Research Travel Grant Report:

PhD student Shan He pre-commercial trials of research outcomes at industry partner: Simplot Australia

Shan He

Project No: 2011/753

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NON-TECHNICAL SUMMARY

PROJECT NO: 2011/753: Pre-commercial trials of research outcomes at industry partner: Simplot Australia

("Implementation of PhD research to industry partner Simplot Australia")

PRINCIPAL INVESTIGATOR: Shan He (Australian Seafood CRC PhD student)

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(PROJECT) OBJECTIVES OF RESEARCH TRAVEL GRANT/ INDUSTRY BURSARY

The objective of this research travel grant is to develop Australian Seafood CRC PhD student Shan He's professional knowledge of transferring laboratory-scale results to a pre-commercial food model for industry benefit, and also to build his professional skills and industry experience.

After one and half year's research, Shan has achieved outstanding scientific outcomes. However, these results have not been applied to an industrial application because of the limitations of the biotechnology laboratory at Flinders University in formulating food products, and in the knowledge of the industry partner's food process and formulas. This research travel grant supported Shan to apply these results to commercial food formulations at Simplot Australia, the project's industry partner. The trial activity and industry interaction will train Shan to be an industry-ready PhD graduate in the near future, so as to be able to better serve the Australian seafood industry.

NON TECHNICAL SUMMARY

In the one month industry visit (28th Oct-28th Nov), supported by an Australian Seafood CRC Research Travel Grant, Shan achieved good outcomes at Simplot Australia, in both experimental results and understanding of the pathway for the application of new scientific methods in industry.

In experimental results, Shan applied fish protein hydrolysates into two simulated food formulations: fish cake and battered fish, and found that the fat content of deep fried fish cake can be reduced from about 12% to about 2%, and the fat content of battered fish can be reduced from about 7% to about 4%. These experimental results indicate the great potential of producing low fat content fried food with health benefits, by applying fish protein hydrolysates in fried food formulations. This is an example of how the Australian Seafood CRC's laboratory research outputs can be translated into industrial outcomes.

To understand food manufacturing operations in industry, Shan talked to managers of different divisions in Simplot Australia related to science, such as the New Products Process & Portfolio Manager, Science & Technology Manager, Group R&D Manager etc. Shan

understood their tasks and duties from these talks, and familiarized himself with a key decision making system of Simplot Australia called the Stage Gate System. All these information that Shan gained from the communications developed his understanding of the role of science and technology in industry.

The combined outcomes of the aforementioned two aspects developed Shan's professional knowledge of transferring laboratory-scale results to industry products, built his professional skills and industry experience, and thus successfully prepared him to be an industry-ready PhD graduate in the near future.

However, a large gap between the good experimental outcomes and industrial production of fish protein hydrolysates still exists. This is mainly due to scale-up in production, and the lack of business analysis and business plan, such as production cost calculation. This results in the lack of a strong case for investment. The team plans to develop a rudimentary business plan in 2012 so as to fulfil Australian Seafood CRC's aim which is to transfer laboratory results for industrial benefits. Support from the Australian Seafood CRC is the key to achieving this.

OUTCOMES ACHIEVED TO DATE

1. By replacing 1% fish mince with fish protein hydrolysates in fish cakes, the fat content of deep fried fish cake can be reduced from about 12% to 2% in industry tests.

2. By replacing 1% of fish mince with fish protein hydrolysates into the coating material of crumbed fish fillet, the fat content of final battered fish products can be reduced from about 7% to 4% in industry tests.

3. By communicating with managers of different divisions related to product development in Simplot Australia, and operating in Simplot's product development laboratory, Shan gained better understanding of the the application of science in industry; this trained him to be an industry-ready PhD graduate.

ABOUT THE PROJECT/ACTIVITY

BACKGROUND AND NEED

After one and half year's research, Shan has achieved outstanding scientific outcomes. These include: 1. Understanding the chemical composition of fish processing co-products of Atlantic Salmon and Yellowtail Kingfish; 2. Establishing a processing method to produce fish protein hydrolysates from fish processing co-products of Atlantic Salmon and Yellowtail Kingfish; and 3. Understanding the good physicochemical properties (oil binding capacity, emulsifying capacity and water binding capacity) of fish protein hydrolysates for food applications.

However, these results have not been applied to an industrial application because Flinders University's biotechnology laboratories do not have the capacity and equipment to formulate these products in the same manner as its industry partner Simplot. This research travel grant provided the opportunity for Shan to work at the facilities of his project partner, Simplot Australia, used their capacity to transfer the knowledge of how these protein hydrolysates can be used for improved food manufacturing and healthier consumer products.

RESULTS

(1). Apply fish protein hydrolysates (FPH) in fish cake formulation

Fish cake formulation of this study was applied to simulated fish products. Basa fish mince was blended evenly with mashed potato as the base, in the ratio of 3:2. For original fish cakes without fish protein hydrolysates, a 50g base was mixed with 5g egg white and 5g plain four to represent 'standard' fish cake dough. For fish cakes with fish protein hydrolysates, a 50g base was pre-mixed with 2g (4%), 1g (2%), and 0.5g (1%) of fish protein hydrolysates from four different processing methods (enzymatic process, microwave-intensified process, chemical process, microwave-intensified chemical process), respectively, then 50g each of these mixtures was mixed with 5g egg white and 5g plain four as fish cake dough. Different fish cake dough were put into a cake mould to form the same shape, frozen overnight, then deep fried at 180^{o}C for 8 minutes. The fried fish cakes were stored at -20^{o}C overnight and then their fat contents were tested following a method developed by Simplot Australia (**Fig. 1**).

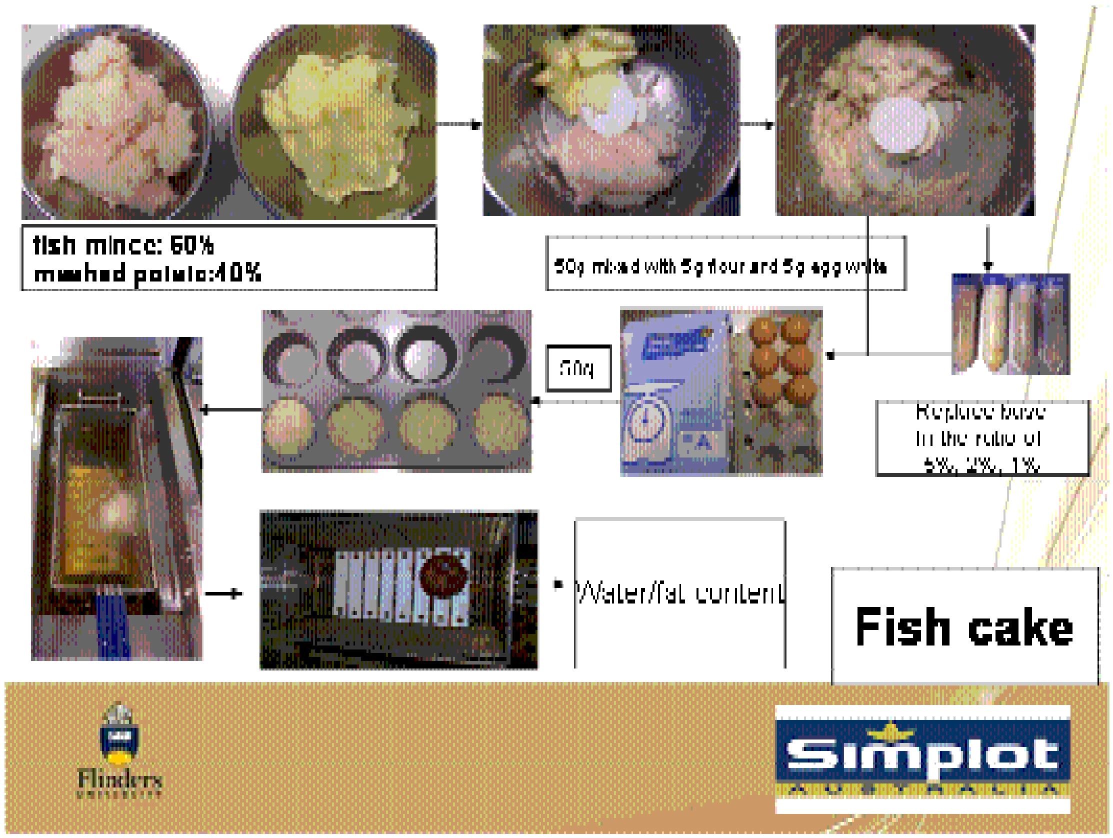

Fig.1 *Flow diagram of producing fish cakes in Simplot Australia (PPT from Shan's final presentation to Simplot Australia)*

Fat contents of different fish cakes are presented in **Table 1**. It shows that by introducing fish protein hydrolysates into the fish cake formulation, the fat content of deep fried fish cakes can be significantly reduced. After cooking by frying in oil, the fat content of fish cakes without fish protein hydrolysates was 11.76%, whereas this fat content can be reduced to as low as 1.27%, by involving 1% fish protein hydrolysates produced by chemical process. This is an **89.2% reduction** in fat content from the absorption of cooking oil!

Table 1

Fat contents* (%) of fish cakes

Concentration of FPH / **Processing Methods**	**4%**	**2%**	**1%**
Enzymatic process	2.74^{aA}±0.08	1.87^{aB}±0.13	2.01^{aB}±0.17
Microwave intensified enzymatic process	3.67^{bA}±0.32	1.93^{aB}±0.21	2.28^{aB}±0.19
Chemical process	6.37^{cA}±0.36	1.27^{bB}±0.17	2.58^{aC}±0.29
Microwave intensified chemical process	4.75^{dA}±0.75	2.43^{cB}±0.16	2.63^{aB}±0.21

Fish cake without FPH after frying: 11.76±0.62

*Average of 3 reading per trial + standard deviation
Within each trial, different lowercase letters and capital letters in superscript indicate significant differences ($p<0.05$) in the same column and same row, respectively, according to one-way ANOVA and LSD test.

(2). Applying fish protein hydrolysates in battered fish

Basa fish fillet was minced, and then formed into oval shape using a fillet mould to simulate commercial fish fillet products. The shaped fish mince (about 70g of each) were frozen overnight at -20C then dipped in three batter layers sequentially (proprietary Simplot formula).

1% of fish protein hydrolysates from the different processing methods were used to replace an equal part of the first layer batter powder and the third layer batter powder separately.

Simulating the processing method of Simplot Australia's commercial battered fish products, the battered fish fillets were deep-fried for 25 seconds at 190^{o}C then frozen overnight. Fat content was tested. Crispiness was tested two minutes after oven-baking the frozen battered fish at 220^{o}C for 20 minutes (**Fig.2**).

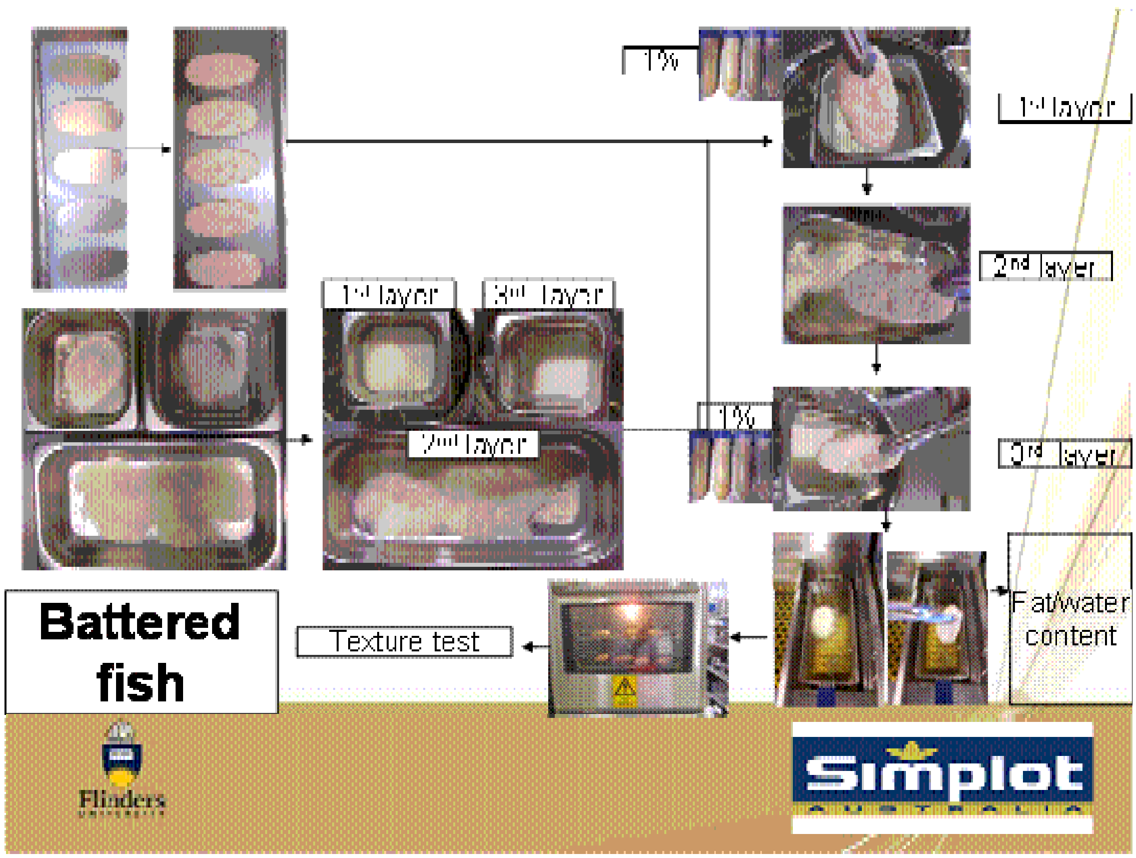

Fig.2 *Flow diagram of battered fish simulated production method at Simplot Australia (PPT from Shan's final presentation in Simplot Australia)*

Fat content of battered fish is demonstrated in **Table 2**. It can be seen that, by involving 1% fish protein hydrolysates in the third layer batter system, the fat content did not change comparing with original battered fish without involving fish protein hydrolysates. However, by introducing fish protein hydrolysates into the first layer batter, 1% fish protein hydrolystates from chemical process can reduce fat content from 7.27% to 4.75% after frying, and hydrolysates from the microwave intensified chemical process can also reduce fat content from 7.27% to 5.50% after frying. However, it was noted that fish protein hydrolysates from enzymatic process and microwave intensified enzymatic process did not produce the same results.

Oil binding capacity of fish protein hydrolysates from these four processing methods, ranked from high to low are: Microwave intensified enzymatic process (16.44 g oil/g hydrolysates), enzymatic process (12.14 g oil/g hydrolysates), chemical process (8.66 g oil/g hydrolysates) and microwave intensified chemical process (6.25 g oil/g hydrolysates). It can be seen that the trend of oil binding capacity of fish protein hydrolysates produced from these four processing methods generally matched the trend of the battered fish's fat content that involved the use of these four fish protein hydrolysates.

Table 2

Fat content* (%) of battered fish

	1^{st} layer batter	3^{rd} layer batter
Enzymatic process	$8.65^{aA}\pm0.45$	$7.34^{aB}\pm0.25$
Microwave intensified enzymatic process	$8.80^{aA}\pm0.49$	$7.79^{aB}\pm0.39$
Chemical process	$4.75^{bA}\pm0.11$	$8.15^{aB}\pm0.76$
Microwave intensified chemical process	$5.50^{bA}\pm0.04$	$9.52^{bB}\pm0.11$

Battered fish without involving fish protein hydrolysates after frying: 7.27±0.05

*Average of 3 reading per trial + standard deviation
Within each trial, different lowercase letters and capital letters in superscript indicate significant differences ($p<0.05$) in the same column and same row, respectively, according to one-way ANOVA and LSD test.

INDUSTRY IMPACT

PROJECT OUTCOMES (THAT INITIATED CHANGE IN INDUSTRY)

Fried food usually contains a high content of fat, which is detrimental to human nutrition and health, with links to the onset of cardiovascular diseases, digestive and metabolic diseases and related conditions such as obesity. Using fried fish cakes and battered fish as models, the outcomes of this project demonstrates that fish protein hydrolysates are able to significantly reduce the fat content of fried food. This outcome is desirable by both the food industry and consumers, and may be able to initiate formulation change of fried foods by the manufactured food industry, especially fried fish-based processed foods with the aim of producing low fat content, fried food for healthy diets. Due to the human health and product value benefits, production of fish protein hydrolysates at industrial scale is worthwhile to be considered in future.

SUMMARY OF CHANGE IN INDUSTRY

(What immediate changes might be expected for business/industry?)

The first change that can be expected for business/industry is the awareness of the health, manufacturing and cost benefits, in both the fish processing and food manufacturing industries, resulting from the manufacture and use of fish protein hydrolysates.

This can result in:

(A) Further investigations of the health and product benefits by processed food companies such as Simplot, to determine the costs and benefits to their products;

(B) Fish processing companies examining the benefits and cost savings to their current waste management systems;

(C) The set up of pilot processing plants to produce sufficient FPH for small scale product development trials, food safety and consumer trials. These trials would enable (1) raw material suppliers to investigate the business potential of integrating this technology into their current production systems; (2) processed food manufacturers to develop new product lines or modify current products to employ the use of FPH. These trials can also be used to develop modular systems and optimised processes for further scale-up.

WHAT FUTURE AND ONGOING CHANGES ARE EXPECTED?

(What will be the impact?)

(1) In the fish processing industry, improved waste management and therefore cost-savings can be expected. By processing fish processing co-products to fish protein hydrolysates as an ingredient for food formulation, rather than dumping the food-grade materials at an average cost of more than $150/tonne, will change this “cost-centre” to “benefit centre” for many fish processing factories.

(2) Between industries, a new material supply pathway and its associated revenue growth can be expected. Fish protein hydrolysates supplier-purchaser chain can be set up by cooperating businesses between industries majoring in fish processing (‘supplier’, due to their large volume of fish processing co-products) and industries majoring in food processing (‘purchaser’, due to their demand of raw ingredient in food formulation).

In the processed food industry, new healthy seafood products can become major new revenue streams for businesses. Businesses can apply fish protein hydrolysates in fried food to improve their formulation, especially fried seafood formulations, to produce fried food (or processed food for frying) with low fat content for customer’s health benefit. These include fish fingers, battered fish patties and fillets, crab sticks (“Surimi”) and battered prawns and squid.

(3) Fish protein hydrolysates can also be applied to other food products due to other food functions, such as emulsifying capacity and water binding capacity, as functional ingredients to improve food’s quality.

WHAT BARRIERS ARE THERE FOR CHANGES TO OCCUR?

1. High production cost: production of fish protein hydrolysates requires the use of enzymes and the purchase of industry-scale equipment if microwave intensification technology is employed. All these costs cannot be ignored especially the equipment costs. It can cost, depending on scale, millions of dollars to purchase suitable equipment but of course, the food industry aims to get its investment back in as short a time as possible – usually 3 years. This is because new products introduced into the market place rarely have a market life beyond 3 years; thus, companies need to get a return for the capital investment in this timeframe. Low volume of fish processing co-products in individual factories. Though there are over 100,000 tons of fish processing co-products produced in Australia annually, these are distributed in different processing factories located in different places. This results in logistic difficulties and high cost of collection for value-added processing. For example, though Simplot Australia realized the value of fish protein hydrolysates, it is not cost-effective for them to produce it because of their low volume of fish processing within their own facilities; however they are willing to purchase it, if it can be supplied by an ingredient supplier.

2. Food safety costs: A fish protein hydrolysate is unlikely to fit the definition of "novel food" as per the FSANZ Food Code, and therefore would only need to comply with the relevant food safety guidelines for production and processing. However, this would be at a cost to the manufacturer of the ingredient. Lack of application studies into fish protein hydrolysates: though functions of fish protein hydrolysates have been broadly studied in the laboratory, its applications in commercial food formulation have not been widely investigated. More research in this field needs to be conducted. The action of this project is an important first step in the right direction.

3. Lack of business analysis and plan: though the functional research into fish protein hydrolysates has a laboratory history, the cost calculations and business plan about scaling up its production for industrial demand and marketing, have not been conducted before. This information is crucial to attract investment for this business and to fulfil Australian Seafood CRC's aim: transfer laboratory result to industry benefit.

IF NOT ALREADY HAPPENING, WHEN WILL THE CHANGES OCCUR?

(e.g. 2 businesses will adopt project findings and two more are expected to adopt findings within 12 months)

Considering this is PhD work, and only at preliminary stages – with no business case at this point, Simplot would need the business case first with the possibility that after 12 months project findings may be adopted. This would also be dependent on the volume available.

WHAT IS THE LIKELIHOOD THAT THESE CHANGES WILL OCCUR?

(e.g. 50% chance that four businesses will adopt project findings)?

There is 70% likelihood that major fish processing factories will adopt the project findings, if food processing companies like Simplot Australia express interest in the FPH product.

Otherwise, export-driven demand can drive the adoption of the technology within Australia, to higher value export markets such as Japan.

WHAT BARRIERS ARE THERE TO ADOPTION OF THESE CHANGES AND WHAT ACTION COULD BE TAKEN TO OVERCOME THESE?

(e.g. to adopt project findings will require group training/sharing equipment/invest additional capital etc.)

<table>
<tr><th>Barriers</th><th>Actions to overcome</th></tr>
<tr><td>High processing cost</td><td rowspan="3">A business analysis and plan is needed. Support from Australian Seafood CRC is crucial to accomplish this. The plan is:

Flinders will talk to fish processing factories in Port Lincoln, and to Simplot Australia, Melbourne, with the aim of mapping a fish protein hydrolysates supply-purchase chain for consideration by the respective participants.

Simplot Australia has expressed interest in purchasing fish protein hydrolysates as an ingredient for use in their products; but the business is unlikely to take up the FPH production technology as it does not fit their business model.

Fish processing factories in Port Lincoln are producing large volumes of fish processing co-products annually. The new technology for value-adding these co-products (rather than disposal at high cost) can be interesting to them. At the same time, processing cost of producing fish protein hydrolysates is relatively low due to the large volume of co-products.

Our cooperation strategy is to:
(1). Set up a pilot processing facility by engaging a fish processor who is willing to champion the technology with (or without) a food industry ingredients supplier.
(2). Approach food companies, such as Simplot Australia, as potential major customers of fish protein hydrolysates.

The strategy is able to make a win-win situation for both ingredient provider and ingredient purchaser.</td></tr>
<tr><td>Low volume of fish processing co-products distributed across individual food processing factories</td></tr>
<tr><td>Lack of production cost calculation, business analysis and plan</td></tr>
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Lack of information about applying fish protein hydrolysates as an ingredient in commercial food formulation	More industry driven food formulation research is need and this can be conducted as a technology translation project through the CRC.

COMMUNICATION OF PROJECT/EXTENSION ACTIVITIES

WHO IS/ARE THE TARGET AUDIENCE/S?

Businesses whose main activities are fish processing (these can be fish protein hydrolysates producers and suppliers, such as fisheries businesses in Port Lincoln) and those involved in food processing (these can be potential purchasers of fish protein hydrolysates, such as Simplot Australia).

WHAT ARE THE KEY MESSAGES?

Fish protein hydrolysates produced from fish processing co-products can be applied in battered and fried seafood to reduce the uptake of cooking oil and in so doing, reduce the fat content of the consumed food. These can be marketed as low fat content fried food for healthy eating.

Food processing companies are interested in this project's FPH as a formulation ingredient if it can be purchased as a ready-made ingredient. Therefore, the initial market for the production of fish protein hydrolysates is almost secured if it can be produced at a reasonable price.

WHAT IS THE CALL TO ACTION?

(What is it you want people to do once you communicate the key message to them – i.e. what change of behaviour or action do you want them to take?)

1. Commitment by fish processing and food processing businesses to a project to investigate the market for FPH, and demonstrate prototype products
2. A seafood business study: Conduct production cost calculation, business analysis and plan of producing fish protein hydrolysates at an industrial scale. Financial support from Australian Seafood CRC is crucial for this.
3. Commitment by a business champion to set up a pilot-scale processing line to produce fish protein hydrolysates using fish processing co-products as raw material. This is best driven fish processing businesses with large volumes of fish processing co-products. The involvement of a food processing business is also essential to ensure market uptake and determine food standards.
4. Commitment by a business champion to set up a pilot-scale processing line to produce fish protein hydrolysates using fish processing co-products as raw material. This is best driven fish processing businesses with large volumes of fish processing co-products. The involvement of a food processing business is also essential to ensure market uptake and determine food standards.

COMMUNICATION CHANNELS

(How can these messages be communicated and by who?):

Channel	*Who by*	*When*
Lincoln Marine Science Centre/ Flinders Marine Bio-products Development Centre to fish processing businesses	Erin Bubner (Australian Seafood CRC PhD graduate, currently working in Lincoln Marine Science Centre/ Flinders Marine Bio-products Development Centre)	Feb/2012

LESSONS LEARNED AND RECOMMENDED IMPROVEMENTS

WHAT IS YOUR FEEDBACK?

(e.g. *What difficulties were experienced in undertaking this research and how did this affect the project*, *what improvements and/or considerations can be recommended for future projects in this area* and *what barriers are there to undertaking further research in this area and how could these be overcome?)*

During the time of undertaking this research, the difficulties I was facing included:

1. Research concept difference between university and industry: university research focuses on scientific discovery, rather than commercialisation. On the other hand, industry research is commercial driven, with market needs as its priority.
2. Difficulty of commercially producing fish protein hydrolysates in order to trial uptake: It is not cost-effective for Simplot Australia to produce fish protein hydrolysates, due to their low volume of fish processing co-products, which leads to high production cost. They would like to purchase fish protein hydrolysates directly as ingredient if it can be produced somewhere else.

Improvements/considerations recommended include:

1. More communications between researchers in universities and industry is needed. It will be helpful if a work experience program for Australian Seafood CRC students in industry can be established. This program can let students understand industry operation systems and work atmosphere, enabling them to connect academic knowledge to industry needs. This will train them to be industry-ready PhD graduates in the near future to better serve Australian seafood industry after PhD graduation.
2. Business analysis and plan, such as production cost calculations for producing fish protein hydrolysates in industrial scale need to be conducted in future. This is crucial for Australian Seafood CRC's aim which is to transfer laboratory outcomes for industry benefit.
3. Develop a scheme to support pilot scale trials so as to encourage uptake of technologies by industry. A fund co-managed by the Seafood CRC, in conjunction with other funds such as Commercialisation Australia, could improve the uptake of technologies by providing much needed funds to reduce business risk.

FURTHER ACTION REQUIRED IN REGARDS TO COMMERCIALISATION?

(e.g. IP protection, licensing, sales, revenues etc)

1. IP protection of processing methods used to produce functional fish protein hydrolysates
2. Production cost calculation, business analysis and plan
3. Market promotion of fish protein hydrolysates

ACKNOWLEDGEMENTS

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