Potential of seaweed utilization for greenhouse gas emissions reduction

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Dr. Jeffrey T. Wright is an Associate Professor in seaweed biology, chemistry and ecology. His current research focusses on applied aspects of seaweed biology to support the sustainable production of seaweed for bio-products and to provide seedstock for restoration. His research also assesses the stability and resilience of seaweed and seagrass populations and their ecological roles as habitat-forming species.

ABSTRACT

Methane is a powerful greenhouse gas that contributes significantly to global warming. Agriculture is the largest contributor to anthropogenic methane emissions (~ 40%) with emissions from livestock via enteric production the dominant process (~ 32% of anthropogenic methane emissions). Because methane has a short atmospheric lifetime of ~ 10 years compared to carbon dioxide, taking action to reduce atmospheric methane could result in rapid reductions in climate forcing. Consequently, a range of approaches to reduce methane emissions are being examined including a major focus on using feed supplements to inhibit enteric methane production in livestock.

Of all the feed supplements tested, the red seaweed *Asparagopsis* demonstrates the highest potential to inhibit methane production in livestock. The two *Asparagopsis* species, temperate *A. armata* and tropical *A. taxiformis*, both produce bioactive compounds of which bromoform is the most abundant. Low doses (0.2-3% dry weight) of *Asparagopsis* incorporated into livestock feed reduces enteric methane production by up to 98%. Importantly, this reduction in methane by *Asparagopsis* is achieved with limited quantifiable effects on the animals or products bound for human consumption. However, in Australia alone, ~ 35,000 tonnes (dry weight) of *Asparagopsis* per year would be required to supply the ~ 1 million cattle feedlots. Until recently, cultivation methods for *Asparagopsis* were not well-established but in the last three years Australian seaweed companies have developed commercial-scale cultivation methods for *Asparagopsis*.

The life-cycle of *Asparagopsis* allows for both sea and land-based cultivation. The larger stage (gametophyte) can be cultivated at-sea attached to lines while the smaller stage (tetrasporophyte) can be grown in land-based tanks and ponds. Both stages can be cultivated via asexual propagation of fragments which grow rapidly and contain high concentrations of the bioactive bromoform. For the gametophytes, naturally occurring 'barbs' on fragments are used to hook the fragments onto lines which are placed at sea. For tetrasporophytes, free-floating fragments and placed in tanks at optimal densities. For both stages, identifying the best propagule type and size appears important to maximizing production. Both stages also reproduce sexually via spores which provides an alternative seeding method for cultivation.

Although *Asparagopsis* represents a significant opportunity, and despite rapid progress, the *Asparagopsis* industry is in its early stages and optimisation of these methods is ongoing. Moreover, there are still many knowledge gaps surrounding its cultivation and future directions will be discussed.

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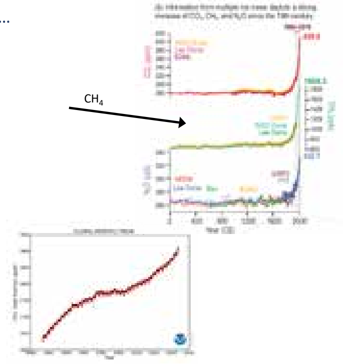
Why reducing methane emissions is important…

- Methane (CH_4) is the second biggest contributor to global warming after carbon dioxide (CO_2)
- Atmospheric methane is ~ 2.6 times greater than pre-industrial levels
- Continues to increase at record levels
- Methane is less abundant than CO_2 but:
  - Absorbs more energy per molecule and has a shorter life-span (~ 10 yrs)
  - Has a Global Warming Potential (GWP) ~ 28 times that of CO_2 (100 years)
- The high GWP suggests reducing methane emissions is one way to rapidly mitigate global warming



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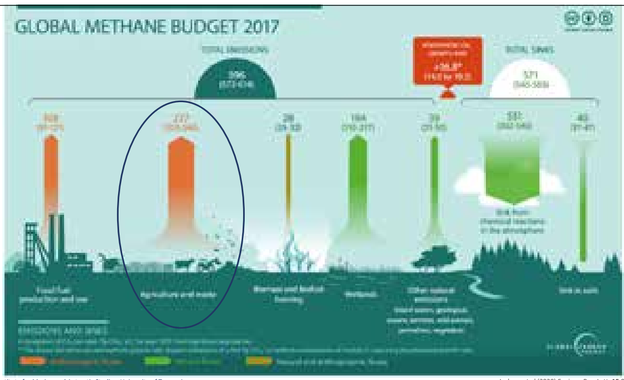
UNEP 2021, IPCC AR6 2022, NOAA 2022



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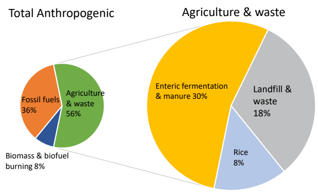
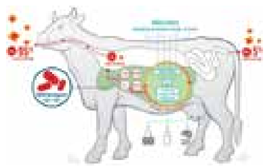
Jackson et al (2020) Environ. Res. Lett. 15 071002

Contribution of enteric fermentation to global methane emissions



Jackson et al (2020) Environ. Res. Lett. 15 071002

- Methane is emitted from cows, sheep, goats (ruminants) during digestion
- Microbes decompose/ferment plant material and methane is released as burps



Glasson et al. (2020) Algal Research 64: 102673

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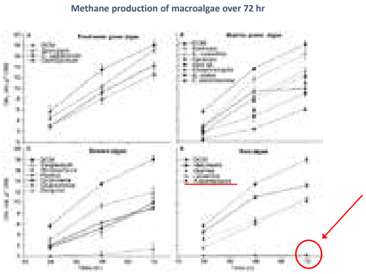
Feed supplements to reduce enteric methane: seaweed

- Range of feed supplements trialled:
  - Macroalgae
  - 3-Nitrooxypropanol (3-NOP)
  - Microbe manipulation
  - Legumes and shrubs
  - Grape marc
- Initial experiments with macroalgae examined effects of different species on *in vitro* CH_4 production of cattle rumen fluid
- 24 macroalgae tested
- *Asparagopsis* reduced CH_4 production by 99%



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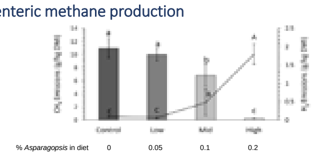
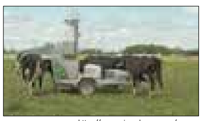
Machado et al. (2014) PLOS ONE 9: e85289

Asparagopsis as a feed supplement to reduce enteric methane production

- *In vivo* experiments in stalls using respiration chambers:
  - 98% reduction in CH_4 production in cattle (0.2% *Asparagopsis*)
- *In vivo* experiments in paddocks using *GreenFeed* system:
  - 68% reduction in CH_4 production (0.5% *Asparagopsis*)





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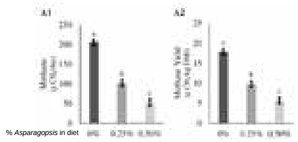

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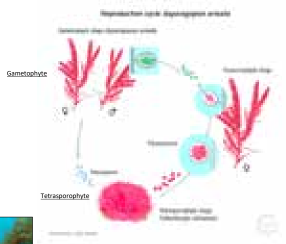
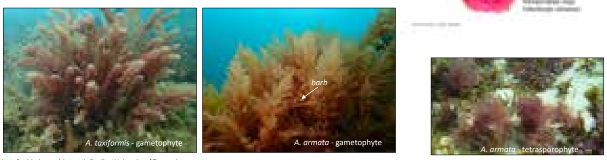
Kinley et al. (2020) J Cleaner Prodn 259:120836, Roque et al. (2021) PLoS ONE 16: e0247820

Asparagopsis: background biology

- Two *Asparagopsis* species being cultivated:
  - *A. taxiformis* (warm temperate-tropical)
  - *A. armata* (temperate)
- Life-cycle: two free-living stages
- Reproduction: sexual (spores) and asexual (fragmentation)
- Gametophytes of *A. armata* have barbs for fragment attachment





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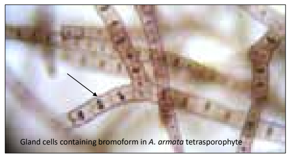
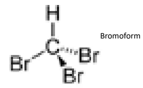
- Gametophytes of *A. armata* have barbs for fragment attachment
- Produce bioactive compounds (bromoform) that inhibit enzymes that produce methane during digestion in ruminants





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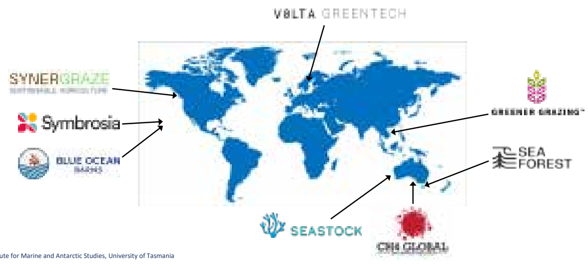
Asparagopsis: aquaculture

- All companies started since 2018
- A number of companies licensed to grow *Asparagopsis* for use as a feed supplement to reduce livestock methane emissions – and several are making good progress on cultivation and are selling it



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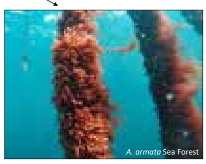
Asparagopsis aquaculture: land and sea-based production

- Land-based for *A. armata* and *A. taxiformis* tetrasporophytes
- Sea-based for *A. armata* gametophytes



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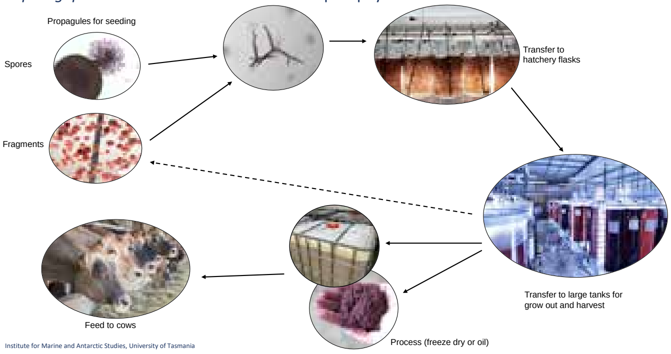
Asparagopsis: land-based cultivation of tetrasporophytes



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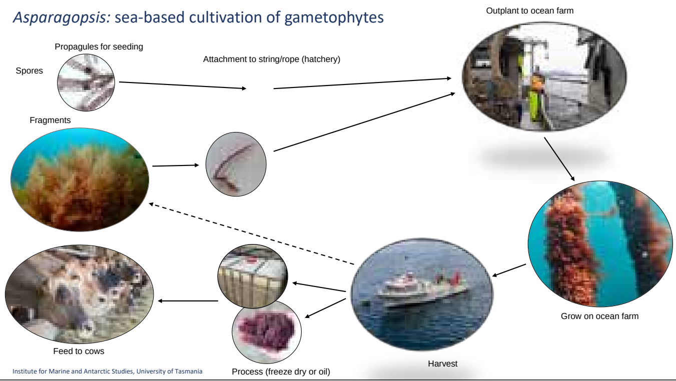
Asparagopsis: sea-based cultivation of gametophytes



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Asparagopsis aquaculture: challenges and opportunities

- Closing of life-cycle for production – commercial sensitivities, information not publicly available
- Improvements to seeding/hatchery/production methods – industry is in its infancy
- Strain selection and/or selective breeding for high-performing strains
- Limitations on access to the ocean (space restrictions for ocean farming of gametophytes)
- Scale of production required
    - Examples of estimated biomass needed (examples):
        - To supply 100% of Australian beef feedlot cattle (1.1 million cattle) ~ 29,000 tonnes dwt / yr (Agrifutures 2022)
        - To supply 20% New Zealand dairy herd (1.26 million cattle) ~ 25,000 tonnes dwt / yr (Glasson et al. 2022)

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Asparagopsis aquaculture: summary

- Methane is a significant contributor to global warming
    - Enteric methane produced by ruminants contributes ~ 30% of anthropogenic methane emissions
- Feeding ruminants small amounts of *Asparagopsis* reduces methane emissions by ~ 65-98%
- Mass cultivation of *Asparagopsis* is feasible but is in its infancy
- Significant opportunities to optimise production of *Asparagopsis* to meet global demand

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Thank you