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2014/704: Waste Transformation for the Catering Market

Final Report

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In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

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Executive Summary

This report summarises the research undertaken under FRDC 2014/704: Waste Transformation for the Catering Market. The project aimed to develop and launch at least two value-added products on the institutional catering market using seafood processing waste.

Initially a variety of different seafood processing waste products including picked and seconds Blue Swimmer Crabs, Snapper, Atlantic Salmon and various reef fish frames, Patagonian Toothfish frames, Western Rock Lobster legs, headed and gutted shark, low value prawns and headed and gutted Leatherjacket were transported to the Abacus Fisheries facility in Carnarvon. Mechanical separation of seafood protein from these products was optimised with subsequent data generated on recoveries, and compositional and microbiological food safety analyses. These various forms of separated seafood protein were then used for new product development trials.

During the project, a number of new technologies for seafood protein separation, stabilisation and reforming were developed that can be applied generally to seafood processing waste recovery and new product development.

These technologies include

a. Optimisation of mechanical separation of seafood protein (as mince) from a range of fish frames, headed and gutted product and cooked crustacea. Separation was optimised as appropriate through 2, 5, 7 and 10mm apertures. Recoveries were optimised and product parameters, including volumes, quality, composition and microbiological food safety, were investigated. The separated protein was then made available for other product outcomes.

b. A screw press separation method was developed to optimise ingredient parameters (eg flavour, stability) for frozen cooked Blue Swimmer Crab mince, a major by-product of the Abacus processing activity. Use of this product was previously limited due to issues of flavour and form on thawing. This improved ingredient can now be added to improve the quality and marketability of a range of value-added products from past and current project development. This technology can now also be applied to other frozen, separated waste materials.

c. Cold-set binding to produce reformed fillets from various forms of finfish separated protein was achieved (in partnership with CSIRO). This binding process was modified and trialled in two commercial food processing facilities. Raw and cooked Blue Swimmer Crab binding was also trialled with limited success.

d. High moisture extrusion (HME) of finfish and Blue Swimmer Crab waste to produce reformed products, was developed to a point where it seems likely an acceptable extruded product can eventually be achieved. It was expected that these reformed extruded products could then be made available as ingredients for further new product development. However, due to initial issues with CSIRO equipment, this further development could not be achieved in the current project timelines.

Using the separated protein, a number of new value-added products were then developed in a collaboration between Curtin University, Abacus Fisheries and two seafood new product development consultants. These consultants generally worked on site at the Abacus facility. The project resulted in the production of 8 possible value-added products from seafood processing waste. At the end of the project, with economic and commercial feasibility evaluated, as well as marketability, one new product (prawn cake) has been launched and has had supermarket share for >2 years, two products have been subject to orders by end-users and final production should commence soon (Blue Swimmer Crab poppers and XO sauce), one product is ready for retail sale but awaiting packaging and production optimisation (Snapper croquette) and four other products were developed to being close to “investment ready” but not being taken forward at this stage due to various issues (lasagne, reformed fillet, escabeche and dumpling filling).

A number of findings, from the project and associated with developing new products from seafood processing by-products, are summarised below.

a. The project builds on the concept of total utilisation of the seafood resource. This was particularly studied in the Snapper example: Snapper products investigated included fillets, wings, belly flaps, mince (of different qualities), head meat and stock from the bones. This seafood total utilisation concept, well established in the meat and pork industries, is well supported by current market and government drivers to demonstrate sustainability and reduction of food waste, and enquiries for further investigation are now being received from major seafood processors.

b. One of the biggest barriers to the development of the new value-added products, generally (see also FRDC 2013/711.30: new opportunities for underutilised species) and from seafood processing waste is access to an economically and commercially viable, consistent supply and sufficient volumes of quality raw material. This becomes more difficult when processing is occurring at remote sites such as the Abacus facility in Carnarvon. Without consistent raw material supply, recipes cannot be standardised and consistent new product supply to end-users cannot be guaranteed.

   This raw material availability is often compromised by the volatile and changeable nature of the commercial fishing industry and aligned markets. As a result, the project saw continuous evolution of new products (and often shelving of earlier versions), as a consequence of this volatility, particularly around raw material availability and fluctuating prices. Some examples are described below:

   - Following trials in 2015 and 2016 on mince protein separated from Snapper filleted frames, the market changed to a headed and gutted form making frames unavailable in 2017. As a result there was little filleting (and therefore little mince recovered during that season) and research effort (and new product development) had to change to focus from products using the mince (reformed fish fillets and the Snapper cake (version 1)), to products that used the head meat chunks (escabeche, Snapper cake (version 2).
   - The price of soft and broken King Prawns and Coral Prawns changed in 2016, due the banning of imports as a result of the white spot outbreak, and hence it was no longer economically feasible to include this product in the prawn cake. The prawn source was therefore expected to be changed to lower value deep sea prawns, but this raw material compromised the final product quality.
   - Markets for Patagonian Toothfish offcuts emerged during the project so that the participating producer company was no longer interested in taking part in product development work.

   One strategy to counteract such changes in the market place is to design robust products, with flexibility for ingredient changes. This was tested successfully with the developed Snapper croquette, Snapper as the fish could be replaced with other species. Similarly the binding methodology developed for the reformed fillets was tested and could be used with a variety of different finfish species.

   Another strategy to offset the issues of raw material supply is to work with larger volume processors where raw material supply can be better consolidated and is less subject to price and availability fluctuation.

c. Economic feasibility of developing new products from processing waste will also likely require the separation and stabilisation of the seafood protein at the primary processing facility. Costs to freeze frames, transport and thaw primary waste product (such as frames) before secondary processing at another site were prohibitive, whereas transport of frozen, separated fish protein was an option. This feasibility was tested at the Abacus factory on site and immediate secondary processing of fresh Snapper filleting off cuts, and subsequent freezing of separated protein for later product development.

d. The project has demonstrated the need to ensure technical expertise and suitable equipment is available when new and emerging food processing technologies are being tested. The timelines and outcomes of the project were compromised when it became apparent, after the signing of the subcontract, that CSIRO did not have the necessary equipment to undertake the HME trials. It may be more prudent in the future to work with commercial producers of the processing equipment. These companies often have test kitchens and technical expertise and are willing to work with producers on new product development. Similarly, as was conducted here, on site trials at the participating processor with appropriate external product development expertise may also result in accelerating commercially viable outcomes.

e. This project has also shown that previous work can be revisited with the subsequent advent of new technologies. As an example the lack of flavour from the frozen Blue Swimmer Crab mince resulted in the lasagne recipe being sidelined in this project and the Blue Swimmer Crab balls/poppers being sidelined in a previous project (FRDC 2010/704: Accelerated New Product Development: Blue Swimmer Crab Pilot). However, the new "screw press" technology to address the Blue Swimmer Crab mince flavour issues as used in the current project is expected to result in improved flavour outcomes for the Blue Swimmer Crab lasagne, and also facilitated the further development of the Blue Swimmer Crab poppers, which have now been ordered by a major supermarket.

f. This project has emphasised the results of previous projects (CRC 2010/775: New product development for low value, high volume species - WA Sardines; 2010/704) in regard to the difficulties encountered by small businesses in developing viable new product distribution strategies. Previously the larger distribution companies employed salesman who would assist small operators with gaining market share for their new products. Now however, the larger distributors tend to only "lift and shift", with an expectation that the small producers would do the marketing (eg visiting chefs and food service/retail outlets) for their own product. Small operators do not have the time or resources to undertake such marketing activity.

In summary the project has resulted in the development of a range of value-added products from seafood processing by-products. Technological advances in separation of seafood protein and subsequent stabilisation and reforming have been made, further work will be required to commercialise these technologies but they do hold promise in continuing to find new value-adding outcomes for seafood processing waste.

1. Introduction

An estimated 59,000 tonnes of Australian seafood processing waste (Howieson *et al*., 2017 (FRDC 2013/711.40: New Opportunities for Seafood Processing Waste) is currently put into land-fill or for low value products because it is produced in many locations in volumes that are below the minimum required for cost-effective further processing. However, as the cost of waste disposal and the potential value of by-products both increase, in line with broader consumer attention to total product utilisation and waste minimisation, more research interest is being focussed on seafood by-product opportunities.

Up to 60% of food loss (including seafood waste) is potentially avoidable. In the case of seafood specifically, at least 50% of the fish is generally lost following filleting and disposal of damaged crustacea such as Western Rock lobster, Blue Swimmer Crab and prawns bring low returns to the producer. Often there is a business cost incurred in removing such seafood processing waste. Reducing and transforming seafood processing waste seems essential to add profitability where possible to the Australian seafood industry.

CRC Project 2010/706 " Accelerated New Product Development: Blue Swimmer Crab pilot, resulted in the successful commercial launch of a Blue Swimmer Crab cake, in which the predominant ingredients was Blue Swimmer Crab mince separated from waste product following the removal of the premium meat. Similarly, and using the same mechanical separation process, an aligned study (Ho, 2016) demonstrated that between 15-28% of extra meat could be separated from various finfish frames following filleting. It was hypothesised that such separated seafood protein could be utilised for further value-added production work.

This project therefore aimed to investigate and optimise mechanical separation of fish protein from a range of seafood waste products. New technologies; cold set binding and high moisture extrusion (HME) were then to be investigated to provide base ingredients for new product development from the separated protein. Lastly, a range of new seafood value-added products were to be developed and market tested.

2. Objectives

To successfully launch at least 2 products produced from seafood processing waste on the institutional catering market.

3. Methods

Generic methods for compositional, microbiological and sensory analyses were undertaken during the project. These methods are described in Section 3.

In subsequent sections, specific methods, results and discussion are summarised in Sections 4 (Sourcing, Preparation and Compositional Analysis of Seafood Waste Material), Section 5 (Development of Reformed Products using Cold Set Binding) and Section 6 (Development of Reformed Products using High Moisture Extrusion). Section 7 summarises the new value-added products developed from the separated seafood protein and aligned methodologies.

Compositional Analyses

It is noteworthy that often compositional analyses were outsourced to the National Measurement Institute (NMI).

Moisture Content

The Association of Official Analytical Chemists (AOAC) official method 950.46 (AOAC, 2008) in meat moisture content was used to analyse the moisture content of a sample. Approximately 10g of each sample was weighed accurately into previously dried and tared aluminium dishes and dried in the 105^0C air oven (Contherm, digital series, oven, Lower Hutt, New Zealand) until constant weight was achieved. Before reweighing and moisture content measured by difference, the samples were cooled in a desiccator. The moisture content was determined by weight difference between before and after the drying process.

Ash

The ash content determination was conducted based on the AOAC official method 938.08 (AOAC, 2005). Approximately 5g was accurately weighed into pre-dried and cooled crucibles. Samples were ashed at 550^0C in a Thermolyne muffle furnace model 48000 Furnace (Thermo Fisher Scientific Inc, Iowa, USA) until constant weight was achieved (around 18 hours). Percentage of ash was calculated by the following equation:

$$\% \text{ Ash} = \frac{(\text{ashed weight} - \text{crucible weight})}{(\text{pre-ashed weight} - \text{crucible weight})} \times 100\ \%$$

Protein

Protein content was measured by using the Kjeldahl method according to the AOAC Official Method 955.04 (AOAC 2005). Approximately 1g of each ground sample was weighed and then put it into digestion tubes containing 1 Kjeldahl catalyst tablet (contains 1g Na_2SO_4 and 0.01g Selenium) and 2 or 3 glass beads to which the 8ml digestion acid (100 parts conc H_2SO_4 and 5 parts conc H_3PO_4) and 4ml of 35% hydrogen peroxide was added. The sample was then digested in a Tecator 2020 Digester (Högänas, Sweden) at 420^0C until a clear straw colour was reached. Into the digest 50ml of 40% sodium hydroxide was added and steam distilled in a Kjjeltec system 1002 distilling unit, (Foss Tecator, Högänas, Sweden). The distillate was captured into a flask containing 25ml of boric acid as an indicator (80g of boric acid, 20ml of bromocresol green solution and 14ml of methyl red solution and diluted to 2L with deionised water). The distillate was titrated against 0.1 M Hydrochloric acid. One gram of sucrose was used as a blank. The percentage of protein in the samples was calculated using the following equation:

$$\% \text{ Protein} = \frac{(\text{sample titre mL} - \text{blank titre mL})}{(\text{mg sample})} \times 0.1\ \text{M HCL} \times 14.1 \times f \times 100\ \%$$

The conversion factor (f) was 6.25, which is the general factor used for meat and fish products.
When specific amino acid species composition was required, samples were despatched to commercial laboratories (usually National Measurement Institute (NMI)) for amino acid breakdown.

Fat

The method for crude fat determination followed the AOAC official method 960.39 for meat (AOAC 2005). Approximately 1.5 g dried sample was ground, weighed and put into a thimble recorded as weight 1. A separation cup, which is a specific glass beaker in which the fat will collect containing a glass bead, was weighed and recorded as weight 2. The fat was separated in a Soxhlet Buchi fat separation unit (Model E-816, Buchi Labortechnik AG, Flawil, Switzerland) over ten cycles or a one-hour period, with petroleum ether (boiling point range 40^0C–60^0C) as the separation solvent. After separation, the separation cup was dried in the 105^0C air oven (Contherm, digital series, oven, Lower Hutt, New Zealand) until it reached a constant weight, and was then cooled in a desiccator. Crude fat was calculated as per the equation below:

$$\% \text{ Crude fat} = \frac{(\text{Wt of separation cup containing fat} - \text{Wt of empty cup})}{} \times 100\ \%$$

(Wt of thimble and sample – Wt of thimble)

When specific components of the fat were required, samples were provided to NMI for Fatty Acid Methyl Ester (FAME) analysis.Oil quality as peroxide levels or free fatty acid measurements were conducted as required by NMI.

Heavy metal analyses when required were outsourced to a NATA accredited laboratory.

Microbiological Analyses

It is noteworthy that often microbiological analyses were outsourced to Merieux.

Where microbiological testing was relevant, samples were sent for analyses at a NATA accredited laboratory. Generally the samples were analysed for Total Plate Count (TPC) and levels of E.*coli, Salmonella, Listeria Monocytogenes* and Coagulase positive *Staphylococcus* were measured as relevant to comply with the Food Standards Code.

Shelf-life testing, where required, was outsourced to a NATA accredited laboratory.

4. Sourcing, Preparation and Compositional Analysis of Seafood Waste Material

The first stage of the project was to identify a range of seafood waste products from which fish protein could potentially be recovered for new product development.

Following discussions with the project team, it was decided to start the project and establish proof of concept with one processing partner. Kailis Bros (Perth) was approached in 2014 and thereafter supplied, at no cost, 1.5 tonnes of frozen fish frames (Atlantic Salmon and various reef fish frames), which was transported to Abacus Fisheries (Carnarvon).

350kg of minced product ('red meat' from Atlantic Salmon and 'white meat' from various reef fish) was produced at Abacus Fisheries from the frames, through existing mechanical separation/ separation equipment with a 2mm or 5mm sieve width. An average recovery of ~26% separated mince was achieved from the supplied frames. The mince was vacuum packed in 3kg bags and frozen. 350kg respectively of cooked and raw Blue Swimmer Crab mince sourced from the Abacus Fisheries operations was also produced, bagged and frozen. The mechanical recovery rate of ~45% from the Blue Swimmer Crab was an improvement on the ~37% previous average for hand-picked and minced product.

These initial trials indicated a larger sieve width in the separation equipment was necessary to achieve the required texture for a higher value product. The original machine had 2mm and 5mm holes which resulted in an adequate mince but the product lacked "chunkiness" to produce a better mouthfeel and texture in any new products developed. Hence 7 and 10mm separation sieves (rather than the 2 and 5mm sizes previously purchased by Abacus) to be added to the mechanical separator were ordered and delivered to the Abacus facility (see Figure 1).

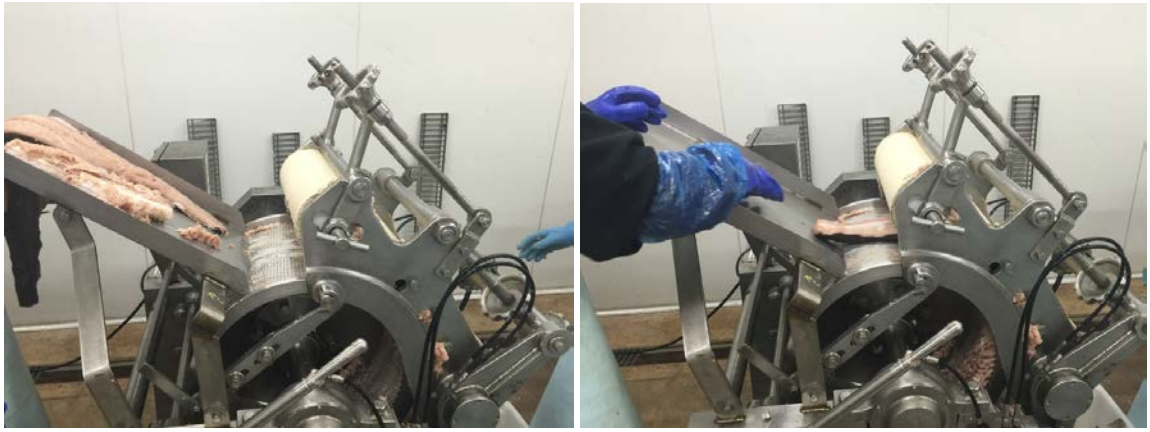


Figure 1: New 10mm separation drum installed at Abacus Fisheries.

A finding from this early part of the study was that labor, transport and other costs incurred in freezing the frames, transporting to Carnarvon and then thawing before separation, meant that fish protein separation at a location away from the initial processing site was unlikely to be cost effective.

As a result of this cost finding, two alternative options to increase economic viability investigated and costed as the project progressed were:

- Use currently unsaleable whole or head and gutted fish delivered to the Abacus fishery and subject to mechanical separation. This would result in higher separation yields (than from the frames) and therefore greater economic return; and
- Investigate the model of installation of separation equipment at the primary processor, processing on site immediately after filleting and then transporting frozen mince directly from this site.

To investigate the first alternative option, whole headed and gutted shark was investigated as an alternate source of separated fish protein. Sourcing of the shark required an application and subsequent granting of an exemption from the WA Department of Fisheries for Abacus Fisheries to catch two tonnes of shark from Shark Bay to trial in the project. Shark was considered favorable because it is often underutilised (especially in larger sizes), resulted in high mince recoveries (~50%) following separation from headed and gutted catch and the lack of scales made the separation process easier and the final product less subject to scale fragment contamination (see Section 4.2).

Similarly, headed and gutted Leatherjacket, also an underutilised species with >50% separation recoveries and no scales was also included in trials (see Section 4.4).

In order to test the second option to increase economic viability, part of the 2016 Abacus Fisheries Pink Snapper catch was filleted on site and then the frames were immediately passed though the 10mm mechanical separator. This Snapper minced product was also used in the reforming experiments. Other by-products of the Snapper filleting process were also investigated (see Section 4.1).

Later sourcing of waste raw material included Patagonian Toothfish frames from Catalanos Seafoods, Western Rock Lobster legs from a Cervantes based Western Rock Lobster processor and lower value prawn species.

Further details and observations from the production of separated seafood protein from the various specific waste products are discussed in Sections 4.1-4.7.

All processing and analytical results are thereafter summarised in Section 4.7. This includes Table 1 (Separation efficiencies and general comments) and Table 2 (proximate, compositional and microbiological analyses. Table 2 results indicate that all frozen separated fish protein samples were within food safety limits. These analyses were used as the basis for developing CSIRO ethics approval for sensory analysis of the reformed fish protein products discussed in Sections 5 and 6.

4.1 Snapper

The 2016 mechanical filleting of Snapper at the Abacus facility ensured that all possible by-product post the filleting process could be investigated for applicability for new product development. This part of the project, encompassing potential total utilisation of the Snapper harvested resource, was considered to have application to a range of aligned finfish species.

The range of products produced from the Snapper after the filleting process are discussed below:

Separation of fish protein (as mince) from Snapper frames.

Three different qualities of Snapper mince flesh were recovered post the filleting process.

- Fillets that were graded as not being suitable to sell as whole sashimi grade fillets were blast chilled until just “crisp” and then processed through the 10mm sieve of the separation equipment. This produced a uniform dice of very high quality flesh that was predominantly white in colour. These dice will be used to develop the texture and mouth feel to value added product and cooked white.

- The frame of the fish left after the filleting process underwent two passes through the drum separation equipment. The "first press” was through the 7mm drum separating machine. This first pass produced a quality minced product without being overly coloured by blood and other impurities from the frames (Figure 2). This cooked to an off white colour.

Figure 2 shows the frame left from the filleting process and the first press 7mm flesh.

Figure 2: First press Snapper mince following separation from the filleted frame.

The “Second Press” of the frames used the 2mm drum separating system. This second pass removed all of the flesh remaining on the frames. A higher level of impurities was also removed with this pass and the resulting fish flesh was more distinctly red in colour (Figure 3). It could be used as a binding agent, or fine puree added into other protein bases. It does not materially contribute positive texture or visual appearance when cooked into a product. It cooked to a grey colour.

Figure 3 shows the three mince products produced: the 10mm dice from the fillet, the first press 7mm flesh and the second press 2mm flesh.

Figure 3: Three mince products produced: the 10mm dice from the fillet, the first press 7mm flesh and the second press 2mm flesh, as well as the stock.

The third outcome from the Snapper frames after filleting was the ribs. The rib section was removed separately from the fillet after it was removed from the frame. The ribs were passed through the 2mm drum separator and approximately 10% by weight was recovered. The meat was similar to the second press from the frame.

Other possible products emanating from the Snapper post filleting

- Belly flaps: The belly flap flesh was of a very high quality and consistent with the expected colour of Snapper fillet. As the source fish was further hand filleted after the mechanical filleting, there was some variation in size and shape and a small percentage still had cartilage or bone attached. Enough of the fillets were this way to require that every fillet be inspected by hand. The flaps cook well and could be sold as a ready to eat cut of flesh.

- Racks: If the racks are minced the flesh does tend to become discoloured from the blood and impurities from the bone, and the immediately adjacent flesh. If the racks are hand filleted in nearly every case it was possible to easily produce a high quality fillet of flesh from each side of the bone. Racks could also be sold as a stand-alone product.

- Head meat: The heads were steamed and the meat recovered from the cheeks and from under the prominent boney structure behind the top of the head (Figure 4). The best time/temperature profile to defrost and steam the heads in order to minimise shrinkage and moisture loss of the meat was not fully optimised. Of the trials that were conducted there was an average recovery of 21% white meat plus 2% dark meat by total weight of the head. The dark meat only comes from the cheek and is a separate muscle that is easily removed from the main cheek piece next to the bone. This dark meat is unlikely to have any commercial use. The white cheek meat has a great Snapper flavour and mouth feel, it was regarded as high quality flesh.

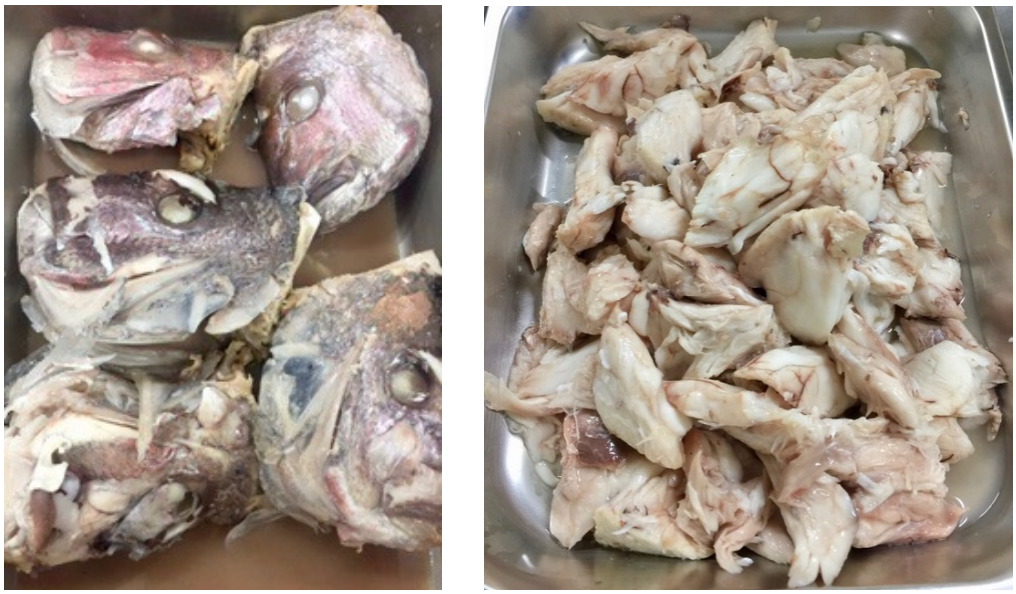


Figure 4: Snapper heads and meat recovered.

- Snapper stock can be prepared from the denuded frames after they have been through the separating system. The stock can be sold as product in its own right or added back into other products to boost flavour profile (Figure 3). The stock when made from Snapper frames/bones makes a very good clear, clean flavourful stock. It was noteworthy that, in contrast to the frames, a stock made from the heads tended to be cloudy and to have an undesirable flavour.

The Snapper results for utilisation of the products produced after filleting were the most extensive of all the species studied and show the various meats/product forms that can be separated as well as the fillets. These results from Snapper total utilization also gave flexibility to final production options for the project.

This flexibility was necessary, because as the project evolved, whole and headed and gutted fish prices improved, so filleting of fish at the Abacus was generally ceased for economic viability reasons, and hence very small amounts of Snapper mince are currently being produced at the Abacus facility. The work with the ribs, belly flaps and head meat gave alternative options for raw Snapper protein materials for the development of the value-added products.

There is an opportunity to extend these findings from Snapper to total utilisation of other similar finfish species.

4.2 Separation from Hammerhead Shark

Initially frozen headed and gutted Hammerhead Shark trunks were sourced from Albany Seafoods.

The trunk was split in two following the line of the cartilage. Using hand filleting techniques the skin and the blood line of the fish were removed so as to leave clean pale coloured flesh. This was then blast chilled until crispy and passed through the 10mm mechanical separating sieve. This type of recovery produced a uniform size dice that may be added back into other value-added products to produce a visual of fish chunks. Figure 5 shows the shark frame after separation.

Alternatively whole fillets can be passed through the 7mm separating system. This method produced a higher recovery rate than the dicing, however the flesh produced has a low quality texture and was clearly visibly much less appealing as it had a higher percentage of impurities from the rest of the trunk (Figure 6). The flesh recovered from this shark species is suitable to use as a filler or binder in other value added products where a higher quality fish provides the dominant texture and flavour profile.

The estimated recovery from the Hammerhead Shark trunk is around 80% by weight, which makes it a very economical way of recovering usable protein.

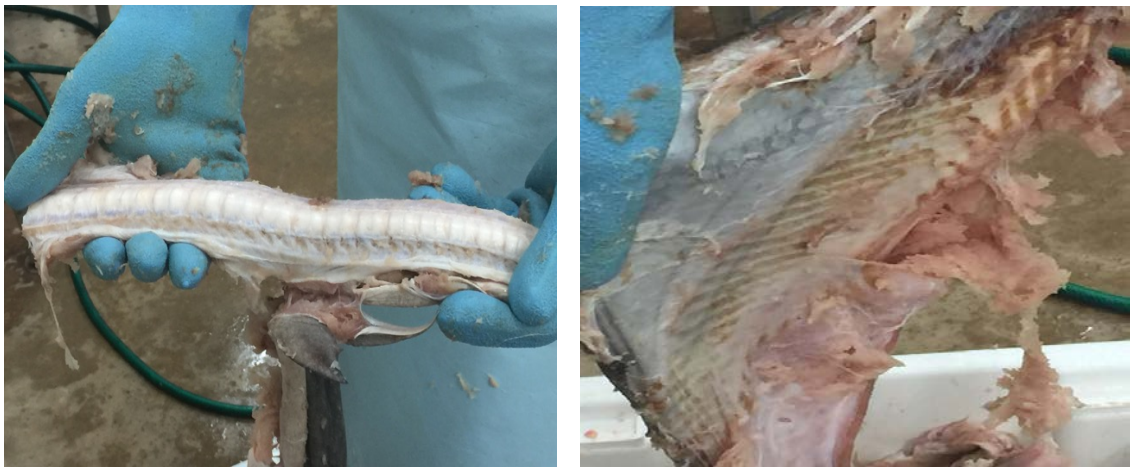


Figure 5: Photos of shark frames after separation of mince.

Figure 6: 7mm mince produced after separation from whole Hammerhead Shark fillets

Abacus Fisheries vessels also harvested shark from Shark Bay (under the exemption described in Section 4. This product was separated, packaged, frozen and despatched under instruction from CSIRO to Werribee for the HME trials. However, due the delay due to equipment replacement (see Section 6), the product deteriorated to a point where it could not be used for experimentation.

4.3 Patagonian Toothfish

Frozen then thawed headed and gutted Patagonian Toothfish were filleted at Catalanos Seafoods (Perth), then the fish frames were frozen before being transported to Abacus (Carnarvon). The frames were defrosted overnight and processed through the 7mm drum separator.

The Patagonian Toothfish had the smallest recovery of usable protein by mass, than any other fish trialled. The flesh did not separate cleanly from the frames as it passed through the drum and several passes were required to get a reasonably clean frame. The flesh recovered was very soft and mushy with no real structure or integrity. A large amount of oil separated from the flesh and, in this separation process, is not recoverable as it flows around the separation equipment. This led to a large loss in recoverable mass, as well as inhibiting the effectiveness of the separating system. A significant amount of small bone also passed through the system and was detectable in the separated flesh product.

It is noteworthy however that positive attributes of the separated fish flesh was the snow-white colour and the ability to retain this colour when cooked. It had a high visual appeal. The flavour was also exceptionally good with no seeming loss of quality from the freezing and separating process.

The cost of recovery of this flesh and the lower recoveries when compared to other species makes this product less likely to be a viable option for fish protein recovery. The very high oil content will also limit the way this flesh may be incorporated into finished value added products. For these reasons Patagonian Toothfish protein was not further investigated in the study, although it could be possible to extract the oil using different separation systems.

4.4 Leatherjacket

As early small scale separation of Leatherjacket mince from headed and gutted product showed a recovery of >50%, flesh quality and initial product development work was promising, and given the underutilised status of this resource it was decided to undertake some larger scale commercial recovery trials.

A large shipment (one tonne) of Leatherjacket samples (offcuts, headed/gutted and skinned and headed and gutted) was transported to the Abacus facility from Port Lincoln, South Australia for commercial trials. Unfortunately and generally the particular shipment was poor quality and highly likely to have been poorly handled prior to despatch to Carnarvon and/or frozen beyond a reasonable time frame. It had a very distinct dirty smell and was clearly ammoniated. More detail of recovery trials for each type of Leatherjacketraw material supplied to Abacus is described below.

- Offcuts: The pieces were all skin on and many contained small fragments of bone or cartilage. This meant every piece had to be handled and examined for bone etc. The pieces were too small to be put through the separating system. It was clear that this potential source of raw material was not economically viable.

- Headed and gutted, skin off: The fish were of poor quality and exhibited a very distinct unpleasant odour. These fish did not go through the separator well, as there was no skin to effectively squeeze against the flesh and push it through the drum. The flesh that did come through became soft and mushy. The flesh needed to be put through the 5mm drum to effectively remove all of the small bone etc.

- Headed and gutted, skin on: These fish were also of poor quality. They produced much better textured flesh when put through the separating system, than the skin off fish. However the current advice from the supplier is that it is highly unlikely fish will be available in this format in the future at a price that would make them commercially viable to transport to Abacus.

These results show the importance of whole of chain quality control for raw material for such waste transformation/value-added production activity. This part of the project also emphasised the preferred option to have the separation/separating unit adjacent to the initial processing line to save costs and also better manage the quality of the raw material.

4.5 Blue Swimmer Crab

Raw Blue Swimmer Crab mince was separated through the separation equipment for some of the reforming trials conducted at CSIRO (Section 5), but generally this process was not considered commercially feasible for large scale production.

With seconds cooked Blue Swimmer Crab, that is those not able to be sold frozen, cooked and whole, premium meat was picked and the carapace removed and discarded as it does not contain any meat or

recoverable protein. The remaining Blue Swimmer Crab carcass was then passed through the separating system, and the separated cooked mince was subsequently frozen for later processing.

Unfortunately the frozen separated mince from the seconds cooked Blue Swimmer Crabs, on thawing, is a product with very little flavour or texture and an unpleasant mouthfeel. A further issue was that the liquid would always separate from the solids upon defrosting or heating. As the proteins had already been cooked they had no ability to bind with the liquids and they were squeezed out of the matrix. This made it difficult to create anything with a desirable texture and mouthful. Cold set binding of the Blue Swimmer Crab mince to produce a formed product was attempted (Section 5), but results were hindered due to the lack of flavor/texture.

A logical outcome for this product was for it to be used as a filler to increase the percentage of actual Blue Swimmer Crab in higher value products. It was considered the best use was to be included in formulations such as sauces, soups, pastes or the like where it could be concentrated to maximise its flavour/umami or in products where texture and mouthfeel are predominantly from other components of the formulation. This concept has already been achieved in the Abacus Blue Swimmer Crab cake retail product (CRC 2010/706) and was forwarded in the lasagna and dumplings work in the current project (Section 6).

However towards the end of the project, a new piece of equipment, a “screw press”, was sourced by Abacus Fisheries and the work on the cooked Blue Swimmer Crab mince was recommenced. Using the screw press the liquid could be effectively separated from the solid cooked protein. Separating the liquid allowed manipulation of the flavour profile in the meat and has reignited the sweetness and slight sea flavour of fresh cooked white Blue Swimmer Crab meat. After the “screw press” process the liquid can be stabilised and blended back into the solids to form a homogenised product. The flavour of the resulting product is fresher and obviously Blue Swimmer Crab. This retextured and stabilised product can now be the base product to work from in all new formulations that may use the Blue Swimmer Crab mince in the future. Samples of this stabilised product have now also been sent to Japan for aligned product development work on Blue Swimmer Crab surimi.

A stock made from the cooked Blue Swimmer Crab mince was a great product of good flavour and depth. It became helpful when producing valued added products to boost the Blue Swimmer Crab /seafood flavour profile.

4.6 Prawn Meat

Prawn meat separation for new product development was undertaken in two scenarios

- Frozen underutilised/low value Coral Prawns, were thawed, peeled, thinly diced through the bowl cutter then mixed with the other ingredients and chilled ready for value-added product development. Frozen Royal Red Prawns were also tested using a similar process, but had insufficient flavour.

- Soft and broken Western King Prawns, were peeled, put through the larger dicer, and then added to the ingredient mix.

4.7 Recoveries, Microbiological and Compositional Results for Separated Seafood Protein

Separated seafood by-products were sent to Symbio Laboratories and Merieux NutriSciences for compositional analysis to assist with product formulation work and microbiological testing for food safety plan. Combined results from all the species tested in the recovery trials are shown in Table 1 (Separation Efficiencies and General Comments) and Table 2 (Proximate, Compositional and Microbiological analyses).

Table 1: Separated Fish Protein Product for Reforming and Product Development Trials

Product	Source	Separation Efficiencies	Comments
Snapper2016 (2mm/7mm)	Samples from fresh frames from filleting machine.	See Appendix 4	See Section 4.1
Raw Blue Swimmer Crab 2016 (7mm)	Abacus Fisheries	25-28% from shell after claw and premium meat removed.	
Raw Blue Swimmer Crab 2014 (5mm)	Abacus Fisheries		
Raw Blue Swimmer Crab 2015# (5mm)	Abacus Fisheries		Salt 1.3%
Cooked Blue Swimmer Crab 2014 (5mm)	Abacus Fisheries	45%	Section 4.5
Hammerhead Shark 2016 (7 mm)	From frozen headed and gutted trunks product (Albany Seafoods).	80%	Section 4.2
Reef fish (trawl) 2014 (5mm)	From frozen frames sent by Kailis Bros (Perth).		
Atlantic Salmon 2014 (5mm)	From frozen frames sent by Kailis Bros (Perth).	30%	
Leatherjacket2015 (7mm)	From frozen H and G product (MG Kailis)	50%	Section 4.3
Patagonian Toothfish 2016 (7mm)	From frozen frames sent by Catalanos (Perth).		Section 4.4
Western Rock Lobster legs 2015	From frozen legs sent by Western Rock Lobster Processor in Cervantes	40.1%	Had to be run through twice,

Table 2: Analysis of Separated Fish Protein for Product Development Trials

Product (all frozen then thawed)	Microbiology	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Comments
Snapper 2016 (2mm/7mm)#	TPC:50,000/g; *E.coli*<3/g; List ND/25; Staph<100/g	79.1	19.8	<0.1	1.5	Samples from fresh frames from filleting machine. 7mm is good quality taken from right end of fillet, 2mm is

Product (all frozen then thawed)	Microbiology	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Comments
						poorer quality taken from left end of fillet. Frozen after separation.
Raw Blue Swimmer Crab 2016 (7mm) Raw Blue Swimmer Crab 2015# Raw Blue Swimmer Crab 2014	TPC:21,000/g; *E.coli*<3; List ND/25; Staph<100/g; TPC 7500/g;Entero <10/g	82.5 81.2	15.1 15.5	<0.1. 0.5	2.2 2.5	 Salt 1.3%
Cooked Blue Swimmer Crab 2014	TPC 50,000/g	79.8	18.1	0.8	2	
Hammerhead Shark 2016 (7 mm)	TPC:250,000/g; E.coli<3/g; List ND/25; Staph<100/g	72.9	28.9	<0.1	1.2	From frozen product.
Reef fish (trawl) Mince 2014	TPC 16,000/g	77.2	18.6	2.5	1.1	From frozen frames sent by Kailis Bros.
Atlantic Salmon mince 2014	TPC40,000/g	56	16.1	22.6	0.8	From frozen frames sent by Kailis Bros.
Leatherjacket 2015# (7mm)	TPC 51000/g; Entero <10/g	81.8/80.13				From H and G product. Salt 0.3%

CSIRO Food safety risk assessment undertaken on these products to allow sensory trials .

5. Development of Reformed Seafood Protein Products using Alginate/Cold Set Binding.

Initial alginate/cold set binding trials to investigate reforming with the various fish protein sources separated from the waste products (as per Table 2) were sub-contracted to be undertaken at the CSIRO

Coopers Plains facility under the direction of Dr Aarti Tobin.

Peter Jecks and Janet Howieson attended the Coopers Plain facility for three days in October 2015 to take part in the Phase 1 CSIRO Trials. These trials focussed on binding/reforming of protein separated from Atlantic Salmon and reef fish, and raw and cooked Blue Swimmer Crab mince.

The trials demonstrated binding of the waste products was possible with mince separated from finfish frames and three (of ten trialled) binding combinations were identified as key for further study. It was found that whilst binding of raw/cooked crustacean mince was possible, it appeared that the raw Blue Swimmer Crab /crustacean material would require a modified binding approach. The detailed results are summarised in a report prepared by Dr Tobin and available on request from Curtin University as Appendix 1 with the final conclusions and recommendations reproduced below.

General Comments from Part 1 (CSIRO) Trials

pH of seafood raw material ranged from 6.22 – 8.04, which is considerably higher than beef (~5.6). This could have had some impact on the effectiveness of the cold-set binders used in these trials, which are also commonly used binders in the red-meat industry.

Due to the high surface area of mechanically deboned reef fish and Atlantic Salmon (5 mm minced type product), and the high pH, the percentage of binder required to form the bind was considerably higher than that previously used for minced red meats like beef and lamb.

Two binding systems (Reform IT200 and 3 part CSIRO alginate binding system) were able to bind reef fish and Atlantic Salmon, resulting in acceptable product that could be sliced and diced.

Cold-set binders used in these trials were unable to bind raw or cooked Blue Swimmer Crab meat. It had been hoped that if a cold-set binding system had worked for either of these raw materials, the results would have been comparable to other crustaceans of interest in the project (prawns, rock lobster).

No sensory studies were undertaken during these trials as there was uncertainty of the microbiological safety and the quality of the raw materials. Both reef fish and Atlantic Salmon had significant amount of bones and scales in it to make them unsafe for consumption. It was also unknown if the raw materials were prepared from "edible" status "waste" (frames) products. In order to conduct sensory studies, the edible status of the product needs to be maintained throughout the processing stages.

Future Work

Part 2 of the seafood cold-binding project should consider using different raw materials, such as shark and Leatherjacket, as these fish do not have scales and would minimise any contamination of the mechanically deboned meat from the frames of these fish with scales. Shark (from sustainable sources) and Leather jacket raw material should be evaluated using the two cold-set binding systems resulted in an acceptable product for reef fish and Atlantic Salmon. These were:

- *3 part CSIRO binding system consisting of alginate, calcium carbonate and glucono-delta-lactone*
- *Reform-IT200 from IMDC Australia Limited.*

Once the 10mm machine is installed at Peter Jecks factory, various forms of the meat (meeting appropriate food safety guidelines to maintain the edible status of the product) should be separated and, following consultation, a mix of composite samples should be developed for retesting at CSIRO (e.g. effectiveness of reforming, impact of cooking, taste/texture, drip loss, impact of thawing etc).

A Phase 2 research program for the cold set binding trials was thereafter developed with Dr Tobin. The Phase 2 Cold set binding fish trials focussed on Atlantic salmon, reef fish, Leatherjacket and Pink Snapper. The detailed results are summarised and available on request from Curtin University as Appendix 2. Peter Jecks sourced a new binder (Activa EB) for the trials as Reform IT200 was no longer available. This binder had superior performance when compared to the other binders tested.

In summary a successful binding process was eventually developed for raw fish separated protein with a Japanese binder (Activa EB), and results indicated that this binding process could be used for all separated finfish protein. Scale up trials (2-5kg) were completed by CSIRO and naked and crumbed (Figure 7) reformed product were subject to informal sensory analysis in November 2016. Rodger Graf from Creative Cuisine was able to successfully test the binder to produce a reformed fish product in a commercially valid context (Figure 8). Raw Blue Swimmer Crab binding was partially successful with the Japanese binder.

The CSIRO phase 2 report stated that:

- The scale-up trial was successful. The bind and texture of the Snapper (reformed) product was not affected by using semi-commercial size equipment.
- Once the product was frozen and thawed: the texture of the product becomes slightly rubbery, chewy and a bit too salty.
- Crumbing of the product gave product a good texture and flavor.

In the next stage of the project the Activa EB binder was tested with separated fish protein in larger scale trials to produce reformed fillets at the Abacus facility. These results are reported in Section 7.5

Figure 7: Cold set bound naked and crumbed Snapper mince product produced by Dr Aarti Tobin at CSIRO.

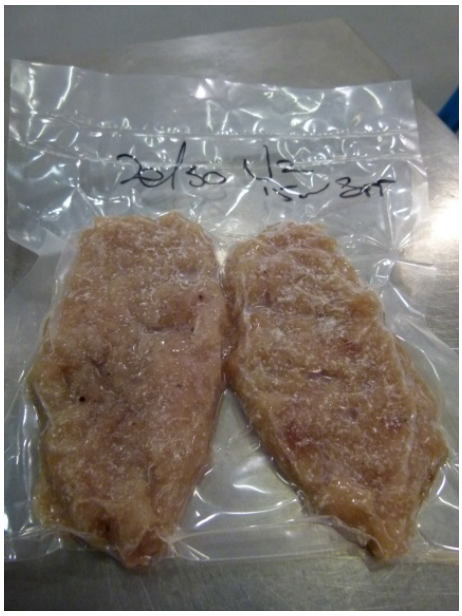


Figure 8: Cold set bound Snapper mince product produced under commercial conditions at Creative Cuisine.

6. Development of Reformed Products using HME

Production of the reformed products from the separated fish protein was also to be assessed using HME. This part of the project was sub-contracted to CSIRO, Werribee in November 2014.

The aim was to separate protein from the fish processing (finfish and Blue Swimmer Crab) waste and see if it could be recombined to form a protein based structure that could then be used as an ingredient in new products. The ultimate aim was to try and achieve something with a moisture level and texture similar to a cooked piece of fish. That product could then be used as a base for finished products like fish patties, sauces, soups, dumplings etc. If successful the technology could be promoted to the entire fishing industry and help to boost productivity and waste recovery across the whole processing industry.

This HME part of the project was delayed for about two years due to the CSIRO Werribee facility not having the correct equipment (specifically a suitable pump and cooling die) to undertake the HME process. This was a disappointing result as, under instruction from CSIRO, >1.5 tonnes of fish and Blue Swimmer Crab separated mince was produced in 2014 at the Abacus facility for the CSIRO extrusion trials, this product suffered considerable deterioration in the project delay period and most of could not be used for experimentation.

CSIRO purchased a suitable pump and commissioned the construction of a cooling die and in November 2016 reported that the system was ready to go. Hence a range of more recent frozen separated products were produced at the Abacus facility and transported to CSIRO and Janet Howieson, Peter Jecks and Seafood NPD consultant Andy Molyneux arranged to be at CSIRO Werribee to oversee the trials from 12-16 September 2016. An extrusion expert, Dennis Forte was also contracted by CSIRO to oversee the trials.

These trials in September 2016 had limited success due to the fact that the cooling die was incorrectly constructed and did not cool the extruded product as it emerged, thereby nullifying the ability to do any work on optimising texture and form. However fish and raw Blue Swimmer Crab mince was extruded in combination with soy protein so it was agreed the methodology did have potential for further investigation. The memo summarising these trials by Dennis Forte is attached as part of Appendix 3. CSIRO committed to rebuilding the cooling die and a new set of extrusion trials were completed on the 24th and 25th October 2016. These trials also presented some operational challenges but eventually 1-1.5kg of extruded Blue

Swimmer Crab and Snapper mince product was produced (Appendix 3). However further work was considered necessary to optimise texture, flavour and the process.

In January 2017 Dennis Forte and Andy Molyneux undertook the next set of trials, and were able to produce the most favourable outcome (see Figure 9) of an extruded product with raw Blue Swimmer Crab , cooked to a slightly yellow cream colour. There was almost no shrinkage on cooling, the product was juicy and moist (just over 75% moisture, with the natural Blue Swimmer Crab being at 80% moisture). It was considered that the finished product would need to retain a moisture of >70% in order to ensure the texture remained favourable.

The key difference for the improved outcomes in the final trial was considered to be in the mixing. In initial trials the fish waste was turned into a puree which was pumped into the barrel of the extruder. A mix of dry proteins and water was also pumped into the chamber at different points. In the final trial, a mixed slurry of all of the ingredients was created, and this combined mixture was pumped into the extruder. The pre-mixing of the Ingredients, gave a much better control of the formulation, and pumping issues were avoided, good texture and flavour was achieved in the final product. Dennis Forte (extrusion consultant) stated he had not seen an outcome like this ever previously.

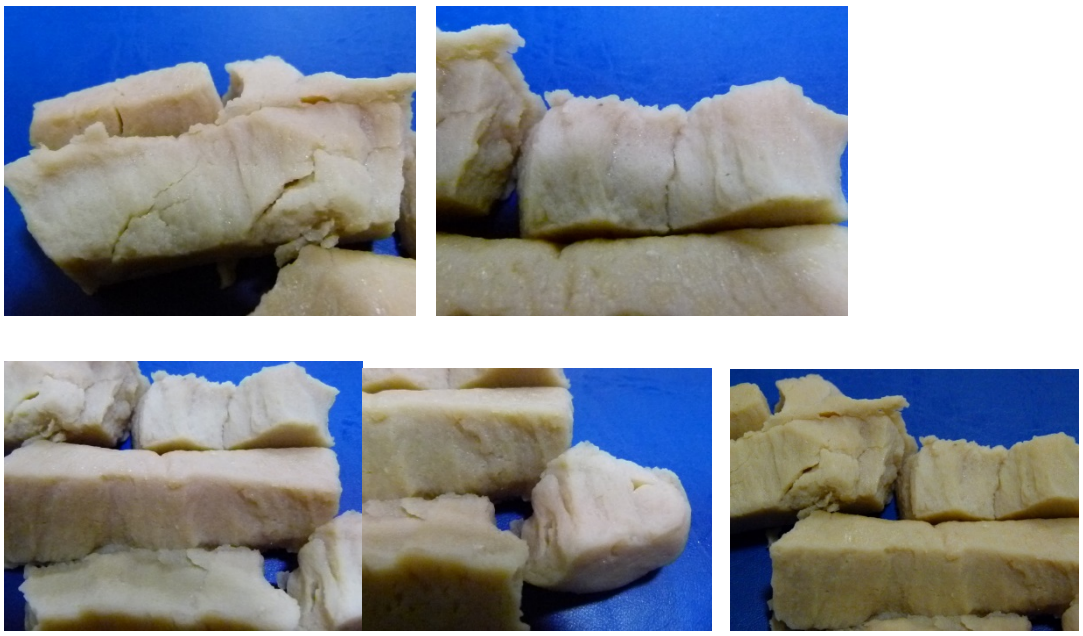
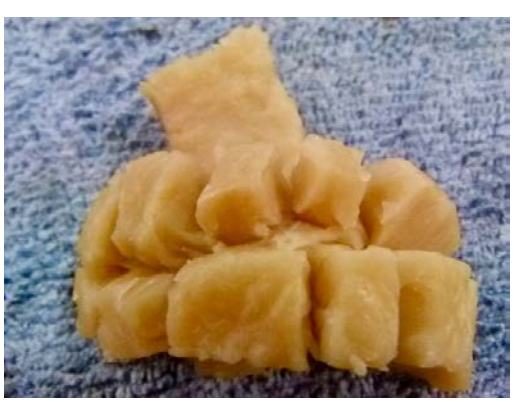


Figure 9: Extruded Blue Swimmer Crab product from January 2017 High Moisture extrusion Trials.



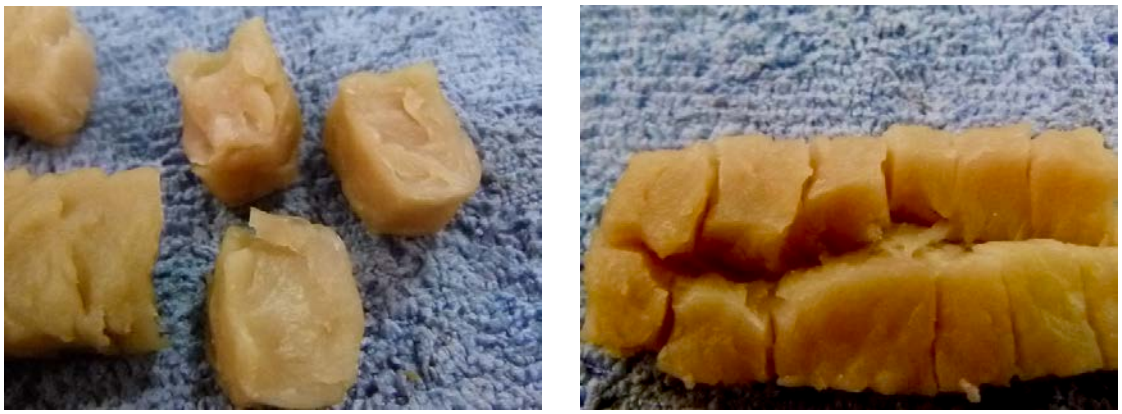


Figure10: High Moisture Extruded product from seafood protein

Unfortunately, as the current project had to be completed, there was insufficient time and availability of the CSIRO facility to conduct further finfish extrusion trials. Such trials would have tested temperature and dwell time in the barrel, as it appeared these were important influencers on the texture: it was noticed that as the temperature approached 120-125˚C the fibrillation improved. Further literature research has suggested temps as high as 140 ˚C would be even more beneficial. A possible commercial piece of catering equipment which could operate at such higher temperatures, the RotaTherm® was investigated, and a commercial trial planned based on pilot equipment availability, but there was insufficient time to do a run and test at higher temperatures on this equipment. Continuation of the HME trials is planned in a new FRDC project proposal.

The CSIRO report (including technical reports and data for all three trials) on the HME trials is presented and is available on request from Curtin University as Appendix 3 with a summary reproduced below.

Seafood by-products were sent out to Symbio Laboratories and Merieux NutriSciences for compositional analysis to assist with product formulation work and microbiological testing for food safety plan. A total of three separate trials were conducted using different screw profiles, cooling die configurations, product feed configurations, product formulations and processing parameters. Technical reports were supplied by the extrusion expert for each of these trials and the outcomes from each separate trials are summarised below:

Trial 1: HMEC equipment configuration and set up
Trial 1 was conducted on Sept 12-14, 2016 followed by plant clean up on the Sept 15.The purpose of this trial was to determine whether a suitable set up for the equipment could be achieved to produce desirable product textures from a number of different formulations. The screw profile, slurry pump, the thermo-regulator and a number of products formulations were starting to develop desirable textural changes. However, the trial was terminated on Sept 14 because the cooling die did not perform its function to cool down the product despite direct hook up to a glycol system running at close to 0 °C (which ruled out that the thermo-regulator is not fit for purpose). This was more significant with product formulation containing Vital Gluten which failed to develop any significant texture.
It was later confirmed through specific tests that the die design was not suitable for purpose due excessive wall thickness and lack of turbulent flow within the cooling cavity. On discussion with industry participant it was also decided that the shape of the product was not ideal and a more fish finger like configuration would be preferred. The decision was made to suspend the trial and redesign the cooling die before trialling the product again.

Trial 2: Validation of new HMEC cooling die
Trial 2 was conducted on Oct 28-29, 2016 followed by plant clean up on the 30th. The purpose of this trial was to continue with the concept product development process using the newly designed and fabricated cooling die. Using the experience and data from trial 1, a new set of screw profile was specified for the experiment to help improve the process. The trial confirmed that the new cooling die design together with

the original thermo-regulator has the desired impact on texture modification. The formulations with 70% soy protein isolate and 30% soy protein concentrate were found to be most promising with fish inclusion levels of up to 40%.

Trial 3: Concept product formulation optimisation and testing
Trial 3 was conducted on Jan 18-19, 2017 followed by plant clean up on Jan 20. The aim of the trial was to make some concept product for further testing and analysis by the industry participant. A number of screw profiles were tested during this trial due to process instability leading to infeed blockages issues encountered during the trials. It was determined that this blockages may be a result of fluctuating water flow and fish slurry flow which was not detected in the second trial probably due to shorter run length. Newer batch of fish waste or Blue Swimmer Crab and different screw profile did not resolve those problems nor did the removal of the cooling die. However, the removal of cooling die did create an interesting texture that was of interest to the industry participant. Due to on-going blockage it was decided that a pre-mix slurry should be prepared with all ingredients using the chopping bowl and fed directly into the extruder to minimise inconsistent feed. A number of samples were prepared using this process with promising results.

7. Development of New Value Added Products and Commercial Trials at Abacus Facility

The next stage of the project was to take the learnings from the results presented in Sections 4, 5 and 6 and undertake new product development under semi-commercial conditions at the Abacus factory. Andy Molyneux and Andrew Sankey, experienced seafood chefs and product development specialists, were appointed to undertake these trials. In all three product development sessions were conducted at the Abacus facility from August 2016 until October 2017. This section describes the various products that were developed from processing waste and offcuts during that time. Whilst the majority of effort was on several versions of Snapper cakes and croquette; a Western King Prawn cake, and reformed finfish fillets; putative premium, niche retail products such as Blue Swimmer Crab lasagna, Blue Swimmer Crab Poppers (balls); Escabeche and XO sauce were also developed using the experimental processing offcuts material. Where available final recipes, production protocols, nutritional labelling information and other details of the new products are available on request from Curtin University but not included in this public document.

7.1 Snapper Cake (Version 1)

Based on early feedback from the market including chefs and small supermarket chains, the initial product development work focussed on using the Snapper mince (high and low grade mince from different Snapper fillet waste products through the 2mm and 7mm separator (see Section 4.1) to produce a Snapper cake. Diced chunks of lower grade fish fillet were added to the mince for the cake production, but it was hoped that these chunks would be replaced by extruded diced product once the HME processes were optimised. The detailed results of the Snapper cake product development work are summarised (including nutritional profiles and production processes) and available on request from Curtin University as Appendix 4.

In these trials it was also demonstrated that the principles of using Snapper mince as the raw material for the Snapper cake could also be extended to other species so future commercial trials could also include testing of other species including Blue Swimmer Crab, shark, Leatherjacket and catfish in the same recipe.

Figure 11: Snapper Cake (Version 1)

7.2 Snapper Cake (Version 2) and Snapper Croquette

Based on market feedback it was decided to change the original version of the Snapper cake, as later end-user feedback indicated that the recipe needed to be boosted with larger chunks of reformed fish, and these had not (as hoped) been produced from the HME research (see Section 6). Also changes in the marketability of the Snapper products from 2016 to 2017 meant that market preference (and improved profitability) was for a whole or headed and gutted Snapper product. Filleting and therefore production of frames for separation of Snapper mince was therefore mostly ceased. In addition, economic and logistical assessment of the Snapper Cake (Version 1) demonstrated that a number of the ingredients were going to be difficult to access due to seasonality. So the Version 1 recipe and production protocols were documented and thereafter set aside (in an "investment ready" form) until a lower cost way of adding the larger fish pieces was achievable, and availability of seasonal herbs and Snapper mince was improved.

A new Snapper cake recipe was developed to utilise the larger chunks of Snapper flesh separated from the head (See Section 4.1). Some potato was added to reduce costs. The advantage of using the head meat was an improved flavour and a much better visual when biting into the cake. The Snapper mince cooks to a grey or brown colour and so it was necessary in the Snapper cake Version 1 to disguise the colour. By contrast the white flakes of the head meat were easily visible in the newer version and had an obviously better texture. Also it is not generally acceptable good manufacturing practice to combine a cooked protein (ie the head meat) and a raw protein (ie the mince) into the same formulation. All ingredients in the new version of the Version 2 of the Snapper cake were therefore pre-cooked before mixing.

The Snapper cake (version 2) recipe was modified to gain the correct umami balance, sodium levels, and ratio of proteins (see mixture of ingredients in Figure 12). Yield recovery and process on the potato mash were calculated and documented, the final recipe and production protocols were documented and available on request from FRDC.

Figure 12: Snapper cake (Version 2) mixed ingredients

Crumbing trials on the Version 2 product once the recipe had been optimised were extensive, with ten crumbing formulations and crumbing adhesion combinations tested. It was further considered desirable that a suitable (and potentially gluten free) coating be developed. These detailed crumbing results are available on request.

Generally the panko crumb was used for the Version 2 Snapper cake. However, in formulating a gluten free crumb, the trials resulted in a 50/50 blend of rice and corn being preferred for the base of the dry coating. This mix was found to be very robust with extended cooking, with no sign of over colouring or burning even with an extended cook time. It was quite neutral in flavour and therefore did not detract from the flavour of the fish cake. The rice did not colour at all and the corn cooked to a pleasing golden yellow, so visually the end product was quite attractive. At this ratio no corn flavour could be detected.

A number of different texturising elements were then added to the base crumb and 25% rice, 25% corn, 25% cooked white quinoa flake, 20% puffed amaranth, and 5% sesame seeds was considered to give the best result (See Figure 13 and 14).

Figure 13: Crumbed Snapper cake (Trial 6) (gluten free) after cooking.

Figure 14: Optimised gluten free crumbing mix and crumbed Snapper cake after cooking.

The new Snapper cake (Version 2) recipe allowed the option to easily modify the seafood protein form and the other ingredients due to seasonality issues. Because of the versatility of the base recipe it will be possible to make different flavour profiles with minimal alterations to the formulation. These can be altered or introduced to the market as required or as a promotional line in different seasons.

Similarly the base crumbing mix takes advantage of a base that can have additional dry ingredients added to make flavour variations without having to change any of the other ingredient ratios. This means the recipe has potentially a good commercial life as it can be constantly reinvented.

Pricing and costing for the Snapper cake (Version 2) are now being completed and packaging formats are being finalised. The major factors that will affect the cost will be the formulation of the coating and the ratio it is applied to the cake, and the ratio of the head meat included in the formulation.

The Snapper croquette was a further evolution that could allow greater volume of finished product to be produced because of the inclusion of a significant percentage of potato into the formulation. The addition of higher proportions of the potato was the reason behind the decision to rename the product as Snapper croquettes. Feedback from major retailers on price point was also taken into consideration, and influenced the decision to develop the croquette formulation as well as a Snapper cake format. The coquette coating will be the standard small panko crumb and batter as used on other commercial Abacus Fisheries products. The internal formulation is gluten free. The optimised gluten free crumb developed for the cake could be applied to the croquette product if there was a demand from the market.

A final production formulation for the Snapper croquette has been decided and a trial batch was produced in the production machinery during October 2017.

The Version 2 Snapper cake and Snapper croquette product are “investment ready.” The producer is investigating packaging options and cost benefit analysis. However commercial launch is planned for late after the intended finish date of the current project.

7.3. Western King Prawn Cake

The Western King Prawn was developed in this project following the continued commercial success of the Abacus Blue Swimmer Crab cake (CRC 2010/706), and in response to an offer from a local prawn company to supply lower value coral prawns and soft and broken king prawns to Abacus Fisheries for potential use in value-added products. Market/end-user interest was also a factor in the prawn cake development.

The prawn cake was developed utilising thinly diced Coral Prawns as a binder and larger dices of Western King Prawn for texture and mouthfeel (see Section 4.6). The product also contains garlic reduction, lemon zest and spring onions, with a Panko crumb. More than 24 versions were developed before optimisation of the final formulation.

The frozen product was launched in a retail pack (see Figure 15) in Easter 2015 and remains on sale in IGA and Farmer Jacks supermarkets.

However, production was temporarily ceased in 2017 due the increase in price of the raw prawn ingredients, which resulted from the prawn white spot disease outbreak and the subsequent banning of importation of prawns into Australia. This increased price for the coral and soft and broken king prawns made commercial production of the prawn cakes temporarily economically unviable. Pending prawn prices, production is hoped to recommence in 2018.

Figure 15 Crispy King Prawn Cakes retail pack.

7.4 Blue Swimmer Crab Lasagna

Based on end-user requests a Blue Swimmer Crab lasagna was developed using the cooked Blue Swimmer Crab mince in the meat layer and the stock as the base flavour of the white sauce that is spread between the layers of pasta. Premium Blue Swimmer Crab body meat was also added separately to the lasagna mix. Photos of the Blue Swimmer Crab lasagna production process can be seen in Figure 16.




Figure 16: Different stages of the Blue Swimmer Crab lasagna production process.

Several versions were made to optimise the ratio of pasta to white sauce and to determine the correct number of layers of pasta that gave the most pleasing bite. Variations in the amount of red sauce and the assembly method of the pasta were trialled. Wine, cheese and fresh and dried herbs were trialled in various stages to help develop the flavour profile. In one version fresh cooked claw meat was substituted for the premium frozen meat. This meat was not thought to bring a sufficiently better flavour profile to justify the extra cost of the claw. A test sample of the lasagna was put through the high pressure pasteurization (HPP) facility (600 psi for 8 minutes). Informal tasting indicated that the HPP seemed to have helped accentuate the flavour of the Blue Swimmer Crab in the product.

Informal sensory analysis determined that the Blue Swimmer Crab lasagna was not ready for market due to flavor and texture issues. Further development suggestions included:

i. More trials need to be done to determine if fresh cooked premium body meat has a texture and flavour advantage over using previously frozen premium body meat. This may mean the lasagna would be produced only during the Blue Swimmer Crab fishing season and on the same days as the Blue Swimmer Crab is cooked and picked.

ii. Work needs to continue to see if it is possible to increase the Blue Swimmer Crab flavour. More combinations of different cheese that may bring more umami need to be trialled. The red sauce base also needs to be worked up to perhaps boost its flavour, and maybe to sweeten it to help match the sweetness of the Blue Swimmer Crab. If the product is to be sold as a fresh chilled product and subjected to the HPP process then work needs to be done to stabilise the red sauce, as this appears to have split during the HPP trial. A suitable method to roll the pasta also need to be developed. A consistent assembly method will be crucial to ensure there is a minimum of weight variations between individual portions.

The Blue Swimmer Crab lasagne has not yet been finalised. The difficulties with the last trial batch were identified as being mainly associated to the already described flavour problems (see Section 4.5) with the Blue Swimmer Crab mince as the ingredient. It is expected that the stabilisation and retexturing of the mince as described in Section 4.5 and subsequent use as an ingredient in the lasagna will result in improved flavour, leading to a close to final formulation. This optimisation, beyond the timelines of the current project, is hoped to be completed in a subsequent new project.

7.5 Reformed Fish Fillet

Reformed fish fillets using cold set binding were further developed to pilot commercial level at the Abacus Fisheries facility, following on from the preliminary work conducted at CSIRO with Dr Aarti Tobin. The final reformed fillet product included Snapper mince, belly flap and the fillet recovered from the Snapper racks. Snapper stock from the bones was used to rehydrate the Activa binder before addition to the fish mix. Two out of three members of the informal tasting panel agreed this produced a very acceptable reformed fish product (see Figure 17). As in the preliminary CSIRO trials described in Section 5 crumbed and naked fillets, in chilled and frozen forms, were produced.

Figure 17: Reformed fillet trials.

Some further findings/observations from the reformed fillet product work are summarised below:

- Leatherjacket as a partial replacement of Snapper was tested as the source of finfish. As mentioned in Section 4.4 the bulk Leatherjacket supplied was poor quality and was of little value in the product development work. However, given the subtlety of flavour found in Snapper flesh, the opinion was that reducing the percentage of Snapper and substituting it with Leatherjacket would diminish the quality and credibility of the product. It is therefore not recommended to mix different species in the reformed fillet. It is probably noteworthy that the CSIRO trials described in Section 5 indicated that

the reforming methods developed were equally applicable across a range of finfish raw materials, so a range of reformed fillet types from different finfish species could potentially be produced.

- Using different sources of Snapper protein (eg from mince, belly flap and rack fillets) for the production of the reformed fillets will maximise the use of the filleting processing by-products. However consideration needs to be given to the correct ratios of the different sources of fish by-products so as to achieve the optimum mouth feel and texture, and also to ensure that each source of protein can be produced in the correct volumes from the waste available from the primary processing. The final reformed fillet product showed the value of having the three types of fish protein as it was possible to produce a dense structure with a minimum of cavities as the different sizes of the recovered proteins all bound together well with a minimum of mixing.

- CMC (methyl cellulose) addition was trialled in the reformed fillet as this compound prevents drip loss in both fresh and frozen products. Drip loss on thawing of frozen product can result in moisture in the crumbs, wet crumbs tend to burn rather than cook nicely. However the trials did not support the proposed inclusion of CMC. Additions at all of the CMC levels trialled (up to 2%) all produced a pasty mouth feel in the reformed fillet once it had been cooked.

- Glycerin addition was trialled, as this compound can act as cryoprotectant for the proteins in the formulation following freezing. The glycerin (up to 2%) had no discernible effects on the flavour, texture or organoleptic qualities of the reformed fillet, and did not interfere with the reforming action of the binder. The impact of extended freezer storage and measurement of drip loss on defrosting and analysis of mouthful needs to be further investigated to determine if the glycerin has had the desired cryoprotectant effect. Formulations with different percentage inclusions need to be undertaken as part of later trials.

- Various starch product additions were tested as starch can take up moisture loss to prevent droplets of water moving to the surface of the fillet on cooking. Different starches were trialled to determine the starch with the most desirable function qualities. Starch addition can also prevent splitting of the product on cooking. A modified tapioca starch (1450) was deemed most suitable. This starch formed a nice gel, cooked clean and had no impact on flavor. Further trials are required to determine the best balance of mouthfeel verses moisture retention and synthesis once cooked. Extended freezing trials are also suggested.

Although a reformed Snapper finfish fillet, naked and crumbed, chilled and frozen, was successfully produced, a very precise and repeatable process needs to be developed. As well longer term freezing trials need to be conducted.

In 2017 work was halted on the production of the reformed fillet, as it was considered to be not economically viable if the large Snapper pieces needed for adequate mouthfeel had to be sourced from the Snapper head or fillets. It was always part of the planning that these chunks would be sourced from the extruded product expected to be produced from lower quality Snapper mince following optimisation of the high moisture extrusion trials at CSIRO.

The lack of raw material was another reason this line of experimentation was halted. As discussed in Section 7.2, the market changed such that other non-filletted Snapper products generated a higher rate of return, thereby reducing the level of filleting and therefore the amount of mince that was produced from the frames. Leatherjacket from Port Lincoln, South Australia was considered as an alternate source of raw material. However, the bulk order was delivered in very poor condition and was ammoniated. This was after a very difficult and protracted exercise to even secure supply, it was decided the economics of trying to source from an inconsistent supply and the achievable wholesale margin did not warrant further investigation of this raw material opportunity, unless the equipment was at the source of the supply.

The reformed fillet results remain a potential opportunity to be forwarded when a consistent, quality supply of raw material(s) can be obtained. This potential has been highlighted for institutional catering as the technology allows ~98% fish product, portion controlled.

7.6 Blue Swimmer Crab balls/poppers

The preliminary formulation of the Blue Swimmer Crab and corn popper/Blue Swimmer Crab balls commenced in a previous project (CRC 2010/706) have, through the course of this project, evolved into a finished retail ready product. Three formulations have been finalised, structured around a core base mix with different flavours added into the base. The three flavours are a basic seafood Blue Swimmer Crab ball, a Blue Swimmer Crab and corn variation, and a lemon, ginger and coriander and Blue Swimmer Crab version. The retexturing and stabilisation of the frozen Blue Swimmer Crab mince (Section 4.6) was instrumental in being able to develop these three products. The products were also developed with the sourcing of the ginger and coriander from local growers. The naked formulation is gluten free and a gluten free coating can also be applied to these if there is a demand. The current coating formulation is a panko crumb.

The Blue Swimmer Crab balls are retail ready, orders have been received from a major Victorian food retail distributor, nutritional and labeling information have been submitted and this supermarket group are awaiting samples for presentation/packaging trials etc. Once these trials are completed the supermarket group has indicated that a large order (initial order of sixteen pallets) are expected in 2018. It is hoped that raw material supply and production protocols will be developed such that this possible order can be filled.

7.7 Escabeche

An escabeche product was produced using the Snapper head meat (see Figure 18).

Figure 18:Escabeche product formation

The escabeche is a finished formulation and retail ready, with preliminary retail trials completed at a local Carnarvon outlet in 2017. Informal shelf life testing is showing the product is still in good condition almost 12 months after the first trial batch was packaged. However this shelf-life testing needs to be formalised.

However, the Snapper market again changed and in 2017 whole fish were the most economical product and therefore there were no heads available for extracting the head meat for escabeche production. Retail release of this product will depend on emerging market conditions for pink Pink Snapper.

7.8 XO Sauce

Traditionally XO sauce has always been made with dried scallop and dried prawns. It is a revered product in China and Hong Kong, and is very expensive in these markets. It was considered that a new form of XO sauce, using Australian wild harvest Blue Swimmer Crab meat, could be a premium niche Asian product.

Late in the current project, a new form of XO sauce was produced using the original frozen Blue Swimmer Crab mince, roasted to reduce moisture, and adding bacon, local chilies, shallots, peppers and garlic, Shaoxing wine, fish sauce, brown sugar, fresh lime juice. No preservatives were trialled.

A local market has been identified in Carnarvon.

High pressure pasteurisation trials were conducted to try and extend the shelf-life of the product (Figure 19). Results of these trials are forthcoming. Further development of the XO sauce could not be completed in the time frames of the current project.

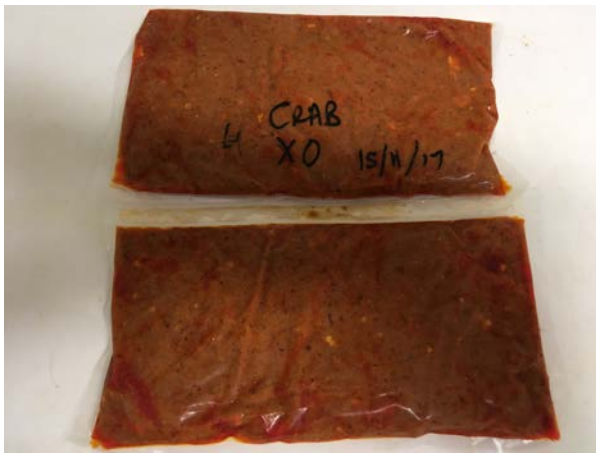


Figure 19: XO sauce product (without (top) and with HPP treatment.

7.9 Seafood Dumplings

Late in the project, a Blue Swimmer Crab mince dumping filling was produced using the retextured frozen Blue Swimmer Crab mince (Section 4.5) and local garlic, sesame oil, spring onion and Shaoxing wine. There has been interest from another major processor who would also like to explore making a dumpling utilising waste from their own operation. The major obstacle going forward is access to a dumpling line to do the trials. This product has great export potential, however further development was not possible in the current project timelines.

8. Market launch

A summary for the current status and market trials for each of the value-added products produced in the project is listed below. It is noteworthy that in response to a request from FRDC the current project was completed, before final formulations of some of the products could be developed. It is expected that such final formulation and also the extension of the project outputs to other finfish processors will be undertaken in a subsequent project under consideration by the relevant FRDC committee.

- Snapper Croquette: The Snapper croquette is ready for large scale commercial trials/production. Packaging is on order before large scale production commences. Due to market fluctuations, long term supply of suitable Snapper raw materials remains problematic. Snapper Cake 2 will not be commercially viable unless extruded product chunks can be produced to add larger lumps of fish to improve mouthfeel and texture. Snapper cake 1 was ceased due to lack of raw material (Snapper mince from frames).

- Western King Prawn cake: This product has been on the market and selling in local supermarkets.

- Lasagna: Flavour testing with the restabilised Blue Swimmer Crab mince (Section 4.5) needs to be completed. Economic viability and markets needs to be assessed. May require minor adjustment of tomato sauce.

- Reformed Fillet: Binding technology has been successfully developed for flesh dice and mince from a range of finfish species, and crumbed and naked product forms produced. Final formulations and production protocols need to be optimized. Market feedback is required to establish preferred format (chilled/frozen, naked/crumbed (gluten free?) and portion size. Commercial viability needs to be established, it is likely that high moisture extrusion trials or similar reforming technology needs to be optimised to produce chunks for improved texture at lower costs.

- Escabeche: Small scale retail trial was very successful, but Snapper head meat became unavailable due to market changes. There is a need to identify niche markets and do formal shelf-life testing.

- Blue Swimmer Crab balls/poppers: Three versions of this product are retail ready, and a major supermarket has committed to orders pending agreement on labelling, packaging, production protocols and price. Production is expected to commence in 2018, pending raw material supply and economic viability.

- XO Sauce: Market interest has been established, there is a need to finalise formulations and production protocols and undertake formal shelf-life testing.

- Dumpling filling: Product is possible to produce but specialized factory equipment is needed for large scale production.

9. Reporting and Extension.

Milestone reporting was undertaken as described in the project application.

Table 3 summarises the extension activities and publications from the project.

Table 3: Extension Activities and Publications.

Publication/Product	**Detail**	***Status***
YouTube Video	*Seafood Waste Transformation (initial and proposed project was a winner of the Curtin University (Health Sciences) Commercial and Innovation Award.*	*U-Tube release (through Curtin University) in late 2014*
Workshop Presentation	*Industry Perspective: Fisheries'* *RIRDC Food loss workshop, Canberra, April 24th 2015 (invited).*	*Delivered in April 2015*
Workshop abstract/presentation	*3rd National Workshop on Blue Swimmer Crab. CESSH Post-harvest research and extension update for the Blue Swimmer Crab (invited).*	*Delivered in June 2015*
Conference presentation/abstract	*World Seafood Congress, Grimsby 2015:* New Opportunities for Seafood By-Products: An Australian Perspective.	*Delivered in September 2015*

Conference presentation/abstract (joint between J.Howieson and Peter Jecks)	*Seafood Directions 2015: Reaching our End User: Examples from the small seafood business world.*	*Delivered in October 2015*
Conference presentation/abstract	*High protein Opportunities from Seafood(invited) AIFST National Conference (Brisbane)*	*Delivered in June 2016*
FISH Magazine	*Seafood Waste article*	*Published September 2016*
ABC Radio	*Interview with Peter Jecks on waste transformation*	*April 2017*

It is noteworthy that a submission summarising the results of CRC 2010/706 (Accelerated New Product Development: Blue Swimmer Crab pilot project) and preliminary results from the project reported here, was successful in winning the Curtin University (Health Sciences) Commercial and Innovation Award for 2014. A video highlighting the success/potential of the research was produced by Curtin University Marketing.

10 Conclusions

10.1 Challenges and Barriers to Value-added Product Development

A number of findings, from the project and associated with developing new products from seafood processing by-products, are summarised below.

a. The project builds on the concept of total utilisation of the seafood resource. This was particularly studied in the Snapper example: Snapper products investigated included fillets, wings, belly flaps, mince (of different qualities), head meat and stock from the bones. This seafood total utilisation concept, well established in the meat and pork industries, is well supported by current market and government drivers to demonstrate sustainability and reduction of food waste, and enquiries for further investigation are now being received from major seafood processors.

b. One of the biggest barriers to the development of the new value-added products, generally (see also FRDC 2013/711.30: new opportunities for underutilised species) and from seafood processing waste is access to an economically and commercially viable, consistent supply, of sufficient volumes of quality raw material. This becomes more difficult when processing is occurring at remote sites such as the Abacus facility in Carnarvon. Without consistent raw material supply, recipes cannot be standardised and consistent new product supply to end-users cannot be guaranteed.

    - This raw material availability is often compromised by the volatile and changeable nature of the commercial fishing industry and aligned markets. As a result, the project saw continuous evolution of new products (and often shelving of earlier versions), as a consequence of this volatility, particularly around raw material availability and fluctuating prices. Some examples are described below:
    - Following 2015 and 2016 trials on Snapper protein (as mince) separated from the filleted frames, in 2017 the market changed to make headed and gutted Snapper product the most market favourable. As a result there was little filleting (and therefore little mince recovered during that season) and research effort (and new product development) had to change to focus from products using the mince (reformed fish fillets and the Snapper cake

(version 1)), to products that used the head meat chunks (escabeche, Snapper cake (version 2)

- The price of soft and broken king prawns and coral prawns changed in 2016, due the banning of imports as a result of the white spot outbreak, and hence it was no longer economically feasible to include this product in the prawn cake. The prawn source was therefore expected to be changed to lower value deep sea prawns, but this raw material compromised the final product quality.
- Markets for toothfish offcuts emerged during the project so that the participating producer company was no longer interested in taking part in product development work.

One strategy to counteract such changes in the market place is to design robust products, with flexibility for ingredient changes. This was tested successfully with the developed Snapper croquette, Snapper as the fish could be replaced with other species. Similarly the binding methodology developed for the reformed fillets was tested and could be used with a variety of different finfish species.

Another strategy to offset the issues of raw material supply maybe to work with larger volume processors where raw material supply can be better consolidated and is less subject to price and availability fluctuation.

c. Economic feasibility of developing new products from processing waste will also likely require the separation and stabilisation of the seafood protein at the primary processing facility. Costs to freeze frames, transport and thaw primary waste product (such as frames) before secondary processing at another site were prohibitive, whereas transport of frozen, separated fish protein was an option. This feasibility was tested at the Abacus factory on site and immediate secondary processing of fresh Snapper filleting off cuts, and subsequent freezing of separated protein for later product development.

d. The project has demonstrated the need to ensure technical expertise and suitable equipment is available when new and emerging food processing technologies are being tested. The timelines and outcomes of the project were compromised when it became apparent, after the signing of the subcontract, that CSIRO did not have the necessary equipment to undertake the HME trials. It may be more prudent in the future to work with commercial producers of the processing equipment. These companies often have test kitchens and technical expertise and are willing to work with producers on new product development. Similarly, as was conducted here, on site trials at the participating processor with appropriate external product development expertise may also result in accelerating commercially viable outcomes.

e. This project has also shown that previous work can be revisited with the subsequent advent of new technologies. As an example the lack of flavour from the frozen Blue Swimmer Crab mince resulted in the lasagne recipe being sidelined in this project and the Blue Swimmer Crab balls/poppers being sidelined in a previous project (FRDC 2010/706). However, the new “screw press” technology to address the Blue Swimmer Crab mince flavour issues is expected to result in improved flavour outcomes of the Blue Swimmer Crab lasagne, and also facilitated the further development of the Blue Swimmer Crab poppers, which have now been ordered by a major supermarket.

f. This project has emphasised the results of previous projects (CRC 2010/775; 2010/706) in regard to the difficulties encountered by small businesses in developing viable new product distribution strategies. Previously the larger distribution companies employed salesman who would assist small operators with gaining market share for their new products. Now however, the larger distributors tend to only “lift and shift”, with an expectation that the small producers would do the marketing (eg visiting chefs and food service/retail outlets) for their own product. Small operators do not have the time or resources to undertake such marketing activity.

10.2 Technological Outcomes

Despite the challenges a number of technologies have been developed that can be applied generally to seafood processing waste new product development.

These technologies include

a. Optimisation of mechanical separation of seafood protein (as mince) from a range of fish frames, headed and gutted product and cooked crustacea. Separation was optimised as appropriate through 2, 5, 7 and 10mm apertures. Recoveries were optimised and product parameters, including volumes, quality, composition and microbiological food safety, were investigated. The separated protein was then made available for other product outcomes.

b. A screw press separation method was developed to optimise ingredient parameters (eg flavour, stability) for frozen cooked Blue Swimmer Crab mince, a major by-product of the Abacus processing activity. Use of this product was previously limited due to issues of flavour and form on thawing. This improved ingredient can now be added to improve the quality and marketability of a range of value-added products from past and current project development. This technology can now also be applied to other frozen, separated waste materials.

c. Cold-set binding to produce reformed fillets from various forms of finfish separated protein was achieved (in partnership with CSIRO). This binding process was modified and trialled in two commercial food processing facilities. Raw and cooked Blue Swimmer Crab binding was also trialled with limited success.

d. High moisture extrusion (HME) of finfish and Blue Swimmer Crab waste to produce reformed products, was developed to a point where it seems likely a positive outcome can eventually be achieved. It was expected that these reformed extruded products could then be made available as ingredients for further new product development. However, due to initial issues with CSIRO equipment, this further development could not be achieved in the current project timelines.

10.3 Economic Evaluation and Market success

The project resulted in the production of eight possible value-added products from seafood processing waste. Then, with economic and commercial feasibility evaluated, as well as marketability, one new product (prawn cake) has been launched, two others have identified markets (Blue Swimmer Crab poppers and XO sauce), one ready for retail (awaiting packaging) (Snapper croquettes) and four others developed but not being taken forward at this stage due to various issues (lasagne, reformed fillet, escabeche and dumpling filling). It is perhaps noteworthy that due to earlier delays in the project, it was requested to be finalised before some of the final product formulation work could be completed. It is hoped that this work can be completed in a new project currently under consideration by the relevant FRDC committee.

In discussions with the industry partner two critical areas when examining economic evaluation and market success of new products, particularly for smaller businesses, are:

- Ensuring consistent quality supply of the raw material, at a consistent price. Many of the developed products whilst “investment ready” and sometimes launched, were not able to be developed into consistent prolonged production due to either the raw materials becoming either unavailable or not price competitive due to market changes.

- This project has emphasised the outcomes of previous projects (CRC 2010/775; 2010/706) in regard to the difficulties encountered by small businesses in developing viable distribution strategies for new products. Previously the larger distribution companies employed salesman who would assist small operators with gaining market share. Now however, the larger distributors tend to only “lift and shift”, with an expectation that the

small producers would do the marketing (eg visiting chefs and food service/retail outlets). Small operators do not have the time or resources to undertake such marketing activity.

11. Recommendations and Next Steps

A number of next steps are advised, in particular around the cold set binding and HME technologies and in further developing the new products produced in the project. It is noteworthy that further trials are intended to be conducted in a new project, currently under FRDC assessment, after the current project report is finished. This is because due to technical issues and delays due to CSIRO in the HME work, it was not possible to finalise development and evaluation of all the possible options for rigorous and reproducible protocols for fish protein recovery and reformation by HME in the current project timelines.

11.1 Separation and Reforming Technology

Cold Set Binding

This methodology to produce reformed finfish fillets from processing by-products has been shown to be technologically viable. Final formulations and production protocols need to be optimised. Market feedback is required to establish preferred format (chilled/frozen, naked/crumbed (gluten free as an option) and portion size. Commercial viability needs to be established, it is likely that high moisture extrusion trials or similar reforming technology needs to be optimized to produce chunks for improved texture at lower costs.

High Moisture Extrusion

The three CSIRO trials succeeded in generating some interesting concept product textures and even unexpected learnings that was not anticipated. Whilst further HME work is required to be able to further refine the process for potential commercialisation it does show that this can succeed given the proper set up and product formulation. More work is required to make this happen by trialling a number of product formulations using premixed ingredients and varying HME run parameters with and without the cooling die. It has also become apparent during the trials that at least two different product concepts were discussed, one being a fish finger like frozen retail product (with cooling die) and the other a crumbed fish like texture analogue for incorporation as fish substitute in culinary recipes (without cooling die). The decision will have to be made which will have more potential and fully develop one concept before proceeding to the next.

Investigation of other reforming technologies.

At a late stage in the project, the project team was introduced to a new technology, the RotaTherm®. The manufacturers considered that a new piece of equipment, RotaTherm®, which can cook up to 140˚C, might be a novel means to produce a product format similar to the extruded product from the HME trials. The possible benefits of increasing the cooking temperature are explained in Section 6.

It was suggested that the separated fish protein could be processed/heated with the RotaTherm® then the product bound back together and/or build the fibrillation with an aligned secondary working section. This secondary working section stretches and works the product aligning the protein to create long chains.

The manufacturers offered a free trial of the equipment but, this trial offer did not fall into the timelines for the current project. It is therefore intended that this new technology be trialled with separated finfish product in the proposed new project currently being assessed for funding by the FRDC.

11.2 Strategies for Improving Economic Opportunity for new Value-added Seafood Products on the Market.

A number of value-added products produced in this project were of significant interest to end-users but for various reasons large scale production was not conducted. As described in the conclusions, these reasons were mainly associated with difficulties in gaining consistent, cost effective supply of quality raw material, and a lack of marketing and distribution support.

Final recommendations therefore are

a. Such research work should be undertaken in cooperation or partnership with larger seafood processing operations so that technology development is supported and longer term production is less likely to be compromised by a lack of or change to supply of consistent quality raw material at a reasonable cost.

b. Work in cooperation with distribution networks or develop collaborative distribution strategies (eg hubs) that can assist with sustained market development and distribution particularly for smaller, regional operators.