Organic nutrient media for cultivation of *Asparagopsis taxiformis* – research and development recommendations

For *Asparagopsis* seaweed production to become viable onshore, there is a need to source high-quality, low-cost nutrients. Treated waste streams could provide nutrient-rich media suitable for *Asparagopsis* production. However, very little research has been conducted on cultivating *Asparagopsis* on nutrients derived from organic waste resources.

Learnings to date on nutrient media used for cultivation have been based on synthetic nutrient media or commercial-grade organic compounds, such as urea. Outcomes from preliminary research as part of the project *Developing Asparagopsis cultivation at scale for rapid industry growth* indicate that waste streams, such as the frass from black soldier fly larvae (*Hermetia illucens* L.; BSFL), can provide a rich source of nutrients to sustain growth, but further research is needed.

BSFL are known for their ability to convert organic waste quickly and efficiently into high-quality protein and fat, making them an excellent candidate for use in sustainable agriculture and aquaculture systems. BSFL frass is a nutrient-rich organic waste product that is becoming increasingly popular as an agriculture fertiliser.

Seaweed farming onshore can be economically challenging due to the high cost of nutrients required for it to grow. Seaweed requires a variety of nutrients, including nitrogen, phosphorus and potassium, as well as micronutrients such as iron, zinc and magnesium. Currently, these nutrients are supplied through synthetic fertilisers, which can be expensive; seaweed farmers also need to compete with traditional agricultural farmers for access to reasonably priced synthetic nutrients. Furthermore, waste streams are often not sterile, and the nutrient media requires additional processing and sterilisation before being included in seaweed production systems.

Our research has shown that BSFL frass can be transformed into a range of available nutrients, and this appears to be dependent on the BSFL diet and biodigestion conditions (Figure 1), including the microbiome and environmental parameters. Preliminary outcomes suggest that the available nutrients after our rudimentary process are useful to sustain *Asparagopsis* growth (Figure 2). There are, however, challenges facing development of BSFL frass into a commercially viable seaweed nutrient media.

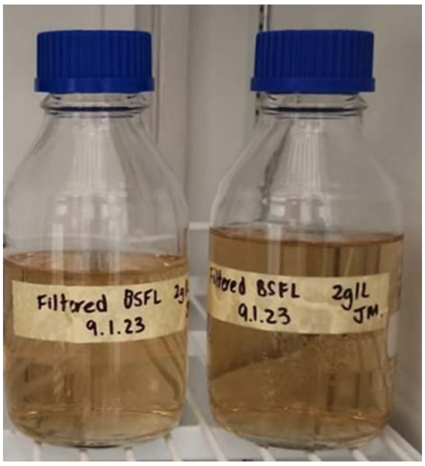

Figure 1. Black soldier fly larvae frass after biodigestion and filtration.

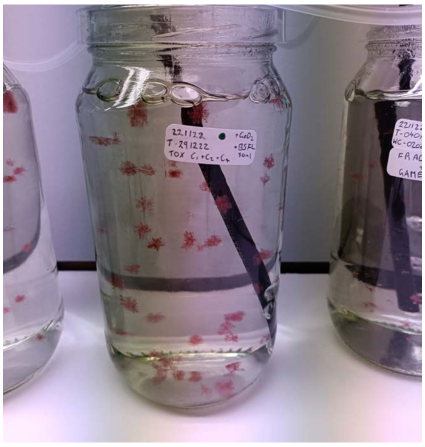

Figure 2. *Asparagopsis taxiformis* growth from carpospores to tetrasporophytes on black soldier fly larvae frass nutrient media.

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These could be addressed with research that aims to develop a highly efficient and controlled remineralisation process for BSFL frass within a biodigestor for the generation of targeted nutrient profiles that optimise *Asparagopsis* growth.

Below, we address these challenges by identifying the knowledge gaps, the research and development required, and specific work packages to improve our understanding of an optimised organic nutrient media for cultivation of *Asparagopsis taxiformis*, leading to beneficial industry-specific outcomes.

1

Knowledge gap: What are the specific characteristics of the microbial community in a biodigester under varying environmental conditions?

Research questions

What specific microbial species are prevalent in the biodigester under different environmental conditions, and how does their composition change with variations in pH, temperature, dissolved oxygen, frass biomass and BSFL diet?

How do the microbial communities in the biodigester interact with and influence each other during the digestion process, and how does this affect nutrient remineralisation?

Work packages

Work package 1 – Microbial species identification

- Collect samples under various environmental conditions.
- Conduct DNA sequencing and analysis to identify dominant microbial species.
- Collaborate with microbiologists for in-depth characterisation.

Work package 2 – Microbial community functionality

- Investigate the metabolic activities of identified microbial species.
- Analyse the roles of these species in the digestion process and nutrient remineralisation.
- Develop a comprehensive microbial community profile.

Outcome

A database of microbial communities that can be used to inoculate biodigesters based on the biodigester environmental conditions and target nutrient profiles.

2

Knowledge gap: How do changes in biodigester conditions impact nutrient profiles, and what are the specific alterations in nutrient concentrations and ratios under different environmental parameters?

Research questions

What are the key mechanisms through which environmental conditions (pH, temperature, dissolved oxygen concentration, biomass, frass quality) affect nutrient profiles, and can these mechanisms be quantified?

Are there specific nutrient or growth-stimulating compounds that are particularly sensitive to changes in biodigester conditions, and how do these changes impact the overall nutrient/growth stimulant balance?

Work packages

Work package 1 – Quantification of environmental effects

- Design controlled experiments to alter environmental parameters.
- Measure changes in nutrient profiles and ratios.
- Create a database of how pH, temperature, dissolved oxygen, biomass and frass quality affect nutrient composition.

Work package 2 – Sensitivity analysis

- Identify the most sensitive nutrients to changing moving bed biofilm reactor (MBBR) conditions.
- Explore the underlying mechanisms behind these sensitivities.
- Develop predictive models for nutrient alterations.

Outcome

A compendium of nutrient profiles formulated to generate organic, nutrient-rich media for onshore seaweed cultivation.

3

Knowledge gap: What methods or procedures are used to assess the quality of the end product (nutrient profile, contamination, stability) after cleaning and sterilisation, and how are these procedures optimised?

Research questions

What specific techniques or methodologies are most effective for post-digestion filtering to remove total suspended solids (TSS) and dissolved organic material (DOM), and how do these procedures compare in terms of efficiency?

What is the optimal combination of UV sterilisation, pasteurisation and activated carbon (AC) filtration to ensure the highest-quality end product in terms of nutrient profile, growth stimulants, contamination removal and tannin elimination?

Work packages

Work package 1 – Post-digestion filtration optimisation

- Test various filtration methods and materials for TSS and DOM removal.
- Analyse filtration efficiency, cost effectiveness and scalability.
- Develop standardised filtration protocols.

Work package 2 – Sterilisation and contamination control

- Investigate the efficacy of UV sterilisation, pasteurisation and activated carbon filtration.
- Optimise the combination of these techniques for maximum contamination removal.
- Ensure the stability and safety of the end product.

Outcome

Standard operating procedures for conditions that promote targeted nutrient profiles and clean, market-ready product.

4

Knowledge gap: In the context of seaweed growth, are the growth rates of seaweed supplied with BSFL nutrient media (presumably a nutrient source) equal to or better than those achieved using commercially available nutrient media when tested under the same environmental conditions in both laboratory-scale and production systems?

Research questions

What are the critical nutrients or compounds provided by BSFL nutrient media that contribute to seaweed growth, and how do they compare to nutrients or growth stimulants found in commercially available nutrient media?

Can the performance of seaweed grown using BSFL frass be enhanced or optimised through specific adjustments in environmental conditions, and if so, what are these conditions?

Work packages

Work package 1 – Key nutrient analysis

- Analyse the composition of BSFL to determine essential nutrients for seaweed growth.
- Conduct controlled growth experiments using individual nutrients to validate their impact.

Work package 2 – Optimisation of environmental conditions

- Undertake experiments to optimise the environmental conditions for seaweed grown using BSFL frass.
- Collect data on growth rates, biomass and nutrient uptake.
- Identify the optimal conditions for production systems.

Outcome

Demonstration of the efficacy of BSFL frass nutrient media on seaweed growth.

5

Knowledge gap: What are the potential benefits of the product range mentioned, and who are the target customers for these products? Additionally, what investment opportunities are associated with this product range?

Research questions

What unique features or advantages do the product range offerings possess compared to existing alternatives, and how can these be effectively communicated to potential customers?

What are the specific market segments or industries that would benefit most from the product range, and what investment strategies or opportunities are available to support their development and growth?

Work packages

Work package 1 – Feature identification

- Assess the unique features and advantages of the product range.
- Conduct market research to understand customer needs and preferences.
- Develop clear value propositions for each product.

Work package 2 – Market targeting and investment planning

- Identify specific market segments and industries that align with the product range.
- Develop a marketing and communication strategy tailored to these segments.
- Research and evaluate investment opportunities and partnerships for scaling up production and distribution.

Outcome

Marketing of the product range to the onshore seaweed industry, addressing specific industry needs, and presentation of investment opportunities to potential industry stakeholders.