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Developing food-waste-derived aquafeeds for Australian aquaculture production

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1. Purpose

This paper summarises the independent research CSIRO has conducted on Food Recycle Ltd's treated food-waste streams as aquafeed ingredients across three species, what the results show about technical feasibility, and what a full-scale facility at Goulburn would enable for the Australian aquaculture sectors.

2. Key points

- Three separate CSIRO feeding trials (black tiger prawn, barramundi, jade perch) have evaluated Food Recycle's treated waste streams at the Bribie Island Research Centre under controlled, replicated conditions with formal animal ethics approval.
- In barramundi, a diet containing 67% food-waste ingredients increased weight gain by 35% and feed intake by 13% relative to a commercially relevant control, at a feed conversion ratio below 1.0. A 50:50 blend (33.5% food waste) matched control performance.
- Prawns and jade perch fed food-waste diets ate less and consequently grew more slowly than the control diets containing traditional feed ingredients. The evidence points to palatability and antinutritional factors rather than nutrient supply, and both are solvable through waste stream selection and formulation.
- Waste stream quality and species-effects varies: Nutrient digestibility differs markedly between waste streams and between species. Bakery waste was highly digestible for prawns but poorly digested by barramundi; vegetable and fruit waste was poorly used by both and actively impaired protein digestion in prawns.
- The environmental impact assessment from replacing traditional ingredients with Food Recycle's waste streams differed between species. Barramundi feed using food waste produced ~70% lower greenhouse gas emissions than the control diet. Prawn feed using food waste was lower on land-use, fossil resources and waste but one third higher on greenhouse gas emissions due to the need to add a high protein soy concentrate, compared to its absence in the control. Jade Perch diets were not assessed in this report. Emission considerations for the Food Recycle's waste streams were conservative and treated as a burden-free input and deliberately excluding any credits for avoiding landfill emissions.
- Consistent, characterised, segregated waste streams are the single biggest determinant of feed value. A purpose-built facility that can segregate streams, apply a validated treatment step and report composition batch-by-batch is a critical advantage for successful conversion into commercial aquafeeds.

3. CSIRO's role and the nature of the collaboration

CSIRO participated in this work as an independent research partner to Food Recycle Ltd. The project was funded through CSIRO Kick-Start, a program that provides innovative Australian start-ups and small and medium enterprises with dollar-matched funding to access CSIRO's research expertise and facilities. CSIRO provided the scientific expertise, research methodology and specialised facilities required to assess Food Recycle's waste streams as aquafeed ingredients for three Australian species: black tiger prawn, barramundi and jade perch.

Food Recycle supplied a set of segregated waste streams for assessment. CSIRO's contribution comprised of

- Analytical characterisation: each waste stream was analysed for proximate composition and nutrient content to establishing the contribution of each stream to a diet.
- Formulation: diets were formulated based on those compositions to meet the known nutrient requirements of each target species. Diets were benchmarked against commercially relevant formulations built from conventional feed ingredients.
- Nutrient quality assessment: apparent digestibility trials were conducted for each individual stream in barramundi and prawns, so that future formulations could proceed on digestible nutrient value rather than gross composition
- Feed manufacture: All experimental diets were produced at CSIRO's feed manufacturing facility, ensuring diets were made to a consistent and commercially representative standard.
- In vivo evaluation: Barramundi and prawn diets were tested in environmentally controlled experimental bioassay systems; the jade perch diets were assessed in a covered greenhouse aquaponics system. Growth performance metrics were obtained to benchmark these novel food waste ingredients against diets containing well-known conventional ingredients and derisk the food waste products for industry adoption.
- Process advice: CSIRO advised on waste stream processing and storage methods that preserve the nutrient quality of the resulting ingredient for aquafeed production.
- Data analysis and interpretation: CSIRO analysed the data, provided critical assessment of the results, and disseminated findings through web articles, conference presentations and manuscripts in preparation.
- International stakeholder engagement: A CSIRO delegation met Food Recycle's Vietnam-based partner (JBI Equity) in Ho Chi Minh City, Vietnam in late November 2025 to jointly discuss sustainable circular aquaculture systems research with Vietnam National University. CSIRO facilitated the research proposal to assess the application of Food Recycle's processed ingredients in Vietnam. CSIRO's contribution was advisory and CSIRO was not involved in conducting the Vietnam research trial.

4. Evaluating food-waste streams

Seven food-waste streams were analysed across the research collaboration with Food Recycle between 2021 and 2024: seafood waste combined with spent grain (sourced from seafood markets and breweries), pub and restaurant waste, bakery waste, meat and bone meal (sourced from abattoirs), vegetable and fruit waste (sourced from fresh food markets), blood combined with spent grain (sourced from abattoirs and breweries); and oyster waste (sourced from seafood markets).

The collaboration spanning over four years and successive trials, showed that composition and nutrient digestibility can vary between streams, and the same stream did not behave the same way in different species. For example, bakery waste was the best-digested stream tested in prawns yet among the poorest in barramundi. Vegetable and fruit waste was poorly used by both, and in prawns actively impaired digestion of protein supplied by the rest of the diet.

From these findings it was clearly demonstrated that streams segregated at source was a practical advantage to achieve flexible formulations across multiple species. Dependable nutrient characterisation of each batch is a necessity for formulating aquafeeds to nutrient specification. A feed manufacturer cannot formulate to a specification it cannot measure, and an aquaculture producer will not adopt a feed whose composition varies unpredictably between deliveries. A facility capable of segregating streams and characterising each batch is important for converting a variable waste resource into a specifiable feed ingredient.

5. Trial results

5.1 Black tiger prawn (*Penaeus monodon*)

Design: growth trial, 12 x 100 L flow-through tanks, 4 replicates per diet, 10 prawns per tank at 5.07 +/- 0.04 g. Three iso-nitrogenous, iso-energetic diets: control (commercially relevant, traditional ingredients), 56.5% food waste, 70.4% food waste. Separate 3-week digestibility trial, 24 tanks, 5 prawns per tank at 28.4 +/- 2.8 g.

Main findings

- Replacement of traditional ingredients with food waste ingredients reduced growth, from 11.7 g final weight in the control diet to 9.2 g in the food waste diet, due to decreased feed intake which indicates a likely palatability issue. Here the food waste diets were formulated to replace 100% of the traditional fish meal which is a consistent response observed for black tiger prawns. Feed attractants and palatability enhancers should be considered to improve the feed intake of the food waste diets for prawns.
- Prawn survival was not influenced by diet after 8 weeks of feeding and remained high at >80%.
- The vegetable & fruit waste stream was shown to impede digestion of protein in prawns. Vegetable + fruit waste is known to contain various antinutritional factors which likely resulted in the growth and feed intake reductions observed in prawns fed food waste-based diets. Future diets for prawns would likely need to avoid inclusion of vegetable and fruit waste streams if the anti-nutritional factors cannot be reduced.
- The food waste prawn diet achieved a lower environmental impact compared to the control diet in terms of land use, fossil resources and water consumption. However, the need to increase the protein content of this diet using soy protein concentrate increase the global warming emissions and freshwater eutrophication. Other higher protein ingredients should be considered instead of soy protein concentrate to optimise the benefits of a food waste diet for prawns
- **Recommendations for improvement:** fruit and vegetable waste showed a clear negative effect on nutrient digestion and growth in prawns. Thus, waste streams high in fruit and/or vegetables should be limited or excluded entirely from prawn formulations. To further facilitate higher intake of food waste-based feed, the addition of a feed attractant is recommended.

5.2 Barramundi (*Lates calcarifer*)

Design: 6-week growth trial, 12 x 300 L flow-through marine tanks at 30°C, 20 fish per tank at 133.5 +/- 12.4 g, 4 replicates per diet. Control, 33.5% food waste (50:50 blend) and 67% food waste. Ethics approval CSIRO QLD AEC 2020-30. Separate digestibility trial, fish at 297.7 +/- 28 g.

Main findings

- The 67% food-waste diet increased weight gain by 35% and feed intake by 13% versus the control, achieving an FCR below 1.0. The 33.5% blend gave numerical improvements over the control.
- The likely driver of this exception response was the predominate inclusion of the seafood waste and grain food waste streams which was a superior nutrient and bioactive source compared to the other food waste streams.
- The protein and lipid digestibility of the seafood waste and grain waste, pub and restaurant waste and meat and bone waste were well utilised by barramundi, while bakery and vegetable + fruit were poorly digested. Bakery waste was the best-digested stream for prawns and one of the worst for barramundi.
- An environmental impact assessment of the barramundi diets showed a beneficial effect of diets containing food waste compared to the control. Replacing traditional ingredients with food waste more than halved global warming emissions, freshwater eutrophication, land use, fossil resource scarcity and water consumption. More sustainable aquafeeds can be developed using local sources of food waste ingredients.

- **Recommendations for improvement:** the food waste-based diet outperformed the traditional diet which was likely a result of the higher dietary protein content of the food waste-based diet and the high inclusion of marine original waste streams (44% seafood waste). Barramundi would benefit from highly digestible food waste streams contributing to high protein diets.

5.3 Jade perch (*Scortum barcoo*) in decoupled aquaponics

Design: 48-day trial, tunnel house at Bribie Island, 3 tank replicates per treatment, 20 fish per tank at ~20 g, decoupled aquaponic systems with red and yellow lettuce. Four treatments: hydroponics only (no fish), control diet, zero-fishmeal Australian plant-protein diet and food-waste diet. Diets extruded on a twin-screw extruder at 4.5 mm.

Main findings

- The food waste diet produced 20% lower growth compared to the control diet (43 vs. 54 g weight gain) due to lower feed intake (97 vs 106 g) which was a similar intake-driven pattern as the prawn trial. It is recommended that a palatability enhancer be added to diets containing food waste to encourage high feed intake.
- The food waste diet did not affect fish survival where no mortalities were observed during this trial period
- There was no significant treatment effect on lettuce wet weight or aerial weight.
- When considering the cost of ingredients to formulate these diets, the food-waste diet was the cheapest at half the cost of the control diet.
- **Recommendations for improvement:** Digestibility was not assessed in Jade perch and so it is not possible to identify which stream, if any, was poorly digested. Based on the findings from the prawn and barramundi trials, the food-waste diet would be expected to improve through excluding streams high in fruit and vegetable material and maximising inclusions of highly digestible waste streams that support a higher dietary protein content.

9. Future benefits to the aquaculture industries

- **Feed security and input diversity:** Feed is the dominant operating cost in intensive aquaculture, and Australia imports a substantial proportion of the fishmeal and soybean meal on which its aquafeeds depend. Both are globally traded commodities subject to price and supply volatility driven by fishery variability, climate disruption and geopolitical conditions. A diverse array of nutrient sources produced domestically would reduce the aquaculture industry's exposure to that volatility.
- **Sustainability and cost:** Where growth performance is maintained, processed food-waste streams offer a more sustainable and cost-effective nutrient source than conventional ingredients. This was demonstrated most clearly in barramundi, where a 67% food-waste diet outperformed a commercially relevant control while carrying approximately 70% lower greenhouse gas emissions per tonne of feed. The context also matters where the superior performance was driven by a higher protein diet containing a high inclusion of seafood offal waste. In prawns, where feed intake and growth were reduced, the cost and emissions advantages of the diet did not carry through to the cost or footprint of the animal produced. Realising the benefit therefore depends on stream selection and formulation.
- **Circular food system:** Using food waste in aquafeeds is a direct demonstration of the circular economy where material that would otherwise be landfilled is diverted, treated and returned to human food production as a nutrient input rather than lost as an emissions liability. Aquaculture is a well-suited entry point, because feed conversion in fish and crustaceans is efficient relative to terrestrial livestock, and because the regulatory constraints that apply to feeding processed food waste to pigs and ruminants do not apply in the same form to aquaculture species. Complementary species selection would drive the success of circular food systems where food waste streams would need to be matched to the aquaculture species being reared, as well as the nutrient availability of the excreted waste for use as a plant fertiliser.
- **Increasing access to fresh food through small scale, peri-urban production:** CSIRO's jade perch work is, to our knowledge, the only Australian assessment of a food-waste-derived diet in an integrated fish-and-plant system. Lettuce yield was not significantly affected by diet, indicating that a food-waste feed can be

used in aquaponics without compromising the crop, although fish growth on that diet was reduced and requires further formulation work. Aquaponic and peri-urban systems produce fresh fish and leafy greens close to the communities that consume them, and typically achieve premium prices. Access to a locally produced, lower-cost feed improves the economics of these small-scale systems, which are otherwise sensitive to input costs.

- **Regional capability building:** Local ingredient availability supports regional communities in producing feed closer to the point of use, improving self-sufficiency and resilience in the aquaculture supply chain and increasing domestic production of high-quality Australian seafood.
- **Benefits of the proposed dedicated facility:** Integrated collection, segregation and processing of multiple waste streams is logistically demanding, and that complexity is precisely why it has not been widely undertaken. The CSIRO trials indicate the effort is warranted: segregation is what allows a single facility to serve multiple species and use cases, and batch-level characterisation is what allows variation in incoming material to be managed rather than passed through to the customer (external feed manufacturers and animal producers). Volume, consistency and quality remain the principal barriers to the wider use of food-waste-derived ingredients in animal feeds. The proposed purpose-built processing infrastructure is the necessary precondition for resolving them.