed industry development in Australia.

FutureFeed is a foundation member of ASSA and provides a Director to the ASSA Board.

Asparagopsis growing cycle



Meet our Licensees

FutureFeed has licensed nine *Asparagopsis* producers and processors around the world and are actively seeking to expand this network in order to meet growing demand.

Blue Ocean Barns, Inc

Locations:

- Kailua-Kona, Hawai'i
- San Diego, California
- Pacific Coast of Mexico

Number of staff: 51

Senior leadership team:

- Joan Salwen, Chief Executive Officer
- Matt Rothe, Chief Technology Officer
- Terry Campbell, Director of Operations
- Will Buster, Director of Financial Planning & Analysis
- Gal Dishon PhD, Sr Manager of Strategic R&D
- Mike Minion PhD, Director of Enterprise Data

About:

Conceived in 2017 as Elm Innovations, Blue Ocean Barns grows *Asparagopsis taxiformis* 'Brominata,' a novel variety patented in the US in 2020 and grown on-land in a continuous filtered seawater medium.

Blue Ocean Barns' growing technology yields chemical compositions with patents pending in Australia, New Zealand, Brazil, Chile, South Africa, China, Indonesia, US, Canada, Mexico and the European Patent Office.

We have a commitment to ongoing research and were the first licensee to co-author peer-reviewed *Asparagopsis* research.

Its research team was also the first to conduct an in vivo trial involving dairy cattle, the first licensee to feed *Asparagopsis* on a USDA certified organic cattle operation and a conventional commercial dairy farm, and the first licensee to be USDA certified, organic for Crop and Handling.

Blue Ocean Barns has recently launched a major expansion of operations and is now growing Brominata in two countries, with plans to expand to 1,000 acres as part of a single project.

Key highlights:

- Obtaining a 9-year purchase agreement with a Global Fortune 200 Company
- Granted regulatory approval to distribute in all US states in which Brominata is sold
- Received the 2023 Hawaii Venture Capital Association Deal of the Year Award
- CEO Joan Salwen was named the 2021 Ag/Clean Tech Entrepreneur of the Year.

Image courtesy of Blue Ocean Barns, Inc

Meet our Licensees

CH4 Global Inc

Locations:

- Arno Bay, South Australia, Ruakaka and Bluff, New Zealand
- Commercial scaled facility being built in Louth Bay, South Australia

Number of staff: 50

Senior Leadership Team:

- Steve Meller, PhD, Chief Executive Officer
- Steve Chun, Chief Financial Officer
- Tim Williams, Chief Operating Officer
- Chris Rose, Chief Business Development Officer
- Rowena Pullan, Chief Marketing Officer
- David Lawson, Chief Technology Officer.

About:

CH4 Global was founded in 2018. All operations are land based, growing *Asparagopsis* in patented vessels that are larger in scale, lower in cost and take up less land area when compared with traditional aquaculture vessels.

A focus on reducing cost of goods sold has seen CH4 Global develop and patent methods for the cost effective growing and processing of *Asparagopsis*. This enables farmers to create a net positive return on investment and CH4 Global to deliver sufficient profitability through its operation to grow the business and scale up production.

CH4 Global does not use freeze-drying or oil extraction for commercial scaled production instead adapting and patenting several complementary methods that are widely used in commercial food production. These methods reduce the loss of volatile bioactives, provide inherent stability and reduce cost, waste and energy use.

Key highlights:

- Global CleanTech top 100 list in 2022 and 2023
- Norrsken top 100 impact award 2023
- Eco Innovation Award 2023
- SA Climate Leaders Award 2023.

Image courtesy of CH4 Global

Meet our Licensees

CleanEyre Global

Locations: Cowell, South Australia

Number of staff: 12

Senior leadership team:

- Ron Tremaine, Chief Executive Officer
- Almendra Rodríguez, Head of R&D
- Ananda Santos, Head of Production
- Danielle Rayner, Production Manager
- Adam Davidson, Project Manager
- Eva Maurel, Asparagopsis Research Technician

About:

CleanEyre Global was founded in 2021 and focuses on land-based production of the tetrasporophytes of the two main varieties of *Asparagopsis, taxiformis* and *armata*, in an upright bag system.

CleanEyre Global's hatchery production consists of two temperature-controlled environments to maximise the production rate of both taxiformis and armata in order to build biomass and establish a nursery production facility at scale, which will then support feedlot and market trials.

With an ongoing commitment to harvesting wild seedstock to optimise genetic diversity, the CleanEyre Global R&D Seedstock Laboratory continues to focus on ongoing trials to optimise growth and bromoform yields.

Processing methods include oil extraction, with processed product stored at four degrees in a blacked out environment, and freeze drying.

With a wide range of research completed, including developing an optimised production methodology, in 2024 CleanEyre Global will carry out feedlot trials with EnviroBeef to add *Asparagopsis* to their omega-3 cattle feed as well as a number of product delivery trials including lick-blocks and water systems.

Key highlights:

- Demonstrated strong performance of the upright bag production system and consistent growth from both indoor and outdoor facilities.
- Developing a range of aquaculture programs for schools across the Eyre Peninsula, to help develop a future workforce, in collaboration with Cowell Area School and Tafe SA
- Member of the 2023 Sparklabs Cultiv8 Cohort start-up accelerator program and the Australian Sustainable Seaweed Association.

Image courtesy of CleanEyre Global

Meet our Licensees

Immersion Group

Locations:

- Bellarine Peninsula, Victoria
- Watermans Bay, WA
- South Island New Zealand (2024)
- Japan

Number of staff: 11

Senior leadership team:

- Scott Elliott, Chief Executive Officer
- Dr John Stratton, Chief Scientist
- Liam O'Shannessy, Chief Commercial Officer
- Harry Van Dyk, Chair

About:

Immersion Group has been operating for three years and is focused on the onshore production of *Asparagopsis armata* and *taxiformis* in a proprietary cultivation system.

This technology optimises growth rate, bromoform and cultivation density for both species of *Asparagopsis*.

This patented technology delivers some of the highest yields relative to capital outlay and carbon footprint of any seaweed produced globally and does not need to be installed in close proximity to the ocean, meaning it can be positioned near other industries to capitalise on beneficial use waste streams such as CO2, heat and brine.

Immersion Group's growing strategy is founded on in-depth research to better understand the optimal conditions for *Asparagopsis* growth, including light, temperature, and nutrient requirements, with stringent contamination control measures at all stages of production from extraction of wild cultures to freeze drying.

Immersion Group produces freeze-dried *Asparagopsis*, achieving significant bromoform concentrations using a stage-based approach to treating the seaweed before it enters the freeze dryer. Bromoform content and providence remain extremely important for quality assurance purposes.

Key highlights:

- Partnership and cornerstone investment with Japan-based Nissui Corporation. This partnership involves significant support in terms of technical subject matter experts, research and development, patents, production engineering and business development into markets/multi-national companies globally
- *Asparagopsis* trials planned with tertiary education institutions, beef feedlotters and dairy processors.
- Established partnerships with research institutions University of Western Australia, University of Melbourne and Deakin University
- Established a new pilot production facility in Victoria.

Image courtesy of Immersion Group

Meet our Licensees

Sea Forest

Location: Triabunna and Swansea, Tasmania

Number of staff: 52

Senior leadership team:

- Sam Elsom, Co-founder and Chief Executive Officer
- Stephen Turner, Co-founder and Chair
- Dion Cohen, Chief Financial Officer
- Emeritus Professor Rocky de Nys, Chief Scientist
- Dr Marie Magnusson, Science Lead
- Shane McHugh, General Manager

About:

Sea Forest is a science-based environmental technology company developing sustainable long-term solutions to the challenges of climate change and global food security.

Established in 2018, Sea Forest combines marine and land-based cultivation of *Asparagopsis* and produces SEAFEED™ a livestock feed additive, scientifically proven to reduce methane production by up to 80%[1].

Led by passionate environmentalist Sam Elsom, Sea Forest cultivates *Asparagopsis* in the ocean on a 1600ha marine lease in Mercury Passage, as well as on land in High Rate Algal Ponds at both Triabunna and Swansea, Tasmania. The company has established world-class *Asparagopsis* research and cultivation facilities.

Processing of the product includes oil-based stabilisation, concentration and blending. SEAFEED™ is a non-GMO vegetable oil-based product that can be readily included into total mixed rations for feedlot cattle or in pellets, loose mixes, lick blocks or molasses-based supplements.

Sea Forest has been involved in a number of important MERiL supported feeding and product development trials as well as partnering with the Tasmanian State Government's Agricultural Development Fund working with livestock producers, and independently with a number of Wagyu feedlot producers.

The company works with Australian burger chain Grill'd and in January 2023 delivered the world's first low emissions burger to consumers.

Key highlights:

- Finalist in the 2023 Earthshot Prize for Climate
- 2022 Telstra Best of Business Awards Winner
- 2022 InnovationAus Awards Winner
- Launch of consumer-facing low-methane products in partnership with retailers.

Image courtesy of SeaForest

Meet our Licensees

SeaStock

SeaStock Pty Ltd

Locations:

- Fremantle, Western Australia
- Abrolhos Islands, Western Australia

Number of staff: 7

Senior leadership team:

- Tom Puddy, Managing Director
- Bryant McLarty, Executive Director/Chairman
- Greg Harvey, Non-Executive Director
- Tom Chaney, Chief Technology Officer
- Tim Whyte, Chief Financial Officer

About:

Having launched in 2021, SeaStock specialises in the on-shore cultivation of Tetrasporophyte in large scale photobioreactors for commercial production, setting up commercial plants in Australia and international locations with a number of strategic partners.

SeaStock has successfully developed a patented dual extraction method for obtaining bromoform for use in canola and vegetable oils and natural pigments.

SeaStock has engaged Flinders University and The University of Western Australia to undertake various research assignments relating to the cultivation of *Asparagopsis* and the extraction and optimisation of key compounds. This research has enabled SeaStock to develop a scalable and commercial business model.

In November 2023, SeaStock started the process to secure funding to develop its first large scale plant.

Key highlights:

- Signed MOU with Geraldton Fisherman's Co-Operative to repurpose existing unutilised infrastructure
- Provisional patent lodged for novel *Asparagopsis* culture method (January 2023) and dual extraction method (July 2023)
- Winner of the in MassChallenge 2023 Louis Dreyfus Climate resilience prize.

Image courtesy of SeaStock

Meet our Licensees

Symbrosia

Locations: Kailua-Kona, Hawai'i

Number of staff: 28

Senior leadership team:

- Alexia Akbay, Chief Executive Officer & Founder
- Avery Kramer, Chief Operating Officer
- Betty McPhee, Vice President of Business Development
- Heather Remo, People & Culture Lead
- Mallory Honan PhD, Product & Animal Science Lead
- Kaulawena Reis-Moniz, Financial Controller
- Andrew Cooper, Lead Biosystems Engineer
- Caroline Harmon, R&D Coordinator

About:

Since launching five years ago, Symbrosia's agile in-house R&D team has developed innovative cultivation and post-processing methods for use at a commercial facility, with the aim of serving 1 million head of cattle by the end of the decade.

Its dedicated business development team is building long-term partnerships with aligned agricultural stakeholders to ensure research trials will not only provide valuable information for product optimisation and effective implementation, but also lay the foundation for scaled adoption in the supply chains of major brands.

Currently utilising freeze drying in processing, Symbrosia is conducting additional research into the stability of freeze-dried *Asparagopsis taxiformis*, having found its heterogeneous biomass to be highly palatable in its freeze-dried form. Symbrosia is also exploring the potential benefits of oil extraction for improving bioactive concentrations and long-term stability.

In 2023, Symbrosia launched two commercial grazing beef studies (Carman Ranch, OR and Parker Ranch, HI) to help inform supplement delivery strategies and further characterise dose responses of *Asparagopsis*, with a third grazing beef study about to start in California.

On the dairy side, Symbrosia has embarked on a six-month study with The University of Minnesota and Organic Valley to understand the impact of extended supplementation, if any, on milk performance, methane emissions, and intake.

Key highlights

- Awarded a plant patent for a high-yield, high-resiliency, high-bromoform strain of *Asparagopsis taxiformis* called Icarus
- Made important strides in *Asparagopsis* cultivation and achieved significant recognition for the impact of its product, SeaGraze™
- USDA Organic Certification
- Numerous high-profile awards including Forbes 30 Under 30 for Social Impact, the Blue Climate Initiatives Ocean Innovation Prize, and Global Warming Mitigation Project's Keeling Curve Prize
- Executed a beef sensory panel in partnership with Oregon State University to establish consumer evaluation insights.

Image courtesy of Symbrosia

Meet our Licensees

SYNERGRAZE

Synergraze Inc

Head Office: Calgary, Alberta

Number of staff: 8

Senior leadership team:

- Tamara Loiselle, Founder & Chief Executive Officer
- Chief Gordon Planes, Chair, Indigenous Community Advisory Board.

About:

Founded in 2020 and leveraging research first conducted in Eastern Canada and later advanced in Australia by CSIRO and FutureFeed, Synergraze has developed proprietary technology that enhances the bioactivity of *Asparagopsis* as well as a variety of seaweeds and algae. Further, Synergraze has developed a patent-pending extraction process to obtain a final methane-reducing cattle feed additive.

In addition to the significant enteric methane reductions of its products, Synergraze's production process reduces GHG emissions by removing two to three tons of carbon dioxide from the atmosphere for every ton of seaweed grown.

To date, commercial demonstrations and rollout of Synergraze Cattle Feed Additive has focused on feedlot operations, with pasture-based environments targeted for 2025.

Synergraze seeks to embody reconciliation in every way, including by building bridges and business partnerships between Indigenous and non-Indigenous communities and businesses.

Key Highlights:

- Development of technology to increase bioactivity of multiple species of seaweeds and algae, including *Asparagopsis*
- Proprietary bioactive extraction process developed
- Emissions Reduction Alberta - Food, Farming and Forests Challenge Award: $5M
- Sustainable Technology Canada Award: $1.3M
- CEO Recipient of a Queen's Platinum Jubilee Medal 2022.

Image courtesy of Synergraze

Meet our Licensees

VOLTA GREENTECH

Volta Greentech

Locations: Stockholm and Lysekil, Sweden

Number of staff: 13

Senior leadership team:

- Fredrik Åkerman, Chief Executive Officer & Founder
- Angelo Demeter, Chief Product Officer & Founder
- Ioannis Dogaris, R&D Director
- Alexander Jönsson, Lead Engineer
- Cora Taylor, Business Developer
- Hanna Tydinger, Product Manager
- Matt Hargrave, Production Research Scientist

About:

Operating for four years, Volta Greentech's algae is produced in shallow ponds in a greenhouse environment, designed by an in-house engineering team which allows for scalability, making it adaptable to various sites and purposefully modular in design.

Volta Greentech manages the full production of its product Lome™ in-house, from cultivation to packaging, utilising two processing methods, freeze drying and oil immersion.

Volta Greentech's next step is to upscale production and make significant investments in facilities, greenhouses, equipment and infrastructure. The aim is to deliver Europe's first large-scale factory for methane reducing feed additives derived from algae.

Between 2021 and 2023, Volta Greentech conducted three on-farm trials which resulted in methane emission reductions between 70 – 90%. The *Asparagopsis* used was from Volta's pilot production facility in Lysekil.

A three-month trial with freeze-dried *Asparagopsis* on a beef cattle farm in the UK is planned for 2024, as is a freeze-dried trial with dairy cows on a commercial Swedish farm where the objective is to determine optimal dosage based on feed intake, milk yield and methane production. The outcome of this trial is to produce the first methane reduced cheese in 2025.

Key highlights:

- On-farm trial data generated by Volta Greentech is freely available online in the form of climate reports for each individual trial
- The launch of Lome beef, the world's first low-methane beef, in Swedish stores and restaurants from cattle fed on *Asparagopsis* produced by Volta Greentech
- Endorsement from the Swedish Environmental Protection Agency.

Image courtesy of Volta Greentech

Processing and Feeding Systems

The two key products *Asparagopsis* is processed into for use as a livestock feed material are dried *Asparagopsis* meal, and *Asparagopsis* oil.

Asparagopsis is one of the most potent methane mitigating seaweeds and its effectiveness can be attributed to the production of halogenated methane analogues.

Bromoform is the most abundant of the bioactive haloform metabolites in Asparagopsis responsible for its anti methanogenic effect.

The production of antimethanogenic metabolites is largely dependent on the environmental growing conditions, such as temperature and geographic location as well as sex and life cycle stage.

The conservation of the sensitive bioactive metabolites in functional seaweed products relies on the application of processing techniques including collection, dewatering, storage, and transportation conditions.

FutureFeed and its licensee partners have been stabilising the bioactives in *Asparagopsis* via their own proprietary techniques.

Processing for freeze-dried *Asparagopsis* includes a saltwater rinse, spin dry, freeze at -20 °C, then freeze dry. It is important to note not all licensee partners use freeze-drying techniques.

How licensee partners package dried *Asparagopsis* is dependent on their target markets and how livestock producers are feeding it to their animals.

Some licensee partners are looking to include dried *Asparagopsis* in a pre-mix or specifically selling it on its own to be added in a total mixed ration (TMR).

The second predominant processing technique is the production of *Asparagopsis* oil. It involves *Asparagopsis* plant matter being steeped into a vegetable oil, with canola oil being the most common vegetable oil fed to animals. There are other types of vegetable oils it can be applied to, including rice bran oil and corn oil.

Once it is steeped, the algae matter is macerated so the bioactives have time to stabilise within the vegetable oil itself. The algae biomass is removed and the oil itself is fed to animals in a feed ration.

Upholding Global Standards

FutureFeed recommends dried *Asparagopsis* should contain a minimum of 6 milligrams of bromoform per gram of *Asparagopsis* material. This is based on scientific trials which have proven that administering feed at a Recommended Effective Intake Level (REIL) will significantly reduce methane emissions in livestock.

Besides bromoform, other bioactive compounds in *Asparagopsis* include bromine and iodine, and there are global standards based on how much total iodine and bromine can be fed to animals.

For iodine, FutureFeed recommends the strict standards set by the European Commission.

For bromine, FutureFeed recommends the strict standards set by the National Research Council in the United States. Prescribed intakes are based on final feed formulation inclusive of the addition of *Asparagopsis*.

FutureFeed develops feeding protocols to help livestock producers calculate correct amounts of processed *Asparagopsis* product required to be fed to animals on a daily basis to achieve targeted methane reduction percentage targets and meet global standards for bromine and iodine.

FutureFeed will be ensuring that all of our licensee partners are aware of the standards for iodine and bromine, so their technologies manage these substances in the biomass they produce.

FutureFeed has serious concerns about companies that are selling *Asparagopsis* but do not have licenses, are not regulating iodine and bromine levels, and are not ultimately adhering to global standards. It is imperative to ensure that the industry maintains minimum standards and upholds the safety and efficacy of the product.

This reinforces the importance of industry sourcing product from FutureFeed's licensee partners only.

Feeding Systems

Scientific trials of *Asparagopsis* as a livestock feed ingredient in reducing enteric methane emissions have predominantly focused on beef cattle in feedlots and dairy cows, and as result, many licensee partners are targeting these feeding systems.

As beef cattle in a feedlot system are fed a total mixed ration (TMR), it is easy to incorporate a feed supplement into their diet in a large group setting and ensuring livestock are consuming it consistently to achieve methane reduction. Methane emission reductions of 80% or more have been consistently achieved in this setting.

For dairy cattle in Australia, where most are in a grazing system, *Asparagopsis* is being incorporated in their feeding regime through a pulse feeding system when they are in a milking parlour twice a day. Methane emission reductions of over 40% have been achieved in this setting, which is an exciting outcome for the first ever pulse feeding studies.

Production systems are different throughout the world and in many countries, most dairies are in feedlots, meaning there is enormous potential to feed *Asparagopsis* as part of a TMR in that setting.

Research into the application of *Asparagopsis* for grazing systems is underway to address at will consumption. The stability of *Asparagopsis* in grazing settings is also being investigated.

Image courtesy of Volta Greentech

Feeding Trials and Results

A significant body of scientific research has been undertaken proving the efficacy of *Asparagopsis* as a livestock feed ingredient in reducing enteric methane and improving productivity of livestock, with more underway or set to start in 2024.

The Appendix provides a summary of some of the most recent scientific studies investigating the effect of *Asparagopsis* on reducing methane emissions, productivity, feed use efficiency, shelf-life stability, meat eating quality, and residues in meat and dairy products.

Feeding trials to date have predominantly focused on beef cattle in feedlots and dairy cows, due to the ability to incorporate *Asparagopsis* into a total mixed ration (TMR), however some other trials have already been undertaken on other ruminant animals such as sheep and goats.

Since the early trials were undertaken, results in achieving significant methane emission reductions have continued to improve as researchers have built upon the knowledge base around factors such as inclusion levels.

Trials have demonstrated if *Asparagopsis* is provided appropriately to livestock at the correct inclusion levels in the feed using the recommended feeding protocol, it is highly effective at reducing methane emissions, particularly in a TMR feeding system.

It is critical that appropriate R&D study design, mechanisms and data management are in place when feeding trials are conducted to ensure correct inclusion levels are being used.

The effect of *Asparagopsis* on reducing methane emissions is close to linear when administering product within the recommended range of effective inclusion levels. However, results are not linear for all inclusion levels – feeding X amount of *Asparagopsis* and getting Y levels of methane reduction doesn't necessarily mean if inclusion levels are doubled, it will double the methane reduction.

While FutureFeed conducts many of its own trials and is involved in others, it does not always have control of external trials and their protocols.

FutureFeed's challenge is that *Asparagopsis* is available from not only our licensee partners but other unlicensed sources, meaning that quality can vary, and study design and conduct can also vary.

As a result, variability in study results can arise from the quality and quantity of *Asaparagopsis* that is provided to animals, the type of feed that the animals are getting, the type of animal, the accuracy of tools used to measure emission reduction, and the researchers who are conducting the trial.

Future Trials

A range of other scientific research trials are currently in progress or recently completed across Australia, New Zealand, the United States and European Union involving beef cattle in feedlots and dairy cows.

Led by FutureFeed, licensee partners and research partners, the feeding trials are utilising both dried *Asparagopsis* and *Asparagopsis* oil.

They are further investigating methane reduction, productivity, feed use efficiency, meat eating quality, and residues in meat and dairy products.

Preliminary results from these trials are positive and will be published in respected scientific journals when complete. Peer review generates trust in the scientific research being published, ensuring the research is valid, and uses appropriate methodology and experimental design.

FutureFeed is focusing on feeding trials in the US and EU, due to the prevalence of TMR feeding systems used in both beef cattle and dairy production systems in those markets.

The US alone represents an enormous opportunity – there were 95.9 million head of cattle and calves on US farms as of July 1, 2023, including 13.1 million head of cattle on feed, according to the US Department of Agriculture (USDA).[7]

In comparison, there were 24.4 million head of cattle (including dairy cattle) in Australia as of June 2022, according to the Australian Bureau of Statistics and reported by MLA.[8]

7. USDA 2023 https://www.nass.usda.gov/Newsroom/2023/07-21-2023.php#:~:text=There%20are%2029.4%20million%20beef,%2C%20down%202%25%20from%202022.
8. MLA 2023 https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/trends--analysis/fast-facts--maps/mla_beef-fast-facts-2023_300523.pdf

Market Access

In many jurisdictions, regulatory approval for *Asparagopsis* product follows two potential pathways – as a feed material, or as a feed additive.

In Australia, the Australian Pesticides and Veterinary Medicines Authority (APVMA) allows for *Asparagopsis* product to be used as a feed material.

Dried *Asparagopsis* is an approved feed material allowing for its commercialisation in a number of markets including Australia, while oil-stabilized *Asparagopsis* can also be used as a feed material in Australia as long as it meets Excluded Nutritional or Digestive (END) requirements.

FutureFeed is prioritising R&D trials to support the approval of the use of *Asparagopsis* product as a feed material and/or feed additive across key markets. The aim is to support regulatory and commercial pathways for our licensee partners where feasible.

Dried *Asparagopsis* can be sold commercially in the European Union (EU) as a feed material.

In the United States, FutureFeed is planning trials using external US-based R&D providers to gain regulatory approval with the US Food and Drug Administration (USFDA).

In Brazil and other markets including Japan, further exploration is planned.

Understanding Bromoform

As previously stated in this report, the bioactives in *Asparagopsis* responsible for its antimethanogenic effects is influenced by bromoform ($CHBr_3$), the most abundant bioactive.

Concerns around the safety of bromoform from a livestock, consumer, and environmental perspective, have been addressed by a range of scientific trials with more underway.

Multiple research studies in both beef and dairy cattle have shown that *Asparagopsis* as a feed material is safe for animal consumption, and the resulting meat and dairy products are safe for consumers.

Consumer sensory evaluations have also consistently shown meat eating quality is not affected by *Asparagopsis*.

Natural standing stocks of seaweeds of all types and phytoplankton are the largest contributors to atmospheric bromoform which is a precursor to subsequent reactive bromine that can contribute to ozone depletion potential (ODP) if it reaches the stratosphere.

Cultivation contributes minimally to overall emissions from standing natural seaweed stocks while cultivation and processing of *Asparagospsis* is designed to retain bromoform as the value prospect stabilised in the final product.

The contribution to ODP from *Asparagopsis* feed production would be negligible (Jia et al. 2022). Bromoform is degraded quickly during feed digestion when *Asparagopsis* products are fed at the prescribed level to cattle and bromoform has not been found in cattle emissions or faeces and does not enter the environment.

Environmental Impacts

Environmental impacts from the growing of *Asparagopsis* at scale in the ocean and in land-based infrastructure have been assessed.

A preliminary Life Cycle Assessment of growing and processing *Asparagopsis* demonstrates adding *Asparagopsis* to cattle feed rations has little or no influence to the environmental impacts of the feed ration.

Nutrient and energy use in the growing cycle is minimal. While energy (electricity) is required during freeze drying, this energy can come from renewable sources where available.

Atmospheric experts have modelled the release of the total of *Asparagopsis* derived bromoform needed to feed Australia's feedlot and dairy cows and the US herd to determine the potential impacts on the ozone. Although the scenario of the total release is highly unlikely its insignificant addition to global oceanic bromoform fluxes puts the risk and impact into perspective. Even in the event of the highly unlikely scenario of collective total bromoform release from all Australia's cultivated stock, the impact on ODP would be negligible (Jia et al. 2022)

Maintenance of the antimethanogenic properties in the feed supplement are fundamental to generating the mitigating effect, and therefore managing the product to reduce risk of bromoform release is a primary focus for licensee partners.

Bromoform is not regulated under the Montreal Protocol on Substances that Deplete the Ozone Layer (the Montreal Protocol), partly because it is thought to be derived primarily from natural sources and belongs to the very short-lived substances (VSLSs) category, lasting less than six months.

Industry Investment

Confidence in the effectiveness of *Asparagopsis* and potential widespread adoption by the livestock and dairy industries globally is reflected in the significant investment FutureFeed and our licensee partners have secured.

Basic research and commercialisation of *Asparagopsis* has attracted what is estimated to be over AUD$350 million in investment in grants, equity funding and environmental prize funding. The immense scale of the addressable market for enteric methane reduction suggests further capital raises and funding will be required so FutureFeed and our licensee partners can scale to meet demand and achieve a self-funding commercial status.

Table 1 summarises capital raises, R&D funding, research grants and awards generated by government, industry, FutureFeed, and its licensee partners from 2018 to 2023.

FutureFeed has leveraged early R&D and industry funding into significant venture capital investment. This investment is funding the acceleration of technology development into 2024 and beyond.

Table 1. Funding sources for Asparagopsis R&D 2018 to 2023[9]

Funding Source	$ AUD million
Licensed production partners' capital raised	236
FutureFeed capital raised	20
Government grants	37
Other grants	15
Industry funded R&D and trials	30
Early R&D funding	20
Awards	7
Total	**365**

Image courtesy of Sea Forest

9. Licensee websites, publicly available grant and research announcements. Total is approximate.

Carbon Markets

FutureFeed, our licensee partners and other stakeholders are collectively working on numerous fronts to ensure that livestock and dairy producers using *Asparagopsis* will have the right set of tools and information to substantiate and monetise claimed greenhouse gas (GHG) reductions.

In order for that to happen, a number of challenges need to be overcome.

The Challenges

- The Australian Carbon Credit Units (ACCU) Scheme does not currently have a methodology for measuring and claiming the abatement from feed additives and this remains a disincentive for adoption by the livestock sector. There is a critical need for an Australian enteric methane method which will subsequently help improve the reputation of carbon credits being used for offsets.
- All project interventions, such as including a feed additive into the diet of livestock, need to be third party audited and implemented using a methodology underpinned by a credible standard such as the ACCU Scheme or international standards that are accredited by appropriate bodies.
- There are currently two international methods under voluntary standards for livestock feed additives to reduce enteric methane available for Australian agribusinesses to adopt, although there are no registered projects to date.
- The emergence of scope 3 emissions reporting throughout beef and dairy supply chains, a key global driver of environmental markets.

What FutureFeed is doing

- FutureFeed is actively developing an Australian enteric methane methodology with government to ensure livestock producers will be able to verify methane reductions from their animals using *Asparagopsis*. This will allow participation with ACCUs or scope 3 reporting.
- FutureFeed has been instrumental in co-funding and establishing an industry working group to progress the development of a methodology under the ACCU Scheme.
- In 2021 the Livestock Emissions Carbon Farming Working Group was established to bring forward the development of a new methodology for all feed additives that reduce enteric methane.
- FutureFeed continues to conduct controlled scientific trials feeding livestock precise amounts of dried *Asparagopsis* or *Asparagopsis-oil* to ensure there is peer reviewed scientific data available to enable environmental market mechanisms, methods and tools.
- Work is complete that will provide a scenario for generating a tonne of CO2-e using *Asparagopsis* as feed supplement to reduce methane. FutureFeed is assessing the option to partner with existing digital tools to be used by industry for calculating the emissions reductions when including the recommended inclusion level of *Asparagopsis* to the daily diet of their livestock.

About the Livestock Emissions Carbon Farming Working Group

The Livestock Emissions Carbon Farming Working Group has over 120 representatives from feed additive companies, the livestock and dairy sectors, carbon project professionals, industry organisations, science academics and government policy makers.

The group was established to prevent the agriculture sector from being burdened with making contributions to national, industry and state targets and reduce the risk of Australia slipping further behind global progress in tackling agricultural and methane emissions.

An important part of this is the finalisation of a framework which paves the way for consultation with government around the development of a new Australian enteric methane methodology.

When finalised, the method will provide a structured and credible approach for the livestock and dairy sectors to measure and account for their emissions reductions from interventions such as including a feed additive in the diet of their livestock. The verified data can be used for creating additional revenue from carbon credits or provision of low carbon intensity/kg of red meat for corporate scope 3 reporting.

Strategic Priorities/ The Future

FutureFeed will continue to play a leading role in the development of *Asparagopsis* as a solution to significantly reduce methane emissions in ruminant animals.

Our focus for 2024 and beyond is on:

- Selection of **additional market participants** through issuance of additional production licenses in key markets.
- **Leading and contributing to scientific and corporate trials** and communicating scientific outcomes.
- **Engaging regulators** to help support regulatory approvals where required.
- **Setting minimum standards** for product formulation, safety and efficacy, feeding quality and certification.
- Development of methodologies to support licensees and other industry participants to **generate value from greenhouse gas (GHG)** abatement.
- Develop tools and frameworks to provide **transparency to buyers and end consumers** of *Asparagopsis* feed materials.

In addition to leading on these programs of work, FutureFeed will continue to work collaboratively with our partners, industry, the red meat, wool and dairy supply chain and the scientific community to:

- Identify obstacles to commercialisation and encourage collaboration to overcome challenges.
- Coordinate the development and use of trademarks and third-party certification where required.
- Support our licensee partners to identify and enter new markets and establish connections with buyers across the value-chain.

FutureFeed is engaged in R&D that accelerates the commercial viability of our licensee partners through approaches to reduce the cost of manufacturing, increase product stability and optimising and standardising product form. This work will be in addition to the ongoing animal R&D program.

The animal R&D program will focus and advance the status of Asparagopsis's antimethanogenic efficacy and animal performance and productivity benefits, and trials to support market access.

This work will be backed by significant direct investment from FutureFeed and support from our expert team into initiatives to support commercialisation of the technology.

FutureFeed believes 2024 will be a pivotal year for the development of *Asparagopsis* technology. Our licensee partners are moving into early stages of commercialisation, scientific knowledge of the biology of growing and feeding *Asparagopsis* is evolving, and stakeholders are keenly watching our progress.

Most of all, if we are to avoid catastrophic human induced climate change, we need technologies such as FutureFeed's *Asparagopsis* to accelerate to provide another option to reduce GHG emissions.

Image courtesy of Sea Forest

Appendix Directory of Trials and Research

In vivo studies:

Beef Production:

Trial Name:	**Mitigating the carbon footprint and improving productivity of ruminant livestock agriculture using a red seaweed**
Reference:	Kinley et al (2020) Journal of Cleaner Production
Location:	Australia
Production System and Method:	Beef feedlot – TMR
Description:	20 Brahman-Angus steers were assigned to one of four Asp-Meal treatments: 0.05%, 0.10%, and 0.20% of diet OM over a 90-day period.

Key Findings:

- CH4 yield decreased by 9%, 38% and 98% and
- H2 yield increased by 0%, 380%, and 1700%, respectively.
- No effect on DMI
- Average daily weight gain improved for Asp-Meal treatment groups 0.10% and 0.20% by:
  - 26% and 22% [full 90 days],
  - 53% and 42% [final 60 days], respectively.
- VFA production:
  - Total VFA was unchanged,
  - Acetate decreased, propionate increased, and beneficially A:P decreased.
- Carcass quality and sensory evaluation was unchanged between groups.
- No bromoform residue found in any sample [meat, fat, edible offal, faeces] for any treatment group.
- Iodide and bromide not tested.

Trial Name:	**Red seaweed (*Asparagopsis taxiformis*) supplementation reduces enteric methane by over 80% in beef steers**
Reference:	Roque et al (2021) PLOS ONE
Location:	United States
Production System and Method:	Beef feedlot – TMR Twenty-one Angus-Hereford beef steers were randomly allocated to one of three treatment groups: 0% (Control), 0.25% (Low), and 0.5% (High) *A. taxiformis* inclusion based on organic matter intake. Steers were fed 3 diets: high, medium, and low forage total mixed ration (TMR) representing life-stage diets of growing beef steers.
Description:	20 Angus-Hereford steers, 3 diets [high, mid, low forage] for 147 days fed one of three treatments; Control (no Asp-Meal), 0.25% OM Asp-Meal, or 0.50% OM Asp-Meal.

Key Findings:

- CH4 yield reductions overall: 45 and 68%
  - High forage: 33% and 52%
  - Mid forage: 45% and 80%
  - Low forage: 70% and 80%, respectively.
- H2 yield overall increased 336 and 590%, respectively.
- ADG, carcass quality, strip loin proximate analysis and shear force, or consumer taste preferences unchanged.
- DMI tended to decrease 8% and 14%,
- FCE tended to increase 7% at 0.25% and significantly increase 14% at 0.5% inclusion,
- Cost savings of $0.18 and $0.37 USD per kilogram of liveweight gain, respectively.
- No bromoform residue found in any sample [meat, edible offal]
- Iodide in meat was elevated in Asp-Meal groups, however, was well within safe levels for human consumption limits.
- Bromide not tested.

Trial Name:	Bioactive metabolites of *Asparagopsis* stabilized in canola oil completely suppresses methane emissions in beef cattle fed a feedlot diet
Reference:	Cowley et al (2023) Meat and Livestock Australia This is an MLA Donor Company (MDC) project [P.PSH1351] and information is published on the MLA website.
Location:	Australia
Production System and Method:	Beef feedlot – TMR
Description:	20 Angus heifers were fed one of four Asp-Oil treatment groups 0, 17, 34, and 51 mg bromoform/kg DMI for 81 days in feedlot finisher diet with 21 d adaptation and 59 d experimental periods.

Key Findings:

- CH4 yield reduced by 64%, 98% and 99%, respectively.
- Rumen temperature, pH, reduction potential, VFA and ammonia were unchanged.
- Rumen wall analysis was not different between groups, including Control.
- Average daily weight gain, FCE, and carcass characteristics were unchanged.
- Sensory evaluation improvements in 34 mg/kg DMI Asp-Oil group compared to Control.
- No bromoform residue found in any sample [meat, fat, edible offal, faeces]
- Iodide and bromide residues were maintained at levels safe for human consumption.

Trial Name:	Effect of *Asparagopsis* extract in a canola oil carrier for long-fed Wagyu cattle
Reference:	Cowley et al (2023) Meat and Livestock Australia This is an MLA Donor Company (MDC) project [P.PSH1353] and information is published on the MLA website.
Location:	Australia
Production System and Method:	Wagyu feedlot – TMR
Description:	Eighty head of Wagyu cattle fed for 275 days with two types of diets, a grower and finisher diet, were given one of two treatments; Control [no Asp-Oil] or Asp-Oil [25 mg bromoform / kg DMI].[1]

Key Findings:

- CH4 production and yield reductions of 28 and 22%, respectively.
  - no losses in efficacy (i.e adaptation) over 275 days.
- DMI was decreased which subsequently resulted in reduced liveweight gain.
- FCE, carcass grading, and sensory evaluation unchanged between groups
- Bromoform not detectible in meat or offal.

1. Diets of these studies contained more forage than other beef feedlot studies due to the specific feeding strategy of long-fed wagyu cattle in feedlots. Additionally, the inclusion rate is ~30% less than FutureFeed's global standard recommendations for feedlot cattle. These changes might have contributed to reduced methane reduction potential along with possible Wagyu breed effects.

Dairy Production:

Trial Name:	**Inclusion of *Asparagopsis* armata in lactating dairy cows' diet reduces enteric methane emission by over 50 percent**
Reference:	Roque et al (2019) Journal of Cleaner Production
Location:	United States
Production System and Method:	Dairy – TMR
Description:	Twelve lactating cows were randomly assigned to each of the three treatment groups [Control, 0.5% OM Asp-Meal, and 1.0% OM Asp-Meal for 3- 14 days periods (Latin-square design).

Key Findings:

- CH4 production decreased by 26.4% and 67.2%,
- CH4 yield decreased by 20.3% and 42.7%,
- CH4 intensity decreased by 26.8% and 60%, for 0.5% and 1.0% OM Asp-Meal, respectively.
- DMI was decreased and subsequently milk production and milk protein similarly decreased.
- FCE increased 20% and 75%, respectively.
- Bromoform content of the milk was found in all groups:[2]
  - 0.11 µg/L for Control,
  - 0.15 µg/L for 0.5% and 1.0% OM Asp-Meal
- Bromide and iodide not tested in this study.

Trial Name:	**Effects of the macroalga *Asparagopsis taxiformis* and oregano leaves on methane emission, rumen fermentation, and lactational performance of dairy cows**
Reference:	Stefenoni et al (2021) Journal of Dairy Science
Location:	United States
Production System and Method:	Dairy – TMR
Description:	4 studies conducted [two *in vitro* and two *in vivo*]

Key Findings:

- Experiment 1: In vitro, 1% Asp-Meal DM inclusion rate and resulted in 98% CH4 reductions.
- Experiment 2: 6 dairy cows fed 3 Asp-Meal inclusion rates [0.25, 0.50, and 0.75% DM inclusion]
  - 0.50 and 0.75% Asp-Meal levels resulted in CH4 yield reductions of 80%.
- Experiment 3: 20 dairy cows were fed one of four treatments; Control, 0.25% Asp-Meal DM, 0.5% Asp-Meal for 28 days.
  - CH4 yield unchanged for 0.25%, but decreased by up to 65% for 0.50%
  - H2 yield increased by 134% and 527%, respectively.
  - DMI & Milk yield was unchanged in 0.25% DM group, however DMI decreased in the 0.50% Asp-Meal group and subsequent changes in milk yield & lactose were observed.
  - No changes in sensory characteristics of milk.
  - Bromoform content of the milk was found in both groups:[3]
    - 16.5 µg/L for Control,
    - 28.9 µg/L for 0.5% and 0.5% DM Asp-Meal
  - Milk iodide [2.96 ug/mL] and bromide [40.4 ug/mL] were observed for the 0.50% Asp-Meal DM group.[4]
- Experiment 4: Asp-Meal was stored in different conditions [light vs dark & over time] for 120 days and bromoform degraded linearly over time which explains why CH4 was not reduced similarly between experiment 2 and 3 and within the last two 28 d periods of experiment 3.

2. The concentrations detected were demonstrated to be considerably lower than published safe concentrations in milk for human consumption (100 ug/L).
3. The concentrations detected were demonstrated to be considerably lower than published safe concentrations in milk for human consumption (100 ug/L).
4. Iodine and bromine in the Asp-Meal were not reported, however this was a wild-harvested product thus was likely to be higher than global cultivated Asp-Meal standards. The Asp-Meal used in this study would not deliver expected quality standards.

Trial Name:	**Effects on rumen microbiome and milk quality of dairy cows fed a grass silage-based diet supplemented with the macroalga *Asparagopsis taxiformis***
Reference:	Krizsan et al (2023) Frontiers in Animal Science
Location:	Sweden
Production System and Method:	Dairy – TMR
Description:	The objective was to determine the effects on rumen microbiome and milk quality of reducing the CH4 using Asp-Meal to the TMR diets of 6 Nordic Red dairy cows for 21 days.

Key Findings:

- CH4 production decreased by 60%,
- CH4 yield decreased by 54%,
- CH4 intensity decreased by 58%
- DMI was decreased and subsequently milk production and milk fat yield similarly decreased.
- FCE increased 9.8%.
- Bromoform content of the milk was found in both groups.[5]
  - 4.09 µg/L for Control,
  - 4.92 µg/L for Asp-Meal
- Bromide was detected in the milk of both groups.[6]
  - 5.1 mg/L for Control,
  - 43.2 mg/L for Asp-Meal
- Iodide was detected in the milk of all groups.[7]
  - 139 ug/L for Control,
  - 2105 ug/L for Asp-Meal
- Increased propionate, decreased acetate for the Asp-Meal group.
- Shift from Methanobrevibacter to Methanomethylophilaceae.
- Lower relative abundance of Prevotella bacteria.
- Changes in milk fat odd-numbered and branched chain fatty acids.

5. The concentrations detected were demonstrated to be considerably lower than published safe concentrations in milk for human consumption (100 ug/L).
6. Bromide contents of both treatment groups are considered safe for human consumption.
7. Iodide contents of both treatment groups are considered safe for human consumption.

Trial Name:	**Twice daily feeding canola oil steeped with *Asparagopsis* Armata reduced methane emissions of lactating dairy cows with no effect on intake or milk yield**
Reference:	Alvarez-Hess et al (2023) Animal Feed Science and Technology
Location:	Australia
Production System and Method:	Dairy - Pulse-fed
Description:	39 dairy cows were fed one of three treatment groups over a 32 day feeding period; Control (no Asp-Oil), ASP1 (Asp-Oil without seaweed biomass), and ASP2 (Asp-Oil with seaweed biomass) both fed at inclusion rates of 16.7 mg bromoform / kg DMI.[8]

Key Findings:

- CH4 production decreased 44% and 39%
- CH4 yield decreased 42% and 34%
- CH4 intensity decreased 38% and 31%, respectively.
- Bromoform was detected in the milk of all groups.[9]
  - 0.30 ug/L for Control,
  - 2.13 ug/L for ASP 1 (without seaweed biomass)
  - 2.69 ug/L for ASP 2 (with seaweed biomass)
- Bromide was detected in the milk of all groups.[10]
  - 2.67 ug/L for Control,
  - 4.76 ug/L for ASP 1 (without seaweed biomass),
  - 4.92 ug/L for ASP 2 (with seaweed biomass).
- Iodide was detected in the milk of all groups.[11]
  - 0.47 ug/L for Control,
  - 0.51 ug/L for ASP 1 (without seaweed biomass),
  - 0.69 ug/L for ASP 2 (with seaweed biomass).

8. Consumption of Asp-Oil at an inclusion of 16.7 mg bromoform/kg DMI was determined by the dairy cows' willingness to consume the grain-based supplement. This is likely due to the highly concentrated feeding of Asp-Oil to achieve the cow's daily intake's worth of Asp-Oil in two pulse feedings.
9. The concentrations detected were demonstrated to be considerably lower than published safe concentrations in milk for human consumption (100 ug/L).
10. Bromide contents of all treatment groups are considered safe for human consumption.
11. Iodide contents of all treatment groups are considered safe for human consumption.

In vitro studies:

Trial Name:	Changing the proportions of grass and grain in feed substrate impacts the efficacy of *Asparagopsis taxiformis* to inhibit methane production *in vitro*
Reference:	Kinley et al (2021) American Journal of Plant Sciences
Location:	Australia
Production System and Method:	*In vitro* – grass versus grain diets
Description:	5 diet gradients between 100% Rhodes grass (RG) to 100% barley grain (BG) and Asp-Meal inclusion rates were applied [0, 0.05, 0.08, 0.11, 0.14, 0.16 mg bromoform / kg OM] were tested for 24, 48, and 72 hours of fermentation.

Key Findings:

- CH4 yield
  - decreased with higher Asp-Meal,
  - decreased with higher BG,
  - efficacy of Asp-Meal was enhanced with higher BG.
- Digestibility
  - increased with fermentation duration,
  - increased with higher BG,
  - no change from Asp-Meal.
- total VFA
  - increased with fermentation duration,
  - increased with higher BG,
  - no change induced by Asp-Meal.
- Acetic and propionic acid ratio (AA:PA)
  - decreased with higher BG,
  - decreased with higher Asp-Meal.

Trial Name:	Exploration of methane mitigation efficacy using *Asparagopsis*-derived bioactives stabilized in edible oil compared to freeze-dried *Asparagopsis in vitro*
Reference:	Kinley et al (2022) American Journal of Plant Sciences
Location:	Australia
Production System and Method:	*In vitro* – Asp-Meal versus Asp-Oil
Description:	Asp-Meal and Asp-Oil were tested at similar inclusion rates in vivo for 24, 48, and 72 hours.

Key Findings:

- CH4 yield reductions similar between Asp-Meal and Asp-Oil
- Total gas production, dry matter digestibility, or VFA were not different between Asp-Meal, Asp-Oil, and Control groups.

Trial Name:	**Reducing methane production from stored faeces of dairy cows by *Asparagopsis taxiformis***
Reference:	Ramin et al (2023) Frontiers in Sustainable Food Systems
Location:	Sweden
Description:	Faeces of cows from Kriszan et al 2023 was used in an in vitro study that evaluated faecal CH4 production with and without Asp-Meal [0.5% OM] application. Faecal samples from the two groups were divided into two subsamples [4 treatment groups total].

Key Findings:

- Dietary Asp-Meal effects on manure CH4 production
  - Control 1 (no dietary or faecal Asp-Meal) vs Control 2 (dietary Asp-Meal, no faecal Asp-Meal)
    - CH4 production, bacterial & methanogen populations unchanged.[12]
- Faecal Asp-Meal application on manure CH4 production
  - Control (no Asp-Meal) vs Faecal Asp-Meal application
    - 44% reduction in CH4 production.[13]

Trial Name:	**Evaluating the effect of phenolic compounds as hydrogen acceptors when ruminal methanogenesis is inhibited in vitro – Part 2. Dairy goats**
Reference:	Romero et al (2023) Animal
Location:	Spain
Production System and Method:	*In vitro* study - goats
Description	Performed four in vitro incubation experiments to evaluate H2 acceptors during CH4 inhibition using rumen inoculum from Murciano-Granadina adult goats.

Key Findings:

Experiment 1: Asp-Meal was added to *in vitro* batch fermentation vessels at different concentrations (0, 1, 2, 3, 4 and 5% DM basis) in 24 h incubations for the purpose of CH4 mitigation.

- CH4 production decreased by up to 99%, 2% DM Asp-Meal plateau
- increase in rumen H2 accumulation.
- VFA profile changed by the inclusion of Asp-Meal
  - Decreased acetate,
  - Increased propionate,
  - Decreased acetate: propionate,
  - total gas production, pH, lactate, and ammonia concentration unchanged.

Experiment 2: Phenolic compounds [phenol, catechol, resorcinol, hydroquinone, pyrogallol, phloroglucinol, gallic acid and formic acid] at 6 mM with Asp-Meal at 2% DM in sequential batch cultures for 5 days.

- Phloroglucinol
  - decreased H2 accumulation,
  - increased total gas production, VFA production and the acetate: propionate ratio.

Experiment 3: Phloroglucinol at different concentrations (0, 6, 16, 26 and 36 mM) combined with Asp-Meal in sequential batch cultures for 5 days

- decreased H2 accumulation,
- decreased abundances of archaea, protozoa and fungi abundances,
- increased total gas production, total VFA production and the acetate: propionate ratio.

12. This indicates that the CH4 reduction capability of Asp-Meal fed to cattle does not persist in the gastrointestinal tract of the animal through to faecal processing. This may be beneficial to producers who have invested in anaerobic digesters where the production and capture of CH4 is important.
13. This may be a beneficial strategy to producers who want to decrease overall farm emissions and don't have capabilities to build anaerobic digester infrastructure.

Bromoform Studies:

Trial Name:	Potential environmental impact of bromoform from *Asparagopsis* farming in Australia
Reference:	Jia et al (2022) Atmospheric Chemistry and Physics
Location:	Global
Production System and Method:	*Asparagopsis* farming and respective bromoform production
Description	Australian scenario includes supply 50% of beef feedlots & dairies with *Asparagopsis* at 0.4% DM Asp-Meal daily. 35 tonnes of Asp-Meal/year.

Key Findings:

Australian Scenario: Under normal growing conditions, bromoform release would be:

- less than 0.9% of Total Australian bromoform emissions
- less than 0.01% of Total Global bromoform emissions (from both natural & anthropogenic sources).

Global Scenario: includes assuming a 30x scalability of Australian scenarios for global *Asparagopsis* supply sourced from Australia. 1,000,000 tonnes of Asp-Meal/year. Under normal growing conditions, bromoform release would be:

- Less than 0.5% of Total Global bromoform emissions (from both natural & anthropogenic sources).

Important to note that these estimates come from assumptions made on 1.) average growth rate and bromoform synthesis of *Asparagopsis* and 2.) open ocean and a subset of terrestrial confinement systems, all of which have and will continue to improve over time.

Trial Name:	Shelf-life stability of *Asparagopsis* bromoform in oil and freeze-dried powder
Reference:	Tan et al (2022) Journal of Applied Phycology
Location:	Australia
Production System and Method:	*In vitro* – bromoform stability in Asp-Meal and Asp-Oil
Description:	Asp-Meal and Asp-Oil were tested under different circumstances to determine bromoform stability within each *Asparagopsis* product.

Key Findings:

- Asp-Meal
  - Not affected by fluorescent light.
  - Sensitive to temperatures above 4°C for periods longer than 4 weeks.
- Asp-Oil
  - Negatively affected by fluorescent lighting at temperatures above 25°C.
  - Negatively affected by exposure to open-air.
  - Not affected by temperatures ranging from -20°C to 40°C in airtight containers & absent of fluorescent light for at least 24-weeks.

Trial Name:	Rumen microbial degradation of bromoform from red seaweed (*Asparagopsis taxiformis*) and the impact on rumen fermentation and methanogenic archaea
Reference:	Romero et al (2023) Journal of Animal Science and Biotechnology
Location:	Spain
Production System and Method:	*In vitro* study
Description	*In vitro* study that evaluated the degradation process of bromoform from Asp-Meal (2% DM inclusion) in the rumen and whether this process is diet-dependent.

Key Findings:

- CH_4 production decreased by 98% over 72 hours.
- Acetate:propionate decreased significantly.
- Bromoform 90% degraded within the first 3 h of incubation.[14]
- di-bromomethane increased first 6 h then decreased towards the end of the incubation.
  - Both bromoform and di-bromomethane were affected by the type of diet.
  - Fermentation rate is not a driving factor involved in bromoform degradation.
- Methanogen growth inhibited by bromoform inclusion.

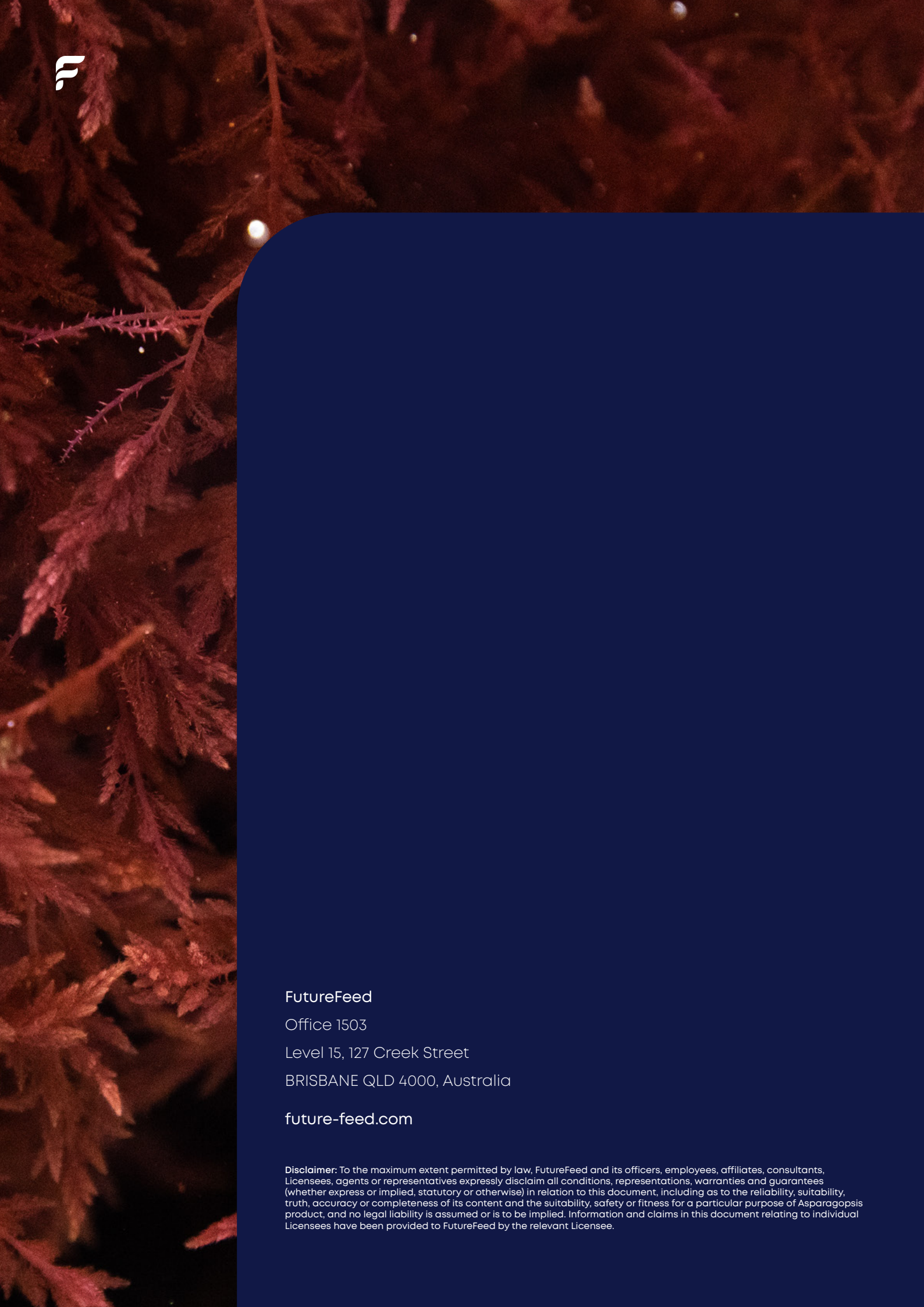
In addition to the published studies above, other scientific and corporate trials continue to progress globally, with encouraging efficacy results, and productivity gains when coupled with high efficacy date, when measured. FutureFeed expects some of these trials to be published during 2024.

FutureFeed continues to be available to help support scientific trials as required to ensure quality standards and feed protocols are followed.

Appendix List of abbreviations

Abbreviation	Description
Asp-Meal	Dried, ground *Asparagopsis* product
Asp-Oil	*Asparagopsis* derived bioactives in edible oil
CH4 intensity	Methane in grams per kilogram of weight gain OR energy corrected milk
CH4 production	Methane in grams per day
CH4 yield	Methane in grams per kilogram of dry matter intake
DM	Dry Matter
DMI	Dry Matter Intake
FCE	Feed Conversion Efficiency as average daily weight gain per kilogram of dry matter intake
H2 intensity	Hydrogen in grams per kilogram of weight gain OR energy corrected milk
H2 production	Hydrogen in grams per day
H2 yield	Hydrogen in grams per kilogram of dry matter intake
OM	Organic matter
TMR	Total Mixed Ration
VFA	Volatile Fatty Acids

14. The study demonstrated that bromoform from Asp-Meal is quickly degraded to di-bromomethane in the rumen which is also degraded over time. These results provide an explanation as to why bromoform residues are not found in Asp-Meal animal studies.



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