School of Public Health

The feasibility of using waste cook water to produce a crab stock concentrate

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Abstract

Three thousand litres of potable water is used each day to cook the blue swimmer crabs which are caught by Abacus Fisheries. The crab cook water is expensive for the company to dispose of and contributes to water pollution due to the high BOD. The cook water has a good flavour profile as it contains volatile compounds, proteins and minerals. Therefore the company wanted to know if it was feasible to utilise the crab cook water to produce a crab stock concentrate. The cadmium levels in the cook water were minimal and well below the maximum residue limit even when concentrated, therefore it did not pose a risk to consumers. Proximate analysis conducted on the crab cook water determined that an increase in the crab cook load led to an increase in the components of total solids, protein, sodium and pH. The volume of crab cook water remains the same each day but the cook load does not. So, an equation was developed using the protein vs total solids regression line to determine the amount of water that had to be removed from the crab cook water to produce the stock at the desired concentration. Three different processing technologies (boiling, vacuum drying, freeze drying) used to produce stocks were evaluated and sensory analysis conducted on the products. It was determined that the concentrated liquid crab stock produced using the vacuum dryer was the most acceptable by the consumer panel. Although the acceptability ratings for the vacuum dried concentrated liquid crab stock did not have a high overall acceptability rating, this was hypothesised to be due to the fact that stock is not normally consumed as a product, but used a base ingredient or flavouring in cooking so it was not rated highly. High quality fruits and vegetables grown in Carnarvon are being underutilised so they were used to produce two value added stocks using the crab stock base (herb flavoured crab stock and a chilli tomato crab stock).

Sensory analysis conducted on the value added stocks indicated that both of the products were rated acceptable amongst the consumer panellists; however the chilli tomato crab stock was the most preferred. It was predicted that the value added crab stocks would have high acceptability ratings as it resembled more soup-like characteristics. In conclusion, the results from the research indicate that it is feasible to use the crab cook water to produce a crab stock concentrate and could also be potentially used to develop other food products.

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Chapter 1 Introduction

1.1 The seafood Industry

The industry of commercial fishing is ranked fifth as the most valuable rural industry in Australia, after wool, beef, dairy and wheat (Department of Foreign Affairs and Trade 2008). This includes lobster, crab, fish and prawns. In 2007-08, Australia's total value of fisheries production was $2194.7 Million (ABARE 2009). As the Australian seafood industry produces substantial amounts of product each year, this also means that there is a large amount of waste being generated. Waste includes seafood that does not meet the required standards and by-products such as shells & wastewater.

Abacus Fisheries is a company involved in integrated fishing that catches, processes and markets premium crab products (Abacus Fisheries 2009). It is located in Carnarvon in the Gascoyne region of rural Western Australia 906 km's north of Perth. The crabs that are caught and processed at Abacus Fisheries are Blue Swimmer Crabs which are also known as *Portunus pelagicus*. The main products produced from this species are raw and cooked whole crabs and premium crab meat. Abacus Fisheries exports their high quality crab meat to many overseas countries.

1.2 Problems

Mr Peter Jecks, of Abacus Fisheries estimates that each day they waste 3000 L of potable water which was used to boil the blue swimmer crabs (pers.comm., February 3rd 2009). The water contains volatile compounds, proteins, and minerals which have leeched out of the crabs resulting in a high BOD effluent flow. With high BOD levels found in waste water disposed by the seafood industry, plus the other incurred costs, consequently the seafood companies need to spend large amount of money disposing the effluent. For a company, disposing of 3000 L of water a day, seven days a week, this will cost over $6000 a day. Water is used for many processes in the industry such as cleaning raw seafood and cooking.

The amount of effluent that is currently being discarded into clean waterways and the ocean needs to be reduced. Water is not cheap and its supply is not as endless as it used to be. As a result there is a problem with water sustainability in many regional areas. As it is costing the company to discard this effluent, it would be preferable to find a solution to minimise the effluent being discarded. The solution could be to utilise the waste water to produce a product or to treat the water so it becomes reusable. One of the possible solutions is to treat the waste water. The problem with treatment is that not enough land is available around the factory to build a waste water treatment plant. The factory is located at the mouth of the Gascoyne River and is surrounded by residential areas so water treatment is not a viable option.

The alternative idea is produce a crab stock with the crab cook water. As the waste water already contains the volatiles from the crab, proteins and minerals, it would be a suitable option to concentrate the liquid down to produce a stock. Stock is a widely used base ingredient for many products such as chowders and soups. The production of a base ingredient potentially means a larger target market as its use is not limited.

For the stock production, inclusion of other ingredients to enhance the flavour is also a possibility. A diverse range of produce is grown in Carnarvon, including vegetable and tropical fruits crops like tomatoes, capsicums, asparagus, beans, mangoes, citrus, papaya, avocadoes, grapes and stone fruit (Shire of Carnarvon 2009). As tonnes of the perfectly edible vegetables are discarded each day, it would be ideal to incorporate this local produce into the crab stock to further enhance the flavour. Not only would it produce a higher quality product, but would also reduce the amount of waste from the horticulture industry.

1.3 Hypothesis

Abacus Fisheries faces a problem with disposing of crab cook water which is costing the company money and could be a source of potential profit for the company. The crab cook water has valuable flavour components and if turned into a crab stock concentrate would decrease the cost of disposal and produce a value added product which is innovative and new.

1.3.i Aim

The aim of this project is to determine the feasibility of developing a crab stock from blue swimmer crab cooking water and further value add it using the underutilised vegetables produced in Carnarvon.

1.3.ii Objectives

There are three objectives of this project are:

- Determine the proximate composition of the crab cook water
- Develop stocks of different concentrations using different processing technologies.
- Develop a flavoured stock using underutilised local produce.

Chapter 2 Literature Review

2.1 New Product Development

The food industry is an industry that is constantly changing. With the list of consumer demands ever changing, new products need to be developed to satisfy the consumers (Mattsson and Helmersson 2007). Companies also want to develop products which are original and have the potential to increase their share of a certain market (Mattsson and Helmersson 2007). There are also developments made in new processing technologies and scientific information that could potentially be used to create new types of products. The development of new food products or the modification of existing ones is a costly, labour intensive and long process (Naes and Nyvold 2004).

There are certain driving forces which push the food companies to develop new food products (Fuller 2005). For example, the need for food companies to reduce the cost of waste management can motivate a company to conduct research on the by-product which they are currently discarding (Fuller 2005). The research goes into finding ways to upgrade the by-product into a value added product that has a potential use as a food ingredient (Fuller 2005). The new product development process involves use of experience, creativity and scientific tools plus subjective decisions (Naes and Nyvold 2004). The goal of producing a product which consumers like and at a suitable cost can only be achieved with the incorporation of all of these elements (Naes and Nyvold 2004).

The process of new product development can be broken down into several steps but many disagree about the names, order and number of the steps (Fuller 2005). The flow diagram of the product development process (Figure 1) can be interpreted as placing a big emphasis on research and development (Fuller 2005). However many people disagree with this diagram as the new product development process represented in Figure 1 depicts the process as linear, but in reality that is not the case.

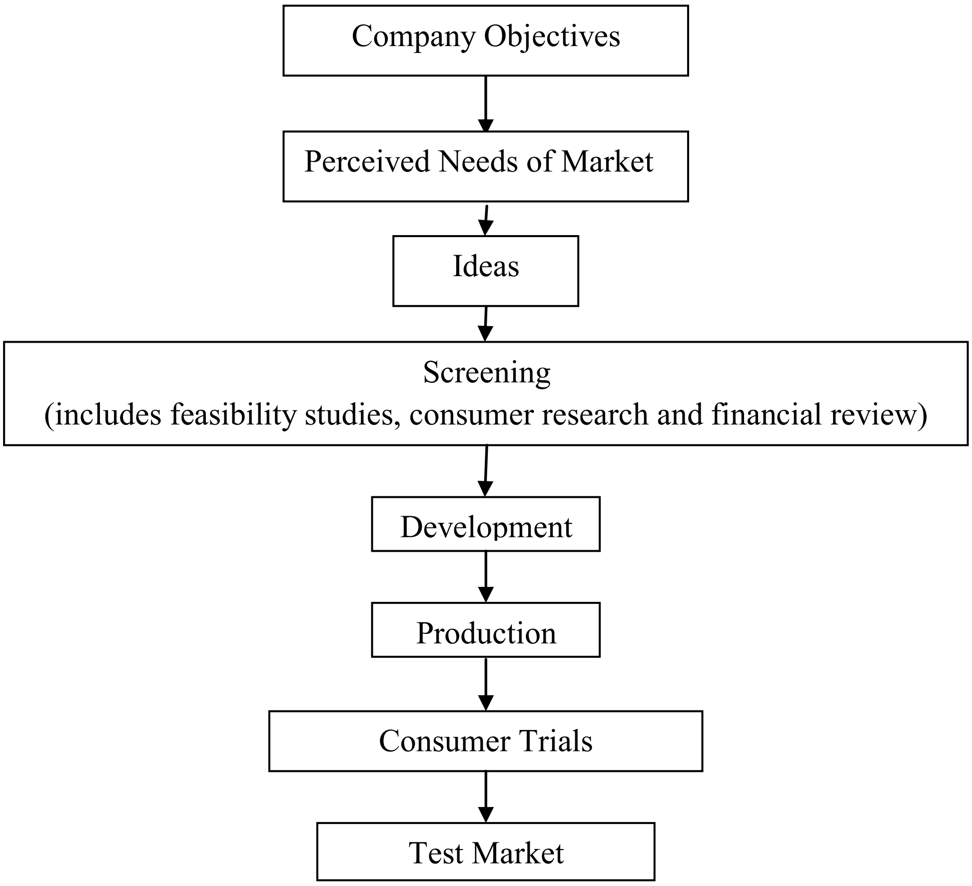


Figure 1: Phases in new food product development (Adapted from Fuller (2005))

A more realistic flow diagram is shown in Figure 2 (Fuller 2005). New product development is progressive and information gathered from each stage will influence the decisions made in the other stages. The exchange of information back and forth between each stage in product development resembles a feedback loop (Figure 2) rather than a linear process (Figure 1). The information then aids in developing standards for other factors in the process such as ingredients, equipment required and raw materials (Fuller 2005).

New information retrieved from steps later in the process can be used in earlier phases to help improve it. Therefore Figure 2 is more realistic for the reason that as development continues, new information can be used to make decisions which are more informed (Fuller 2005).

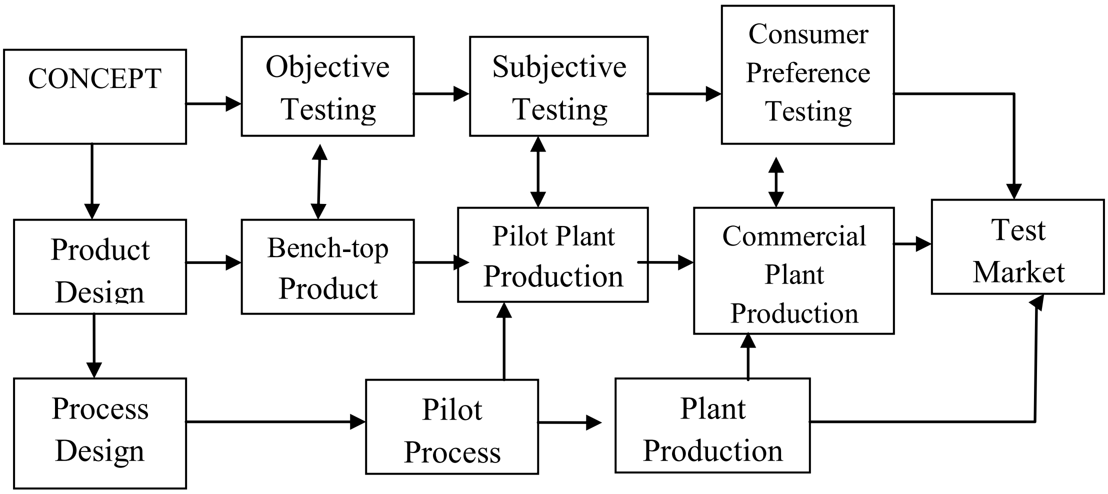


Figure 2: Idealized representation of activities flow in product development. Source Fuller (2005)

Determination of the company objectives is the step that precedes all other steps (Fuller 2005). The objectives of the company act as the basis for the product concept. In the project concept (strategy) phase, the possible new product ideas are noted. These ideas should satisfy the objectives that have been set by the food company. Earle, Earle and Anderson (2001) suggest that the sub stages of project strategy are:

- defining the project
- developing the product concept;
- identification of processes, distribution and marketing;
- development of product design specifications;
- planning of the project;
- predictions of project costs and financial outcomes.

Defining the project is the first stage of product development and is where ideas are formulated. In the initial research stage, the four aspects of consumers, technology, market and product ideas are developed as detailed aims which help shape the project (Earle, Earle, and Anderson 2001). The research conducted in this sub stage is classified as 'desk research'. This means research is conducted using the information that is within the company, published textbooks and outside records that are easily assessable (Earle, Earle, and Anderson 2001).

The project design specifications sub stage includes researching and designing. Market research is conducted to determine the needs of the target population and consumers (Fuller 2005). Market research includes looking at competitors, pricing and if the product would sell if it was produced. Technical research is also conducted in this phase. It involves searching for literature of a technological and scientific nature to conduct the preliminary investigation into the products which can possibly be made, and their physical distribution and processing methods (Earle, Earle, and Anderson 2001). The technical study describes the possible processes, products, costs and time frame required to develop and produce the product (Earle, Earle, and Anderson 2001).The tests required for chemical analysis must be determined to ensure the safety of the product for consumption. Once an idea is chosen, the specifications of the product characteristics must be noted. This acts as guidance for the food technologists which will eventually create the product.

The feasibility of developing the product is shaped by the results retrieved in the previous sub stages. The options need to be weighed up as to whether or not the different factors will affect each other which may cause the scraping of certain parts of the idea.

Constraints are an important part of product development as they, along with the aims and objectives, control and direct the project (Earle, Earle, and Anderson 2001) Constraints can be any factor that defines the area of the project (Earle, Earle, and Anderson 2001). The recognition of constraints is required but they can't be too limiting as it could possibly restrict the creativity for the process development and product design (Earle, Earle, and Anderson 2001). Environmental constraints can occur at the government level. For example, The Food Standards Australia and New Zealand sets out how much of each food additive can be included into a product. This can be a constraint if the product the company is developing exceeds this limit. The company constraints could be the lack of experienced staff to undertake the task of developing a new product. The equipment at a processing plant can act as a processing constraint if it is an older version that cannot complete the task that the company requires to produce the product. This is related to financial constraints as the company needs to determine if expense is an issue that may prevent buying the upgraded version. The product constraints can occur if development of the product will produce levels of a certain mineral or additive that compromise the safety of the consumers if they consume it.

Below is a list of areas in which other possible constraints can be recognised in development of a product (Table 1)(Earle and Earle 1999).

Table 1: Project constraints: a checklist for product development projects.

AREA:	**Product**	**Processing**	**Marketing**	**Financial**	**Company**	**Environment**
CONSTRAINTS	Eating quality	Equipment	Channels	Fixed capital	Strategy	Local government
	Composition	Capacity	Distribution	Working capital	Structure	National government
	Nutrition	Raw materials	Price	Investment	Expertise	Industry agreements
	Packaging	Wastes	Promotion	Project finance	Location	Farmers' agreements
	Shelf life	Energy	Competitors	Cash flows	Management	Economic status
	Use	Water	Size	Profits	Innovation	Business cycle
	Safety	Personnel	Product mix	Returns	Size	Social restrictions

Source: Earle and Earle (1999).

Product design and process development is the second step in new product development. Earle, Earle and Anderson (2001) state that the important outcomes of this phase are:

- Having a final prototype product which is clearly defined and that is accepted by the consumers;
- Product specifications (physical distribution, method of processing);
- Market strategy (promotion, pricing, distribution);
- Estimation of financial outcomes and investment required;
- Probability of completing project.

The third stage is product commercialisation which includes the steps of consumer preference testing, production at a larger scale and marketing. The use of sensory evaluation is required to determine if the product is liked by the target market.

Product Launch and Evaluation is the final step of new product development. The launch is usually the single most expensive step in new product development (Di Benedetto 1999). There are three important aspects involved in the launch of a product: activities, demand outputs and strategy (Earle, Earle, and Anderson 2001). Although the product is now on the market doesn't mean that it will always stay like that. There needs to be emphasis put on the requirement to monitor the product so improvements can be made when required (Alison, Paul, and David 2001). An example is to look at the sales and if there is a drop, the competitors and formulation should be looked at. A continuously changing environment and factors affect the food product therefore constant evaluation and improvement must be made for the product to continue to be successful.

There are a few interrelationships that are of significant importance in the product development process which is made up of four aspects. As there is interaction between the four aspects, it represents a sequence. The first part of the sequence is critical points which occur between each of the main stages of product development and play a vital role in the whole process of product development (Earle, Earle, and Anderson 2001). The next part of the sequence is the outcomes which is the information retrieved from the research conducted. The information influences the critical evaluation and decisions made about the product and project at the critical points (Earle, Earle, and Anderson 2001). The third part of the sequence is activities. The activities are specific for the research to build the knowledge making this related to the outcomes (Earle, Earle, and Anderson 2001). The last part of the sequence of interrelationships is technique. Technique is related to activities as the research teams are required to use different techniques to complete the activities (Earle, Earle, and Anderson 2001). This means that for the research team to get to the end result, they must take little steps to lead up to the big decision that needs to be made at the critical point.

The product development process involves the collaboration of different departments and good communication. If the objectives and plans are not clear at the beginning, there is a possibility problems will occur. Looking at the realistic process diagram (Figure 2), each of the three flows are dominated by certain departments. The food technologists are responsible for the middle flow, involving the development of the prototype (Fuller 2005). In this section objective testing would occur. This includes chemical analysis of the prototype to determine its composition and if it is safe for human consumption. The marketing department looks after the upper flow which involves interaction with consumers and the lower flow is the role of the production and engineering department where the equipment and ingredients are dealt with (Fuller 2005). Going from left to right with the progression of product development, there is constant exchange and interplay of ideas occurring between all the flows (Fuller 2005).

A reason for food companies to invest in new product development is to utilise the waste by-products that are being disposed of. In many cases the by-product has high quality characteristics such as good flavour profile and if it was utilised, it could be turned into a potentially marketable value added product. The development of waste by-products into a value-added product has to go through a similar new product development process to the one discussed. The project concept would involve thinking of possible creations that could be produced from the waste by-product. Market research is important in determining which products would be valued by end users. This information can then be used to figure out the products which can be possibly produced using the waste by-product. The different processing techniques for developing the product should be examined and development of prototypes could start. Research should be conducted into the technical aspects of possible constraints and also the processing technologies that could be used. The product produced would then have to go through the product design and process development stage to determine whether or not the prototype was accepted by the consumers. Sensory evaluation is required to determine the acceptability. Based on these results, it can be determined if the prototype is a suitable option to continue with commercialisation and product launch.

In the seafood industry wastes and by products are produced in large amounts as a result of the large quantities of shrimp, fish and other seafood being processed (Islam, Khan, and Tanaka 2004). Figure 3 details the processing steps that currently occur at the Abacus Fisheries factory. Several steps are required to turn the blue swimmer crab into the final product for market.

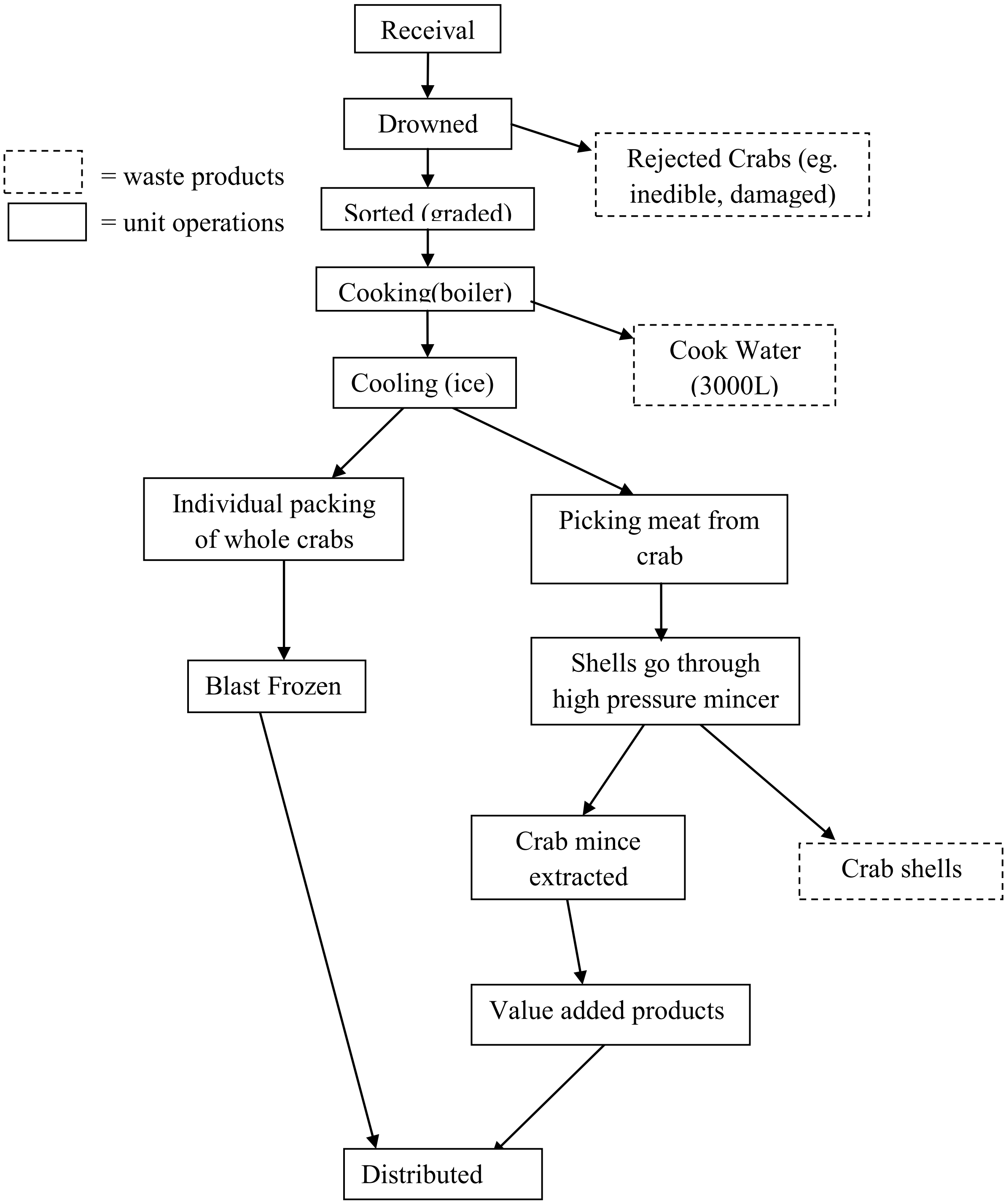


Figure 3: Flow Diagram of the blue swimmer crab processing factory

The live crabs are taken straight to the port which is situated in Carnarvon. They are transferred to the factory where the crabs are drowned prior to cooking (Abacus Fisheries 2009). The crabs then undergo different processes to produce the products which are then distributed to buyers in overseas countries or local businesses.

The waste that is produced during crab processing is comprised of crab shells, crabs that have been injured or physically damaged and the cook water that has been used to boil the crabs prior to the removal of the crab meat. Abacus Fisheries has invested in high pressure extracting machinery to remove the remaining crab meat from the crab shells. The crab meat is used to make value added crab products and is sold to food service providers. The finely ground crab shells are then disposed into large bins. The cost of disposing the crab shells is decreased as it is finely ground, therefore taking up less volume and less bins are required. The crab cook water is currently being discarded which accounts for a large amount of the waste generated by the company. The company's next aim is to find a way to utilise the crab cook water which has potential uses.

2.2 Issues with effluent cook water

The seafood processing industry is characteristically one which consumes high levels of water and produces a variety of aqueous effluents that are to a certain extent salted (Vandanjon et al. 2002). The effluent produced by the seafood industry can impose extreme pressure on public sewerage systems due to the heavy biological load contained in it (Birch, Parker, and Worgan 1976). In today's society, depending on the pollution load of the effluent, it is either simply screened prior to being taken to a public wastewater treatment site or the effluent is directly disposed of into the environment (Vandanjon et al. 2002). Mr Peter Jecks, of Abacus Fisheries estimates that each day they waste 3000 L of potable water which was used to boil the blue swimmer crabs (pers.comm., February 3rd 2009). Up to 3 tonnes of crabs are cooked per day in the water so the organic matter builds up and this leads to high level of biological oxygen demand (BOD). The contents of the cook water are made up of the components that have leeched out of the crab during the cooking process. This includes: protein, free amino acids, fat, minerals such as sodium and potassium, soluble solids and haemolymph. Due to the high levels of organic matter in the effluent, it is consequently financially expensive for the company to dispose of and may lead to a negative impact on the environment in the long term.

In the majority of processing operations liquid effluent is produced and disposed of in waterways resulting in negative impacts on the environment (Cha, Cadwallader, and Baek 1993). Wang (2006) noted that the water used in seafood processing becomes highly contaminated resulting in waste water with a high biological oxygen demand (BOD). The high BOD is due to the significant contamination with fat and proteinacious materials (Wang 2006). The contents of the seafood waste water could potentially deteriorate the aquatic environments quality in which it is discarded (Sohsalam, Englande, and Sirianuntapiboon 2008). Depending on the contents of the effluent, not all are treated prior to be being drained off into waterways. As Abacus Fisheries is located in close proximity to Shark Bay, the effluent would eventually deteriorate the marine life that lives there. This would lead to less produce and possible endangering marine species.

There are also many financial costs associated with the disposal of seafood effluent. The WA Water Corporation is in charge of supplying water to many of the businesses in Western Australia as well as the disposal of the waste water generated by the companies. The businesses pay fees for the industrial waste they dispose of, based on three components: Annual Permit Charges, Quality-Quantity Usage Charges and Activity-Based Charges (Water Corporation 2009).

The Quality-Quantity Charges are based on the parameters such as: biological oxygen demand (BOD), oil & grease, metals, nutrients and salts (Water Corporation 2009). For the BOD parameter, the Water Corporation charges $2.00 /kg for the disposal of waste water with levels of BOD over 5000 mg/L (Water Corporation 2009). With the high BOD levels found in waste water disposed by the seafood industry, plus the other incurred costs, consequently the seafood companies need to spend large amounts of money disposing the effluent. So, as Abacus Fisheries is disposing at least 3000 L of effluent a day with a high BOD content, it will cost the company at least $6000 a day, plus other incurred costs. For a small business, that is a large amount of money to be spending on effluent disposal considering the factory runs seven days a week.

2.3 Possible Solutions

Techniques for waste water minimisation can greatly cut the costs related to effluent production and water use (Watson, Archer, and Denton 1999). Abacus Fisheries want to utilise the crab cook water, for which they are currently paying a high cost, to produce a value added food product or to treat the water so it becomes reusable. There are several options available for the utilisation of the crab cook water. The components of the water such as fat and protein could be extracted out of the product to produce amino acid hydrolysates, which does not occur at high enough levels. However this would require a very high concentration of the compound in the base liquid. Two other ideas are to recycle the water using waste water treatment and another was to produce a crab stock concentrate. These two possibilities will be examined below.

2.3.i Waste Water Treatment

Like most wastewaters produced by industries, the wastewater from the processing of seafood contains contaminants which includes an undefined combination of substances, with the majority being of organic nature (Wang 2006). The waste water produced is characterised by the physiochemical parameters of nitrogen, phosphorus and organic waste water content. (Wang 2006). High salinity also has a significant impact on the treatment of biological wastewater (Intrasungkha, Keller, and Blackall 1999).The removal of BOD and carbon (COD) by the activated sludge process inhibits the sodium and chloride ions (Intrasungkha, Keller, and Blackall 1999).

There are various types of ways to treat the effluent including biological treatment, land disposal, disinfection and physicochemical treatment. The inherent disadvantage of conventional biological waste water treatment plants are that materials which are potentially valuable become useless as it is degraded down to an unusable sludge (Birch, Parker, and Worgan 1976). The degraded sludge then becomes a problem for disposal (Birch, Parker, and Worgan 1976). The use of chemical precipitates are used for the removal of proteins but consequently the end product can't be used for the purpose of nutrition (Birch, Parker, and Worgan 1976). For example iron salts can be used to precipitate the protein, but the iron salts are then part of the precipitate. However as they are toxic compounds they make the protein precipitate useless as a food (Birch, Parker, and Worgan 1976).

There are five different stages in the waste water treatment process. They are: preliminary treatment, primary treatment, secondary treatment, tertiary treatment and sludge treatment (Allen 1998). The development of waste water treatment facilities to suit the need of the Abacus Fisheries would be very expensive. Which raises the question: If there is not enough water being produced and the cost of the construction of the plant is very expensive, will it be financially worth it in the long run?

Water used for processes such as cooking would contain more biological components and would therefore require the highest level of waste water treatment compared to water which is used for washing. The construction of the waste water treatment plant would have to cater for the removal of the contents found in the cook water. Therefore the necessary equipment needs to be bought and the land that is required to hold the water needs to be obtained. Construction costs and the equipment required make wastewater treatment an expensive option. Only if a substantial amount of effluent is being discarded would the option of investing in a wastewater treatment plant be a cost effective solution.

Also the Abacus Fisheries factory is located on the port of Carnarvon, where the amount of land available is not sufficient to construct the facilities required for a waste water treatment plant. Carnarvon is a small rural town where everything is close together, so the factories are located in the close proximity to the residential area. Odours emitted from waste water treatment plants are not pleasant, due to the organic matter decomposing which then releases volatile diamines, amines and occasionally ammonia (Wang 2006). The issue of odour is of significant importance in the public's perceived thoughts and acceptance of the construction of wastewater treatment plants (Wang 2006). Wastewater treatment plants are relatively harmless, but it can affect the local residents by causing sickness and stress (Wang 2006). In the urban towns, waste water treatment plants are generally located a fair distance away from the residential areas. Therefore the development of waste water treatment facilities near the factory is not a viable option.

2.3.ii Stock Production

Stock, which is also referred to as bouillon, is derived from plant or animal tissue extracts and is used as the base flavouring for many cuisines (Kazuyo et al. 2005). There are many different factors that have to be considered to determine if the potential production of crab stock concentrate is a viable option. This includes the contents of the crab cook water, the competitors that are currently in the market and the different technologies and knowledge available to produce stock.

Viability of producing stock

The production of flavour extract and recovery of volatiles from the utilisation of by-products produced in during crab processing should be explored(Cha, Cadwallader, and Baek 1993). Research conducted on snow crab cooker effluent by Cha, Cadwallader, and Baek (1993) shows that as the desired volatile compounds that contribute to flavour are retained in the cooker effluent it is a viable option to produce a flavour concentrate that could have potential marketability.

Cooking water from seafood production contains two different flavouring compounds (Vandanjon et al. 2002). The first type are compounds of low molecular weight (MW) (~400 gmol-L) (Vandanjon et al. 2002). These compounds are quite volatile and contain a number of chemical classes such as: ketones, esters, aldehydes, alcohols, S- and N- groups (Vandanjon et al. 2002). These compounds give the seafood product its characteristic pleasant aroma which can be described as almond/nutty, cucumber/green, potato etc (Vandanjon et al. 2002). The second type are flavour compounds which are water soluble including free amino acids with low molecular weight (glycine, glutamic acid, taurine etc), nucleotides derived from purine, peptides, sugars (ribose, glucose), organic acids such as lactic acid, quaternary ammonium bases and salts of inorganic nature which includes: potassium, chloride and sodium (Vandanjon et al. 2002). With these different flavour compounds present, the cook water could produce an aromatic crab stock concentrate.

Currently available stocks

Stock is used as a base ingredient in many dishes produced around the world. There are many different flavours that exist and can be found in the local supermarket and in speciality Asian food stores. Popular and commonly used stocks around the world are chicken and beef stocks (Kazuyo et al. 2005). In Japan, stock made from dried bonito is commonly used, as well as chicken and beef stock (Kazuyo et al. 2005). In other Asian countries, anchovies are one of the most popular flavouring agents.

At this present time there are several forms of stocks available on the market. They include: dehydrated solids, concentrated liquid, reduced liquid and liquid. The most common type of stock on the market is the dehydrated form which is either a loose powder form or in compressed cubes. An advantage of the dehydrated form is the lowering of water activity to a point where microbiological activity won't occur and the deteriorative biological and chemical reactions rates are at a minimum which therefore preserves it (Toledo 1991). The reduction in bulk and weight of the dehydrated products along with it being a shelf stable product reduces the distribution and storage costs (Toledo 1991). In contrast the liquid stocks maintain a high water activity so once it is opened it must be stored in a refrigerator.

Stock is a highly versatile ingredient in the food industry. In the commercial food industry the dehydrated form of crab stock concentrate could potentially be used as flavouring for chips and other salted savoury snacks such as biscuits and crackers. The concentrated liquid crab stock could possibly be used in the commercial food industry for the production of canned soups, in the fast food chains to enhance the flavour of the products and restaurants where the chefs could use it to intensify the flavour of their dishes. The company itself, Abacus Fisheries could also use the stock as an ingredient to produce other value added products. From the consumer's perspective, the stock would be used as a base flavouring for certain dishes such as soups, chowders and as a flavour enhancer in other dishes. There are currently no crab stock concentrates available on the market in Australia.

A common trend in the market place at this time is a strong focus on the food and diet relationship. More consumers are becoming more conscious of the food choices they are making. Therefore, the food companies are developing and changing the formulation of the current products to fit in with what the consumer wants. Looking on the shelves in the local supermarket, the stock section holds a number of products with reduced salt. The sodium levels have been reduced by 50% in the chicken and beef bouillon produced by Campbell's, but with increased potassium content. The stocks that are based on seafood have not been reformulated to have reduced levels of sodium. The reduction in salt levels means that other additives are required to enhance the flavour of the stock. With this increased trend in low sodium food products, the possible production of crab stock would have to take into consideration a reduction in salt content to meet the consumers wants.

4.3.iii Different Technologies

In the industry of stock concentrate production, there are many techniques that can be used to dehydrate the original sample. Each technique has its own advantages and disadvantages, which makes certain techniques inappropriate to use depending on the product being dehydrated. Some of the techniques that can be used to concentrate down the cook water are: boiling, vacuum drying and freeze drying. The most vital aspect in the development of the crab stock concentrate is the retention of the volatile compounds. The volatile compounds contribute to the aroma and taste of a product. If the technology used is not capable of retaining the volatile flavour components, the final product will loss a substantial amount of the characteristic aroma and flavour.

Boiling

Boiling is a commonly used technique which has been used for many years in the commercial food industry but more commonly in the everyday household. The technology of boiling is based around concept of evaporation. There are several forms of evaporation but the easiest form is called atmospheric evaporation. Toledo (1991) states that atmospheric evaporation is a process in which an open pot containing the liquid is heated up and the exposure to the heat drives the vapours off and it is dispersed through the atmosphere. One of the advantages with boiling is that the brix° measurement can be easily assessed; therefore the liquid can be concentrated down to different levels without any difficulty. Brix is the measure of the total soluble solids in a liquid. The ability and ease of measuring the brix of the cook water being boiled is very important because to produce the crab stock at several different concentrations requires the brix measurement to determine if it has reached the desired solids content. With vacuum and freeze drying, the brix cannot be easily assessed. Boiling is a fast method which is used to remove large amounts of liquid from the initial volume.

Although this is a simple process, the energy utilisation is inefficient (Toledo 1991). Another problem of atmospheric evaporation is related to the properties of the food product. The majority of food products are sensitive to heat and exposing it to direct heat for an extended period of time causes off-flavours or the degradation of the products general quality (Toledo 1991).

Vacuum drying

Vacuum drying involves the removal of water using the variables of temperature and pressure. The pressure within the system is lowered with the use of a vacuum pump and the temperature is supplied by the heating plate at the bottom of the oven. The conditions usually used for vacuum drying are a vacuum pressure of 50 mm mercury absolute or lower and a temperature of 75°C or less for the heating plate (Jaya and Das

2003). The low pressure within the system would decrease the boiling point of the crab cook water, therefore the water turns into steam at a lower temperature. The lowering of the boiling point means the crab cook water would lose less volatiles compared to the atmospheric boiling point of 100°C. Retaining volatiles in the crab cook water is a very important aspect in the production of the crab stock. The current applications of the vacuum drying include dehydration of apple flakes, fruits which are heat sensitive, citric juices and products in which the factor of Vitamin C (ascorbic acid) retention is important (Greensmith 1998).

There are several advantages of using vacuum drying, according to Greensmith (1998) such as: the product has a reduced susceptibility to protein damage, 'browning', denaturation and there is a reduction in the loss of constituents which are highly volatile. These advantages are due to the conditions of lower temperatures for drying under vacuum conditions and a drying cycle which is shorter (Greensmith 1998). The moisture is removed in the system where no oxygen is present, therefore oxidative degradation (browning) is less likely to occur in the end product (Jaya and Das 2003). With the temperature of the system being maintained below 75°C, materials that are heat and oxygen sensitive are able to be dried without degradative changes occurring (Jaya and Das 2003).

The equipment is expensive and the process is generally operated as a batch system which is a disadvantage of using the vacuum dryer (Greensmith 1998). The equipment used for condensers involves a high operating and installation cost (Greensmith 1998). As vacuum drying is an expensive process, the usage of vacuum dryer is often limited to products that require moisture reduction to very low levels without heat damage or raw materials that are of high value (Greensmith 1998).

If a liquid is dehydrated using the vacuum dryer, at the end of the process it tends to adhere to the surface on which it is being dried on. However, once it is removed from the dryer the end product absorbs moisture from the atmosphere very quickly. The term used to describe this is hydroscopic. It is not ideal to dry hydroscopic products with the vacuum dryer unless is it going to be rehydrated straight after or if an anti-caking agent is added to the product. Another disadvantage is the brix° of the product cannot be checked as the process will have to be interrupted continuously.

Freeze drying

Freeze drying is a method of dehydration where the ice that occurs in the frozen state of the original product undergoes sublimation to produce a dehydrated product (Brennan 1990). The water within the solid phase is vapourised from the product due to the low absolute pressures within the freeze dryer (Toledo 1991). The product must be frozen before it is to be freeze dried. Francis (1999) states the advantages of freeze drying include a decrease in thermal damage on the product and the volatile compounds are well retained. Another advantage of freeze drying is that the product will have a long shelf life. However this is if the end product is correctly packaged and rehydration of the product is rapid (Francis 1999). The qualities of the original product such as flavour, nutrients and structure are preserved to the highest level with the use of freeze drying (Francis 1999). The quality of the final product is excellent as this process requires low temperatures and the liquid water is absent in the product, therefore the majority of the microbiological reactions and deterioration would have stopped (Ratti 2001). The product's shape and primary structure is also maintained as the water is in its solid state during the freeze-drying process, which therefore minimises any reduction in volume in foods that does not contain large volumes of water (Ratti 2001).

Although this technique combats the important issue of retaining product quality, there are some disadvantages of using this technology. The process is an expensive one and it is a slow process, therefore only products of high value or large sales volume would be worth processing in this manner (Francis 1999). Also, products that are freeze-dried absorb moisture rapidly unless it is packed so that the humidity is kept low (Francis 1999).

The pressure within the freeze dryer holds the vessel tightly shut. If the samples were to be removed from the freeze dryer, pressure would need to be released exposing the product to the external environment. Exposing the sample to the external environment will change the end product which is undesirable. The use of the digital refractometer to check the brix° of the product during the freeze drying process would interrupt the freeze drying process. Therefore, the freeze dryer is only practical to produce the crab cook water into a fully dehydrated crab stock powder.

2.4 Other waste produce

The tropical weather in Carnarvon provides the perfect conditions for its thriving horticulture industry. A diverse range of produce is grown in Carnarvon, including vegetables and tropical fruit crops like tomatoes, capsicums, asparagus, beans, mangoes, citrus, papaya, avocadoes, grapes and stone fruit (Shire of Carnarvon 2009). Most of the produce is transported to other states and countries, some with higher standards than others. Therefore, tonnes of the fruits and vegetables are discarded each day even if they are perfectly edible. As Abacus Fisheries is a company that believes in waste utilisation, it would be ideal for them to incorporate this local produce into the crab stock to further enhance the flavour and increase the product value. For the horticulture industry this means a decrease amount of produce being wasted and they will get an increase in profit as they would be selling produce to Abacus Fisheries.

2.5 Chemical analysis

The proximate analysis of the main constituents of the crab cook water is important for several reasons. Part of product development is to ensure the product being produced is safe for the consumer. Consumer safety is one of the most important issues to be dealt with. If the product cannot be made with ensured safety it should not go on the market. In the past, there have been minor issues in the seafood industry with certain minerals naturally found in seawater. The accumulation of some minerals in the human body over a long period of time, have been known to cause major health problems. The exact amounts of the minerals need to be determined as there could be a potential safety hazard if the levels are too high in the stock. As the crab cook water would be concentrated down to less than half of the original volume, the concentration could lead to levels that would be unsafe for human consumption.

Sea water contains the natural trace component cadmium which is found at levels lower than 0.05 µg/L (Francesconi, Moore, and Edmonds 1994). Marine invertebrates have the ability to accumulate cadmium in their tissues to levels higher than that contained in sea water (Francesconi, Moore, and Edmonds 1994). They can however combat the potentially dangerous effects of cadmium by detoxification mechanisms which involve synthesis of proteins that bind cadmium or intracellular granules of an inert nature (Francesconi, Moore, and Edmonds 1994). These proteins effectively remove cadmium from regular biochemical functions within cells (Francesconi, Moore, and Edmonds

1994). Although crustaceans such as blue swimmer crabs have these mechanisms to help remove cadmium from their systems, the minerals may be released during cooking so it is important to run chemical tests to measure the cadmium levels. As the development of the crab stock involves the concentration of the cook water to levels of minimal water activity, it is important to ensure that the cadmium concentration will not be a risk to consumers. The Food Standards Code does not state a maximum residue limit of cadmium for blue swimmer crabs, so it should be compared to the maximum residue limits of molluscs. The Food Standards Code states that the maximum residue limit of cadmium in molluscs is 2 mg/kg (Food Standards Australia New Zealand 2009).

Proximate analysis should be conducted on the crab waste water to determine the amount of fat, protein, soluble solids and minerals that it contains. These are the components which are most likely to leech out from the crab meat, shell and other parts. The results will also effectively determine if concentration of the cook water is a viable option with due consideration to concentration of the potentially harmful minerals.

Regardless of the amount of crabs caught per day, a total volume of 3000 L of potable water is used by the cooker. The cook load can range from less than 1 tonne a day to over 3 tonnes. With different cook loads, the amount of each component leeched into the water will vary from day to day. In a research project conducted on seafood cooking waters such as shrimp, it was determined that the composition of the cook water varied depending on the amount of product that's cooked in it (Vandanjon et al. 2002). The other reason to conduct proximate analysis is to develop an equation to determine the amount of water that needs to be removed from the cook water each day. The cook load varies each day depending on the season and the location but the volume of water remains the same. The varying crab cook load would affect the amount of the components contained within the cook water. To develop the same product on a day to day basis with the same nutritional composition means that calculation of the levels is required to ensure the final product remains the same every time. The easiest factor to alter would be the amount water that is removed from the crab cook water to produce the crab stock based on the composition of the cook water.

2.6 Sensory evaluation

The Sensory Evaluation Division of the Institute of Food Technologists (1975) has defined sensory evaluation as quoted:

"Sensory evaluation is a scientific discipline used to evoke, measure, analyse and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch and hearing."

The Institute of Food Science and Technology (2008) states that sensory evaluation is now part of the whole life cycle of a product where it is applied in:

- product development (which includes the determination of preference)
- analysis of competitors
- development of a new concept
- product optimisation and design
- targeting the consumer segments based on sensory
- figuring out the drivers for liking in sensory
- cost reduction and scaling up

The sensory characteristics of a product contribute significantly as to whether or not a product will be successful if it was commercialised. The branding and advertising entice the consumer to try a product, but if the consumer does not like the product's texture, flavour, aroma or appearance, they won't repurchase it (Institute of Food Science and Technology 2008).

The final stages of the reformulation cycle and product development is when consumer sensory evaluation is conducted (Lawless and Heymann 1998). Sensory evaluation is an important part of new product development to determine how acceptable the product is. If the product does not do well in the consumer acceptance testing, it is highly likely it will fail in the market even if the marketing for the product is excellent (Lawless and Heymann 1998).

Many things need to be considered when conducting sensory evaluation. It can be critical in the retrieval of specific information and interpretation of results. This includes the type of sensory test, the type and number of panellists required.

2.6.i Test type

The types of tests conducted in sensory analysis can be split into two groups: difference testing and hedonic testing. Difference testing is when two samples are compared to each other to identify which is different based on perceived differences (Stone and Sidel 1985). Hedonic testing is when samples are measured based on preference or liking. There can be more than two samples compared in each test. The most frequently used approaches to consumer sensory testing in consumer and food products is the measurement of acceptance and preference (Lawless and Heymann 1998). Both of these types of sensory analysis are hedonic. Preference testing is where two products are compared and one is chosen over another based on the products appeal (Moskowitz et al. 2006). Whereas acceptance testing which is also referred to as liking, uses a scale where the consumer panellists will rate how much they like the product(Lawless and Heymann 1998).

The use of acceptance testing is very important as it can answer numerous questions and it is very useful in many business scenarios (Moskowitz et al. 2006). Moskowitz et al. (2006) states that some questions acceptance testing can answer are for example:

- Overall performance: degree of liking for the products being tested, or the percentage of consumer panellists (target population) which rate one product better than the other.
- Diagnostics: acceptability rating for the different sensory attributes of the product (appearance, aroma, flavour) - shows how the product performs in specific aspects.
- Relationships among variables: responses given by the consumer panellists can be related to the information generated chemical and physical measurements

The sensory properties of the product determine the product acceptance which is estimated by the consumer acceptance test (Moskowitz et al. 2006). The information is very important to the sensory researcher and product developer as it acts as a basic idea as to the magnitude of consumer liking (Moskowitz et al. 2006). However this does not guarantee the product will succeed once it is on the market (Moskowitz et al. 2006).

In terms of consumer sensory evaluation of different crab stock concentrates, acceptance measurement would be the more appropriate option as the area of interest is the degree of liking of the samples. Sensory evaluation would be used to screen in product development as it is being used to determine the most acceptable sample to be used in the later stages in the product development.

There are several tests that can be used for acceptance testing. They are: paired comparison test, ranking and rating. Paired comparison test involves the testing of one pair of samples and the panellist indicates which of the pair they prefer (Stone and Sidel 2004). It would not be appropriate to use this method if the number of samples is large. When there is only two samples involved, the analysis is easier and the test is easy to conduct. Ranking is a method of sensory evaluation where the panellist is simultaneously given at least three samples that they must rank in relation to the attribute being assessed or overall acceptability (Standards Australia 2005). The samples are ranked in order with the most preferred sample ranked 1. A disadvantage of this method is that equal ranks cannot be given. With ranking, the samples are placed in a particular order and the degree to which the panellists like the product cannot be shown. Also the use of ranking does not give the researcher a good indication as to whether the samples that were not ranked first were liked or disliked by the consumer. As they are ranked in order of preference, it does not give a clear indication as to whether or not the panellists even liked the taste of the most preferred sample. It could be that it is the best out of the worst.

The other popular method used is rating. Rating is a test method where the panellists indicate on an interval scale the degree of liking of the sample based on the specific attribute or overall preference (Standards Australia 2005). The rating method is ideal to use when the researcher wants to determine the degree of difference between each sample. This is useful for new product development of crab stock concentrate as the preference for a sample can be distinctly shown by the rating on a scale. For this research project it would be most appropriate to use rating as the method for acceptance testing of crab stock concentrate. This could be used as part of the screening phase in new product development to see which sample should be taken on to further development of the product.

2.6.ii Panellists

Choosing the panellists to take part in consumer acceptance testing is critical part of the test set up (Lawless and Heymann 1998). In acceptance testing the most important thing is the panellists are representative of the target population as they will be the ones potentially buying the product. Untrained panellists are preferred for acceptance testing as trained panellists can detect certain characteristics of the product which are not important when it comes to acceptability of the product. Trained panellists are not classified as the target population. When academic research is conducted in the laboratory, the more convenient way to recruit panellists is to get staff or students to participate in the sensory evaluation involving acceptance testing (Lawless and Heymann 1998).

When screening for consumer panellists, they must be informed of the category of food they are testing. This is important as many people have serious food allergies to certain foods. For example if someone wants to take part in sensory evaluation of crabs, they must not take part if they have an allergic reaction to seafood. Other disqualifying factors included: being pregnant, heavy smokers and dislike of seafood. Heavy smokers are unable to take part as their taste buds would have been affected, therefore affecting their sense of taste. Pregnant women were unable to take part due to potential risks. People that do not like seafood would not be representative of the target population. As they dislike seafood they would not be using the crab stock concentrate. A dislike of seafood would mean they would have much lower acceptability ratings. The participants must be given an information sheet and consent form to fill out so they are aware of the research they are partaking in.

The researcher also needs to reward the participating panellists. People are volunteering their time to take part in the research and should be shown some appreciation by being given a token gift. It also gives the panellists some incentive to take part. This is called a token incentive. This means the incentive has to be enough for a consumer to take part, but not enough to push it as the sole reason for participating (Lawless and Heymann 1998). When the panellists are staff or students of the research institute take part, there are other reasons other than incentives to lead them to participating. This includes feeling positive for helping in the sensory testing programme (Lawless and Heymann 1998).

2.6.iii Test conditions and set up

The randomisation of sample order is a very important in sensory analysis to ensure each sample goes before and after each other to control for order bias. One of the experimental designs which can be used to randomise sample order is the latin square. A latin square is form of double grouping where every column and every row of each square is a total replication (Cochran and Cox 1957). The use of the latin squares means that every sample appears before and after every other sample the same number of times (Cochran and Cox 1957). An advantage of using the latin square is there is more opportunity for the error to be reduced (Cochran and Cox 1957). Figure 4 represents the latin square design for four samples which can then be applied in the randomisation of samples for sensory analysis.

4 x 4

1	2	3	4
A B C D	*A B C D*	*A B C D*	*A B C D*
B A D C	*B C D A*	*B D A C*	*B A D C*
C D B A	*C D A B*	*C A D B*	*C D A B*
D C A B	*D C B A*	*D C B A*	*D C B A*

Figure 4: 4 by 4 Latin squares(Cochran and Cox 1957)

Sources of error in sensory analysis include carry over effect and order effect. Carryover effect occurs when the panellist has difficulty cleansing their palates after tasting one of the products which may have a very prominent mouth feel, odour or aftertaste (Carpenter, Lyon, and Hasdell 2000). This will then consequently effect the panellist's perception of the samples immediately following the sample with the prominent characteristics. Therefore it will affect the scores given to the following samples. Order effect is when the order that the samples are presented for tasting during sensory analysis effects the panellists' perception of the products (Carpenter, Lyon, and Hasdell 2000). This means that the sampling order can affect the panellists rating score for each of the samples. Both the carryover effect and the order effect cannot be eliminated from sensory analysis, however the use of the latin square experimental design can decrease the amount of error from these two factors.

Once the experimental design is determined, sample preparation must be considered. Sample preparation must be controlled and uniform to avoid inconsistent samples which could lead to misleading results. The samples being tested have to be uniform. This means the amount of sample must be the same each time and the serving temperature is constant. To maintain the anonymity of the samples being tested, the samples are labelled with a random three digit number. The use of randomised number is to limit bias (Lawless and Heymann 1998).

The sensory answer sheet is given to consumers to complete. There are four types of measurement scales that can be used in rating tests which are: ordinal scales, interval scales, categorical scales and ratio scales. Ordinal scales involve allocating a value which corresponds with the order in which the attributes being rated is perceived (Standards Australia 2005). Interval scales are similar to ordinal scales as the equal distances which occur between the values corresponds with the differences to do with the attributes being measured. An example of interval scales is hedonic scales. For acceptance testing, the most common format of the answer sheet used is the hedonic scale. The nine point hedonic scales are easier to analyse statistically but the degree of liking is important with the sensory analysis of the preferred crab stock concentrate. With hedonic scale it cannot be identified if the panellists' opinion is on the borderline of two of the categories or that exactly that category.

Line scales are also commonly used but harder to statistically analyse. But when the degree of liking is being determined, the line scale with no markings gives a degree of freedom when recording the answers. When line scales are used, the answers are placed on a graphic line which is 10 cm in length and there are anchors on the endings of the scale only. The line scale would be very advantageous for the acceptance testing of the crab stock as it is a new product and it should be determined which of the samples are most favoured but also if any of them are rated acceptable or not.

The location for the sensory tests depends on how external factors will affect the results and what is being determined. The three main locations used for acceptance testing are at home, central location or at a laboratory. Examples of central locations are shopping malls, office buildings and places where large numbers of the general public have access to (Stone and Sidel 1985). Each location has its advantages and disadvantages.

The disadvantages of using the central location and at home for sensory testing include the inability to control biasing factors from the environment. Other people are able to influence the panellists' decision in these locations which could affect the results of the analysis. As there are more biasing factors involved, the number of participants has to be increased to ensure the results are statistically significant. Although the at home location provides the advantage of testing the product under the conditions it would be used, the amount of money spent to conduct the testing is very costly (Stone and Sidel 1985). More preparation needs to be spent developing the packaging of the product and instructions for the panellists as they will be testing the product as the consumers would buy it from the shops. The use of the central location to conduct sensory analysis has the advantage of being able to recruit a large number of participants and they will not be familiar with the product being tested (Stone and Sidel 1985). However if the product being tested requires preparation before being tested or has a limited holding time this is a major problem. The facilities that would be available for preparing of the product for sensory analysis would be limited. Inconsistency in the product being tested leads to unreliable results as the product has changed over time. The inconsistency is a very important factor in sensory analysis that must be controlled to ensure reliable results.

The use of sensory laboratories is the most common location. The laboratory is built to limit biasing factors with facilities on site for the food preparation. The advantages are in being able to control the conditions of the room, rapid feedback of data, low cost and 'test-wise' subjects (Stone and Sidel 2004). Laboratories are usually found within a food company or on the campus of the institute where it is being conducted. The recruitment of participants is easier as there are staff and students of the institute on site. They are representative of the consumer population as the participants cover a wide demographic range. The use of the laboratory to conduct the sensory analysis is the least expensive location compared to the other two and less time consuming making it the more suitable option. The only main disadvantage of using the laboratory to conduct the sensory analysis is the panellists could be familiar with the product being tested (Stone and Sidel 1985).

2.7 Conclusion

In summary, the waste cook water that is produced from Abacus Fisheries contains high levels of BOD and volatile compounds which are currently being discarded. The effluent is expensive for the company to discard and may have a negative impact on the environment. The company wants to find a way to turn the crab cook water into a viable value added product. Wastewater treatment is not a viable option but the production of alternative products such as crab stock concentrate may be feasible.

For Abacus Fisheries the driving force to develop a new product is the problem with waste water disposal relating to the financial cost, the damage on the environment and wastage of a potentially valuable product. There is also a large amount of waste from the local horticulture industry which could also be potentially used in production of a value added product with the crab cook water. The importance of following the new product development process is to create a successful value added product. There are many phases in the product development cycle which all contribute significant amounts to the success of the product. This includes the research into different ways to develop the crab stock concentrate and conducting chemical and sensory analysis.

Chemical analysis is important in new product develop to determine the proximate composition of the product and to ensure that the end product will be safe for human consumption. Cadmium is the only mineral in the crab cook water which would be a potential risk to the consumers. The proximate analysis is also important in the development of the crab stock. The levels of each component are unknown and if ingredients such as salt are to be added to the cook water, the initial concentration is required.

Evaluation of different technologies to produce a new product is the key in determining which technology would be ideal in producing the highest quality product. Although the production of a product with the highest quality is desired, other aspects such as cost, time, application of the technology and space need to be considered to determine whether the technology is suitable for the company. For the production of the crab stock from crab cook water, the three technologies which are viable options are: freeze drying, vacuum drying and boiling.

Sensory analysis is one of the most important steps in the process of new product development. It will essentially determine if the product will be successful once it is commercialised. The main objectives of conducting sensory analysis on a new product is to determine if the products are deemed acceptable by the consumer panellists and which of the products are most preferred. There are many types of test methods available but each have different applications. As there are different types of technologies being used to produce the same product, it would be ideal to conduct acceptance testing to determine how acceptable each of the potential crab stocks would be. The use of rating with a line scale would be the most suitable option as the information that can be retrieved includes how acceptable the different crab stocks are, how acceptable each of the sensory attributes of the product are and how the different crab stocks compare to each other. This will enable determination of which of the samples is most preferred.

Chapter 3 Methodology

3.1 Materials

The waste crab cook water was supplied by the industry partner. Two litre samples of the crab cook water collected on 14 different days of crab production at Abacus Fisheries in Carnarvon in March 2009. 100 Litres of cook water was collected and frozen in 10kg block in June 2009. This was used for product development of the crab stock. The samples were blast frozen and sent to Perth.

3.2 Proximate Analysis of crab cook water

All samples were analysed for total soluble solids (brix°), pH, protein content, sodium content and cadmium content. Fat and potassium content were not done after preliminary tests showed very low expected levels (< 1mg/100g and <0.05% respectively). All tests were conducted in triplicates.

3.2.i pH

The pH of the samples was determined using a pH meter (Model: TPS. AQUA- pH). The pH meter was calibrated with solutions of a known pH. Solutions of pH of 4, 7 and 10 were used for calibration.

3.2.ii Brix

The total soluble solids of the samples (brix) were determined using the Digital refractometer DR-103L handheld digital refractometer (Bellingham & Stanley Ltd.). The digital refractometer was calibrated using deionised water. A transfer pipette is used to place a drop of the sample onto the prism at room temperature. Once the sample is placed on the prism, the button is pressed so the refractometer can read the brix° of the sample. The brix° value is shown on the digital screen.

3.2.iii Protein Content

The protein content of the crab cook water was determined using a modified version of the AOAC Official Method 991.22 (AOAC International). For the Kjeldahl Method, three 10 g samples of crab cook water were weighed out. For the blank sample, a pinch of sucrose was used. The samples were placed in digestion tubes along with one Kjeltab (Kjeldahl tablet), a glass bead, digestion acid and hydrogen peroxide. The BUCHI Digest System K-437 digester was set at 420°C and run until the sample appeared clear. 75 mL of deionised water was added to the sample once it cooled down. 50 mL of 40% 10 M Sodium Hydroxide was then added to the sample before it underwent steam distillation in the BUCHI Distillation Unit K-314. The condensate from distillation was collected in a receiving flask containing 25 mL of 4% boric acid until the flask volume reached 125 mL. The contents of the receiving flask were titrated with 0.1 M hydrochloric acid. The following equation was used to determine the percentage of protein in the sample based on the wet basis.

% Protein (wet basis) =

$$\frac{(\text{sample titre (mL)} - \text{blank titre (mL)}) \times M(HCl) \times 14.007 \times 6.25 \times 100}{\text{weight of sample (mg)}}$$

The conversion factor for generic foods of 6.25 was used to convert the percentage of nitrogen in the sample to percentage protein. This value has been incorporated into the above equation.

3.2.iv Sodium Content

The sodium content in the cook water was determined using a modified version of AOAC Official Method 985.35. The Flame Atomic Absorption Spectrophotometry (AAS) method involves sample preparation to remove organic compounds and the precipitation of proteins so they won't interfere with the results. However in this case the removal of organic compounds was not required as the level of organic compounds in the crab cook water is minimal. 10 g of crab cook water was weighed out into a beaker. As the sample was a liquid, wet digestion was required to precipitate the protein. Approximately 10mL of concentrated nitric acid was added to the beaker and placed onto a hot plate and heated gently until the solution appeared clear and the particles within had dissolved. Once cooled, the contents were poured into a 20 mL volumetric flask and made up to volume with deionised water. As the expected levels of sodium were high and the AAS machine can only read the concentration of sodium between 5-50 ppm the sample was diluted ten fold to get it within range. 1 mL of the sample and 1 mL lanthanum were mixed and topped up with deionised water in a clean 10mL volumetric flask. The lanthanum is required to suppress the ionisation of sodium ions when exposed to the flame. The sample is then ready for analysis.

The wavelength for sodium was set at 589 nm. The wavelength is changed when testing the levels of different metals. Before the sample was analysed, the AAS machine was calibrated and standard solutions of sodium used to create a standard curve. The standard solutions were prepared at sodium concentrations of 5 ppm, 10 ppm, 20 ppm and 50 ppm. The sodium 'stock' at 1000 ppm was diluted to the desired concentration with deionised water in a 100 mL flask. Each 'stock' also contained 10 mL lanthanum and 1mL concentrated nitric acid.

The result obtained from the AAS machine was the concentration of sodium in parts per million (ppm). This value was then used to determine the concentration of sodium in 100 g of sample (represented as mg/100g). The calculation to determine the sodium content in mg/100g requires several steps as describe below:

$$\text{Sodium } (\mu g/mL) = (\text{ sample conc} - \text{blank conc}) \times \text{dilution factor}$$

$$\text{Sodium } (mg/\ 10mL) = \frac{\text{sodium } (\mu g/mL)}{100}$$

$$\textbf{Sodium (mg/100g)} = \frac{\textbf{sodium (mg/10mL)}}{\textbf{Wt sample (kg)}}$$

Figure 5: Calculation to determine sodium content in mg/100g

3.2.v Potassium Content

For the analysis of potassium, the Flame Atomic Absorbance Spectrophotometry method (AOAC: 985.35) was used. The sample preparation required for the analysis of potassium was the same as the method used for the analysis of sodium content. The only element that had to be modified to read the potassium levels was the light source. Potassium emits light at the wavelength 766.5 nm. Below is the steps required to determine the amount of potassium present (mg/100g).

Potassium (μg/mL) = sample conc – blank conc

$$\text{Potassium (mg/ 10mL)} = \frac{\text{Potassium (μg/mL)}}{100}$$

$$\textbf{Potassium (mg/100g)} = \frac{\textbf{Potassium (mg/10mL)}}{\textbf{Wt sample (kg)}}$$

Figure 6: Calculation to determine the potassium content in mg/100g

The potassium content in the crab cook water (with a high cook load) was conducted using the same samples used to test the sodium content for the trial. Potassium was not detected in the crab cook water. Therefore, there was no need to test each of the 14 samples as the trials showed no traces of potassium present.

3.2.vi Cadmium Content

The Flame Atomic Absorbance Spectrophotometry method (AOAC: 973.34) was used for the analysis of cadmium in the cook water. The sample preparation for cadmium was similar to the preparation of the sample for analysis of sodium. The expected level of cadmium present in the sample was minimal; therefore the sample did not have to be diluted. As minimal levels of cadmium were expected, standard solutions of cadmium were prepared at concentrations of 0.025 ppm, 0.05 ppm and 0.1 ppm. The removal of organic compounds was not required as the level of organic compounds in the crab cook water is minimal. 10 g of crab cook water is weighed out into a beaker. As the sample was a liquid, wet digestion was required to precipitate the protein. Approximately 10 mL of concentrated nitric acid was added to the beaker and placed onto a hot plate and heated gently until the solution appeared clear and the particles within had dissolved. Once cooled, the contents were poured into a 20 mL volumetric flask and topped up with deionised water. The use of lanthanum was not required as cadmium is a mineral that does not ionise as easily when exposed to the flame. The wavelength at which cadmium emits light is 228.8 nm. Below is the calculation required to determine the amount of cadmium present in the crab cook water.

$$\text{Cadmium } (\mu g/mL) = \text{sample conc} - \text{blank conc}$$

$$\text{Cadmium } (mg/\ 10mL) = \frac{\text{Cadmium } (\mu g/mL)}{100}$$

$$\textbf{Cadmium (mg/100g)} = \frac{\textbf{Cadmium (mg/10mL)}}{\textbf{Wt sample (kg)}}$$

Figure 7: Calulation to determine cadmium content in mg/100g

3.2.vi Fat Content

To determine the fat content, a modified version on the Rose Gottlieb Method (AOAC: 989.05) was used. The official AOAC method specifies that ammonia is used to precipitate protein from products with high expected protein levels. However, the expected protein concentration in the crab cook water was low; therefore this step was not required. A larger sample volume was required due to the expected low fat content. 450 mL of the crab cook water sample and 50 mL of petroleum ether was placed into a Monjonnier fat extraction flask with a fitted cork. It is then shaken vigorously and left to sit for 30 minutes before the clear ethereal layer is decanted off into a pre-weighed beaker. This process was repeated three times, with the addition of 20 mL petroleum ether each time. The beaker weighed before solvent addition and after being dried off in an air oven overnight at 100°C. Before the beaker is reweighed, it was placed into a desiccator to cool. Below is the calculation which was used to determine the fat content:

$$\% \text{ Fat} = \frac{\text{(Weight beaker after (g) – Weight beaker before (g))}}{\text{Weight sample (g)}} \times 100$$

Figure 8: Calculation to determine percentage of fat

The proximate analysis of crab cook water samples with the highest cook loads available indicated that the percentage of fat was insignificant. As the average fat content of the crab cook water from a high cook load was 0.0046% and well below 0.05%, it was deemed unnecessary to conduct fat analysis on the other samples. As the percentage of fat in the crab cook water was negligible, this indicates that the likelihood of oxidative rancidity occurring is decreased.

3.3 Processing of crab stock concentrates using different technologies

Three different technologies were used to turn the crab cook water into crab stock concentrates. They were concentrated down to different levels which were: dehydrated, concentrated liquid (15°brix) and reduced liquid (1.4°brix). The only ingredient that was added into any of the stocks was 100% pure non-iodised cooking salt at levels dependant on level of concentration to be achieved and the initial sodium concentration in the cook water. The aim was to produce products that had a standard salt content of 0.5% when diluted to 1.4° brix total solids.

3.3.i Boiling

Two 4 L aluminium double boiler pots were used to reduce the crab cook water into crabs stocks of two different concentrations: reduced liquid and concentrated liquid. Once each of the stocks was produced, they were placed in labelled 400 mL takeaway containers and placed in the freezer for storage.

For the development of the reduced liquid crab stock, 3 L of the crab cook water was placed into the boiler with 6.86 g of salt to make up the final products sodium content to 0.5% when using a 50% reduction. It was estimated that when the brix° of the crab stock reached 1.4° when the cook water was reduced by 50%. Therefore, the brix° reading was taken at different stages of the boiling process and once it reached 1.6°, the process was stopped. Before the brix° was tested each time, the sample was taken using the transfer pipette and cooled in a beaker filled with ice to ensure the sample was at room temperature. Deviations in the sample temperature would lead to inaccurate readings.

The concentrated liquid crab stock used a similar method as above but the sample had different characteristics. 4 L of the crab cook water was boiled over a direct flame until the volume had been reduced by 50%. The stock was then placed into a double boiler in which it was reduced further until the desired brix° content of 15° was reached. The end volume of the concentrated liquid crab stock from 4 L was approximately 200 mL. The amount of salt required to make the sodium content to 3.6% was 6.349 g.

3.3.ii Vacuum Drying

The vacuum dryer (NATIONAL Appliance Company) was used to concentrate the crab cook water to a concentrated liquid crab stock. The vacuum dryer conditions were set at 50°C at the pressure of 15 inch mercury (50 kPa).

With the production of the concentrated liquid crab stock, the end product was to have a brixº reading of 15. Due to constraints with time, the size of the vacuum dryer and the diluted values of the cook water, the cook water was boiled until it was reduced by 50% before being placed in the vacuum dryer. 3.9 L of the crab cook water was boiled along with 6.349 g of salt. Before commencing, the vacuum dryer had to be preheated to 50ºC. The cook water was made into concentrated liquid crab stock by placing 150 mL of the boiled cook water onto a large evaporating dish and was placed inside the vacuum dryer. The sample was dried to complete dryness overnight.

Once the sample was dehydrated, approximately 15 mL of water was used to dissolve the sample to produce the concentrated liquid crab stock. The sample was placed into a container which was stored at -18 °C.

3.3.iii Freeze Drying

When using the freeze dryer, the sample had to be frozen before the process could commence. The CHRIST Alpha 1-2 LB Plus freeze dryer was used for dehydrating the cook water. Due to time constraints and the efficiency of the machine, the volume of crab cook water (3.6 L) was reduced to 50% in a large aluminium stock pot along with 1.154 g of 100% pure non-iodised cooking salt. The sodium content for the fully dehydrated end product was 16%. Once the cook water was reduced, 100 mL of it was poured into a take away container and placed into the freezer until it was completely frozen. The freeze dryer was pre-chilled for 20 minutes before the sample was placed inside without the lids. The temperature was below freezing point and vacuum set at 1 mbar for the main drying setting. The sample was left there for 24 hours. After this period, the machine was placed on the final drying setting for 2 hours before it was removed. The pressure is lowered to 0.01 mbar during the final drying stage.

The freeze dryer only concentrated the crab cook water to the dehydrated state. The sample was then placed in the freezer for storage.

3.4 Proximate analysis of different crab stock concentrates

The proximate analysis of the different crab stock concentrates produced underwent the same chemical tests as the initial crab cook water. The steps for the analysis are similar, except a smaller amount of sample is required (ranging from 5 g -10 g depending on chemical test). This was due to the fact that as the stock is a concentrated version of the crab cook water, which correlates with a higher concentration of each of the components.

3.5 Processing of flavoured crab stock concentrates

The third objective of the project was to produce value added crab stock concentrates with the use of fresh vegetables and fruit grown in Carnarvon. Using the method of boiling to produce a reduced crab stock, two different flavours were produced.

The chilli tomato flavoured ‘real’ stock was made by boiling 3.5 L of crab cook water and 5.612 g of salt in an aluminium stock pot until it had been reduced by 50%. The stock was then placed in the stock pot with 525 mL of tomato puree, two deseeded fresh red chillis, 1 ½ brown onions, 3 celery sticks, 1 cup of chopped parsley, 1 T sugar and salt. The method for the production of the chilli tomato crab stock is as follows:

1. Pour crab cook water into large pot and add 6.25 g cooking salt. Boil down until it reaches a volume of 1.5 L.
2. In another large stock pot add cooking oil, celery, onion, parsley, tomato puree, chilli and sugar. Cook until the onion becomes transparent.
3. Add the boiled cook water to the stock pot with the other ingredients and add a tablespoon of salt.
4. Simmer over low heat for 1 hour.
5. Remove from heat and pour through a strainer lined with a chux cloth into a container. Store in freezer.

For the production of the herb flavoured 'real' stock, the method for the chilli tomato flavoured stock was applied but different ingredients were added. Instead of adding chilli and tomatoes before it is boiled in the double boiler, 1 ½ brown onion, 3 celery sticks and the fresh herbs parsley and thyme were incorporated.

Method:

1. Pour crab cook water into large pot and add 6.25 g cooking salt. Boil down until it reaches a volume of 1.5 L.
2. In another large stock pot add cooking oil, celery, onion, parsley and thyme. Cook until the onion becomes transparent.
3. Add the boiled cook water to the stock pot with the other ingredients and add a tablespoon of salt.
4. Simmer over low heat for an hour.
5. Remove from heat and pour through a strainer lined with a chux cloth into a container. Store in freezer.

3.6 Sensory Analysis

Sensory analysis of the different crab stock concentrates and value added products was required to determine which sample was more accepted by the consumers. Acceptance testing was used and the test method was rating.

Rating was the test method of choice where the panellist rates the different attributes of the sample (appearance, taste, aroma, saltiness and overall acceptance) based on acceptance on a line scale. Overall there were 6 different samples that were analysed by the panellists. Four of the samples were the various crab stock concentrates and there were two value added samples which had other ingredients incorporated. As there was an assumed significant difference between the original stocks and the value added crab stocks, two different comparisons were conducted. The four crab stock concentrates samples were rated first on the Sensory Evaluation of a Novel Seafood Product– Part 1 form (Appendix 1) and the two value added crab stocks were compared with each other on the Sensory Evaluation of a Novel Seafood Product– Part 2 form (Appendix 1). Based on power calculations it was determined that at least 40 people were needed to take part in the sensory panel.

3.6.i Recruitment of panellists

The panellists had to be untrained as they were representative of the consumer population. The consumer acceptance panel was made up of staff and students from Curtin University. Several posters were placed around the campus to inform students of sensory evaluation (Appendix 1). Emails were also sent out to all staff and students within the school of Public Health.

Before the people that signed up could become a part of the consumer sensory panel, they had to fill in a pre-screening form to determine their eligibility for the study (see Appendix 2). People that had any food allergies, are pregnant, trained panellist, heavy smokers and/or dislike seafood were unable to take part as they were not representative of consumers. The pre-screening form also included a section on country of birth, age and favourite seafood. Participants were also required to read and sign an informed consent form acknowledging they knew what they were taking part in (see Appendix 2).

After the undergoing the pre-screening test, 64 people were eligible to take part. Of them, one person did not complete the sensory form properly; therefore there were only 63 valid results. From the panellists that took part in the sensory panel, 30% were male compared to 70% which were female. The country of birth was also a factor noted. There were 2 pre-screening forms that could not be found, therefore only 61 of the panellists had identifiable country of birth and age. Out of the panellists, 25 were born in Australia, 25 were born in South-East Asia and the remaining 11 panellists were categorised in the 'other' group. This group included panellists that were born in Mauritius, Europe and the Middle-East. The panellists were also categorised according to their age. There were 4 different categories: 18 - 20 years old (12 panellists), 20 - 30 years old (35 panellists), 30 - 40 years old (5 panellists) and 40 + years old (9 panellists). The majority of the participants were within the 20 – 30 year old range.

3.6.ii Preparing for sensory analysis

Each panellist was given 20 mL of each sample to taste. The samples were made up to a standard concentration with a brix reading of 1.4°. The reduced crab stock and the two different value added stocks did not require the addition of water. But with the concentrated crab stocks, 2.5 mL of the stock was added with 18 mL of boiling water to make up with product. To make the stock from the freeze dried crab stock powder required 0.2 g of the sample to be dissolved in 20 mL of boiling water. As the product is a stock, the samples had to be heated to just below boiling point prior to tasting and kept at that temperature to ensure the product was served up how it would be used in the household. The temperature was controlled by placing several samples into a beaker and placing it into a water bath to keep the temperature constant. The other factor that had to be controlled was the sediments at the bottom of the beakers. The samples had to be stirred well before being poured into the sample cups to make sure the sample was homogenous.

As there were 4 samples a Latin square was used for the randomisation of sample order. All four blocks of the 4 x 4 latin square design were used (Table 2).

Table 2: Latin square for 4 samples-randomising order for sensory evaluation of the crab stock concentrates produced using different technologies (Adapted from Cochran and Cox 1957).

Block Number	Test number	Sample 1	Sample 2	Sample 3	Sample 4
1	**1**	A (876)	B (358)	C (697)	D (849)
	2	B (358)	A (876)	D (849)	C (697)
	3	C (697)	D (849)	B (358)	A (876)
	4	D (849)	C (697)	A (876)	B (358)
2	**5**	A (876)	B (358)	C (697)	D (849)
	6	B (358)	C (697)	D (849)	A (876)
	7	C (697)	D (849)	A (876)	B (358)
	8	D (849)	A (876)	B (358)	C (697)
3	**9**	A (876)	B (358)	C (697)	D (849)
	10	B (358)	D (849)	A (876)	C (697)
	11	C (697)	A (876)	D (849)	B (358)
	12	D (849)	C (697)	B (358)	A (876)
4	**13**	A (876)	B (358)	C (697)	D (849)
	14	B (358)	A (876)	D (849)	C (697)
	15	C (697)	D (849)	A (876)	B (358)
	16	D (849)	C (697)	B (358)	A (876)

3 digit numbers were chosen at random to represent the four samples as shown in Table 2. The reduced boiled crab stock was represented by '876', the vacuum dried concentrated crab stock was represented by '358', the freeze dried crab stock powder was represented by '697' and the concentrated boiled crab stock was represented by '849'. The samples were then placed in the order as shown in Table 2 and repeated four times to give a total number of 64 panellists tasting each of the samples.

As the product being tested was seafood based, the use of acidified water (15% apple, 85% cold water) was required along with a water cracker between each sample to cut through that taste and cleanse the panellists' palette.

3.7 Statistical Analysis

The statistical analysis was conducted using the SPSS (version 17.0) software and Microsoft Office Excel 2007.

3.7.i Proximate Analysis

The proximate analysis of the crab cook water was analysed using descriptive statistics and simple linear regression. The purpose was to determine if a relationship existed between the individual component and different crab cook loads used in the production of the cook water. The simple linear regression line is important if the cook water was used on an industrial scale to determine the nutritional content and amount of salt required to produce the desired characteristics in the final product. The significance of the relationship between the crab cook load and the different components was tested using the correlation table.

3.7.ii Sensory Analysis

The data retrieved from the sensory analysis of crab stocks produced using different technologies was analysed using the one way analysis of variance (ANOVA) test. Post-hoc analysis was done using Tukey's test. The test was conducted to determine if any of the crab stock concentrates were significantly better than the others. The results from the data analysis would then determine which crab stock concentrate was most preferred and would be used a part of the third objective.

For the sensory analysis conducted on the two value added flavoured crab stocks, the data was analysed using Mann-U-Whitney test. This is the non parametric version of the 2-independent sample t-test. The test was used to determine if a significant difference exists between the two different crab stocks.

The results from the sensory evaluation were analysed against the panellists age and country of birth to determine if either of these factors contributes to the panellists acceptability rating of the crab stock concentrates produced using different technologies. The analysis was conducted using Multivariate Analysis of Variance (MANOVA). This test was repeated for the value added crab stocks.

Principal Components Analysis (PCA) was used to determine which of the variables was the biggest influence on the acceptability rating scores of the crab stock concentrates.

Pearson's correlation and simple linear regression was used to determine if any of the five sensory attributes was related to each other.

Chapter 4 Results and Discussion

At Abacus Fisheries they are disposing of 3000 L of crab cook water each day which contains minerals, proteins and volatile compounds which have potential uses. The feasibility of using the crab cook water to produce a crab stock concentrate was explored.

The crab cook water had to undergo proximate analysis to determine its composition before being produced into a crab stock concentrate. The cadmium level of the crab cook water had to be checked as the mineral naturally accumulates in blue swimmer crabs. The information from the analysis of the brix, protein and sodium content can be used to determine an equation for the amount of water that has to be removed from the cook water to produce the crab stock concentrates based on the varying crab cook load.

The different technologies that were used to develop the crab stock concentrate from the cook water were analysed to determine the most effective methods for the stocks production. To determine the feasibility of using the waste cook water to produce the stock required sensory analysis on the crab stock concentrates produced by different technologies. Sensory analysis was used to determine the acceptability of the crab stock. If the samples are not accepted by the consumers then the consumers won't buy it if it's commercialised.

With a high amount of quality horticultural produce being disposed each day in Carnarvon, the idea was to incorporate some of the fruits and vegetables with the crab cook water to develop value added crab stocks. Recipes were developed and to determine if the value added crab stocks would be feasible to produce and sell, they were compared together to determine the acceptability of the products.

4.1 Limitations of research

With new product development research comes various limitations. At Abacus Fisheries, on a good day, approximately 3000 kg of crabs are caught. However, in the period in which the crab cook water was collected for proximate analysis; the volume of crabs was below 1700 kg each day. The reason being it was nearing the end of the blue swimmer crab season. Our results were not able to include the higher end of the crab cook volume range which would have provided stronger evidence for validation of the data.

Objective 2 of the project was to develop crab stocks of different concentrations with the use of different technologies. The initial idea was to use all three technologies (boiling, freeze drying and vacuum drying) to produce crab stocks at 3 different concentrations (reduced, concentrated liquid (15° brix) and dehydrated). The limiting factors were due to technological constraints with the equipment.

- Boiling of the crab cook water in large stock pots was limited to the production of crab stock as a concentrated liquid at 15 brix° and reduced crab stock (real stock). The dehydrated crab stock was an unsuitable option using the boiling method as the final product cooked to the side of the stock pot, which made it very difficult to remove it. As the water reduced to a minimal level, the remaining crab stock became burnt and produced an unpleasant odour.
- The vacuum dryer was only used to produce the concentrated liquid crab stock concentrate as the production of a dehydrated stock was not a viable option. The dehydrated crab stock was hydroscopic, meaning it absorbed moisture well. As soon as the evaporating dish containing the stock was taken out of the vacuum dryer, it started absorbing moisture. The only way the crab cook water could be produced into a dehydrated crab stock using the vacuum dryer would involve the addition of an anti-caking agent to reduce water absorption. The other reason why only a concentrated liquid stock was produced using the vacuum dryer was due to the dehydrated stock adhered to the evaporating dish very strongly and the only way to remove the stock was to add water to dissolve it. To scrape the dehydrated stock was too difficult and not all of it would have been removed.
- The third technology used to produce the crab stock concentrate from the crab cook water was the freeze dryer. The freeze dryer works as a closed batch system which cannot dry the samples in large volumes. The system stays closed by the use of a vacuum pump which keeps the pressure low within the system. Any break in the system exposes the product to the external temperature which leads to the product melting, which means that the brix° could not have been read to determine if the product was at the required level. Therefore it was not a viable option to produce crab stock concentrates in liquid concentrated form as the product was solid and the system was closed.

Another limitation of the study was keeping the samples for proximate analysis and sensory analysis homogenous. The crab cook water used for producing the crab stock was frozen in 10kg blocks, which made it difficult to get a homogenous solution. It was too difficult to defrost the 10kg blocks as it would take up lots of space and would take over a couple of days to completely defrost. This affected the proximate analysis of the crab stocks as this could have caused variation within the results.

The third objective of the research project was to use the crab stock concentrate which was most accepted by the consumer sensory panel to produce into a flavoured crab stock. Due to time limitations the flavoured crabs stocks were not produced using the most accepted crab stock concentrate. Instead, the flavoured stock was made using the boiling technique as this was the easiest to do and the most controllable.

With the evaluation of results from sensory analysis, the number of people in some of the age and country of birth categories was low which could have affected the results from the statistical analysis. For the country of birth categories, there was an insufficient number of panellists from distinct countries so they were combined into the 'other' countries group. As the group was so diverse, strong assumptions about this particular group based on statistical analysis could not be made.

4.2 Proximate Analysis of crab cook water from different cooks

The purpose of analysing the different components of crab cook water in 14 samples with differing cook loads was to determine if an increase in the crab cook load was related to an increase in the amount of each of the different components. The existence of a strong relationship at a significant level meant that an equation can be produced and utilised (Table 3). It would be utilised to determine the amount of water needed to be removed from the crab cook water to produce the amount of each component required to ensure the end products matched the desired final nutritional composition.

Table 3: Pearson's correlation and significance levels between components of crab cook water and crab cook load.

Correlations

		cook load	brix	protein	sodium	cadmium
Pearson Correlation						
	brix	.918				
	protein	.878	.796			
	sodium	.925	.901	.944		
	cadmium	-.180	.109	-.197	-.122	
	pH	.808	.777	.796	.775	-.090
Sig. (1-tailed)						
	brix	.000	.			
	protein	.000	.000	.		
	sodium	.000	.000	.000		
	cadmium	.269	.356	.249	.339	.
	pH	.000	.001	.000	.001	.380

The correlations table (Table 3) indicates that significant relationships exist between the crab cook load and the protein, total solids, pH and sodium levels in the crab cook water. An increase in the crab cook load increased the amount of each of these components. The Pearson's correlation coefficients are quite high for natural variables where nothing was controlled. The cadmium levels were not significantly related to the crab cook load.

The descriptive statistics of the results (Table 4) from the proximate analysis shows the results from the analysis of the 14 different crab cook waters.

Table 4: Descriptive statistics from the proximate analysis of the crab cook water

Trial	**Cook load (kg)**	**Brix°**	**pH**	**% Protein**	**Sodium (mg/100g)**	**Cadmium (mg/kg)**
1	1462	0.56	7.91	0.2162	32.36	0.000802
2	1624	0.6	7.91	0.176	28.38	0.00109
3	1548	0.56	7.93	0.195	29.52	0.000583
4	1228	0.56	7.84	0.202	30.04	0.00177
5	1457	0.63	7.96	0.173	28.95	0.00158
6	1505	0.5	7.95	0.203	28.97	0.00162
7	1414	0.633	7.85	0.151	27.57	0.001568
8	1635	0.767	8.06	0.223	32.2	0.002838
9	1443	0.667	7.93	0.173	32.22	0.00243
10	1289	0.6	7.81	0.137	24.4	0.00242
11	702	0.233	7.56	0.091	17.58	0.00223
12	756	0.267	7.74	0.106	18.24	0.00157
13	653	0.233	7.67	0.083	14.88	0.0018
14	1149	0.467	8.05	0.153	24.08	0.00166
Mean	1276	0.52	7.87	0.163	26.38	0.001
Standard Deviation	339.37	0.116	0.14	0.045	5.76	0.0006

4.2.i pH

The results from the pH readings indicate that a relationship exists and an increase in cook load will produce an increase in pH. The results are represented in Figure 9.

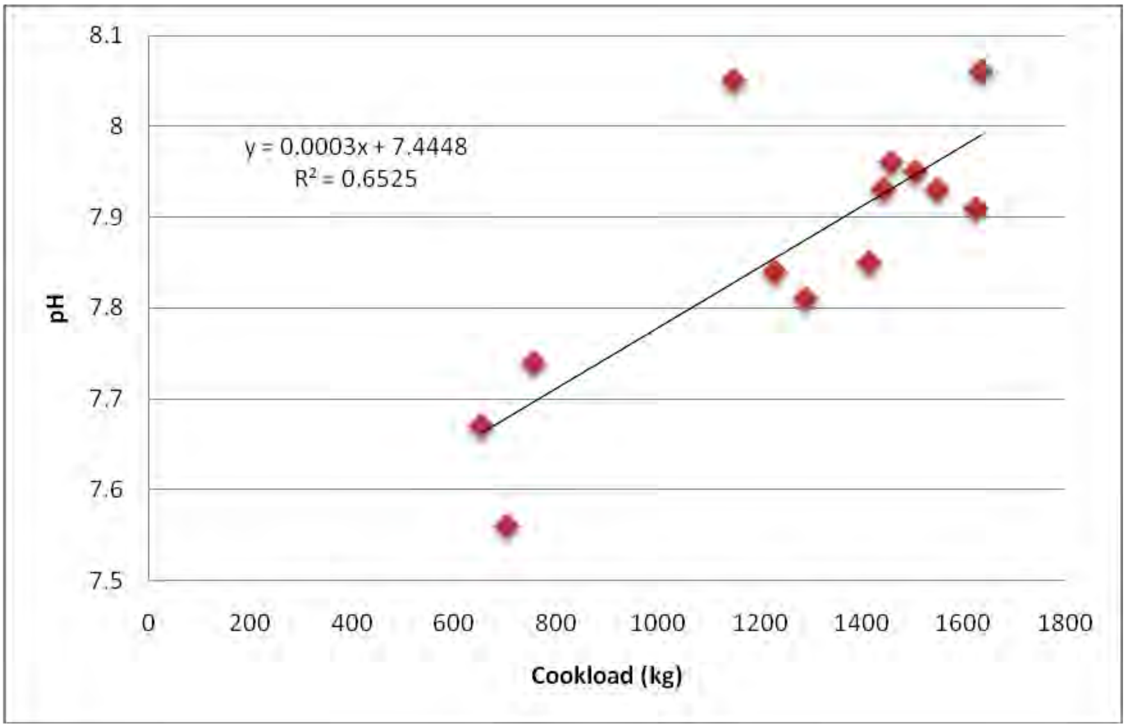


Figure 9: pH of crab cook water with differing cook loads

The use of the Pearson's Correlation table (Table 3) indicates that the relationship between pH and cook load is significant ($p < 0.05$). The correlation coefficient indicates a strong linear relationship. The higher volume of crab being cooked produces a more alkaline cook water. This can be associated with more sodium leeching out of the blue swimmer crabs during the cooking process. Sodium is associated with alkalinity and the significance of a strong linear relationship between pH and sodium levels indicates this (Table 3).

4.2.ii Brix°

The results of the brix readings of the crab cook water were analysed using simple linear regression and it was place in a scatter plot with a line of best fit (

Figure *10*).

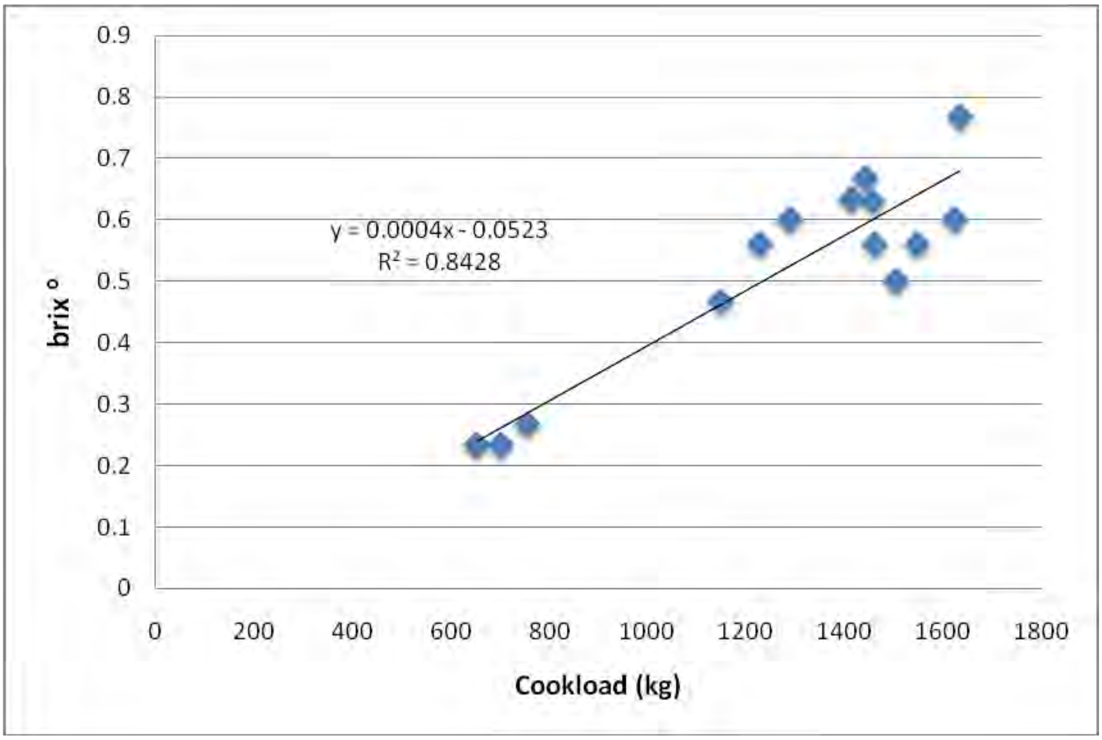


Figure 10: Brix° reading of crab cook water

Figure 10 indicates that a positive linear relationship exists between crab cook load and brix°. Using the Correlations table, it indicates that the relationship between crab cook load and brix° is significant ($p < 0.05$). As the blue swimmer crab cook load increases, the percentage of soluble solids (brix) increases. The high coefficient of determination (R^2) indicates linearity between the two variables and the Pearson's correlation r =0.918 indicates that the relationship is very strong. The strong correlation is due to more Blue Swimmer Crabs in which the protein will leech out of. As more protein leeches out, this increases the total solids (brix) which accounts for the strong correlation between these two variables.

4.2.iii Protein

The results from the analysis of protein content in the crab cook water indicates that the relationship between the crab cook load and protein was significant. The graph showed a clear positive linear relationship between cook load and protein content (Figure 9). The coefficient of determination (R^2 =0.77) and the Pearson's correlation coefficient was 0.878 indicating there was a strong correlation between an increase in crab cook load and the increase in percentage of protein.

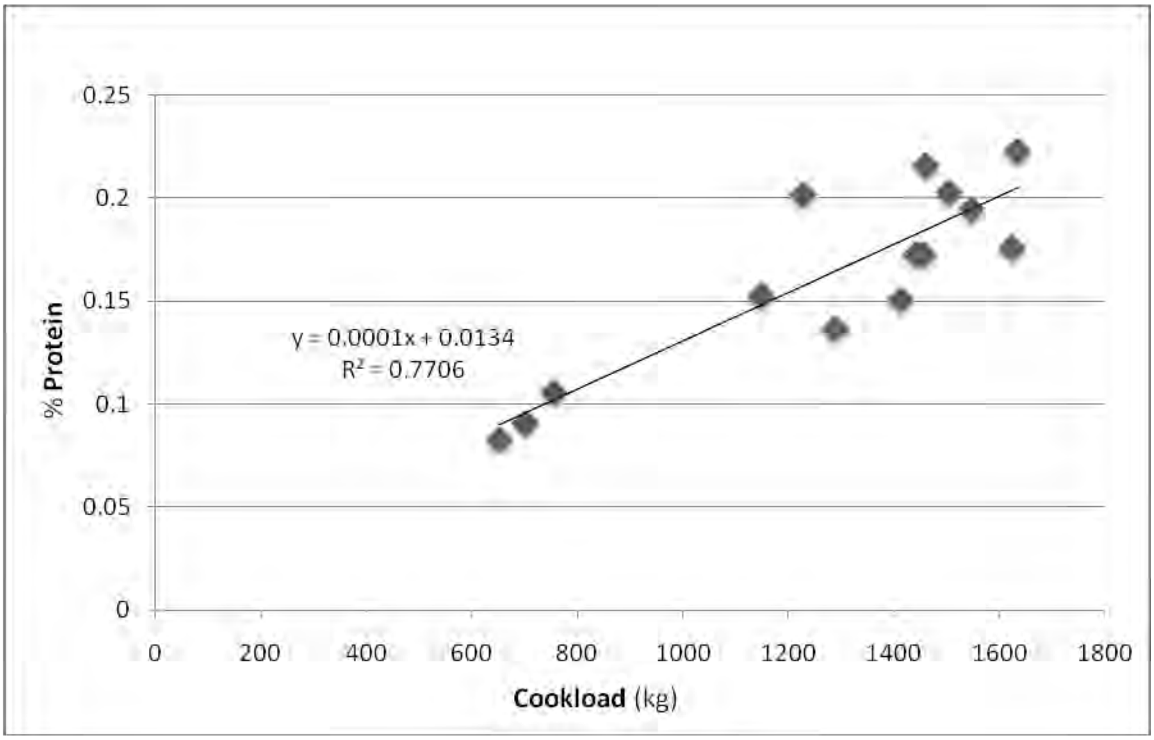


Figure 11: Protein content of the crab cook water

More crabs means more protein will leech therefore leads to the higher protein content. However the overall protein content is very low. The low percentage of protein in the crab cook water is expected as the volume of water is very large compared to the volume of blue swimmer crabs.

4.2.iv Sodium

The analysis of the crab cook water indicated that a significant relationship exists between the crab cook load and the level of sodium present (Table 3). The relationship is a linear positive relationship which is indicated by the line of best fit in Figure 12. The strength of the relationship between the two variables is strong as indicated by the coefficient of determination (R^2 =0.8552) and the correlation coefficient (r =0.925).

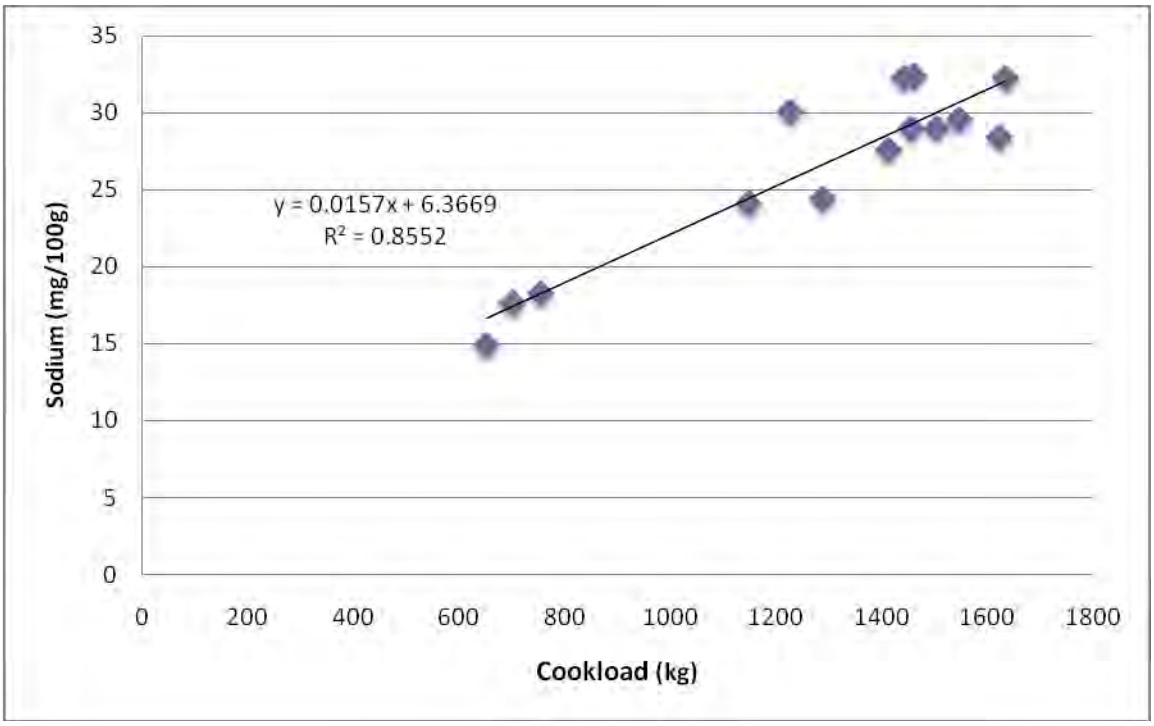


Figure 12: Sodium content of the crab cook water

The sodium content in the crab cook water is important in the processing of the crab stock concentrate. As the sodium content of the crab cook water differs on a daily basis, it was necessary to determine how much salt must be added to the crab cook water to ensure the desired sodium levels for the final product. For the company to use chemical analysis to determine the sodium content daily is expensive and very time consuming. The use of the regression equation from Figure 12 to determine the amount of salt to add to the crab cook water would save time and money. As the amount of cooking salt added would be altered depending on the crab cook load each day the regression equation would determine the initial sodium content in the cook water. Here is a worked example:

Example: The crab cook load boiled in the water was 1200 kg. Determine how much salt would need to be added to make up the final sodium concentration to 0.5% in 1000L.

- Determine sodium content in crab cook water (initial)

$$Y=0.0157\,(1200) + 6.3669$$
$$= 25.207 \text{ mg/100g}$$
$$= 2.521 \text{ g/1000L}$$

- Determine amount of salt to add

  0.5% of 1000 L = 50 g salt (desired sodium content)

  Amt salt to add= desired sodium content – initial sodium content

  = 50 – 2.521

  ANSWER: = 47.479 g salt needs to be added to crab cook water

Table 5 shows a few examples of the amount of salt to add which is dependent on the crab cook load.

Table 5: Examples of the amount of salt to add to the crab cook water to reach desired sodium concentration

Cook load (kg)	**Sodium (mg/100g)**	**Sodium (g/100L)**	**Salt added (final conc 0.5%)**
700	17.35	1.735	48.265
1200	25.207	2.521	47.479
2000	37.7669	3.778	46.222

4.2.v Cadmium

Cadmium is a naturally occurring mineral found in seawater that can pose a risk to humans if consumed in the high doses. The cadmium levels required testing to ensure the crab stock concentrate would be safe for human consumption. The levels of cadmium present in the crab cook water were below the maximum residue limits as stated in the Australian Food Standards Code. The code stated the maximum residue limit is 2 mg/kg (FSANZ 2009) for molluscs. The results from the proximate analysis are shown in Figure 13.

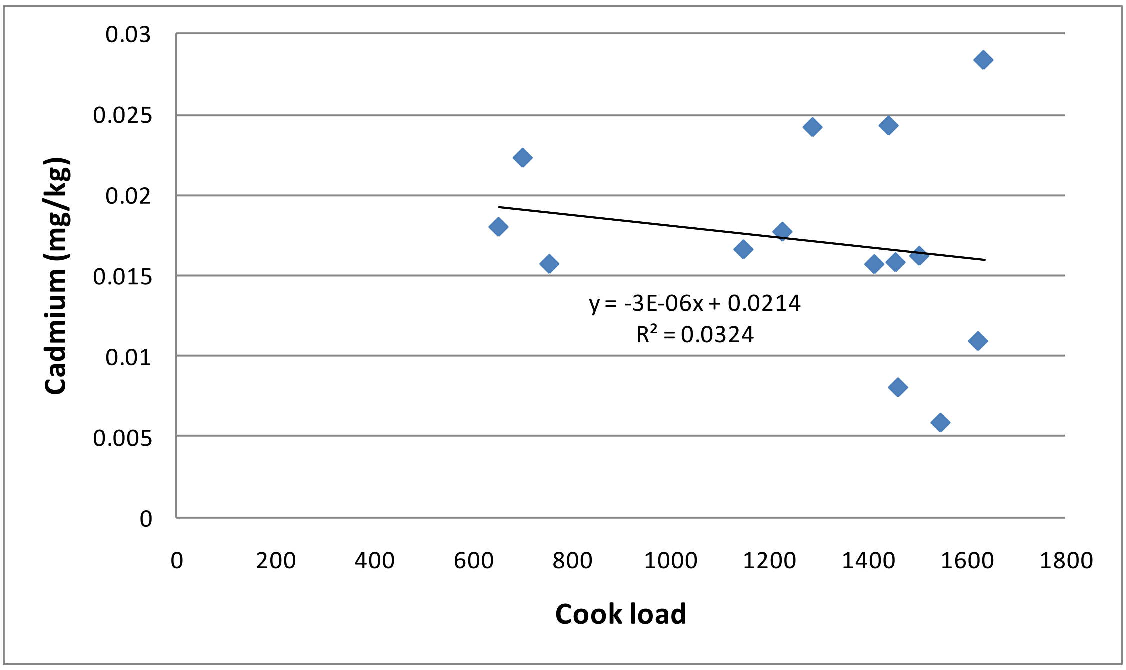


Figure 13: Graph of the amount of cadmium (mg/kg) found in crab cook water with differing cook loads.

The graph indicates the presence of cadmium at minimal levels. The correlation table (*Table 3*) indicates the significance of the relationship between the crab cook load and cadmium is p =0.269. This is enough evidence to conclude that no significant relationship exists between the two variables. The regression coefficient R^2= -0.03 also indicates that the relationship is very weak and therefore it was concluded that no significant relationship exists between the increase in crab cook load and cadmium levels.

Although the crab cook water will be concentrated down to different concentrations ranging from 2 x and 100 x, the final crab stock will also be dilute with water when it is being used as an ingredient in cooking. The crab stock will be consumed at most 2 x more concentrated. The calculations indicated that concentration would not lead to cadmium levels exceeding the maximum residue limit of 2 mg / kg. Therefore the crab stock concentrate used as a base in cooking will not be a safety risk to the consumers.

4.3 Crab cook water for product development

The proximate analysis of the crab cook water used for the development of the different crab stocks for sensory evaluation was necessary to determine the composition of the crab cook water.

Table 6: Composition of the crab cook water used in sensory analysis

	pH	**Brix°**	**% Protein**	**Sodium (mg/100g)**	**Cadmium (mg/100g)**	**Cadmium (mg/ kg)**
Average	7.61	0.27	0.099%	21.278	0.008	0.08
Standard Error of the Mean	0.038	0.033	0.003	0.585	0.005	0.047

The results in Table 6 were the expected results from the proximate analysis. Comparing the results from the initial proximate to the results in Table 6 it can be concluded that the cook load was very low for the crab cook water which was used in the product development of the crab stock.

4.3.i Equation for cooking

At Abacus Fisheries, the crab cook load volume varies each day depending on the amount of blue swimmer crabs caught per day. The amount of potable water used to cook the crabs each day remains the same at 3000 L. When producing crab stock it would be practical for the company to have an equation to refer to, to determine the amount of water to be removed from the original crab cook water. The proximate analysis of the crab cook water showed a relationship between crab cook load and the amount of each component. The correlations shown in Table 3 indicate that protein content and total solids (brix) are strongly correlated at a significant level (< 0.05). These two components are related as protein makes up the largest percentage of solids within the crab cook water and the brix° is the total of soluble solids within a liquid. With this in mind, the equations for the brix° and protein content were combined to produce an equation that can be used to determine the amount of water that has to be removed.

Figure 14 indicates that the percentage of protein is directly correlated with the total solids (brix) of the crab cook water at a significant level. A positive linear relationship exists between the two indicating as the amount of soluble solids increases, the percentage of protein in the cook water increases.

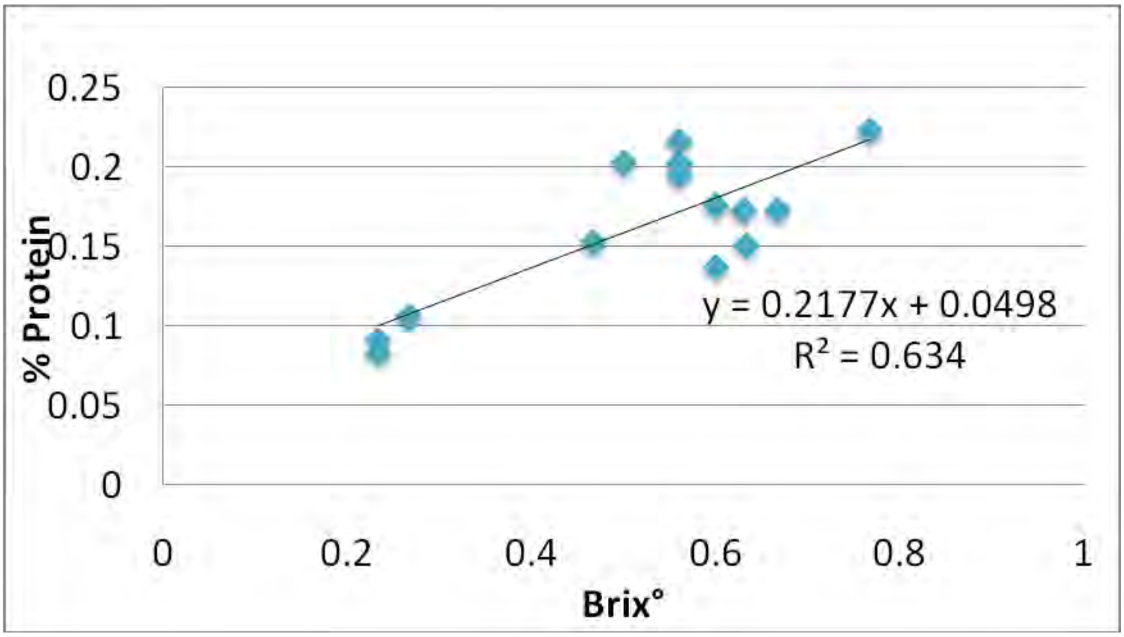


Figure 14: Protein content vs brix of crab cook water

It can be concluded that the brix° can be used as a predictor to determine the percentage of protein in the crab cook water. As these two components are strongly correlated with each other, the equation in Figure 14 can be used in the production of crab stock concentrate to determine the amount of water will need to be removed from the initial crab cook water. To check the protein content using the Kjeldhal method would be more expensive and time consuming than determining the protein content with the above equation.

The crab cook water was collected from the boiler and using the digital refractometer the brix° of the water was measured. The brix° reading will then be used in the equation below which was generated from Figure 14.

$$y=0.2177x + 0.0498$$

Equation 1: To determine the percentage of protein in cook water using the brix reading

The equation will generate the percentage of protein present in the crab cook water. The percentage of protein must be converted into the concentration of protein (g/L). This value would be used in Equation 2, which would determine the amount of water that has to be removed from the crab cook water to produce the final crab stock concentrate.

$$V^2 = V^1C^1 \div C^2$$

Equation 2: To determine the final volume of the crab stock

Where:

V^1= Initial volume of crab cook water (L)

V^2= final volume of the crab stock (L)

C^1= Initial protein concentration in crab cook water (g/L)

C^2= desired protein concentration of crab stock (g/L)

The V^2 value will then have to subtracted from V^1 to determine the amount of water that needs to be removed from the crab cook water to produce the crab stock with the desired protein concentration. Here is a worked example:

<u>Example:</u> Today's crab cook water (3000L) had a brix reading of 0.6°. How much water needs to be removed from the crab cook water to produce a crab stock with a protein concentration of 15 g/L?

- Step 1 : Determine the % protein of the crab cook water

  % protein = 0.2177 (brix) + 0.0498

  = (0.2177 x 0.6) + 0.0498

  = 0.18% protein in cook water

  concentration = 1.8 g/L protein

- Step 2: Determine the final volume of the crab stock

  V^1=3000 L

  V^2= ?

  C^1=1.8 g/L

  C^2=15 g/L

  $$V^2 = \frac{V^1C^1}{C^2}$$

  $$V^2=\frac{3000 \times 1.8}{15}$$

  V^2= 360 L (final volume of crab stock)

- Step 3 : Determine the amount of water to remove from crab cook water

  Amt water to remove = $V^1 - V^2$

  = 3000 – 360

  = 2640 L

  ANSWER = It was determined that to produce a crab stock concentrate with a protein concentration of 15 g/L, 2640 L of water had to be removed from the crab cook water. (Leaving a final volume of crab stock concentrate = 360 L).

4.4 Crab stock production by different technologies

In the new product development process, different ways of producing products are looked at to determine which option is the most ideal. For the production of the crab stock concentrate there were three different technologies which were available options at Curtin University that were viable. These were: vacuum drying, freeze drying and boiling.

4.4.i Evaluation of different technologies

Product Development generally involves a lot of trial and error before the product meets the required expectations. In the production of the crab stock concentrates, each technology had to be assessed to determine the recovery rate and the effectiveness. Trials of each technology to concentrate the crab cook water to different concentrations were conducted with the crab cook water to determine the ratios of salt required and the amount of water that had to be removed.

To get an idea of what the sodium content of the crab stock concentrate should be, commercial stocks were analysed (Table 7). The percentage of sodium in the commercial stocks is quite low. 0.5% sodium was the highest which was for the real chicken stock. As blue swimmer crabs naturally have high levels of sodium which leeches out into the cook water, the desired sodium content for the crab stock concentrate was set at 0.5% (after being diluted with water).

Table 7: Sodium content in commercial stocks

Type of Stock	Sodium (mg/100g)	% Sodium
Real Chicken Stock	521mg	0.5%
Real Beef Stock	450mg	0.45%
Chicken Oxo cube	388mg	0.38%
Beef Oxo Cube	399mg	0.4%
Vegetable Oxo cube	306mg	0.3%
Real Fish Stock	290mg	0.29%
Dried Bonito Stock	290mg	0.29%

Freeze Dryer- Dehydrated crab stock

After looking at the commercial powdered stocks (before being made up), the average percentage of sodium was 16%. This was used as the guide for producing the dehydrated crab stock concentrate. Trials were run to determine the percentage of sodium contained within the sample. The percentage of sodium present was then used to calculate the amount of salt required to make the dehydrated crab stock's sodium content to up 16%. The results obtained from the trials are in Table 8.

Table 8: Amount of dehydrated crab stock produced via freeze drying method

Trial	Sample weight (g)	Sample after freeze drying (g)	Water Loss (%)
1	61	0.1538	99.7
2	59	0.1322	99.6
3	57	0.1453	99.6
4	100	0.3284	99.7
5	100	0.3749	99.6
6	100	0.2929	99.7

For each of the trials, no salt was added to the samples. However after calculations, it was determined that 1.154 g of salt had to be added to 3.6 L of crab cook water to make the sodium content of the freeze dried crab stock powder to 16%.

Due to the capacity of the freeze dryer and time constraints the 3.6 L of crab cook water had to be reduced by 50% before being placed in the freeze drier. Otherwise there would not have been enough samples for sensory analysis.

Boiling

To boil the samples down to different levels required trials to determine the amount of water that had to be removed and the amount of salt to added to the crab cook water. For the concentrated liquid crab stock concentrate, trials were conducted using 8L stock pots. The results are in the Table 9.

Table 9: Trials for production of the concentrated boiled crab stock

Trial	Sample volume	End Volume (mL)	Salt added	Brix°(End)	Water loss (%)
1	700mL	10mL	-	17	98.5
2	500mL	10mL	-	15	98
3	500mL	10mL	0.5g	17	98
4	600mL	25mL	0.88g	7.9	95.8

From the trials it was established that the crab cook water had to be reduced by approximately 95% to produce a crab stock concentrate at 15 brix°. To make up the final products sodium content to 0.5%, 6.349 g of cooking salt had to be added to the crab cook water before boiling commenced.

After looking at the brix° of the commercial ‘real’ stocks, the average brix was 1.4°. This was used as a guideline for producing the reduced liquid crab stock (‘real’ stock). Trials were conducted to determine the amount of water that had to be removed to produce the reduced crab stock with the desired characteristics. Table 10 represents the data collected from the trials.

Table 10: Trials for the production of the reduced boiled crab stock

Trial	Start Volume	End Volume	Salt Added	Brix° (end)	Water loss(%)
1	600mL	300mL	-	1.3	50
2	1 L	500mL	-	1.4	50
3	1 L	500mL	-	1.2	50
4	3 L	1.5L	6 g	1.3	50
5	3 L	1.5L	6 g	1.4	50

From the trial results, it was determined that 50% of the water had to be removed to produce the reduced crab stock with a brix° of 1.4.

Vacuum Dryer- Concentrated Liquid crab stock

The final technology evaluated for producing a crab stock concentrate was the vacuum dryer. The dryer removes water from the sample leaving the other components. Several trials were run to determine the time it would take to produce a crab stock of different concentrations. The results are shown in Table 11.

Table 11: Trials results from the production of the concentrated liquid crab stock using the vacuum dryer

Trial	Sample weight (g)	Time in vacuum dryer	Status of end product
1	100.9866	18 hrs	Completely dry
2	100.2502	18 hrs	Completely dry
3	52.317	8 hrs	50% reduction
4	66.0434	8 hrs	50% reduction
5	40.9066	4 hrs	1.5° brix
6	40.5456	4 hrs	2.4° brix

After several trials using the vacuum dryer to remove the water from the crab cook water for different lengths of time, the most viable option was to completely dry the crab cook water and then rehydrate it with water to make it a concentrated crab stock. This was because it was too hard to scrape off the completely dehydrated crab stock as it adhered to the evaporating dish, however once a small volume of water was added to it, the stock dissolved completely in the water.

4.4.ii Proximate Analysis of the crab stocks

The crab stock concentrates produced using different technologies underwent chemical analysis to determine the amount of protein, sodium and cadmium within each sample. The cadmium levels were to ensure that the safety requirements for the product were met. The other components were important in the development of the nutrition composition. The different crab stock concentrates were diluted with water so they were representative of how the stock would be used in cooking.

The pH of the crab stock concentrates varied between each other (Figure 15). Although, each crab stock had an alkaline pH (>7). The pH of the reduced boiled crab stock was significantly lower than the other 3 crab stocks. The reason for the lower pH in the reduced boiled crab stock could be due to less sediment in the stock. The reduce boiled crab stock did not have to be rehydrated with water, therefore the minerals and protein are evenly dispersed within the product. However, the other crab stocks had sediment which formed large clumps, therefore could have interfered with the analysis causing an increase in the pH. The sediment contains the minerals and protein which make the product more alkaline.

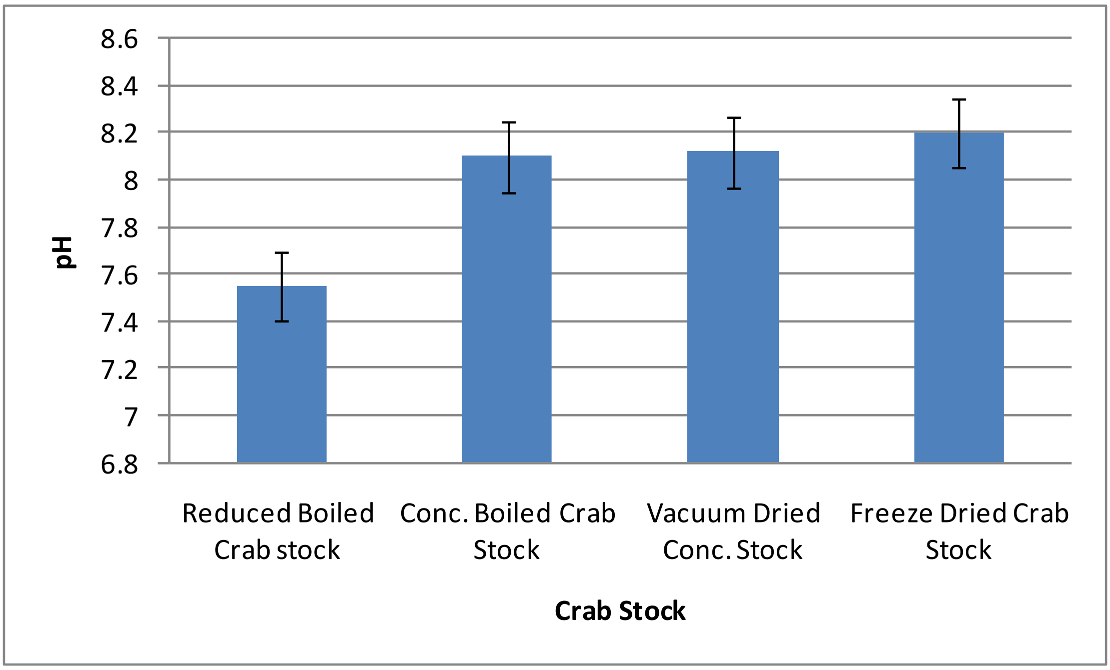


Figure 15: pH levels of the crab stocks produced using different technologies (x ± SEM).

The total solids of the crab stock concentrates were quite varied amongst each other (Figure 16). The freeze dried crab stock powder had the biggest brix° reading at 2°. This was significantly higher than the other three crab stocks which were all below 1.3° brix. The reduced boiled crab stock had the lowest brix° reading at 0.8°. The value is double the brix reading of the crab cook water which was used for the production of the crab stock. It was expected as the water was reduced by 50%, therefore the brix° would double the original amount. The two concentrated crab stocks had very similar brix° readings. The readings were higher than the reduced boiled as they were concentrated substantially and water was added back to it before being used. The vacuum dried concentrated crab was produced by rehydrating the dehydrated crab stock on the evaporating dish with water. The dehydrated stock might not have been completely dissolved by the water. The sediment could have clumped together and would not be evenly dispersed within the liquid therefore leading to the higher brix° reading. The concentrated boiled crab stock had a higher brix° reading than the reduced boiled stock as the particles in the concentrated stock adhered to each other making it hard to dissolve it to produce a homogenous mixture. The particles were heavy and sunk to the bottom on the container. The homogenous mixture had the large particles contribute to the higher brix reading.

The crab stock powder produced using the freeze dryer had the highest brix reading as there was a problem in completely dissolving the powder. After the addition of boiling water, the particles did not completely dissolve, forming a liquid which had a cloudy appearance. There was also sedimentation of the heavier particles. The undissolved particles contributed to the high brix° reading. Although all the crab stocks contain the same amount of total solids, clumping of the solids will cause an increase in the brix content, therefore accounting for the variability in brix among all the products.

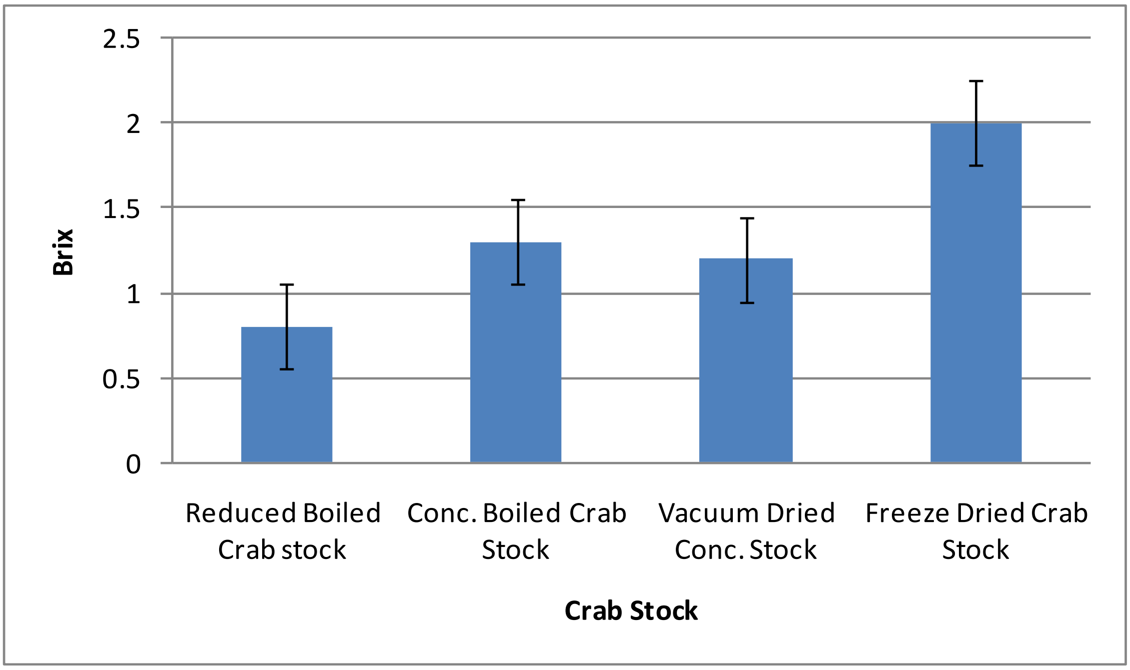


Figure 16: Brix of the crab stocks produced using different technologies (x ± SEM).

The protein content in each of the crab stock concentrates produced using different technologies varied between each other. The results are shown in Figure 17.

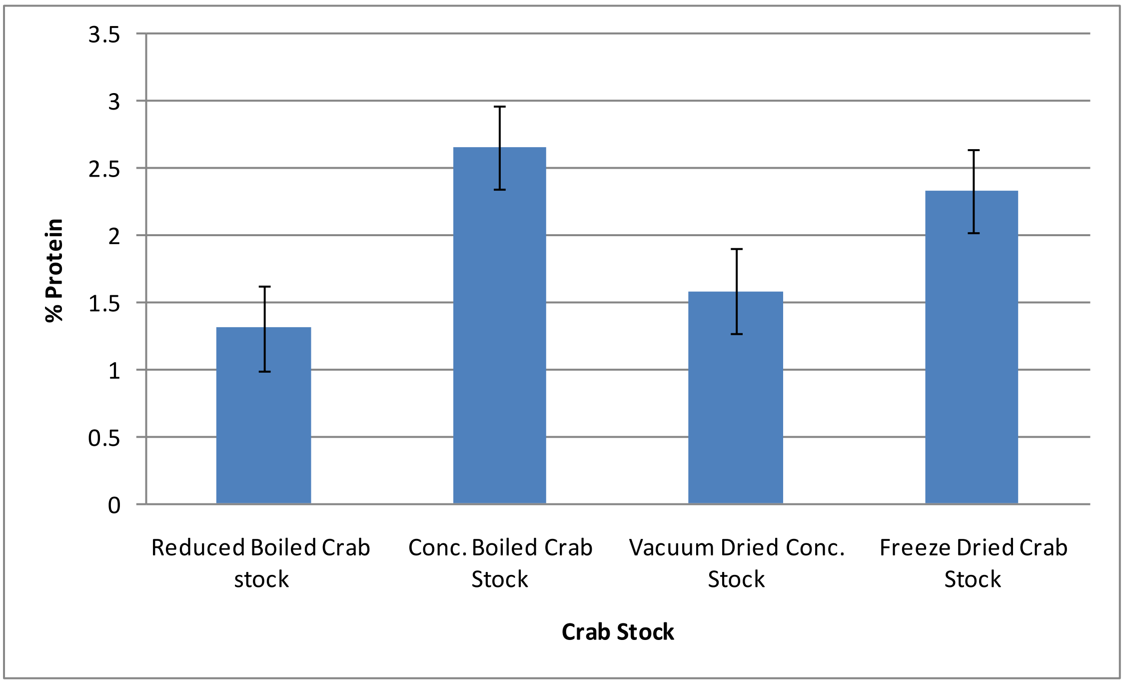


Figure 17: Percentage of protein in the different crab stock concentrates produced using different technologies (x ± SEM)

The crab stocks produced using the different technologies contained less than 3% protein. There were significant differences in the protein content of the different crab stocks. The reduced boiled crab stock and vacuum dried concentrated crab stock had the lowest percentage of protein. This was also noted with the brix readings. The reason for the lower protein could be due to the product not being homogenous when the samples were taken. The sediment sunk very quickly when it was being mixed making it very difficult to get a homogenous samples.

The sodium content among the different crab stock concentrates varied between each sample (Figure 18).

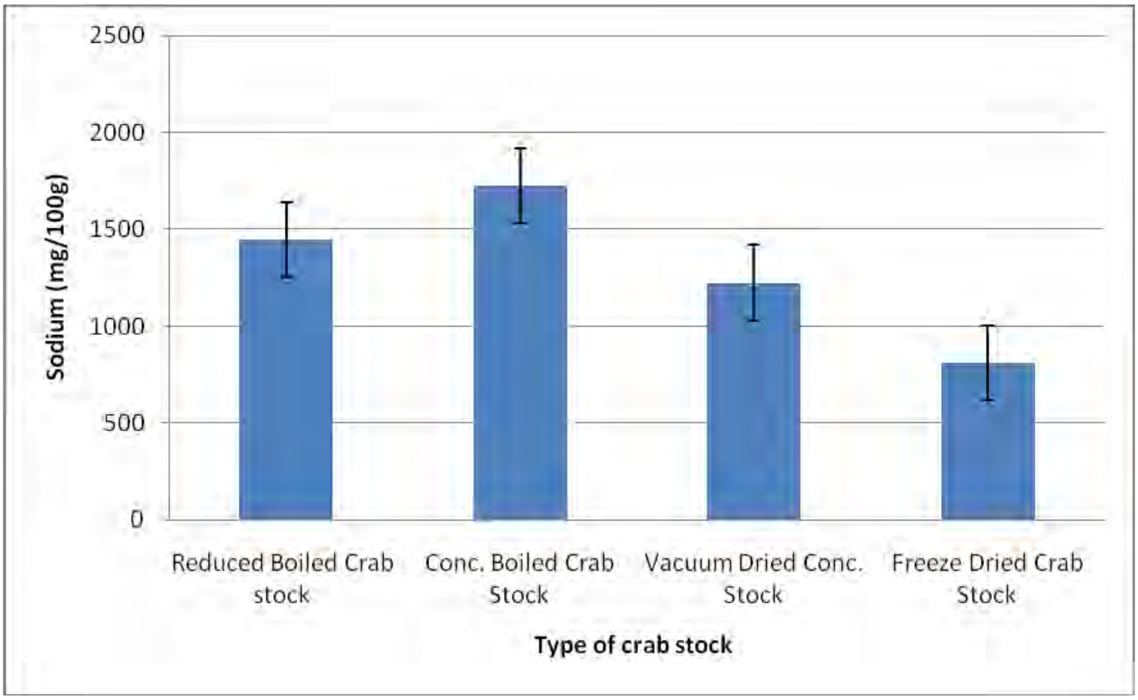


Figure 18: Sodium content in crab stocks produced using different technologies(x ± SEM).

As shown in Figure 18, there were varying sodium levels between the 4 different crab stock concentrates. The freeze dried sample contained less than 1% sodium. With the crab stock concentrates produced using the vacuum dryer and the concentrated boiled stock; they had to be diluted down with water before being consumed. If not enough water was added to the concentrated stock, it could account for the higher sodium levels found within these two crab stocks.

The sodium content in the crab stock concentrates were all above 0.5%. However, in the commercial chicken, beef and vegetable stocks, the average sodium content was 0.5%. Sodium is a mineral naturally occurring in seafood. It is also found in the crab shells and the environment in which the crabs grow. Although there are naturally high sodium levels in the crab cook water, it does not necessarily mean it contributes to the saltiness of the product. With the majority of the crab stocks with levels of sodium above 1% which is double the commercial stocks, the effect of the higher sodium levels was assessed by a consumer acceptance panel in the sensory analysis. The results of this will be discussed in detail later in the paper.

The cadmium content in the crab stock concentrates produced using different technologies was hypothesised to be minimal. As mentioned previously, the maximum residue limit for cadmium in molluscs is 2 mg/ kg (FSANZ 2008). As the maximum residue limit for cadmium in blue swimmer crabs was not stated by FSANZ, the maximum residue limit for molluscs was used as it was the most closely related food. All the crab stock concentrates produced using different technologies were well below the cadmium maximum residue limit, indicating the food is safe for human consumption. These safety tests are a very important step in new product development.

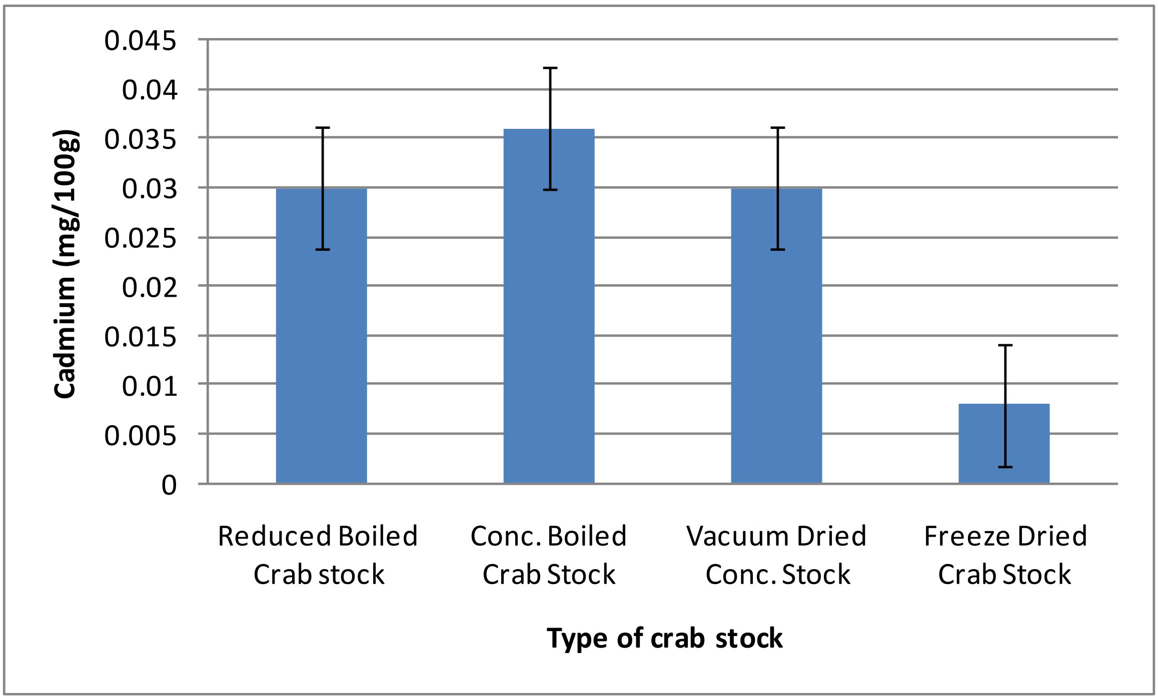


Figure 19: Cadmium content in crab stocks produced using different technologies (x ± SEM).

4.4.iii Sensory analysis of crab stocks produced using different technologies

Sensory analysis was conducted on the four crab stocks that were produced using different technologies at different concentrations to determine which product was the most accepted. The crab stock concentrates were compared based on the five sensory attributes of appearance, aroma, flavour, saltiness and overall acceptability. The crab stocks were assessed by a consumer acceptance panel consisting of 63 participants.

One-way ANOVA (analysis of variance) was used to analyse the data to determine if there was a significant difference between any of the samples. Post hoc analysis was conducted using Tukey's test. The assumptions for the one-way ANOVA were met.

However, the Shapiro Wilk p-value for all the dependant variables of appearance, aroma, flavour, saltiness and overall acceptability was below 0.05 which violates the assumption for normality. As the sample size for the sensory analysis was 63, this makes the data robust, therefore the Shapiro-Wilk p-value was ignored and one way ANOVA was used. Normality and the homogeneity of variances was met with Levene's p-value more than 0.05. Table 12 represents the results from sensory analysis of crab stock concentrates produced using different technologies.

Table 12: Descriptive statistics from sensory analysis of crab stock concentrate produced using different technologies using one way ANOVA

Descriptives

		N	Mean rating score	Std. Deviation	Std. Error
Appearance	Reduced Boiled	63	41.67	22.397	2.822
	Concentrated Boiled	63	45.75	22.830	2.876
	Vacuum Dry conc	63	50.98	21.764	2.742
	Freeze Dry dry	63	42.11	25.738	3.243
	Total	252	45.13	23.394	1.474
Aroma	Reduced Boiled	63	41.89	22.279	2.807
	Concentrated Boiled	63	41.22	21.800	2.747
	Vacuum Dry conc	63	45.25	23.877	3.008
	Freeze Dry dry	63	38.57	22.781	2.870
	Total	252	41.73	22.687	1.429
Flavour	Reduced Boiled	63	33.27	23.145	2.916
	Concentrated Boiled	63	39.87	27.174	3.424
	Vacuum Dry conc	63	41.52	25.870	3.259
	Freeze Dry dry	63	35.06	23.092	2.909
	Total	252	37.43	24.964	1.573
Saltiness	Reduced Boiled	63	36.30	23.017	2.900
	Concentrated Boiled	63	40.97	26.824	3.380
	Vacuum Dry conc	63	45.03	25.614	3.227
	Freeze Dry dry	63	42.75	24.183	3.047
	Total	252	41.26	25.009	1.575
Overall Acceptability	Reduced Boiled	63	36.56	25.962	3.271
	Concentrated Boiled	63	40.19	26.100	3.288
	Vacuum Dry conc	63	43.44	25.630	3.229
	Freeze Dry dry	63	37.03	24.763	3.120
	Total	252	39.31	25.616	1.614

The results retrieved for all the sensory attributes of appearance, aroma, flavour, saltiness and overall acceptability with a p-value over 0.05. There is no evidence to reject the null hypothesis and it can be concluded there is no significant difference between any of the crab stock concentrates produced using different technologies. Therefore, the use of different technologies to turn the waste crab cook water into a crab stock concentrate does not produce a significant difference between the samples.

Trends in the descriptive statistics (Table 12) indicate that none of the samples were overly accepted. The mean acceptability rating score for the majority of crab stocks for each attribute rated lower than 50. This indicates the samples were not popular among the consumer panel. However it was hypothesised that this would be the case as stock is not normally consumed as a food product, but used as a base ingredient in cooking. Some of the comments from the panellists pointed out they would like the crab stock as a base but not as it was consumed in the sensory evaluation. This indicates the product has potential to sell without the addition of other ingredients except for salt. The vacuum dryer concentrated crab stock was the most accepted sample amongst the consumer panellists with a mean overall acceptability rating of 43.44. The reduced boiled sample was the least accepted by the consumer sensory panel with an overall acceptability rating of 36.56.

Prolonged exposure of the crab cook water to high temperatures could result in the loss of volatile compounds. Volatiles are an important flavour component of a food product and a loss of volatiles leads to a decrease in quality. The addition of salt to the crab cook water increased the boiling point. The higher boiling point means that more volatile compounds are being lost during the cooking stage which leads to a lower acceptability rating. As well as the loss of volatiles, the higher temperature meant that the crab cook water developed a burnt odour later in the process.

The vacuum dryer controls the internal environment within the closed system. It works on the principle of keeping a low pressure at a controlled temperature which decreases the boiling point of the water in the product. Decreasing the boiling point of the crab cook water by lowering the pressure in the system meant the crab stock was not exposed to high temperatures. This proves advantageous in retaining the heat sensitive volatiles in the crab stock contributing to a higher quality product and higher consumer acceptability rating.

The crab stock that was produced using the freeze dryer contained a much higher level of naturally occurring sodium, so a minimal amount of salt was added. However the natural level of sodium does not necessarily contribute to the salty taste associated with sodium chloride. This factor could contribute to the low acceptability rating.

The small molecule volatile compounds are the most volatile which also means they are strongly flavoured. These volatiles compounds would be completely retained in the freeze drying process and may be partially lost in the vacuum drying process. The use of the boiling process would lead to the highest loss of the small molecule volatiles. The crab stock produced using the freeze dryer retained the most of these small molecule volatiles which produced a crab stock where the flavour was possibly too strong. This would account for the lower acceptability ratings. As the vacuum dryer retained less of the volatile compounds, the flavour was not too strong leading to a more accepted product.

Process used to develop the crab stock concentrates influence on panellists' acceptability ratings

The process used to produce the crab stock concentrate did not have a significant effect on the panellists' acceptability rating for each of the sensory attributes (Table 13). This was predicted as the results from analysis of the acceptability ratings for the crab stock concentrates using one way ANOVA indicated that there was no significant difference between the acceptability ratings of the crab stocks produced using different technologies. As there was no significant difference between acceptability ratings, the different processes used would not have a significant effect either.

Table 13: Significance of the process used to produce the crab stock concentrates on the panellists' acceptability rating

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
process	Appearance	1924.676	3	641.559	1.168	.323
	Aroma	537.883	3	179.294	.361	.782
	Flavour	1980.116	3	660.039	1.141	.333
	Saltiness	1042.493	3	347.498	.580	.629
	Overall Acceptability	2842.941	3	947.647	1.530	.208

Panellist's demographic influence on acceptability rating of crab stock

On the pre-screening forms filled out by the panellists, they were asked about their country of birth and age. There was a diverse range of panellists so this information was used to see if any of panellists' characteristics would have influenced their acceptability ratings of the crab stock concentrates produced using different technologies. The test was conducted using MANOVA (Multivariate Analysis of Variance) and post hoc analysis of data was conducted with the use of Tukey's test. The sample size for the MANOVA test was N= 61, as two panellists did not fill out the pre-screening forms prior to sensory analysis.

Panellists' country of birth vs acceptability rating of crab stock concentrates produced using different technologies.

Amongst the 61 panellists, there was a diverse range of people born in countries other than Australia. There were 25 panellists' born in South-East Asia and 25 panellists born in Australia. There were several that were born in other countries around the world that were placed into the 'other' group (11 panellists) as there was not enough from single countries to represent each area. This meant the 'other' grouping is made up of very diverse individuals.

Before the analysis can be conducted, the data must meet the assumptions for MANOVA. The assumption homogeneity of variance was met as the Box test indicated F (165, 18613.316) = 1.088, p-value= 0.210.

Table 14 shows the results retrieved from the comparison of the panellist's acceptability rating vs panellist's country of birth. After analysis using MANOVA, for the attributes of appearance, aroma and overall acceptability, with a p-value > 0.05, there was not enough evidence to reject the null hypothesis and it was concluded that the panellist's country of birth did not significantly influence the panellist's acceptability rating of the crab stock concentrates.

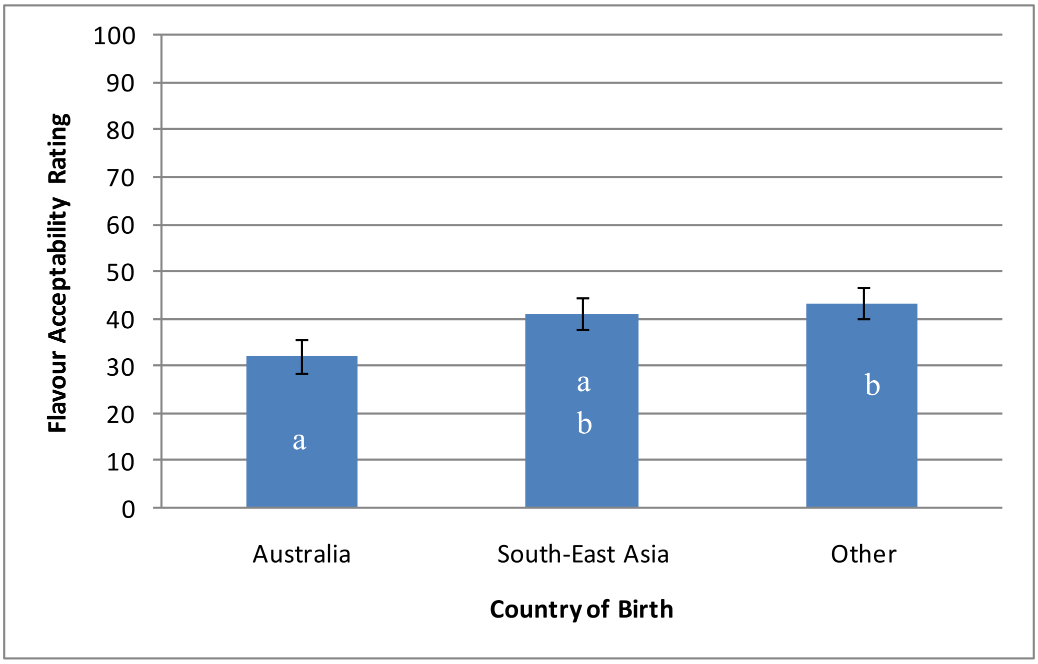
Table 14: Significance of panellist's country of birth on their acceptability rating of the crab stock concentrates

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Country	Appearance	2953.823	2	1476.912	2.708	.069
	Aroma	2273.189	2	1136.594	2.249	.108
	Flavour	5698.042	2	2849.021	4.683	.010
	Saltiness	9042.828	2	4521.414	7.642	.001
	Overall Acceptability	1853.642	2	926.821	1.400	.249

However, for the sensory attributes of flavour and saltiness the p-values were 0.010 and 0.001 respectively. With p-values below 0.05, there was enough evidence to reject the null hypothesis and conclude that the panellist's country of birth had a significant effect on the panellist's acceptability rating of the crab stock concentrates in the attributes of flavour and saltiness. Post hoc analysis using was conducted using Tukey's test to determine the significant differences.

The flavour acceptability ratings given by the panellists' born in South-East Asia was not significantly different from the panellists born in Australia and Other countries. However there was a significant difference in flavour acceptability rating between panellists born in Australia and panellists born in 'other' countries. The Australians acceptability rating was the lowest. The results are shown in Figure 20.

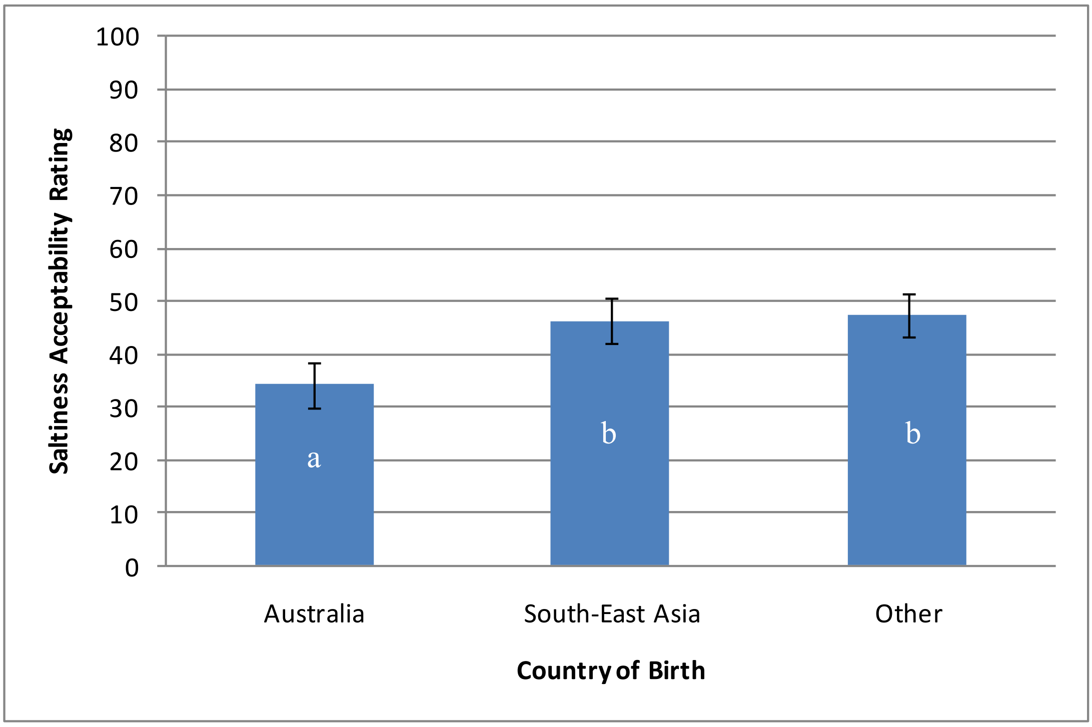


N.B: Different letters denotes significant differences

Figure 20: Flavour acceptability rating of crab stock concentrates produced using different technologies (x ± SEM)

The reason for this could be accounted for by tradition. Australians usually consume thick and creamy soups, therefore this is what they would associate the word soup with. The crab stock concentrate resembled a clear thin broth which is commonly consumed in South-East Asian countries. The Australians might not have been used to the seafood taste in a watery broth. There are food products sold in South-East Asian countries which taste similar to the crab stock concentrate. In Australia there aren't. The panellists' lower acceptability rating of the crab stock concentrates flavour could be due to the unusual taste that they are unfamiliar with.

The panellists' acceptability rating of the saltiness of the crab stock concentrates produced using different technologies is shown in Figure 21.



N.B: Different letters denotes significant differences

Figure 21: Saltiness acceptability rating of crab stock concentrates produced using different technologies (x ± SEM)

The panellists born in South-East Asia and 'Other' countries had saltiness acceptability scores which were not significantly different from each other. However the panellists born in Australia had significantly different saltiness acceptability scores when compared to panellists born in South-East Asia and Other countries. It was hypothesised that depending on preference, the crab stock concentrates could have either been too salty or not salty enough, therefore this resulted in lower acceptability ratings.

In conclusion, from the findings of the acceptability rating of the crab stock concentrates produced using different technologies based on the panellists' country of birth, there was a significant effect for the sensory attributes of flavour and saltiness. Panellists born in Australia had the lowest acceptability ratings. The reason for this is possibly due to the unfamiliarity with the taste of the crab stock concentrate which does not resemble any of the foods normally consumed by Australians. The panellists born in South-East Asia were expected to have the highest acceptability ratings as the crab stock concentrates tasted similar to food products sold in parts of South-East Asia.

Panellists' age vs acceptability rating of crab stocks produced using different technologies.

To determine if the age of the panellists affected their acceptability rating of the different crabs stocks, MANOVA was used. The assumptions of homogeneity of variance- covariance matrices were met as the p-value from the Box's test was > 0.001.

Table 15: Significance of panellist's age on their acceptability rating of the crab stock concentrates

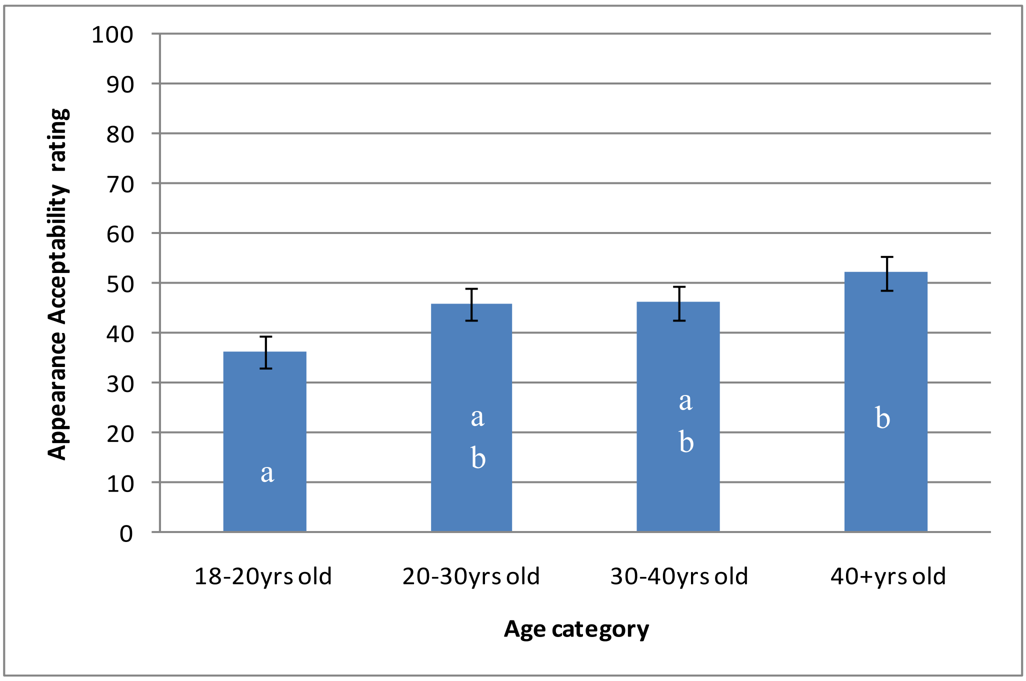
Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Age	Appearance	5639.255	3	1879.752	3.421	.018
	Aroma	6500.140	3	2166.713	4.357	.005
	Flavour	12605.890	3	4201.963	7.261	.000
	Saltiness	8272.924	3	2757.641	4.603	.004
	Overall Acceptability	10406.957	3	3468.986	5.599	.001

As $p < 0.05$ (Table 15) for all the attributes of appearance, aroma, flavour, saltiness and overall acceptability, there is enough evidence to reject the null hypothesis and conclude that age does have a significant effect on the panellists acceptability rating of the crab stock concentrate produced using different technologies. The panellist's acceptability rating of the crab stock for each attribute is significantly affected by how old the panellist is. Post hoc analysis was conducted using Tukey's test to determine which of the age groups was significantly different in their ratings of the crab stock concentrates.

Among all the acceptance ratings of the crab stock concentrates produced using different technologies, for all the sensory attributes, the 18-20 year old age group had the lowest acceptability rating scores. Amongst the other three age categories the order of acceptability varied with different sensory attributes.

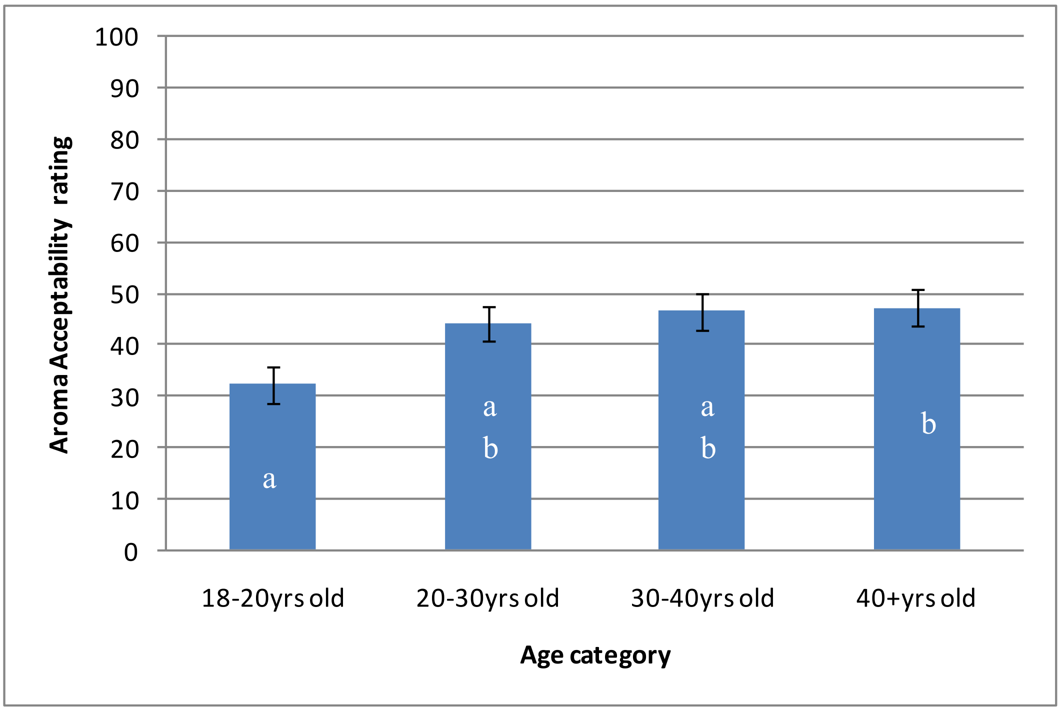
The 18-20 year olds rated the appearance of the crab stock lowest at with an average mean acceptability rating of 36.19. This rating was grouped in a different subset to the appearance acceptability rating by the 40+ year olds group. The panellists within this age category rated the crab stocks higher than the younger age groups with a mean acceptability rating of 52.08. The 20-30 year old and 30-40 year old age groups acceptability rating was not significantly different from either of the other age groups. The reason could be that the younger panellists are more critical of the appearance of the samples than the older panellists. The younger panellists are more picky when it comes to what they eat due to lack of experience in diverse food choices. If they see something unusual they are more likely to be less accepting. Another reason for the 18-20 year olds rating the acceptability of the crab stocks lowest could be due to food neophobia. A person with food neophobia has a fear of trying new foods that they are unfamiliar with (Henriques, King, and Meiselman 2009). They also tend to avoid trying these new foods if given the option. Food neophobia is very common in the younger population which could account for the 18-20 year old panellists' giving the crab stocks a lower acceptability than the other panellists'.



N.B: Different letters denotes significant differences

Figure 22: Panellists age vs the appearance acceptability rating of the crab stock produced using different technologies

The panellists between the age of 20- 30 years old, 30 - 40 years old and 40+ years old had aroma acceptability ratings which were not significantly different from each other. The 20-30 year old panellists group had acceptability ratings not significantly different to the panellists aged between 18-20 years old. However, the aroma acceptability ratings of the crab stock concentrates produced using different technologies for the 18-20 year old age group was significantly different to the 30-40 and 40+ year old age group. The youngest group (18-20yr olds) gave the lowest acceptability ratings for the aroma of the crab stock concentrate (32.35). The results are shown in Figure 23

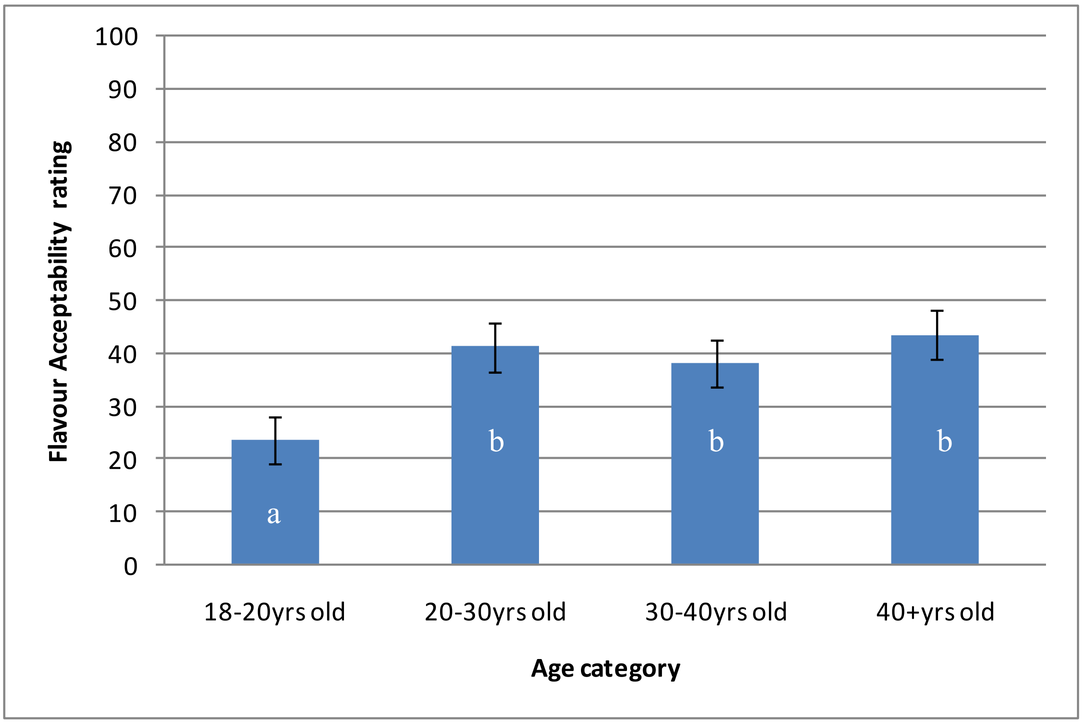


N.B: Different letters denotes significant differences

Figure 23: Panellists age vs the aroma acceptability rating of the crab stock produced using different technologies

The post hoc analysis of the flavour acceptability rating of the crab stock concentrate to determine which age group was significantly different than the others indicates results similar to the comparison of aroma acceptability rating. The 18-20 year old age group flavour acceptability rating was significantly different compared to the other 3 age categories. There was no significant difference in rating scores between the other 3 groups. The 18-20 year olds rated the acceptability of crab stock concentrates flavour as very low with mean rating of 23.52. The closest average acceptability rating was 38.05

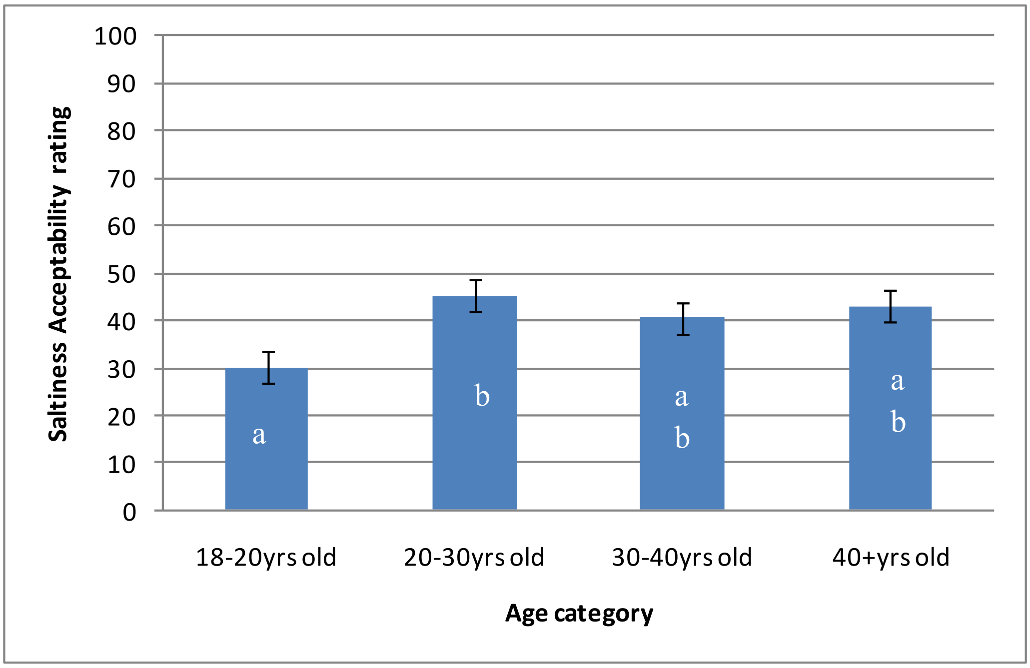
given by the 30-40 year old age group. There is 15 points different between the two scores which reinforces the significant difference. The results of the post hoc analysis are in Figure 24.



N.B: Different superscript letters denotes significant differences

Figure 24: Panellists age vs flavour acceptability rating of the crab stock produced using different technologies

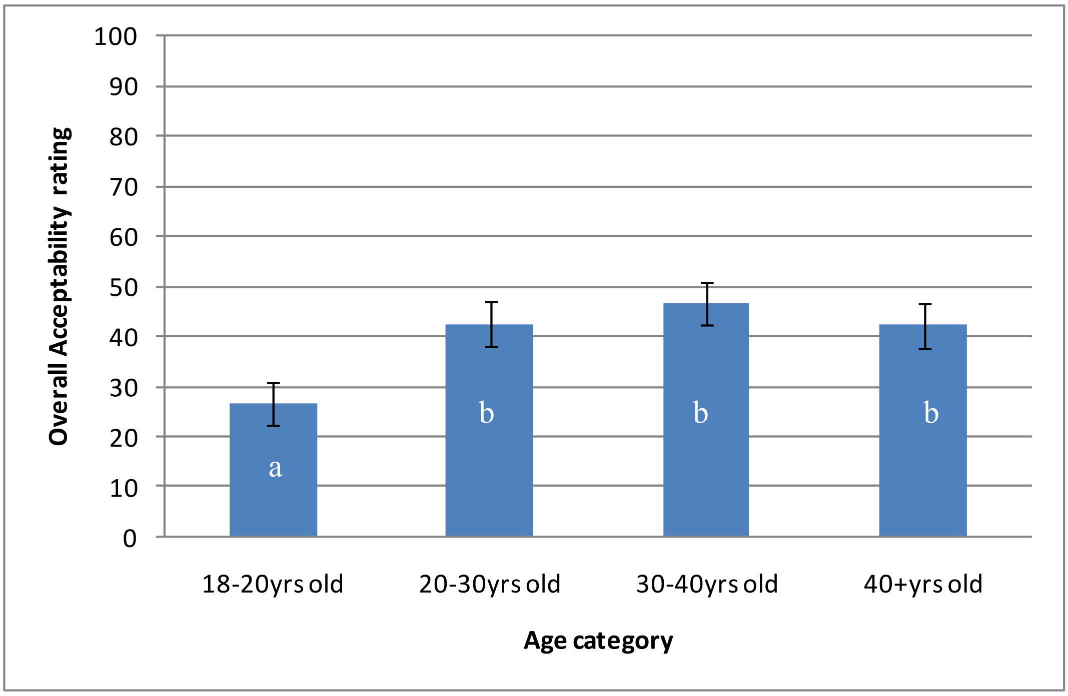
The panellists' age was a significant factor in the acceptability rating of the saltiness of the crab stock concentrate produced using different technologies. The 3 age groups above 20 years old did not have significantly different rating scores to each other. This is represented below in Figure 25.



N.B: Different letters denotes significant differences

Figure 25: Panellists age vs saltiness acceptability rating of the crab stock produced using different technologies

The 30-40 year old and 40+ year old panellists were not significantly different to the panellists in the 18-20 year old age category. However there was a significant difference in the acceptability rating between the 18-20 year old and 20-30 year old age groups. The 18-20 year olds rated the acceptability of the crab stock concentrates saltiness at 30.13, whereas the 20-30 year old group had an average rating score of 45.25. Post hoc analysis on the overall acceptability ratings for the crab stock concentrate indicates that there is no significant different in acceptability rating between the age categories of 20- 30 years old, 30-40 years old and 40+years old which is indicated by the 'b' in Figure 26. However the overall acceptability rating for the panellists in the age category 18-20 years old was significantly different than the other age categories. The average overall acceptability rating given by the 18-20 year old panellists was 26.69 which was the lowest acceptability rating. The highest overall acceptability rating was given by the 30-40 year old age group with an average rating of 46.60.



N.B: Different letters denotes significant differences

Figure 26: Panellists age vs overall acceptability rating of the crab stock produced using different technologies

It was hypothesised that the panellists between the age of 18-20 years old would rate the acceptability of the crab stock concentrates produced using different technologies the lowest. The reason for the 18-20 year old age group having the lowest acceptability rating for all of the sensory attributes of the crab stock concentrate produced using different technologies could be attributed to maturity. The younger panellists may not have been exposed to food products similar to the products tested during sensory analysis. The taste buds of the older panellists could be more mature and have acquired different tastes that they may not have accepted when they were younger. The younger panellists also would have a stronger sense of smell and taste so the bitter notes in the crab stock concentrates would have been more prominent to their taste buds. This would be the same with the aroma attribute. All these factors could be related to the lower acceptance rating scores given by the 18-20 year old panellists.

Principal Components Analysis (PCA)

Principal Component Analysis (PCA) was conducted on the data retrieved from the sensory evaluation of crab stock concentrates produced using different technologies to determine which of the variables were the biggest contributors to the acceptability rating. The variables analysed were the five sensory attributes (appearance, aroma, flavour, saltiness and overall acceptability).

For the analysis of the different sensory attributes the overall MSA for the set of variables included in the analysis was 0.805, which exceeds the minimum requirement of 0.50 for overall MSA.

The variables included in the analysis were: overall acceptability, flavour, saltiness, aroma and appearance. The eigenvalue was set at 1 so components that were above this value were considered important contributors to the acceptability rating of the crab stock concentrate. Table 16 shows the different components and the eigenvalues.

Table 16: Total variances explained - Components and their eigenvalues for the PCA of sensory attribute variables

Total Variance Explained

	Initial Eigenvalues		
Component	Total	% of Variance	Cumulative %
1	3.129	62.582	62.582
2	.886	17.720	80.302
3	.510	10.193	90.494
4	.290	5.793	96.288
5	.186	3.712	100.000

Table 16 indicates that Component 1 was the biggest influence on the acceptability rating of the crab stock concentrate with an eigenvalue 3.129. This means that component 1 accounted for 62.582% of the variance. The scree plot in Figure 27 shows that the other components did not significantly influence the acceptability rating of the crab stock concentrates.

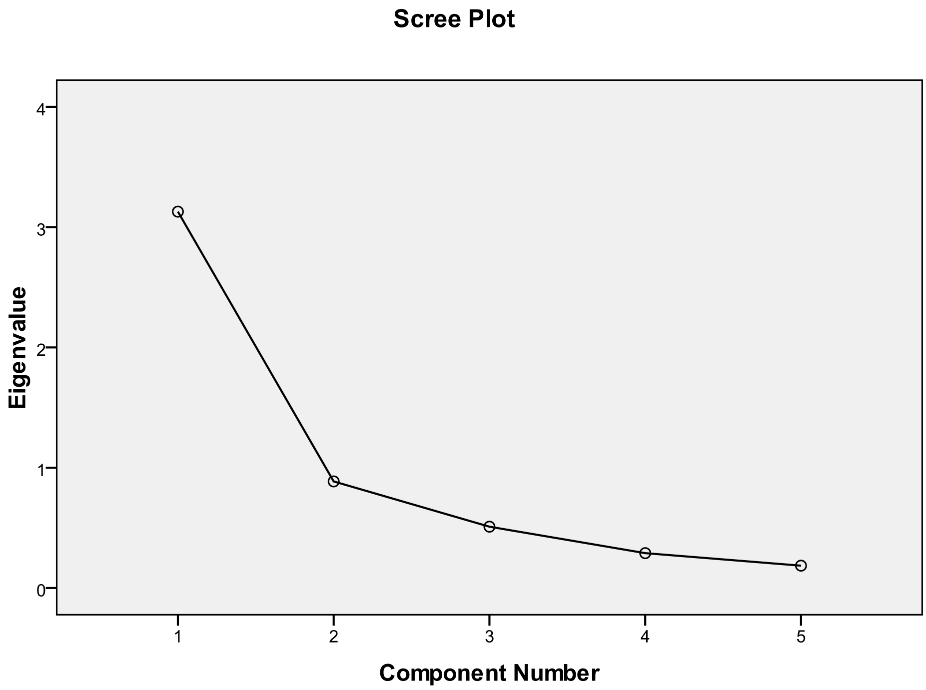


Figure 27: Scree plot indicating the components with the biggest influence on the acceptability rating of the crab stock concentrate

The component matrix was then generated to determine how much of each of the variables makes up component 1. Table 17 shows that the all of the tested variables contributed in influencing the acceptability ratings of the crab stock concentrates, however they did not all have the same strong influence. The overall acceptability, flavour and saltiness acceptability ratings were strongly correlated to component 1. From this it was concluded that these three acceptability ratings had the biggest influence on the acceptability ratings on the crab stock concentrate produced using different technologies.

Table 17: Component matrix of component 1 for the influence on the acceptability rating of the crab stock concentrate

Component Matrix[a]

	Component
	1
Overall Acceptability	.905
Flavour	.889
Saltiness	.817
Aroma	.724
Appearance	.573

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Relationship between sensory attributes (different technologies)

Simple linear regression was used to determine if the panellists' acceptability rating of the crab stocks in different attributes were related to each other. Each of the attributes were compared with each other. Table 18 shows the results from the correlations table.

Table 18: Pearson correlation and significance table for the sensory attributes tested in the sensory analysis of crab stock produced using different technologies (values significant @≤ 0.05).

Correlations

		Appearance	Aroma	Flavour	Saltiness
Pearson Correlation	Aroma	.456			
	Flavour	.337	.517		
	Saltiness	.251	.422	.727	
	Overall Acceptability	.427	.526	.807	.713

Each attribute was compared with each other and from the table above as the p-value is below 0.05 for all the pairings, there is enough evidence to reject the null hypothesis and conclude that a relationship exists between all the attributes of appearance, aroma, flavour, saltiness and overall acceptability. Although relationships exist between all the attributes, not all of them are strongly correlated with each other. There were only 3 significant relationships which were strongly correlated. It was between: flavour and saltiness, flavour and overall acceptability, and saltiness and overall acceptability.

Appearance is significantly related to aroma, flavour, saltiness and overall acceptability. However it is not strongly correlated compared to the relationships between the other attributes. This was expected because logically the appearance of a food product does not give an indication as to how the product tastes, smells or how salty it is. Therefore the relationship between appearance and the other 4 attributes is not of importance.

The sensory attribute of aroma is strongly related to flavour and overall acceptability. The strong correlation between aroma and flavour ($r = 0.517$) was predicted because if the sense of smell is blocked and a person tries a food, the flavour is different. The aroma of a product influences the flavour the mouth tastes. The aroma of the all crab stock concentrates produced using different technologies resembled the smell of seafood. The flavour would be described in the same way. Therefore the aroma of crab stock concentrates was a predictor of the taste of the stock. The relationship between the overall acceptability and aroma ($r = 0.526$) would be similarly explained by the relationship between flavour and aroma. Saltiness was not strongly related to aroma. It was expected as smelling a product does not predict the saltiness of a product. Therefore the relationship is not of significant importance as it logically does not make sense.

The relationship between flavour and saltiness is a strong positive linear relationship with a correlation of 0.727. The reason for the relationship existing is if the sample is too salty or not salty enough to the panellists tastebuds, that in turn will affect their acceptability rating of flavour as the salt level would either override the flavour or not enhance the other flavours. Therefore if the salt level is just right for the panellists, the flavour acceptability rating would be higher. The saltiness acceptability rating of the value added crab stock was significantly related to the other four sensory attributes. However the saltiness acceptability rating cannot logically be a predictor of the appearance and aroma acceptability rating of the value added crab stock. The flavour and saltiness acceptability ratings for the value added crab stock was strongly correlated. The saltiness of the value added crab stock was strongly correlated with the overall acceptability with a correlation coefficient of 0.819. This was one of the strongest correlations amongst the influence of acceptability ratings of the value added crab stock. The outcome was hypothesised because if the crab stock was too salty or not salty enough, the panellists would rate the saltiness of the product with a low acceptability rating. The acceptability rating would then affect the overall acceptability. Food products which do not have enough salt or are too salty are not enjoyable to eat. Therefore this would lower the overall acceptability acceptance rating.

The flavour of the crab stock concentrates produced using different technologies was strongly correlated to the overall acceptability. With a correlation coefficient of 0.807, it can be concluded that the overall acceptability of the crab stock concentrate depended very strongly on the flavour of the stock. The strong correlation was expected as a food product with a very unacceptable flavour rating would contribute directly to a low overall acceptability rating as seen in the results in Table 12. The flavour acceptability ratings were very similar to the overall acceptability rating of the different crab stock concentrates. Both of these attributes had low acceptability ratings. Although the flavour and overall acceptability of the crab stock concentrate was not overly accepted by the consumer panellists, stock is not normally consumed as a soup.

The overall acceptability of the crab stock concentrates was strongly correlated to the sensory attributes of aroma, flavour and saltiness. If a food product is too salty and does not smell or taste nice it will effect the consumer's perception of the product. A product that does not taste nice will not sell as the consumers will not re-purchase a product they did not find enjoyable the first time they tried it. Therefore sensory evaluation is vital part of the new product development cycle. If the consumer panel does not rate the flavour acceptability this affects the overall acceptability rating.

In conclusion, there were significant relationships existent between all the acceptability ratings for the crab stock concentrates produced using different technologies. From the correlations table (Table 18) it can be concluded that the overall acceptability of the crab stock concentrates produced using different technologies was influenced the most by the crab stocks' aroma, flavour and saltiness acceptance.

4.4.iv Conclusion

From the results of the sensory analysis on the crab stock concentrates produced using different technologies it was concluded that there was no significant differences in the acceptability ratings of the different crab stocks. However the mean acceptability ratings indicated that the concentrated liquid crab stock produced with the vacuum dryer was the most accepted amongst the consumer acceptance panel. The hypothesis that the acceptability ratings of the different crab stocks would be low held true. This is because stock in general is not consumed as a product on its own, but as a base ingredient in cooking.

It was also found that the panellists' age was a significant influence on the panellist's acceptability ratings of the crab stock. The panellists aged between 18-20 years old gave the lowest acceptability ratings which is due to lack of exposure to a product which was similar to the crab stock concentrates and their taste buds are most sensitive as younger ages.

4.5 Value added crab stock

The horticulture industry in Carnarvon produces a large amount of quality produce which is being underutilised. The third objective of the project was to use this produce and develop two different value added stocks with the crab cook water being the base ingredient. The ingredients to be used were based on the common flavours used in seafood, which horticultural produce was being wasted and the accessibility of the produce. The two flavoured crab stocks were developed:

- Herb flavoured crab stock
- Chilli tomato crab stock

Recipes were formulated and modified until the product had the desired flavour. Below is the ingredients list for the recipes used to produce the stocks for sensory analysis.

Herb Flavoured Crab Stock

Ingredients:

3 L crab cook water

3 celery sticks (chopped)

1 ½ brown onions (chopped)

1 cup chopped parsley

1 T cooking oil

26 g Salt

Sprig of thyme

Chilli Tomato Crab Stock

Ingredients:

3 L crab cook water

3 celery sticks (chopped)

1 ½ brown onions (chopped)

1 cup chopped parsley

2 red chilli's (chopped and deseeded)

525 mL tomato puree

1 T cooking oil

26 g Salt

1 t sugar

The formulation of the two different variations in flavour is based on the ingredients which are easily accessible in Carnarvon and are commonly found vegetables. Tomatoes are grown in large volumes in Carnarvon but tonnes of them are wasted each day. The utilisation of the waste product would decrease horticultural waste and costs. Turning waste into value added foods would increase the company's profit as well as help the environment. The Chilli Tomato Crab Stock was cooked using tomato puree instead of whole tomatoes. The tomato puree is 99% tomato. If the stock was going to be produced at Abacus Fisheries using fresh tomatoes, the tomatoes would have to be pre prepared by crushing before being added into the crab stock. All skins and seeds would be removed during the straining stage of the stock preparation

4.5.i Proximate analysis of value added crab stock

The value added crab stocks underwent chemical analysis to determine the amount of protein and sodium within each sample. The other components were important in the development of the nutrition panel.

Table 19: Proximate composition of the value added crab stocks

Type of crab stock	**pH**	**Brix°**	**% Protein**	**Sodium (mg/100g)**
Herb	5.95	3.0	2.86	2276.2
Chilli Tomato	4.88	6.2	7.08	2346.2

The pH of the value added stocks were acidic with readings below 7. The pH readings are very low compared to the crab cook water which was used to produce the stock. The drop in the herb stock pH was due to the addition of other ingredients. The chilli tomato crab stock had the lowest pH reading at 4.88 which is due to the addition of a large volume of tomatoes to the stock. Tomatoes are an acidic fruit which would explain the low pH readings.

The brix reading of the value added crab stocks are quite high. The readings are not just made up of the protein content but also other components which were introduced with the addition of other ingredients. The higher brix reading for the chilli tomato crab stock is due to the addition of tomatoes. The tomato pulp is quite thick therefore contributing significantly to the brix reading.

The value added crab stocks had high protein content. However, the protein content in the chilli tomato crab stock was significantly higher than the herb flavoured crab stock. On average, 7.08% of protein was found in chilli tomato crab stock compared to 2.86% in the herb crab stock. The reason for the higher protein content is due to the addition of bulk ingredients such as tomatoes and celery to the crab stocks during the cooking stage. During this stage, protein leeched out of the fruits and vegetables, which led to a high protein content.

The sodium levels in the value added crab stock were very similar to each other. During the cooking stage for the flavoured crab stock an extra tablespoon of cooking salt was added to enhance the flavour of the additional ingredients. Therefore the sodium content on average is above 2% for the flavoured crab stocks. The effect of adding more salt to the two flavoured crab stocks was evaluated in the sensory analysis to see if the saltiness of the product is acceptable.

There is some data missing for the cadmium levels in the value added crab stock. This is because the samples had too many particles within the solution after the wet digestion. This was a problem as it would block the AAS machine. As the base crab stock was from the same batch of crab cook water used in the production of the crab stock concentrates produced using different technologies it was safe to assume the cadmium levels would be similar (Figure 13). Therefore the cadmium content of the value added crab stock is well below the maximum residue limits.

4.5.ii Sensory Evaluation of value added crab stock

The data that was analysed did not meet the assumptions for normality. The data was skewed to the left and the p value for Shapiro-Wilk was less than 0.05 (see Appendix 2). Therefore the analysis of the two different value added crab stocks was conducted using Mann-U-Whitney test. The test was conducted to determine if there was a significant difference in the acceptance rating between the value added crab stocks. The Mann-U-Whitney test is the non parametric version of the two-independent sample t-test.

As the p-value was less than 0.05 for the sensory attributes aroma, flavour, saltiness and overall acceptability, there was enough evidence to reject the null hypothesis. It was concluded that there was a significant difference in acceptability ratings between the two different flavoured crab stocks (Table 20). However for the acceptability rating of appearance, the p-value was $0.132 > 0.05$. From this it was concluded that there was no significant difference in the panellist's appearance acceptability rating of the value added crab stock concentrates.

Table 20: Mann Whitney test- results from sensory evaluation of value added crab stock

	Appearance	**Aroma**	**Flavour**	**Saltiness**	**Overall Acceptability**
Mean	59.080	69	66.694	61.68	68.252
Std.Deviation	23.4782	20.0479	23.393	24.4412	23.87775
Asymp. Sig. (2-tailed	0.132	0.040	0.001	0.003	< 0.001

The mean ranks were used to determine which of the value added crab stocks was most accepted by the consumer panellists. Comparison of mean ranks for the value added crab stocks indicates that the Chilli Tomato Crab Stock was more accepted by the panellists compared to the Herb Crab Stock (

Figure *28*). However it can also be concluded that the herb flavoured crab stock was also rated acceptable by the consumer panellists as the ratings were above 50 for each of the attributes (

Table ***21***).

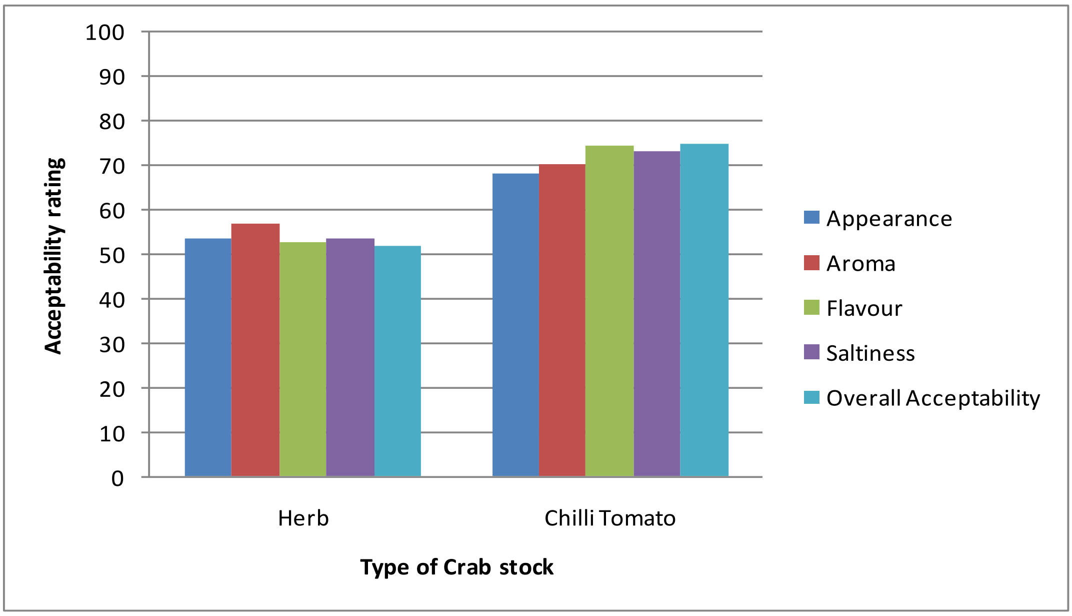


Figure 28: Graph representing the mean rank acceptability ratings of the value added crab stock

Table 21: Mean ranks of the value added crab stock acceptability ratings for each attribute

Sensory Attribute	**Flavour**	**Mean Rank**
Appearance	Herb Chilli Tomato	53.60 68.40
Aroma	Herb Chilli Tomato	56.83 70.17
Flavour	Herb Chilli Tomato	52.67 74.33
Saltiness	Herb Chilli Tomato	53.79 73.21
Overall Acceptability	Herb Chilli Tomato	52.04 74.96

As the sensory attributes of aroma and flavour are strongly correlated (see Table 25) the mean ranks were quite similar. The two value added crab stocks both had distinctly different smells and flavour. The acceptability rating scores given by the panellists indicate that the flavour and smell of the chilli tomato crab stock was much more acceptable than the herb flavoured crab stock. The difference in acceptability rating can be explained by the panellists' preference of certain flavours therefore influencing their acceptability rating. Also the reason for the chilli tomato crab stock rating higher amongst the panellists is the flavour is very prominent and lingers. The herb flavoured stock is more subtle and the flavour does not stand out as much.

Although the sodium content in the value added crab stocks was above the levels found in commercial stocks, to the consumer acceptance panel the saltiness was very acceptable. The results indicate that the higher than average sodium levels do not make the stock too salty, but very acceptable. With the addition of ingredients such as tomatoes, celery and onions, the addition of salt enhances the flavours. Tomatoes are sour fruits and salt was required to counteract the sour taste. Even though the stock was saltier than the base stocks, it is still a relatively low salt product at 2% or less.

The overall acceptability of the chilli tomato crab stock was 74.96 compared to the herb flavoured crab stock which was 52.04. Therefore it was concluded that the chilli tomato crab stock was the most accepted by the consumer acceptance panel. The results for the overall acceptability rating were the same amongst the other sensory attributes. This was expected as the there was a significant relationship between the attributes of aroma, flavour, saltiness and overall acceptability (Table 25).

Although the Mann-U-Whitney test indicated there was a significant difference in acceptability ratings of the value added crab stock, this does not necessarily indicate that the herb flavoured crab stock was rated unacceptable by the consumer acceptance panel. Both of the value added crab stocks had mean ranks which were above 50. This indicates that both samples were rated very acceptable by the sensory consumer panel although the chilli tomato crab stock was the favoured sample.

Comparing the mean acceptability ratings of the value added crab stocks and the crab stocks concentrates produced using different technologies, there is a considerable difference. None of the crab stocks produced using different technologies rated above 50, whereas the value added crab stocks had acceptability ratings all above 50. It can be concluded that the addition of horticultural ingredients such as tomatoes and onions to the waste crab cook water can significantly increase the acceptability of it.

Type of value added crab stock vs panellists' acceptability rating

The type of value added crab stock had a significant effect on the acceptability ratings given by the panellists', with a p value <0.05 except for the sensory attribute of appearance (

*Table **22***). This was expected as the results mirrored the statistical analysis conducted to determine which of the value added crab stocks was most favoured. As there was a significant difference found between the acceptability rating of the two value added crab stocks, it was expected the type of stock would affect the acceptability ratings given by the panellists'. As chilli tomato crab stock was significantly more accepted than the herb flavoured crab stock, there was an expected difference.

Table 22: Significance of type of value added crab stock on the acceptability ratings given by the panellists'

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Type	Appearance	992.085	1	992.085	1.880	.173
	Aroma	1898.768	1	1898.768	4.895	.029
	Flavour	4818.270	1	4818.270	9.684	.002
	Saltiness	4800.689	1	4800.689	8.932	.003
	Overall Acceptability	6091.938	1	6091.938	12.399	.001

Panellists age vs value added crab stock acceptability rating

With the crab stock concentrates produced using different technologies, age was a significant factor in the panellists acceptability rating of the crab stock. The same test was conducted on the flavoured crab stock to see if age had the same effect. MANOVA was used to analyse the data to determine if the age of the panellists is a significant factor in their acceptability rating of the value added crab stock.

The p-values for all the sensory attributes were above 0.05. Therefore there is not enough evidence to reject the null hypothesis and it can be concluded that the panellists' age did not significantly affect the panellists' acceptability rating for any parameters of the value added crab stock (Table 23).

Table 23: Significance of panellist's age on their acceptability rating of the value added crab stock

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Age	Appearance	218.249	3	72.750	.138	.937
	Aroma	2185.403	3	728.468	1.878	.137
	Flavour	2830.926	3	943.642	1.897	.134
	Saltiness	4329.844	3	1443.281	2.685	.050
	Overall Acceptability	3336.213	3	1112.071	2.263	.085

Panellists country of birth vs value added crab stock acceptability rating

MANOVA was used to determine if the panellist's country of birth had a significant influence on their acceptability rating of the value added crab stock. As the p-value >0.05, it was concluded that the country of birth was not a significant factor in the panellist's acceptance of the value added crab stocks regarding the sensory attributes of appearance, aroma and flavour (Table 24). However for the sensory attributes of saltiness and overall acceptability, the p-values were below 0.05, therefore there is enough evidence to reject the null hypothesis and conclude that there is a significant difference between the panellists' country of birth and their acceptability rating of the value added crab stocks saltiness and overall acceptability. Tukey's test was used to conduct post hoc analysis on all the sensory attributes. The analysis determined the panellists born in which countries had significantly different acceptability ratings.

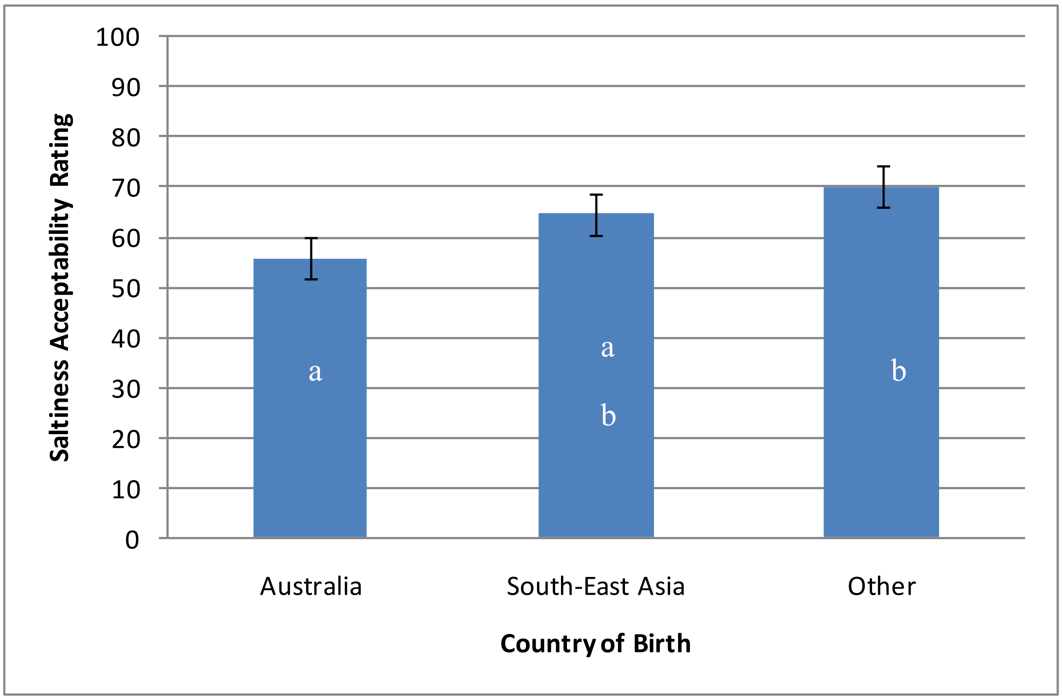
Table 24: Significance of panellist's country of birth on their acceptability rating of the value added crab stock

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Country	Appearance	2792.609	2	1396.304	2.784	.066
	Aroma	101.820	2	50.910	.127	.881
	Flavour	664.333	2	332.166	.649	.524
	Saltiness	3639.727	2	1819.863	3.378	.037
	Overall Acceptability	3026.010	2	1513.005	3.089	.049

From the post hoc analysis of the panellists saltiness acceptability rating based on country of birth it was determined that the panellists born in Australia and South-East Asia did not have significantly different ratings. The panellists from South-East Asia's saltiness acceptability rating were also not significantly different to the rating scores of the panellists born in 'Other' countries such as Mauritius. However, there was a significant difference in saltiness acceptability ratings between panellists born in Australia and Other countries (Figure 29).

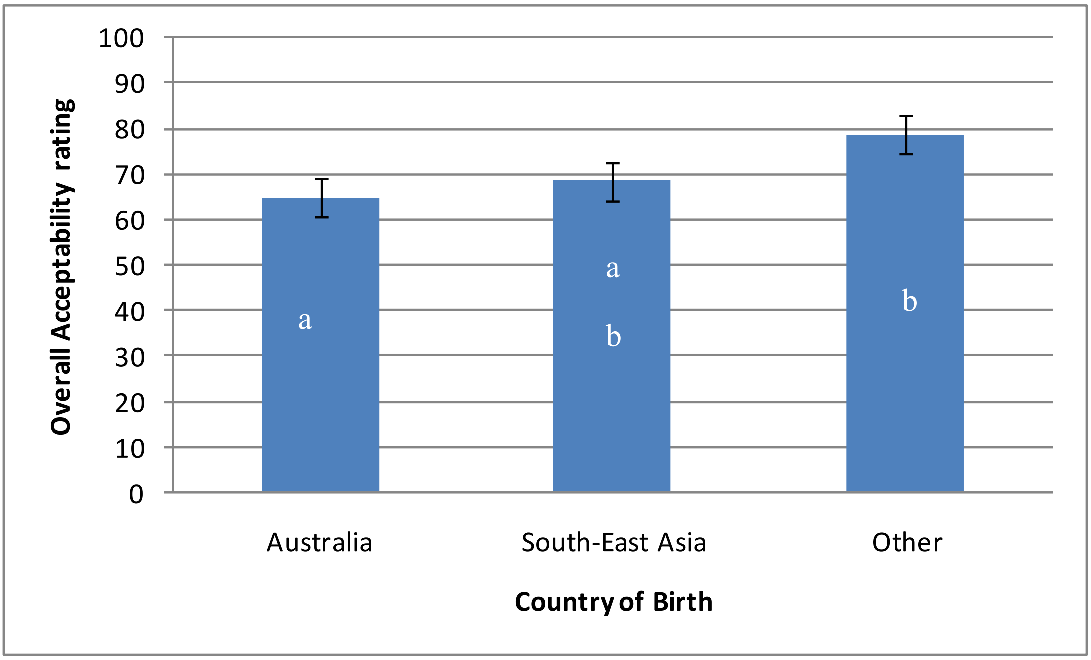
The results achieved from the analysis were expected. It was seen that the panellists born in Australia would have the lowest saltiness acceptability rating for the value added crab stocks. With the analysis to determine if the panellists country of birth had significant effect on their acceptability rating of the crab stock concentrates produced using different technologies the results were similar to the value added crab stock (Figure 29). The reasoning behind the results for the saltiness rating of the value added crab stock is the same as for the crab stock concentrates produced using different technologies. Australians tend to have a diet where salt is consumed in large amounts compared with South-East Asia. Therefore the value added crab stock might not have been salty enough which could have led to the lower acceptability rating.



N.B: Different letters denotes significant differences

Figure 29: Panellists country of birth vs saltiness acceptability rating of the value added crab stock

After post hoc analysis it was concluded that the panellists born in South-East Asia had overall acceptability acceptance ratings which were not significantly different to the acceptability ratings of the panellists born in Australia and Other countries. However, the overall acceptability ratings by the panellists born in Australia were significantly different to the ratings by the panellists born in 'Other' countries (Figure 30).



N.B: Different superscript letters denotes significant differences

Figure 30: Panellists country of birth vs overall acceptability rating of the value added crab stock

As mentioned previously, it was not expected that the panellist's country of birth would have a significant effect on their acceptability rating of the value added crab stock. However, it was predicted that the country of birth would significantly influence the panellist's acceptability rating for the sensory attributes of saltiness and overall acceptability. This is because of panellists preference, the saltiness of the flavoured crab stock could have been either too salty or not salty enough, therefore this results in the panellists' born in Australia having lower saltiness acceptability ratings.

Relationship between sensory attributes (value added crab stock)

Simple linear regression was used on the results retrieved from the sensory analysis of value added crab cook water. It was done to determine if a relationship existed between any of the five sensory attributes tested during sensory evaluation (appearance, aroma, flavour, saltiness, overall acceptability). The results are shown in Table 25.

Table 25: Pearson's correlation and significance of relationship between the sensory attributes tested in the sensory evaluation of value added crab stocks (values significant @≤ 0.05)

Correlations

		Appearance	Aroma	Flavour	Saltiness
Pearson Correlation					
	Aroma	.549			
	Flavour	.521	.673		
	Saltiness	.413	.502	.723	
	Overall Acceptability	.532	.667	.822	.819

It was concluded that a relationship exists between the attributes of appearance, aroma, flavour, saltiness and overall acceptability. These results are the same as the results obtained for the crab stock concentrates produced using different technologies (Table 18). Although appearance was significantly related to aroma, flavour, saltiness and overall acceptability, the relationship cannot be logically explained. The three relationships that were the most strongly correlated were: flavour and saltiness, flavour and overall acceptability, and saltiness and overall acceptability. The relationship between overall acceptability and the sensory attributes of saltiness and flavour can be explained such that high acceptability ratings given for these two attributes meant the panellists would rate the overall acceptability of the product high as well. With the value added crab stocks the high acceptability ratings given by the panellists for flavour and saltiness were very similar to the overall acceptability rating, indicating that a strong relationship exists. This was also seen with the results of the acceptability ratings of the crab stock concentrates.

The significant relationships between the sensory attributes are displayed in Figure 31. The very even pentagon shape in Figure 31 demonstrates the relationship of the different sensory attributes with each other. Although they are all significantly related, logically the appearance acceptability rating does not influence the other three sensory attributes. However the even shapes of the pentagons indicate that for both stocks, all variables were of equal importance in determining acceptability.

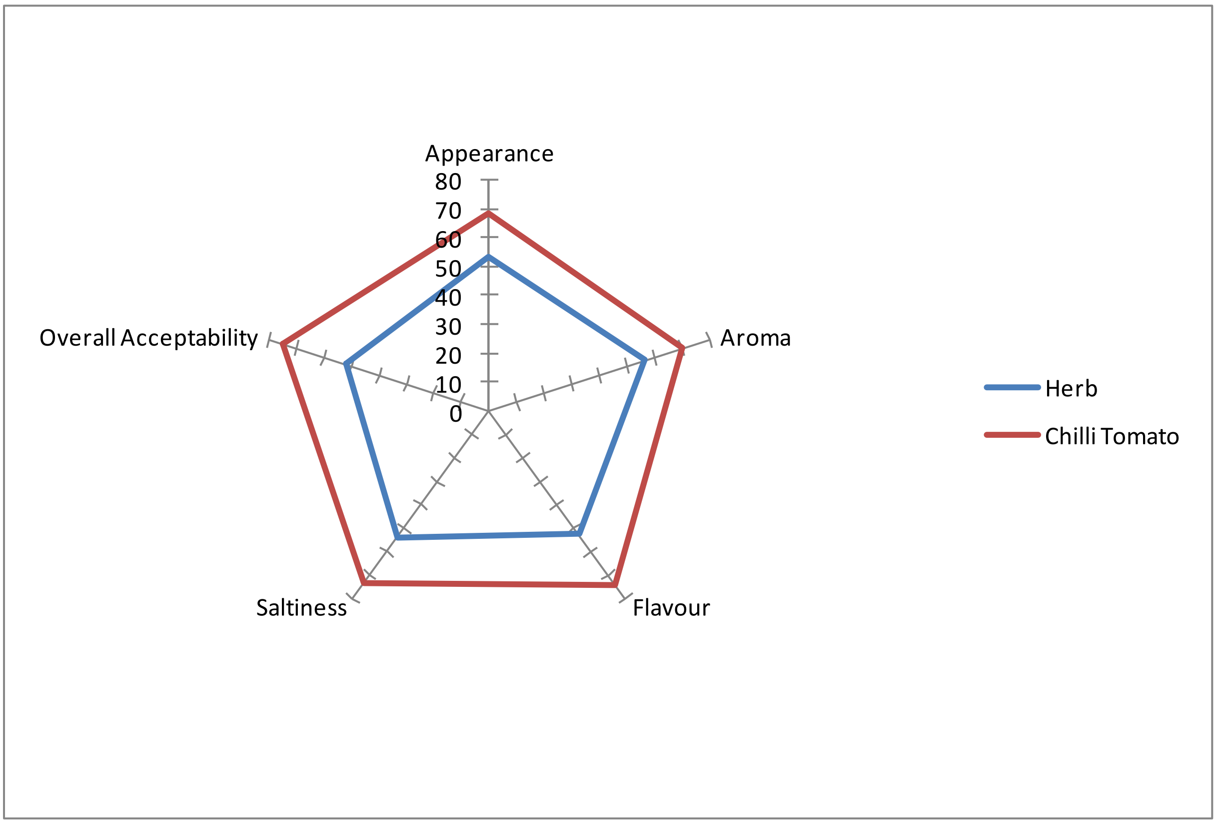


Figure 31: Radar graph for sensory attributes acceptance rating for value added crab stock

In conclusion, there were significant relationships existing between all the acceptability ratings for the value added crab stock. From the correlations table (Table 25) it can be concluded that the overall acceptability of the value added crab stock was influenced by the crab stocks' aroma, flavour and saltiness acceptance.

4.6 Conclusion

The results from the proximate analysis of the crab cook water indicate that there is a significant relationship between an increase in crab cook load and an increase in the components of the crab cook water (protein, pH, total solids, sodium). This means an increase in crab cook load leads to a more concentrated crab cook water, therefore less water will have to be removed from the crab cook water to produce the crab stock. The chemical analysis of the cadmium levels in the crab cook water indicated that it was present at minimal levels below the maximum residue limit of 2mg/kg, therefore it can be concluded that the cook water is safe to use to produce a crab stock.

The vacuum dryer, freeze dryer and boiling methods were evaluated and used to produce a total of 4 different crab stock concentrates. Sensory analysis was conducted on these samples with a consumer acceptance panel. From the results it was concluded that there were no significant differences between the acceptability of the crab stock concentrates, however the concentrated liquid crab stock produced using the vacuum dryer was the most accepted sample. None of the samples had high acceptability ratings but this was thought to be due to the fact that stock is not generally consumed as a food as is but is used as an ingredient in other foods. Therefore the low acceptability ratings were deemed acceptable.

With the use of the underutilised produce from the horticulture industry in Carnarvon, a herb flavoured crab stock and a chilli tomato flavoured crab stock were produced. Sensory analysis was used to compare these two products and from the results it can be concluded that the chilli tomato crab stock had significantly higher acceptability ratings than the herb flavoured crab stock though both were acceptable. It can be concluded that the chilli tomato crab stock was the most accepted product possibly due to the soup like characteristics.

In conclusion, the research showed that it is very feasible to use the waste crab cook water to produce a crab stock concentrate. Sensory analysis indicated that the base stock was acceptable amongst the consumer acceptance panel and chemical analysis showed that the crab stock was safe for human consumption. The addition of other ingredients to the base stock showed that the base stock can be used to produce acceptable and viable products. It also indicated that it is feasible to use the crab cook water to produce a range of other food products.

Chapter 5 Final Conclusion

Abacus Fisheries uses 3000L of potable water each day to cook the blue swimmer crabs which are caught on that day. The crab cook water contains volatile compounds, proteins and minerals which contribute to the high levels of BOD (biological oxygen demand). The crab cook water is expensive for the company to dispose of and contributes to water pollution. As the cook water has a good flavour profile, the company wanted to utilise the crab cook water to produce a crab stock concentrate. This would reduce the amount of waste from the processing plant and save the company money on waste disposal.

From the research conducted, it was concluded that it is very feasible to produce a crab stock from waste cook water from cooking blue swimmer crabs. Proximate analysis on the crab cook water indicated that an increase in the crab cook load led to an increase in the components of protein, brix°, sodium and pH. The cadmium levels in the cook water were minimal and below the maximum residue limit, therefore it was feasible to use the crab cook water to produce the crab stock as it did not pose a risk to consumers.

Crab stock concentrates were produced using the different technologies of freeze drying, vacuum drying and boiling. The four products produced were:

- Dehydrated crab stock powder (Freeze Dryer)
- Concentrated liquid crab stock (Vacuum Dryer)
- Concentrated liquid crab stock (Boiling)
- Reduced 'real' crab stock (Boiling)

Sensory analysis conducted on these products determined that the concentrated liquid crab stock produced using the vacuum dryer was the most acceptable product amongst the consumer acceptance panel. Although the acceptability ratings for the vacuum dried concentrated liquid crab stock did not have a high overall acceptability rating, this was hypothesised as crab stock is not normally consumed as a product, but used a base ingredient or flavouring in cooking.

Two value added crab stocks were developed with the use of fruits and vegetables grown in Carnarvon: herb flavoured crab stock and a chilli tomato crab stock. Sensory analysis conducted on the value added stocks indicated that both of the products were rated acceptable amongst the consumer panellists; however the chilli tomato crab stock was the most preferred. It was hypothesised that the value added crab stocks would have high acceptability ratings as more ingredients were added to it, increasing the acceptability ratings. As the products were more soup-like and may be eaten as a food in their own right.

From all the research conducted, it can be concluded that the development of crab stock concentrates from blue swimmer crab cooking water is feasible. The addition of the underutilised produce from the horticulture industry in Carnarvon significantly increased the acceptability of the crab stock.

5.1 Future research in product expansion

There is still further research that can be conducted in the development of the crab stock concentrate. As crab shells are still being wasted at Abacus Fisheries, to get more out of it, the shells could be added back to the cook water to enhance the flavour of the crab cook water. This is a traditional method in the production of stocks as the shells and remaining tissues still contain a lot of flavouring components. This could effectively increase the amount of certain components in the crab cook water.

Currently the crab stock concentrate is being stored in the freezer in takeaway containers and is defrosted prior to use. It cannot be stored in the fridge as it goes off after a few days. The shelf life of the product could be increased with the development of packaging using aseptic packaging techniques. However studies into shelf stability and microbial safety would also be required.

Only a few of the fruits and vegetables produced in Carnarvon were incorporated into the crab stock. A future endeavour could be to develop new flavours of crab stock with the other types of vegetables locally grown. As the value added crab stocks and crab stock concentrates are not currently being used in cooking, it would be valuable to develop different recipes which incorporate the crab stock. This would enable the potential buyers to have an idea as to what it can be used in.

The dehydrated crab stock powder produced using the freeze dryer had a good flavour profile and could be further developed and potentially used as a flavouring for savoury foods. The addition of anti-caking agents to the dehydrated crab stock could also increase the shelf life of the product.

With the consumer population becoming more health conscious, future research could be conducted to decrease the sodium levels in the crab stock to meet the consumer's wants.

The crab stock concentrate and value added crab stock could also be used by the company itself and incorporated into their own value added products.

Now that there is a product prototype developed the next stage is to explore the market for opportunities of commercialisation or potential buyers. This is part of the market development stage of the product development process (Earle, Earle, and Anderson 2001). This includes bringing the crab stock to different sectors of the food industry to see if there is a market or interest in the product. The food service industry includes chefs at high end restaurants which would be given the stock see if they could incorporate it into some of their recipes or use it to create a new one. Other food companies could be approached to see if they could use the crab stock to produce some of their value added products. The current buyers of the Abacus Crab in other countries would be approached to see if the country they sell in has a potential market for the crab stock.

There are so many different avenues that can be explored with the crab cook water and crab stock and it has a significant potential for further development.

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APPENDICES

Appendix 1: Sensory Analysis Forms

VOLUNTEERS WANTED!!

Sensory Evaluation of Novel Seafood Product

Volunteers are required to take part as a consumer sensory panelist for an acceptance study at the Curtin University Labs.

For Further information please contact Kerri Choo

Email: kerri.choo@student.curtin.edu.au

Please note: If you do have food allergies it is advised you do not participate.

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Pre-screening questionnaire for the consumer acceptability study of a novel seafood product

Please answer the following questions to enable us to determine if you are eligible to participate in this study:

Name:____________________________________ Gender: Male/Female

Contact Phone (Office Hours): ____________________________

Country of birth: _______________________________________

If you were not born in Australia how long have you lived here?_______________

Please tick the one that applies:

Employment: Curtin Staff ☐ Student ☐ Other ☐

Age: 18-20 ☐ 20-30 ☐ 30 – 40 ☐ 40 – 50 ☐ 50+ ☐

Health:

1. Do you have any of the following?

Dentures: Yes ☐ No ☐

Food Allergies: Yes ☐ No ☐

Oral or gum disease: Yes ☐ No ☐

Frequent head colds: Yes ☐ No ☐

Are currently pregnant: Yes ☐ No ☐

2. Are you a smoker? Yes ☐ No ☐

If yes, approximately how many cigarettes per day would you smoke?

____

3. Do you take any medications that affect your senses, especially your sense of touch or oral sensitivity?

____

Food Habits:

1. Are you currently on a restricted diet? Yes ☐ No ☐

If yes, explain

____
____
____

2. How frequently do you eat seafood?

never ☐ monthly ☐ once a fortnight ☐ once a week ☐ more often☐

4. What is your favourite seafood?

____
____

Thank you for taking the time to answer these questions.

If you have any further questions please contact Kerri Choo on 0433 796 488 or email kerri.choo@student.curtin.edu.au

Curtin University of Technology

School of Public Health

Informed Consent Form

My name is Kerri Choo and I am currently carrying out research for my Bachelor of Science (Health Sciences) Honours at Curtin University of Technology. My project is to develop a novel flavouring ingredient from seafood. As part of this I am doing sensory evaluation of components and need participants to be part of a consumer sensory panel.

I am interested in finding out which of the samples that I have developed are most desired by you (the consumer). This will involve taste testing the samples in the sensory laboratory and rating them on different attributes.

Your involvement is entirely voluntary and you have the right to withdraw at any stage without it affecting your rights or my responsibilities. When you have signed the consent form I will assume that you have agreed to participate and that you certify that you have **NO FOOD ALLERGIES**.

Further Information

This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval number SPH162009). If you would like further information about the study, please feel free to contact me on 0433 796 488 or by email: kerri.choo@student.curtin.edu.au . Alternatively, you can contact my supervisor Dr Hannah Williams on 9266 3329 or H.Williams@curtin.edu.au.

If you have any concerns you can contact the Secretary of the Human Research Ethics Committee on 92669223 or email hrec@curtin.edu.au

---

- I understand and received sufficient information on the purpose and procedures of the study.
- I understand my involvement is voluntary and I can withdraw at any time without problem.
- I have been given the opportunity to ask questions.
- **I have certified that I DO NOT have any FOOD ALLERGIES**.

Name ______________________ Signature ______________________

Date ______________________

Sensory Evaluation of a Novel Seafood Product (Part 1)

Instructions: Before tasting each new sample, please take a sip of the water and take a bite of the cracker. Taste the samples from left to right. Write the number located on each cup in the order of tasting next to the line scale or which you recorded the result. An example is shown below.

After tasting each sample, you are asked to mark the horizontal scale with a vertical dash (|) to correspond to your preference on the scale. Once you have tasted all the samples press the button and return the plate. Please wait for the second round of samples.

Dislike Extremely Like Extremely

______ |————————————————|

1. **Appearance**

Dislike Extremely Like Extremely

______ |————————————————|

______ |————————————————|

______ |————————————————|

______ |————————————————|

2. Aroma

Dislike Extremely Like Extremely

____

____

____

____

3. Flavour

Dislike Extremely Like Extremely

____

____

____

____

4. Saltiness

Dislike Extremely Like Extremely

____

____

____

____

5. **Overall Acceptability**

Dislike Extremely Like Extremely

Please press the button once complete and wait for the next samples

Sensory Evaluation of Novel Seafood Product (Part 2)

Instructions: Before tasting each new sample, please take a sip of the water and take a bite of the cracker. Taste the samples from left to right. After tasting each sample, you are asked to mark the horizontal scale with a vertical dash (|) to correspond to your preference on the scale.

1. **Appearance**

Dislike Extremely Like Extremely

587

721

2. **Aroma**

Dislike Extremely Like Extremely

587

721

3. **Flavour**

Dislike Extremely Like Extremely

587

721

4. **Saltiness**

Dislike Extremely Like Extremely

587

721

5. **Overall Acceptance**

Dislike Extremely Like Extremely

587

721

Thank you for participating. Please hand your answer sheet to the desk and collect your reward!

Appendix 2: Proximate composition of crab cook water

2.1 Proximate analysis of crab cook water

Table 26: Descriptive statistics for the proximate analysis of the crab cook water

	Mean	Standard Error of the Mean	Standard Deviation	Skewness	Kurtosis	95% Confidence Interval	
						Lower	Upper
Protein	.1630	.01211	.04532	-.545, .597	-.796, 1.154	.1368	.1892
Sodium	26.385	1.53866	5.75715	-.957, .597	-.284, 1.154	23.0609	29.7091
Brix	.5198	.04429	.16573	-.812, .597	-.235, 1.154	.4241	.6155
pH	7.8729	.03763	.14079	-.878, .597	.516, 1.154	7.7916	7.9541
Cadmium	.001711	.000168	.000628	-.052, .597	-.171, 1.154	.001349	.002074

Table 27: Crab cook load vs components correlation table

		cook load	brix	protein	sodium	cadmium
Pearson Correlation	cook load	1.000	.918	.878	.925	-.180
	brix	.918	1.000	.796	.901	.109
	protein	.878	.796	1.000	.944	-.197
	sodium	.925	.901	.944	1.000	-.122
	cadmium	-.180	.109	-.197	-.122	1.000
	pH	.808	.777	.796	.775	-.090
Sig. (1-tailed)	cook load	.	.000	.000	.000	.269
	brix	.000	.	.000	.000	.356
	protein	.000	.000	.	.000	.249
	sodium	.000	.000	.000	.	.339
	cadmium	.269	.356	.249	.339	.
	pH	.000	.001	.000	.001	.380

Appendix 3: Statistical Analysis : Sensory analysis of crab stock concentrate

3.1 One way ANOVA

Table 28: Shapiro wilk normality testing for one way independant ANOVA

	Appearance	Aroma	Flavour	Saltiness	Overall Acceptability
Statistic	.977	.979	.958	.963	.960
Sig.	.000	.001	.000	.000	.000

Table 29: Homogeneity of Variances assumption for One way independent ANOVA

	Appearance	Aroma	Flavour	Saltiness	Overall Acceptability
Levene Statistic	1.302	.432	1.733	.404	.649
Sig.	.274	.730	.161	.750	.584

Table 30: ANOVA table output for One way independent ANOVA

	Sum of Squares	df	Mean square	F	Sig.
Appearance	3512.794	3	1170.931	2.169	.092
Aroma	1428.710	3	476.237	.924	.430
Flavour	2874.996	3	958.332	1.548	.203
Saltiness	2589.635	3	863.212	1.387	.247
Overall Acceptability	1930.710	3	643.570	.981	.403

3.2 MANOVA: Panellists' country of birth vs crab stock concentrate produced using different technologies acceptability rating

Table 31: Box's Test of equality of covariance matrices for MANOVA (process used vs country of birth)

Box's M	F	df1	df2	Sig.
205.493	1.088	165	18613.316	.210

Table 32: Levene's test homogeneity of variance assumption

	F	df1	df2	Sig.
Appearance	1.395	11	232	.176
Aroma	.753	11	232	.687
Flavour	1.557	11	232	.113
Saltiness	1.090	11	232	.370
Overall Acceptability	2.149	11	232	.018

Table 33: Tests of between-subjects effects (country of birth and process used)

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Country	Appearance	2953.823	2	1476.912	2.708	.069
	Aroma	2273.189	2	1136.594	2.249	.108
	Flavour	5698.042	2	2849.021	4.683	.010
	Saltiness	9042.828	2	4521.414	7.642	.001
	Overall Acceptability	1853.642	2	926.821	1.400	.249
process	Appearance	3861.401	3	1287.134	2.360	.072
	Aroma	833.213	3	277.738	.549	.649
	Flavour	2152.093	3	717.364	1.179	.318
	Saltiness	1662.897	3	554.299	.937	.424
	Overall Acceptability	1552.584	3	517.528	.782	.505
Country * process	Appearance	3237.580	6	539.597	.990	.433
	Aroma	1134.858	6	189.143	.374	.895
	Flavour	311.236	6	51.873	.085	.998
	Saltiness	583.275	6	97.213	.164	.986
	Overall Acceptability	326.838	6	54.473	.082	.998

Table 34: Homogenous subset- post hoc on difference in flavour acceptability rating depending on country of birth

Country of Birth	N	Subset	
		1	2
Australia	100	32.09	
South East Asia	100	41.13	41.13
Other	44		43.30
Sig.		.078	.862

Table 35: Homogenous subset- post hoc on difference in saltiness acceptability rating depending on country of birth

Country of Birth	N	Subset	
		1	2
Australia	100	34.27	
South East Asia	100		46.25
Other	44		47.45
Sig.		1.000	.954

3.3 MANOVA- Panellists' age vs crab stock concentrate produced using different technologies acceptability rating

Table 36: Box's test of equality of covariance matrices

Box's M	F	df1	df2	Sig.
259.744	1.299	165	9772.795	.006

Table 37: Levene's test for homogeneity of variances

	F	df1	df2	Sig.
Appearance	1.582	15	228	.080
Aroma	.521	15	228	.928
Flavour	1.896	15	228	.025
Saltiness	1.993	15	228	.017
Overall Acceptability	2.237	15	228	.006

Table 38: Test of between-subject effects of age and process used

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Age	Appearance	5639.255	3	1879.752	3.421	.018
	Aroma	6500.140	3	2166.713	4.357	.005
	Flavour	12605.890	3	4201.963	7.261	.000
	Saltiness	8272.924	3	2757.641	4.603	.004
	Overall Acceptability	10406.957	3	3468.986	5.599	.001
process	Appearance	1924.676	3	641.559	1.168	.323
	Aroma	537.883	3	179.294	.361	.782
	Flavour	1980.116	3	660.039	1.141	.333
	Saltiness	1042.493	3	347.498	.580	.629
	Overall Acceptability	2842.941	3	947.647	1.530	.208
Age * process	Appearance	1784.058	9	198.229	.361	.952
	Aroma	801.853	9	89.095	.179	.996
	Flavour	2590.712	9	287.857	.497	.875
	Saltiness	2041.618	9	226.846	.379	.945
	Overall Acceptability	4134.376	9	459.375	.742	.671

Table 39: Homogeneous subset for appearance acceptability rating

Age	N	Subset	
		1	2
18-20 Yrs Old	48	36.19	
20-30 yrs old	140	45.79	45.79
30-40 yrs old	20	46.10	46.10
40+yrs old	36		52.08
Sig.		.258	.647

Table 40: Homogeneous subset for aroma acceptability rating

Age	N	Subset	
		1	2
18-20 Yrs Old	48	32.35	
20-30 yrs old	140	44.19	44.19
30-40 yrs old	20		46.60
40+yrs old	36		47.28
Sig.		.099	.931

Table 41: Homogeneous subset for flavour acceptability rating

Age	N	Subset	
		1	2
18-20 Yrs Old	48	23.52	
20-30 yrs old	140		38.05
30-40 yrs old	20		41.21
40+yrs old	36		43.56
Sig.		1.000	.752

Table 42: Homogeneous subset for saltiness acceptability rating

Age	N	Subset	
		1	2
18-20 Yrs Old	48	30.13	
20-30 yrs old	140	40.60	40.60
30-40 yrs old	20	42.97	42.97
40+yrs old	36		45.25
Sig.		.105	.842

Table 43: Homogeneous subset for overall acceptability rating

Age	N	Subset	
		1	2
18-20 Yrs Old	48	26.69	
20-30 yrs old	140		42.19
30-40 yrs old	20		42.51
40+yrs old	36		46.60
Sig.		1.000	.868

3.4 Principal Component Analysis (PCA)

Table 44: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	Bartlett's Test of Sphericity Approx. Chi-Square	df	Sig.
.805	640.496	10	.000

Table 45: Total Variance Explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	3.129	62.582	62.582
2	.886	17.720	80.302
3	.510	10.193	90.494
4	.290	5.793	96.288
5	.186	3.712	100.000

Table 46: Component Matrix

	Overall Acceptability	**Flavour**	**Saltiness**	**Aroma**	**Appearance**
Component 1	.905	.889	.817	.724	.573

3.5 Relationship between sensory attributes correlations table

Table 47: Correlations table

		Appearance	**Aroma**	**Flavour**	**Saltiness**
Pearsons Correlation	Appearance	1.000	.456	.337	.251
	Aroma	.456	1.000	.517	.422
	Flavour	.337	.517	1.000	.727
	Saltiness	.251	.422	.727	1.000
	Overall Acceptability	.427	.526	.807	.713
Sig. (1-tailed)	Appearance	.	.000	.000	.000
	Aroma	.000	.	.000	.000
	Flavour	.000	.000	.	.000
	Saltiness	.000	.000	.000	.
	Overall Acceptability	.000	.000	.000	.000

Appendix 4: Statistical Analysis- Sensory analysis of value added crab stocks

4.1 MANN WHITNEY- significant difference between samples

Table 48: Shapiro Wilk normality testing

Shapiro Wilk	Appearance	Aroma	Flavour	Saltiness	Overall Acceptability
Statistic	.947	.946	.937	.944	.924
Sig.	.000	.000	.000	.000	.000

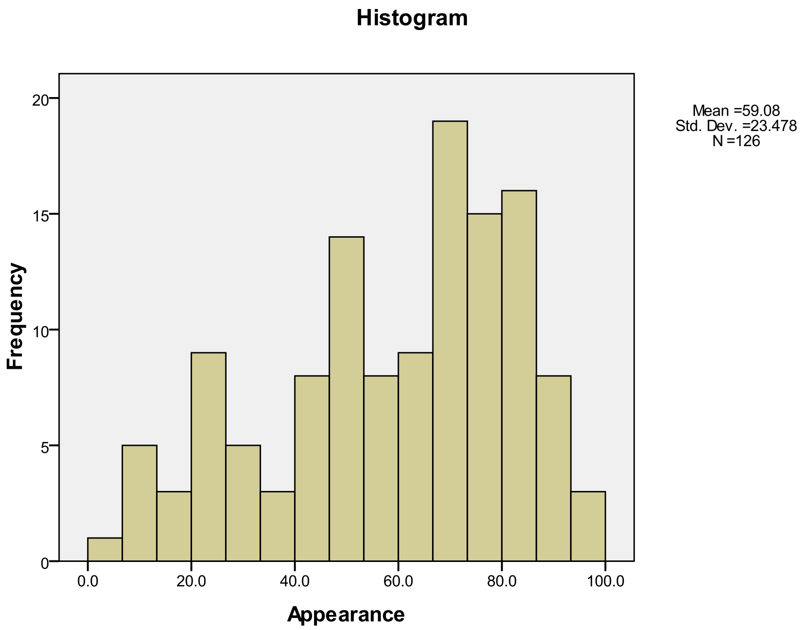

Figure 32: Histogram of appearance acceptability rating

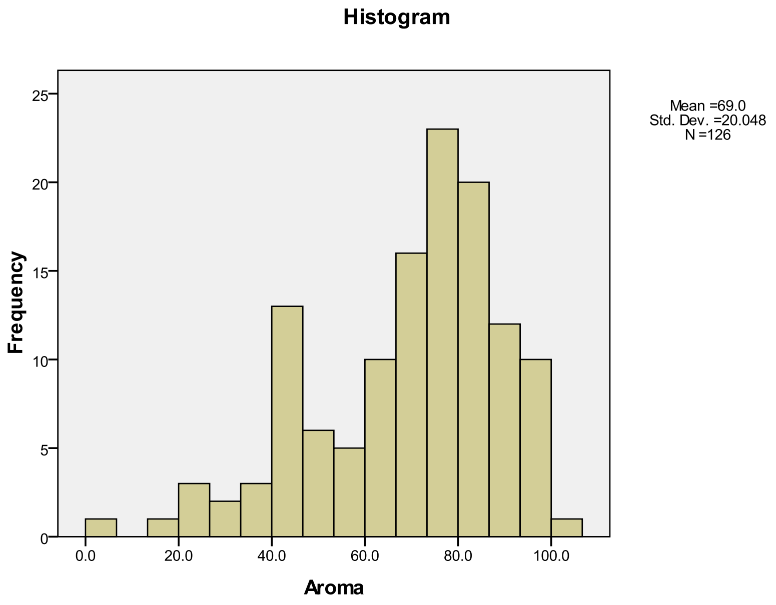

Figure 33: Histogram of aroma acceptability rating

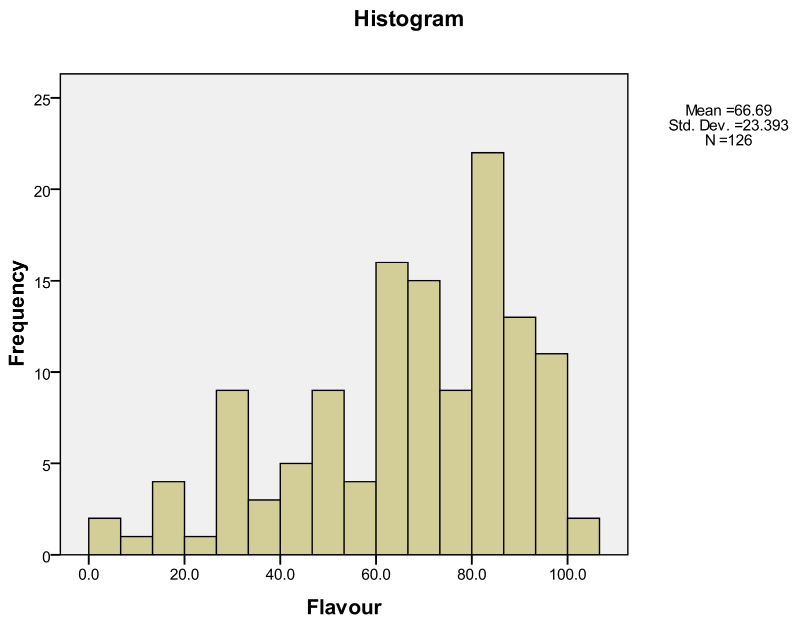

Figure 34: Histogram of flavour acceptability rating

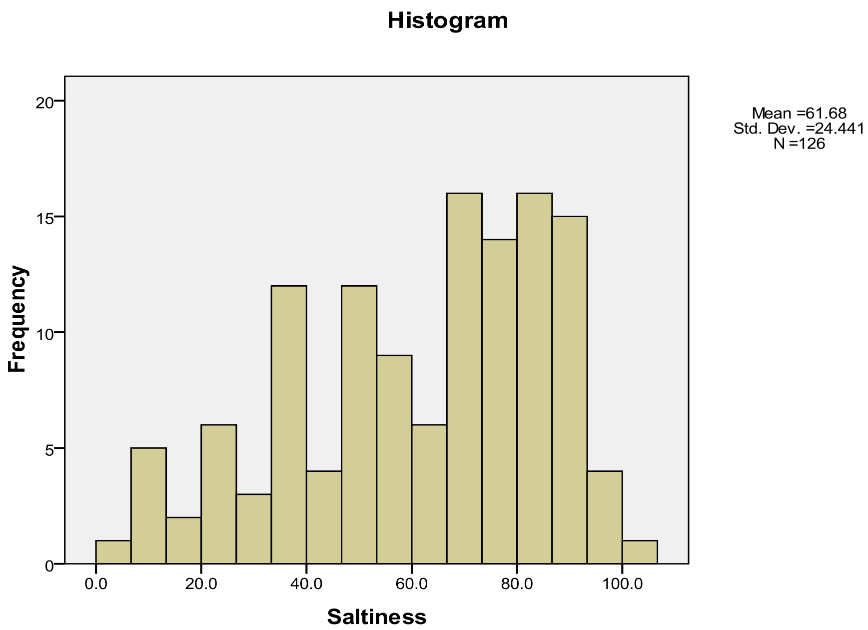

Figure 35: Histogram of saltiness acceptability rating

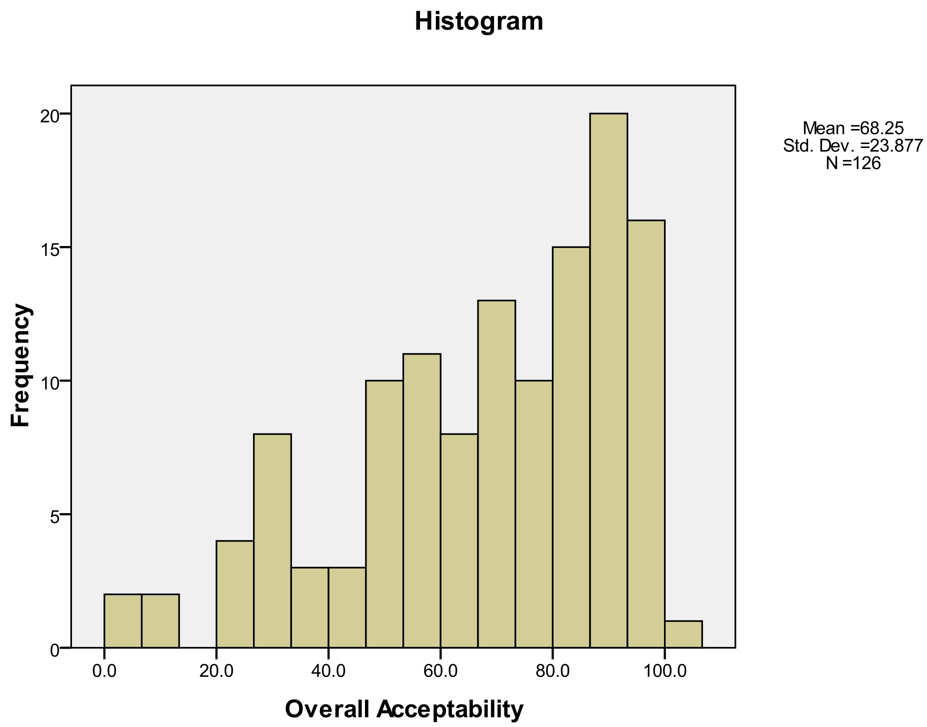

Figure 36: Histogram of overall acceptability rating

Table 49: Mean ranks for value added crab stock

	Appearance		Aroma		Flavour		Saltiness		Overall Acceptability	
	Herb	Chilli Tomato	Herb	Chilli Tomato	Herb	Chilli Tomato	Herb	Chilli Tomato	Herb	Chilli Tomato
N	63	63	63	63	63	63	63	63	63	63
Mean Rank	58.6	68.40	56.83	70.17	52.6	74.33	53.79	73.21	52.04	74.96

Table 50: Test statistic

	Appearance	Aroma	Flavour	Saltiness	Overall Acceptability
Mann-Whitney U	1675.500	1564.500	1302.500	1372.500	1262.500
Z	-1.508	-2.050	-3.328	-2.987	-3.524
Asymp. Sig. (2-tailed)	.132	.040	.001	.003	.000

4.2 MANOVA- Influence of panellists' country of birth on the acceptability ratings

Table 51: Test of between subjects effect

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Country	Appearance	2792.609	2	1396.304	2.784	.066
	Aroma	101.820	2	50.910	.127	.881
	Flavour	664.333	2	332.166	.649	.524
	Saltiness	3639.727	2	1819.863	3.378	.037
	Overall Acceptability	3026.010	2	1513.005	3.089	.049
Type	Appearance	992.085	1	992.085	1.978	.162
	Aroma	1898.768	1	1898.768	4.720	.032
	Flavour	4818.270	1	4818.270	9.416	.003
	Saltiness	4800.689	1	4800.689	8.911	.003
	Overall Acceptability	6091.938	1	6091.938	12.438	.001

Table 52: Homogenous subsets of saltiness acceptability rating

Country of Birth	N	Subset	
		1	2
Australia	50	55.882	
South East Asia	50	64.630	64.630
Other	22		70.041
Sig.		0.259	0.593

Table 53: Homogenous subsets for overall acceptability rating

Country of Birth	N	Subset	
		1	2
Australia	50	64.734	
South East Asia	50	68.610	68.610
Other	22		78.795
Sig.		.744	.135

4.3 MANOVA-Influence of panellists' age on acceptability rating

Table 54: Test of between subjects effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Age	Appearance	218.249	3	72.750	.138	.937
	Aroma	2185.403	3	728.468	1.878	.137
	Flavour	2830.926	3	943.642	1.897	.134
	Saltiness	4329.844	3	1443.281	2.685	.050
	Overall Acceptability	3336.213	3	1112.071	2.263	.085
Type	Appearance	992.085	1	992.085	1.880	.173
	Aroma	1898.768	1	1898.768	4.895	.029
	Flavour	4818.270	1	4818.270	9.684	.002
	Saltiness	4800.689	1	4800.689	8.932	.003
	Overall Acceptability	6091.938	1	6091.938	12.399	.001

4.4 Relationship between sensory attributes (value added)

Table 55: Correlations table

		Flavour	Aroma	Appearance	Saltiness
Pearson Correlation	Flavour	1.000	.673	.521	.723
	Aroma	.673	1.000	.549	.502
	Appearance	.521	.549	1.000	.413
	Saltiness	.723	.502	.413	1.000
	Overall Acceptability	.822	.667	.532	.819
Sig. (1-tailed)	Flavour	.	.000	.000	.000
	Aroma	.000	.	.000	.000
	Appearance	.000	.000	.	.000
	Saltiness	.000	.000	.000	.
	Overall Acceptability	.000	.000	.000	.000