# HIGH PRESSURE PASTEURISATION TRIALS FOR WESTERN AUSTRALIAN SEAFOOD PRODUCT

Report prepared as part of Fisheries Research & Development Corporation

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**New Opportunities for Underutilised Species**

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# 1. INTRODUCTION

A commercial Hyperbaric High Pressure Pasteurisation (HPP) machine was installed and commissioned at Manjimup in 2015. This machine was to be used principally for the horticulture industry, but the Managers agreed to a sub-contract time with the equipment and staff to run seafood trials. This report summarises the results of those seafood trials. Initially a detailed literature review was undertaken to ensure/understand where possible the optimal conditions for each seafood format to be tested in the Manjimup trials.

# 2. LITERATURE REVIEW

## 2.1 What is HPP?

High Pressure Processing ( HPP) which is often referred to as 'cold pasteurisation' or 'cold pressing' is a process that can occur at 5-35°C at 100-800 MPa (Balasubramaniam, Martínez-Monteagudo, and Gupta 2015) in a pressure vessel (Motarjemi, Moy, and Todd 2014). HPP can improve shelf-life and safety of food products by destroying many microorganisms with no adverse effects on nutritional quality or sensory characteristics (Motarjemi, Moy, and Todd 2014). AS well with traditional pasteurisation techniques, the pasteurisation is often conducted on the product before packaging, later processing/packaging steps may increase the risk of recontamination/cross contamination. With HPP, the food product is in its final packaging before it undergoes pasteurisation, minimising risk of contamination. It is noteworthy that the treatment time, pressure and holding time will depend on the impact of HPP on the specific target microorganisms (Motarjemi, Moy, and Todd 2014). There are also interactive factors in food that can affect the HPP effectiveness this including pH and water activity. Bacterial spores may not be rendered inactive by HPP.

Generally ambient chilled temperatures at 400-600 MPa can effectively inactive a range of spoilage and pathogenic vegetative bacteria, molds, yeasts and viruses (Balasubramaniam, Martínez-Monteagudo, and Gupta 2015). The pressure, with thermal treatment above 70°C, it has been effective in the inactivation of bacterial spores (Balasubramaniam, Martínez-Monteagudo, and Gupta 2015).

## 2.2 Types of packaging used in HPP

The product that undergoes HPP is normally vacuum packed prior to treatment, as headspace air, particularly oxygen, can have an adverse effect on product quality when exposed to increased pressure-temperature conditions. (Balasubramaniam, Martínez-Monteagudo, and Gupta 2015). The packaging used should be high barrier, flexible ( >15% volume contraction) (Balasubramaniam, Martínez-Monteagudo, and Gupta 2015) and water resistant. Other packaging requirements include extra tight seals, rounded and reinforced edges and minimal head space. HPP of modified atmosphere packaging (MPA) is possible. The tear strength, puncture resistance and surface smoothness of packaging are generally not affected by HPP

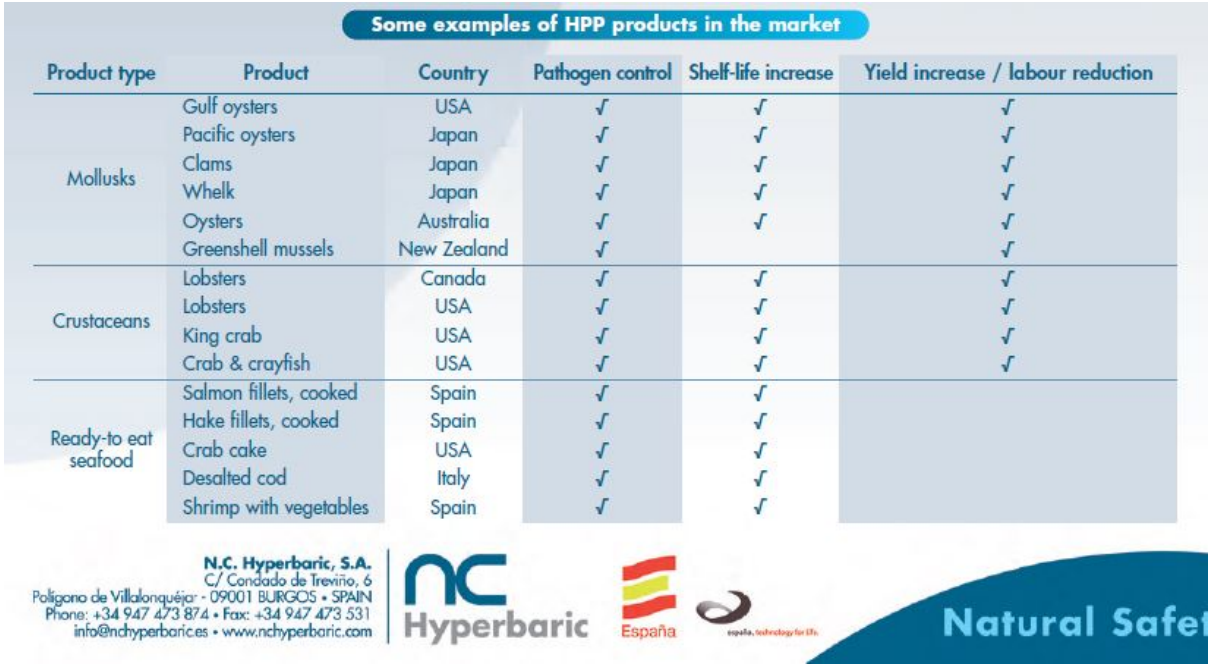
The only material that can be used for packaging HPP products is plastic, as the compressibility must be at least 15% (Huang et al. 2017). Package design, geometry and format should be tailored for the

HPP to take up the most surface area. More information on packaging can be found at the link below:

http://blog.hiperbaric.com/en/packaging-an-essential-part-of-the-success-of-hpp-technology

## 2.3 HPP in the seafood industry

HPP can have three outcomes in seafood: shucking, meat extraction and/or extension of shelf-life. The HPP parameters must be established based on which is the desired outcome. In 2015, HPP seafood products accounted for 5% of the global HPP market (Huang et al. 2017), Figure 1 describes some HPP seafood products on the market. The meat from different shellfish can be easily shucked, with no adverse effect on the freshness characteristics of the raw product including crabs, lobsters and oysters (Motarjemi, Moy, and Todd 2014). This process can increase meat yield compared to the traditional shucking method and the raw meat is also cleanly removed from the lobster to produce a possible sashimi product(Motarjemi, Moy, and Todd 2014). HPP denatures the protein that makes the meat adhere to the shell. There has been research that shows HPP can destroy the allergenic proteins in seafood. Non thermal treatment of crustacea and bivalves at an isostatic pressure between 200MPa-350MPa can extract the meat from crustacea and shuck bivalves (Hiperbaric 2013).



**Some examples of HPP products in the market**

| Product type | Product | Country | Pathogen control | Shelf-life increase | Yield increase / labour reduction |
|---|---|---|---|---|---|
| Mollusks | Gulf oysters | USA | √ | √ | √ |
| | Pacific oysters | Japan | √ | √ | √ |
| | Clams | Japan | √ | √ | √ |
| | Whelk | Japan | √ | √ | √ |
| | Oysters | Australia | √ | √ | √ |
| | Greenshell mussels | New Zealand | √ | | √ |
| Crustaceans | Lobsters | Canada | √ | √ | √ |
| | Lobsters | USA | √ | √ | √ |
| | King crab | USA | √ | √ | √ |
| | Crab & crayfish | USA | √ | √ | √ |
| Ready-to eat seafood | Salmon fillets, cooked | Spain | √ | √ | |
| | Hake fillets, cooked | Spain | √ | √ | |
| | Crab cake | USA | √ | √ | |
| | Desalted cod | Italy | √ | √ | |
| | Shrimp with vegetables | Spain | √ | √ | |



**Figure 1: Examples of some HPP seafood products on the commercial market (Hyperbaric.com)**

The pressure level required for HPP of seafood is lower than what is used in other applications, but it is able to sufficiently reduce the number of microorganism, including viruses (Motarjemi, Moy, and Todd 2014). Reduction in the pathogens on seafood using HPP is valuable as seafood is often consumed raw (Motarjemi, Moy, and Todd 2014). Seafood can be processed at chilled or ambient conditions at 400-600MPa, but should be stored in refrigerated conditions as HPP may not inactivate the enzymes in the product (Balasubramaniam, Martínez-Monteagudo, and Gupta 2015). Table 1 summarises literature on HPP and pathogen response in seafood.

**Table 1 Selected pathogen response to HPP in different seafood.**

| Pathogen | Foodstuff | Processing conditions (MPa/ initial temp (°C) / hold time) | Level of inactivation | Reference |
|---|---|---|---|---|
| *Vibrio parahaemolyticus* | Oysters | 300/10/3 mins | 5 log $_{10}$ reduction | Cook D (2003) Sensitivity of Vibrio species in phosphate buffered saline and in oysters to high pressure processing. Journal of Food Protection 66: 2276–2282 |
| C. *botulinum* type A spores | Crab meat | 827/75/15 mins | 3.2 $\log_{10}$ reduction | Reddy NR, Solomon HM, Tetzloff RC, and Rhodehamel EJ (2003) Inactivation of Clostridium botulinum type A spores by high pressure processing at elevated temperatures. Journal of Food Protection 66: 1402–1407 |
| Hepatitis A virus | Experimentally contaminated pacific oysters ( gigas) | 400/9/1 min | Reduction of >3 log $_{10}$ plague forming units $g^{-1}$ | Calci KR, Meade GK, Tezloff RC, and Kingsley DH (2005) High-pressure inactivation of hepatitis A virus within oysters. Applied and Environmental Microbiology 71: 339–34 |
| *Listeria monocytogenes* | Cold smoked salmon | 450/12/5 min | ~2log $_{10}$ reduction | Medina M, Cabeza MC, Bravo D, et al. (2009) A comparison between e-beam irradiation and high-pressure treatment for cold smoked salmon sanitation: Microbiological aspects.Food Microbiology 26: 224–227 |
| Murine norovirus | Experimentally contaminated oyster tissue | 400/5/5 min | Reduction of $\log_{10}$ 4.05 plague forming units $g^{-1}$ | Kingsley DH, Holliman DR, Calci KR, Chen H, and Flick GJ (2007) Inactivation of norovirus by high-pressure processing. Applied and Environmental Microbiology 73: 581–585. |

## 2.4 Specific Seafood Product Examples

### 2.4.1 Mussels

Shucking of Green shell mussels at 400MPa can potentially benefit by increasing yield, inactivating *Listeria monocytogenes* and improving product quality (Fletcher et al. 2008) https://www.youtube.com/watch?v=D541uY4FZKY&list=PLz-HeIvoO8yAjzhbc_pOhQxtDk5Gwnm1u&index=10

### 2.4.2 Octopus

Autolysis causes spoilage in raw octopus, thereby reducing the shelf life. Trimethylamine (TMA), biogenic amines (BA) and dimethylamine (DMA) are off-flavour compounds produced in the chilled storage of octopus as it deteriorates (Hsu, Huang, and Wang 2014). Results from HPP treated chopped raw octopus by Hsu, Huang, and Wang (2014), showed the formation of BA, DMA and TMA is supressed when treated at pressures of 450 and 600MPa for 6 minutes at room temperature.

*O. vulgaris* treated at pressure between 400-800MPa at 0°C for 5 minutes visually appeared cooked, however it appeared raw at pressures below 400 MPa (Matser et al. 2000). Textural changes were reported at a pressure between 200-400MPa at 7°C for 15 minutes, with an increase in shear strength (Hurtado, Montero, and Borderías 2001).

### 2.4.3 Abalone

In the HPP trials conducted by Briones-Labarca et al. (2012), Hughes et al. (2016) and Jo et al. (2014), the abalone meat was manually shucked from the shell before treatment in the HPP machine. The abalone only has one shell, therefore processing not in packaging could cause explosion. If the whole abalone was to undergo HPP treatment, it would have to be vacuum sealed or shucked and packaged prior.

Farmed abalone (*Haliotis rufescens)* meat post rigor treated with HPP at 100 and 300 MPa for 1,3, and 5 mins was more tender and a lighter colour than HPP abalone meat pre-rigor (Hughes et al. 2015). HPP of post rigor abalone for 10 mins at 300MPa did not affect texture or colour and increased the chilled shelf life with no physical or chemical quality characteristics (Hughes et al. 2016).

Chilled raw abalone normally has a shelf life less than 3 days (Jo et al. 2014). The optimum conditions to process shucked and cleaned abalone (*Haliotis-discus hannai*) meat vacuum packed in poly nylon pouches was 200MPa for 3 minutes at ambient temperature (~16C). The meat was n between pre and post rigor states. The maximum shelf life was 10 days, with minimal changes in water holding capacity and colour observed (Jo et al. 2014).The shear force was the lowest on day 0 at 200MPa (Jo et al. 2014), indicating a more tender meat.

### 2.4.4 Oysters

HPP of bivalve shellfish commercially at approximately 300MPa for 180 seconds, caused the meat to separate from the shell (Kingsley et al. 2015). In the trial conducted by Kingsley et al. (2015), 6” x8” vacuum pouches with 3 mil standard barrier, nylon/PE were used. Research conducted by Cruz-Romero et al. (2004) showed that HPP of pacific oysters (*C. gigas*) appeared juicier and more voluminous than manually shucked oysters, however changes in colour were noted in the hunter L values, with the treated oysters appearing more cooked with increased pressure.

Cruz-Romero, Kerry, and Kelly (2008) found that treatment at 260, 400 and 600 MPa for 5 minutes at 20°C significantly increased the strength required for cutting the pacific oyster meat. The moisture content increases with increase pressurization, in effect Decemberreasing the protein and fat content. With the increased pressure, Cruz-Romero, Kerry, and Kelly (2008) observed an increase in lipid oxidation.

HPP treatment of inoculated raw pacific oysters with $10^{4-5}$ *V. parahaemolyticus (01:K56)* at 293MPa for 120 s at 8 ± 1°C achieved a >3.52-log MPN/g reduction of the pathogen and the processed

oysters had a 6-8 day and 16-18 day shelf life when stored at 5°C and on ice, respectively (Ma and Su 2011). Storage at 5C has a shorter shelf life than live oysters (28 days), with Aerobic Plate Count ( APC) only reduced by 3.0-2.5log CFU/g, allowing the bacteria that survived HPP to multiply and cause spoilage (Ma and Su 2011).

HPP oyster products on the market are shown in Table 2. Product is individually packaged, bag is filled with unopened oysters and liquor, vacuum packed then HPP.

**Table 2: Commercial HPP oyster products**

| Species | Format Sold | Company | Link |
|---|---|---|---|
| Blue seal oysters | Preshucked whole mussels | Goose Point | https://goosepoint.com/fresher-under-pressure/ |
| Pacific Oysters | Shucked on shells | Gold band oysters | |

### 2.4.5 Prawns

Prawns (*P. japonicas)* treated at 200MPa at 7°C for 10 minutes had opaque flesh and there was an increased shear strength (López-Caballero et al. 2000). De-headed and shelled Black Tiger Shrimp (*P. monodon*) processed at 435MPa for 5 minutes at 25 ± 2°C in vacuum packs extended product shelf life to 15 days, in comparison to untreated samples with a shelf life of 5 days (Kaur et al. 2013). With increased pressure, the shrimp flesh appears more cooked with increased whiteness and more opaque, as well as increased hardness (Kaur et al. 2013).

### 2.4.6 Lobster

There are several HPP lobster products on the market which are sold in several formats, listed in (Table 3). HPP can remove 100% of the lobster meat from the shell. HPP lobster has better water retention, leading to higher cooked yields than manually shucked lobsters. Pressures at 250-500Mpa have successfully used to treat lobsters to improve product yields and microbiological quality (Campus 2010).

**Table 3 HPP lobster products currently on the market**

| Company | Species | Products | Format/ description | Link |
|---|---|---|---|---|
| Shedaic Lobster Shop | Atlantic Lobster | Raw Lobster ( whole/netted)<br>Raw lobster tails<br>Raw lobster claws and knuckles<br>TCK lobster meat-whole pieces | Some products come vacuum packed ( after HPP) or within carapace.<br><br>The live lobsters are placed in HPP. | http://www.shediaclobster.ca/products/# |
| Shucks Maine Lobster | American Lobster | HPP tails in shell<br>Whole frozen lobster<br>Split Maine Lobster<br>'naked' main lobster | Split processed with HPP before splitting, cleaned and frozen.<br>'Naked' product is HPP processed and then hand shucked. | http://shucksmainelobster.com/ |
| Clearwater | | Half Split Lobster<br>Raw lobster- claw, knuckle, tail and leg | Frozen and vacuum paacked | http://www.clearwater.ca/en/home/seafood-retail/lobster/split-lobster.aspx#Harvesting_and_Pro |

| | | | | |
|---|---|---|---|---|
| | | meat | | cessing |

Non thermal treatment of crustacea and bivalves at an isostatic pressure between 200MPa-350MPa can extract the meat from crustacea and shuck bivalves (Hiperbaric 2013).

### 2.4.7 Finfish

Colour change, indicated by the Hunter L* value from raw to cooked in fish was observed at pressures between 150-200 MPa (Matser et al. 2000), with increased lightness and reduced redness noted (Christensen, Hovda, and Rode 2017). Measurable quality parameters of lightness, water holding capacity and texture are affected by structural protein changes caused by HPP and less affected by the fish species when treated at 200 and 500MPa for 120 s (Christensen, Hovda, and Rode 2017). However, the TBARS-level, acid phosphatase (ACP) and microbiological levels vary between different species that have undergone HPP (Rode and Hovda 2016).

### 2.4.8 Crabs

HPP treatment of mud crabs (*Scylla serrata*) at 345MPa for 5 minutes altered the meat colour to appear semi cooked and increased hardness (Elamin et al. 2015).

## 3. OBJECTIVES

The objective of this study was to conduct trials using the HPP machine in Manjimup on various packaged seafood products and assess the impact on various parameters including extension of shelf-life, meat extraction, shucking and sensory quality.

## 4. METHODS FOR COMMERCIAL TRIALS OF HPP FOR THE WA SEAFOOD INDUSTRY

### a. Consultation and EoI process.

The following email was sent to potential WA seafood industry partners:

Dear ……

*You may be aware that a new food processing facility has opened in Manjimup. The facility has a High pressure pasteurisation unit and nitrogen tunnel freezer, as well as associated automated packing, and aligned distribution logistics etc.*

*The facility was developed for horticulture products but the part owners, Jennie and Wayne Franceschi, are interested in potential "tolling" for other industries.*

*For myself, I cannot ignore the HPP opportunity for seafood, an example of which is that 2 of the 5 Prix d'elite prizes at Brussels this year were HPP products. HPP can be used in seafood for meat extraction with high recoveries (eg crabs, lobsters and other crustaceans), shucking for shellfish and extending shelf-life, changing texture, for many products, including finfish.*

*I met with Jennie recently about the opportunity to trial some seafood products at their facility. I said I would ask for interest from the seafood industry and if anyone wanted to try, then we could organise the following:*

a. *Desktop research on the specific products of interest to work out optimal packaging, pressures, treatment times etc. This research both from the scientific literature etc but also in association with expertise offered by the HPP manufacturers Hyperbaric, and the new HPP specialist soon to be relocated to Manjimup from Mexico. This will give us a good idea of initial starting parameters for the test products.*
b. *Package test seafood and take to Manjimup with a seafood group for 3-4 days of concentrated trials. The trials would be through the machine and then into a test kitchen for sensory examination, recoveries and then if looking OK sending out samples for shelf-life testing. The cycle times for HPP are 10 minutes so we think we can achieve a lot in a few days with efficient pre-research. We need to do it this way as we need to isolate the seafood trials in the facility due to potential issues with allergens.*
c. *IF these HPP trials for any of the products show promise, and industry keen, then we can consider undertaking larger scale NPD, distribution and marketing activities.*

*If interested industry partners can provide packaged products, organise their own accommodation and travel to Manjimup and fund initial shelf-life testing , then, to expediate the trials, I intend using my existing underutilised species and waste operational funding to support the other costs of these initial trials. It is probably noteworthy that I have been informed that the individual company costs would be eligible for the R and D tax concession.*

*Can you let me know if you are interested in taking part in this initiative, would hope to schedule the trials for before December 2016. .*

*Thanks*

*Janet.*

**Dr Janet Howieson**
**Senior Research Fellow | Centre of Excellence Science Seafood & Health**

From this expression of interest a range of partners and products were selected to take part in the trial. Dr Howieson and Fresh Producer Alliance (FPA) staff developed a experimental schedule based on the products, the intended outcomes and the literature. Advice was also sought from Hyperbaric staff. The trials was scheduled for 6-8 December 2016.

### b. HPP trials and workshop

An experimental plan was developed in conjunction with the literature review, industry and FPA staff (see Table 4). Summary points included:

- Samples using the same pressure and time will be HPPed together. A total of 12 cycles of HPP will be performed
- Seawater (as close to their natural environment as possible) rather than fresh water was recommended for products being HPPed in liquid.

Figure 3 shows photos of the HPP trials.

**Figure 3: Photos from the HPP trials.**

**Table 4a: Experimental Processing plans**

| Species | Proposed outcome | Final product packaging | | HPP* Pressure (Mpa) | | | HPP* time (min) | | Analyses if sensory quality is looking OK |
|---|---|---|---|---|---|---|---|---|---|
| Akoya oyster | Shucking and ability to extend shelf-life in fresh and frozen product. | Whole shell vacuum packed | sealed bag with sea water | 250 | 300 | 350 | | 2 | Shucking effectiveness, Yield. Total Plate Count (TPC) and sensory at designated days |
| Blue mussels (Mytilus edulis) | Shucking/Extend chilled shelf-life. | Whole shell vacuum packed | sealed bag with sea water | 250 | 300 | 350 | | 2 | Shucking effectiveness, Yield, TPC and sensory at designated days |
| Whole Raw Frozen Prawns | Extract meat (raw frozen product) | Sealed bag with sea water | | 250 | 300 | 350 | | 2 | Yield, sensory |
| Whole cooked frozen prawns | Extract meat (raw frozen product) | | | | | | | | |
| Whole raw deep crustacea (deep sea bugs) | Extract meat (raw frozen product) | Sealed bag with sea water | | 250 | 300 | 350 | | 2 | Yield, sensory |
| Whole raw spiny (champagne) crabs | Extract meat (raw fresh product) | sealed containers with sea water | | 250 | 300 | 350 | | 2 | Yield (v hand-picked), sensory |
| Whole cooked blue swimmer crabs | Extend Shelf-life | Points filed and vacuum packed | | | 500 | 600 | | 2 | Shelf-life, sensory |
| Blue swimmer crab meat (*Portunus armatus*) | Extend shelf-life | Cooked extracted meat in vac pack tray | | 250 | 300 | 350 | | 2, 5, 8, 10 | Colour, texture, TPC and sensory at designated days |
| Blue spot emporer raw fillets (Lethrinus sp) | Extend chilled shelf-life | Raw fillets in vac pack | | 200 | 350 | 500 | | 2 | Colour, texture TPC and sensory at designated days |
| Cooked barramundi, painted sweetlip and atlantic salmon | Extend chilled shelf-life | Cooked fillet sin vac pack | | | | 600 | | 6 | Colour, sensory, shelf-life |
| Raw and Steamed Octopus (*Octopus tetricus*) | Tenderising and Extended chilled and frozen shelf-life of packaged raw and steamed product. | Vac Packaged raw and steamed product | | 200 | 350 | 500 | 2 | 5 | TPC and sensory at designated days. |
| Abalone (frozen) | Extended chilled shelf-life of packaged abalone. | Vacuum packed raw product | | 200 | 350 | 500 | 2 | 5 | TPC and sensory at designated days. |

**Table 4b: Experimental processing schedules**

| Date | Time | Locations | Events | Comments |
|---|---|---|---|---|
| 6/12/2016 | 8.00-1.00 | Processing shed | a small amount of each samples will be HPP at different pressures & times | Make sure enough samples for 3 sessions of sensory evaluations |
| | 2.00-4.00 | commercial kitchen | The first sensory evaluations will be conducted to select the most promising treatment | HPP samples & N-HPP samples will be compared; sampels HPPed at different pressure and time will be compared |
| 7/12/2016 | 1.00-3.00 | commercial kitchen | The second sensory evaluations (24 hours after HPP) will be conducted | flavours will be continuously developed after HPP, particularly the first 48 hours. Ideally, we should taste samples at 0, 24 and 48 hours, but if time is a issues, at least at 24 hours |
| 8/12/2016 | 10.00-12.00 | commercial kitchen | The third sensory evaluations (48 hours after HPP) will be conducted | |
| | 1.00-4.00 | HPP processing shed | The selected samples will be HPPed using the most effective pressure and time and tested TPC and sensory at designed days | Make sure sufficient samples size for TPC and sensory; Keep N-HPP samples as the control |

### c. Analyses

#### i. Appearance and Sensory (raw and cooked)

Two chefs were appointed to cook and help assess all the product agisnt the controls. Sensory assessment was informal and included colour, texture, flavour, appearance. Due to the literature stating that quality changes can occur up to 24 hours after HPP, product was sometimes tested at 4 hours and then again at 24 hours after HPP.

#### ii. Microbiological

Samples were assessed at Merieux laboratory for TPC depending on the product being tested and the number of samples that were available. Microbiological testing undertaken is summarised in the individual product reporting.

#### iii. Yields and Extraction

Shucking activity was noted. Yields of extracted meat were calculated by weight as appropriate depending on the product type.

## 5 RESULTS AND DISCUSSION

Please note that champagne/spiny crab results are included in an aligned report (Appendix 4).

## 5.1 Akoya Oysters

### 5.1.1 Product Information

Fresh Akoya oysters, harvested Sunday 4th December 2016, vacuum packed (some dry and some in water) Monday 5th December, sensory HPP on Tuesday 6th December, shelf-life testing following HPP on Day 1, 7 and 14. Samples were tested for shelf-life after being stored chilled or frozen then thawed.

### 5.1.2 Results

**a. Sensory and Quality Results**

| Packaging | Pressure (Mpa) | Time | Pre-Cooking | Cooking method | Taste assessment |
|---|---|---|---|---|---|
| **4 hours after HPP** | | | | | |
| **VP dry** | 250 | 2 | Some shells smashed, slight adhesion | Not cooked | Not tasted |
| **VP dry** | 300 | 2 | Some shells smashed, hasn't separated meat from shell | Not cooked | Not tasted |
| **VP dry** | 350 | 2 | Some shells smashed, slight adhesion | Not cooked | Not tasted |
| **VP wet** | 250 | 2 | Shells all look fine, no change in | Not cooked | Aroma all good, juicy, salty, creamy, sweet, no off flavour, |

| Packaging | Pressure (Mpa) | Time | Pre-Cooking | Cooking method | Taste assessment |
|---|---|---|---|---|---|
| | | | colour or smell after HPP, no/less separation, yield will be Decemberreased | | |
| **VP wet** | 300 | 2 | Shells all look fine, no change in colour or smell after HPP, easy to shuck is unattached, liquid is retained | Not cooked | Aroma all good, juicy, salty, creamy, sweet, no off flavour, a bit brinier, long finish, full length on palate.<br>"delight to eat" Chefs choice is this one but very close, 300 and 350 both great. |
| **VP wet** | 350 | 2 | Shells all look fine no change in colour or smell after HPP , easy to shuck is unattached, great yield, no moisture loss, liquid is retained. | Not cooked | Aroma all good, juicy, salty, creamy, sweet, no off flavour, long finish is sweet and salty, mouth feel smooth, sweet, good texture, good after taste. Little difference between 300 and 350 but 350 has more intense flavour. NO Negative FIZZ, NO ZING, NO SPRITZ. |
| **VP wet** | 500 (fresh water) | 5 | Colour has slightly changed. Plump, good separation, stickiness, fills really nicely, still lovely translucence, | Not cooked | Rich creamy delightful, Very very sweet (a little too sweet?), less brine that 350 pressure. Softened adductor. |
| **VP wet** | 600 (salt water) | 5 mins | easy to shuck, maintains liquid, firmer texture, looks more cooked, colour difference, overdone not as much jelly | Not cooked | Overdone, appears unattractive, too salty richness of flavour has gone. Nice but not terrific. |
| **24 hours after HPP** | | | | | |
| **Control** | | | | | Smooth, salty, creamy, muscle has got slightly crunchy, |
| **VP wet** | 250 | 2 | Have not changed colour or appearance in the 24 hours, lots of liquid | Not cooked | Mucous has slightly thickened cf control, somewhat sweeter odour. Less oyster flavour, briny, |
| **VP wet** | 300 | 2 | Have not changed colour or appearance in the 24 hours, lots of | Not cooked | Mucous has slightly thickened cf control, somewhat sweeter odour. Less oyster flavour, briny. Difference from yesterday is |

| Packaging | Pressure (Mpa) | Time | Pre-Cooking | Cooking method | Taste assessment |
|---|---|---|---|---|---|
| | | | liquid | | sweetness has gone (converted into gel structure??) |
| **VP wet** | 350 | 2 | Have not changed colour or appearance in the 24 hours, lots of liquid | Not cooked | Relaxed a little, firmer, |
| **VP wet** | 500 (fresh water) | 5 | Liquid has come out, gone grey, colour has changed (even more than yesterday), no mucous/slime as noted with lower pressure. | Not cooked | No difference at 500 between fresh and salt water in texture/appearance |
| **VP wet** | 500 (salt water) | 5 mins | Colour has changed but not firmed up, not toughened | Not cooked | |

**b. Shelf-life Results**

| Packaging | Pressure (Mpa) | Time | Any further storage treatment | Time after HPP | Micro results (TPC/g) | Sensory |
|---|---|---|---|---|---|---|
| **VO in water, chilled** | 0 | 0 | | 7 days | 2300 | |
| **VP in water chilled.** | 300 | 2 | | 7 days | 11000 | |
| **VP in water,** | 0 | 0 | Frozen ( 1 week) then thawed and tested | 7 days | Not tested | |
| **VP in water,** | 300 | 2 | Frozen ( 1 week) then thawed and tested | 7 days | 130 | |
| **VP in water chilled.** | 0 | 0 | | 14 days | Not tested | |
| **VP in water chilled.** | 300 | 2 | | 14 days | 37000 | |
| **VP in water,** | 0 | 0 | Frozen (2 weeks) then thawed and tested | 14 days | 290 | Sensory appearance fine, all good, mucous still thick (as per 24 hour chilled results) |

| | | | | | | |
|---|---|---|---|---|---|---|
| **VP in water,** | 300 | 2 | Frozen (2 weeks) then thawed and tested | 14 days | 280 | |

**d. <u>Photos</u>**

**Akoya at HPP 300 Mpa for 2 mins.**

**Akoya untreated control (left) and 300 Mpa for 2 minutes (right).**

**Ease of shucking, shells after HPP and shucking (not affected), crumbed product in shell.**

### 5.1.3 Discussion and Next Steps

The HPP at the lower pressures facilitated rapid shucking. After four hours the flavour was very good at 300 and 350 Mpa for two minutes, but some deterioration in flavour and appearance and thickening of mucous was noticed when samples were tested after 24 hours. AS a result it was considered that it might be better to freeze immediately after HPP then thaw for serving, as after two weeks frozen, thaw back sensory appearance/flavour was very good. The frozen then thawed microbiological counts were good, shelf-life extension after HPP treatment was indicated after 14 days chilled storage (TPC/g 37,000 after 14 days) but there were too few samples and controls for confirmation.

For the next steps it is suggested to redo at 350 Mpa for 2 mins as soon as possible after harvesting and vacuum packing, and freeze immediately after HPP, to maintain flavour as deterioration and thicker mucous was noticed after 24 hours and this is maintained on freezing. In this follow up trial it is also suggested to undertake daily microbiological tasting on thaw back of frozen product to give use by recommendation to chefs. It would also be interesting to compare if chilled shelf-life is extended at 350 Mpa for 2 mins (HPP v non-treated control).

## 5.2 Mussels

### 5.2.1 Product Information

Fresh mussels, harvested Monday 5th December, vacuum packed (some dry and some in water) Monday 5th December, sensory HPP on Tuesday 6th December, Shelf-life testing following HPP on Day 1, 7 and 14. Samples were tested for shelf-life after being stored chilled or frozen then thawed.

### 5.2.2 Results

**a. Sensory and Quality Results**

| Packaging | Pressure (Mpa) | Time | Pre-Cooking | Cooking method | Post cooking assessment |
|---|---|---|---|---|---|
| **4 hours** | | | | | |
| VP dry | 250 | 2 | Most shells smashed | Simmer in water | Cooking time 2 minutes (min),30 seconds (secs)then meat falls out. Tasted cooked. |
| VP dry | 300 | 2 | Most shells smashed | Simmer in water | Cooking time 20 secs then meat falls out. Tasted raw. |
| VP dry | 350 | 2 | Most shells smashed | Simmer in water | Cooking time 20 secs then meat falls out. Tasted raw |
| VP wet | 250 | 2 | Shells all look fine | Simmer in water | Cooking time 2 min 30 sec then meat falls out. Tasted cooked. |
| VP wet | 300 | 2 | Shells all look fine | Simmer in water | Cooking time 20 secs then meat falls out. Tasted raw |
| VP wet | 350 | 2 | Shells all look fine | Simmer in water | Cooking time 20 secs then meat falls out. Tasted raw |
| VP wet | 500 (fresh water) | 5 | Some shells are broken but not like broken quantity in dry packaging. Shells all look fine, very plump and white, fully shucked | Simmer in water | Cooking time 20 secs all meat fallen out from start. Tasted cooked. |
| VP wet | 600 | 5 mins | Shells all look fine, very plump and white, fully shucked | Simmer in water | Cooking time 20 secs all meat fallen out from start. Tasted raw |
| Control | | | As normal | Simmer in water | Cooking time 2 min 30 secs, meat did not fall out. Tasted cooked. |
| 24 hours | | | | | |
| VP wet | 250 | 2 | Shells all look fine | Simmer in water | Cooking time 1 min 10 secs then meat falls out, meat looks terrible, looks cooked, way too salty |
| VP wet | 300 | 2 | Shells all look fine | Simmer in water | Cooking time 1 min 10 secs then meat falls out, way too salty |
| VP wet | 350 | 2 | Shells all look fine | Simmer in water | Cooking time 1 min 10 secs all meat fallen out from start, plump, good texture, not too salty |
| VP wet | 500 (fresh water) | 5 | Shells all look fine, very plump and white, little bit of drip loss on cooking, fully shucked | Simmer in water | Cooking time 1 min 10 secs all meat fallen out from start, looks cooked, slightly tougher |

| Packaging | Pressure (Mpa) | Time | Pre-Cooking | Cooking method | Post cooking assessment |
|---|---|---|---|---|---|
| VP wet | 600 | 5 mins | Some shells are broken but not like broken quantity in dry packaging. Shells all look fine, very plump and white, fully shucked | Simmer in water | Cooking time 1 min 10 secs all meat fallen out from start, slightly tougher |

**b. Shelf-life Results**

| Packaging | Pressure (Mpa) | Time | Any further storage treatment | Time after HPP | Micro results (TPC/g) |
|---|---|---|---|---|---|
| **VP in water chilled.** | 300 | 2 | | 7 days | 180 |
| **VP in water,** | 300 | 2 | Frozen ( 1 week) then thawed and tested | 7 days | 40 |
| **VP in water chilled.** | 600 | 5 | | 7 days | 30 |
| **VP in water,** | 600 | 5 | Frozen (1 week) then thawed and tested | 7 days | 20 |
| **VP in water chilled.** | 300 | 2 | | 14 days | 34000 |
| **VP in water,** | 300 | 2 | Frozen (2 weeks) then thawed and tested | 14 days | 660 |
| **VP in water chilled.** | 600 | 5 | | 14 days | 40 |
| **VP in water,** | 600 | 5 | Frozen (2 weeks) then thawed and tested | 14 days | 100 |

**Appearance of mussels from HPP (in water) for 2 mins at 250, 300 and 350 Mpa then cooked.**

**HPP raw at 600 Mpa (5 mins)** **HPP raw at 500 Mpa (5 mins)**

### 5.2.3 Discussion and Next Steps

The HPP at 250, 300 and 350 Mpa for the mussels needed to be completed in water, as when vacuum packed dry then subject to HPP all the shells cracked. Even at 500 and 600 Mpa in water some shells cracked.

For the 4 hours post treatment sensory assessment, cooking time varied from 20 secs to 2 mins 30 secs mins as cook time was based on when meat fell from shell. Much of the product look cooked but tasted raw and therefore sensory results were very poor. Hence for the 24 hour testing it was decided to repeat the sensory assessment but making sure that the cooking time was standardised for all treatments and not based on meat falling from shells. This agreed cooking time was to 1 min 10 secs, all tasted cooked and the HPP 350 Mpa for two minutes was most favoured by chefs. However, it was commented that the product tasted a bit salty so it might be best to vacuum package in fresh water.

Shucking was complete at 500 and 600 Mpa before cooking and very quick after cooking at lower pressures. Shells were unaffected in appearance by HPP. The 500 and 600 Mpa treatments had an unusual plump, white appearance of the mussels.

Frozen microbiological counts were suitable, shelf-life extension for 600 Mpa at chilled temperatures was confirmed (TPC/g of 40 after 14 days chilled). After 300 Mpa and 14 days chilled shelf-life extension indicated (34,000/g after 14 days) but there were too few samples and controls for confirmation.

The opinion of the producer was that the expense of HPP is not warranted for the common low value mussel product (vacuum packed), however there may be the opportunity to look at a different product based on shucking and immersion in long life flavoured sauces, ready to be poured straight into the pot.

It would be interesting to repeat with improved replicates and controls to see if the chilled shelf-life is extended at different HPP especially at 350 Mpa for 2 mins (HPP v non-treated control) where shucking occurs and there is minimal impact on appearance/flavour.

## 5.3 Abalone

### 5.3.1 Product Information

Frozen vacuum packed abalone, thawed overnight at 4 C.

### 5.3.2 Results

**Sensory and Quality Results**

| Packaging | Pressure (Mpa) | Time | Pre-Cooking | Cooking method | Post cooking assessment |
|---|---|---|---|---|---|
| **Within 4 hours** | | | | | |
| **VP Dry** | **200** | **2** | **No difference in appearance, texture (noting had been frozen), no difference in colour, gut is fine stays intact.** | **Fried** | **Fine, soft, tender** |
| **VP Dry** | **350** | **2** | **No difference in appearance, texture (noting had been frozen), no difference in colour, gut is fine stays intact.** | **Fried** | **Fine, soft, tender** |
| **VP Dry** | **500** | **2** | **No difference in appearance, texture (noting had been frozen), no difference in colour, gut is fine stays intact.** | **Fried** | **Eats very well, more flavour, very nice.** |

**Shelf-life Results**

| Packaging | Pressure | Time | Any further storage treatment | Time after HPP | Micro results (TPC/g) |
|---|---|---|---|---|---|
| **VP** | **350** | **2 mins** | **No** | **17 days** | **$2.6 \times 10^6$** |

### 5.3.3 Discussion and Next Steps

The low number of abalone samples and the fact frozen samples were supplied makes it difficult to make conclusions. However, the shucking advantages are very pronounced, the chefs stating that in all treatments, “come off in a light breeze”, “pulled off shell very easily (with fingernail).” It was their opinion that thousands of samples could be shucked in an hour. The shell appearance was unaffected by the HPP. There was no benefit in meat recovery.

HPP did not appear to impact the colour etc of raw product. Cooked HPP abalone (250, 250 and 500 Mpa) has good texture and flavour. Chefs considered 500 Mpa was the best flavour. There were not enough samples to run untreated controls.

It was not possible to draw conclusions on whether HPP affects texture (softens) as samples had been frozen. But this does seem a possibility.

It was also not possible to draw conclusions on shelf extension due to only one sample tested.

Next steps are for a better planned HPP experimental program on fresh (not frozen), unshucked, product (and comparison to untreated) could answer questions on HPP impact on texture and shelf-life extension.

## 5.4 Raw Prawns

### 5.4.1 Product Information

Raw, frozen Shark Bay King Prawns, thawed, vacuum packed dry and in water, stored chilled.

### 5.4.2 Results

**Sensory and Quality Results**

| Packaging | Pressure (Mpa) | Time | Meat Yield | Pre-Cooking | Cooking | Post cooking assessment |
|---|---|---|---|---|---|---|
| **Within 4 hours** | | | | | | |
| **VP** | 0 | 0 | Not easy to peel | Head stayed intact, liver did not embolise in head, translucent, | Pan fried | Dry |
| **VP (water)** | 250 | 2 | Not easy to peel 48.2% | Head stayed intact, liver did not embolise in head, slightly opaque, texture, colour same as control. | Pan fried | Very good flavour, crunchy, sweet, salty, high prawn taste value |
| **VP (water)** | 300 | 2 | Not easy to peel 50% | Head stayed intact, liver did not embolise in head, more opaque, slightly blanched appearance | Pan fried | Very good flavour, crunchy, sweet, moist, slightly softer texture, stays on tongue slightly longer, high prawn taste value |
| **VP (water)** | 350 | 2 | Not easy to peel 51.6% | Head stayed intact, liver did not embolise in head, more opaque , blanched appearance | Pan fried | Little bit mushy and flavour has washed out |
| **VP dry** | 250 | 2 | Not easy to peel | Head stayed intact, liver did not embolise in head, more opaque , blanched appearance | Pan fried | Softer in middle, (bit mushy?), flavour very |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | good, but soft, compressed, not happy on tongue |
| **VPdry** | 300 | 2 | Not easy to peel | Head stayed intact, liver did not embolise in head, more opaque , blanched appearance | Pan fried | Flavour all there but is chewy, left with rubbery/poor taste in mouth, |
| **VP dry** | 350 | 2 | Devein easily | Head stayed intact, liver did not embolise in head, more opaque , blanched appearance | Pan fried | Lovely texture, sweetness for possible sashimi product |

**Sensory results (2 panellists) Panellist 1 in normal, Panellist 2 in italics**

| Packaging | Pressure (Mpa) | Time | Appearance* | Odour* | Texture* | Flavour* | Acceptability* |
|---|---|---|---|---|---|---|---|
| **Within 4 hours** | | | | | | | |
| **Control** | 0 | 0 | 9 | 9.1 | 9.4 | 8.85 | 9.2 |
| | 250 | 2 | *8.5* | *8.9* | *9.3* | *8.8* | *9.7* |
| | 300 | 2 | 10.3 | 10.4 | 12.1 | 12.4 | 12.1 |
| | 350 | 2 | 9.2 | 9.45 | 8.75 | 8.95 | 9.4 |

- **Dislike extremely is 0 like extremely is 14.89.**

**Shelf-life Results**

| Packaging | Pressure (Mpa) | Time | Any further storage treatment | Time after HPP | Micro results (TPC/g) |
|---|---|---|---|---|---|
| **VP/water** | 250 | 2 | no | 17 days | $1.4 \times 10^7$ |
| **VP/water** | 300 | 2 | no | 17 days | $2.8 \times 10^4$ |

**Photos**


**Photo shows blanching/whitening of prawns with HPP. 3a (250), 3b (300) 3d (350) Mpa respectively.**

### 5.4.3 Discussion and Next Steps

Results were compromised by lack of sufficient samples, however HPP did not appear to impact on ease of peeling (although recoveries might have been slightly enhanced). There was a slightly blanched (whitening effect, appears slightly cooked) at 250, 300, 350 Mpa compared to control. HPP at 250 and 300 Mpa had a very good flavour, considered by the chefs to be better than the control. At 17 days there was a difference in the TPC/g at between 250 and 300 Mpa, indicating some shelf-life extension with increased pressure. It was expected that there would be better shelf-life extension at 600 Mpa but would also expect to see greater impact on prawn colour difference (blanching, appears cooked).

The producer considered that there was little value in continuing work with the raw prawns, due to the change in appearance (whitening/looks cooked) following HPP.

## 5.5 Deep Sea Bugs

### 5.5.1 Product Information

Frozen raw deep sea bugs, thawed, vacuum packed in water, left chilled.

### 5.5.2 Results

**Sensory and Quality Results**

| Packaging | Pressure (Mpa) | Time | Pre-Cooking | Cooking method | |
|---|---|---|---|---|---|
| **Within 4 hours** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Control** | 0 | 0 | | Pan fry after extraction | Meat is pure white, less tasty than HPP treated samples |
| | 250 | 2 | Top is rigid and bottom soft, does not extract easily, quite firm. | Pan fry after extraction | Rich, buttery, creamy, soft texture, full flavour |
| | 300 | 2 | Meat is OK but texture starts to soften | Pan fry after extraction | Rich, buttery, creamy, slightly softer texture, full flavour, slightly more intense (this is the best) |
| | 600 | 5 | Meat has collapsed, not easy to peel. | Pan fry after extraction | Rich buttery, good flavour, but Chewy, residue of strings, |

**Photos**

### 5.5.3 Discussion and Next steps.

There was no advantage in meat extraction, therefore the producer advised no further action.

## 5.5 Cooked Prawns

### 5.6.1 Product Information

Frozen cooked prawns, thawed, vacuum packed dry or in water, left chilled.

### 5.6.2 Results

**Sensory and Quality Results**

| Packaging | Pressure (Mpa) | Time | Meat Yield | Appearance/taste etc after HPP (chef comments) |
|---|---|---|---|---|
| **Within 4 hours** | | | | |
| **Control** | 0 | 0 | | cylindrical shape, soft and spongy texture, flavour is fine, |
| **VP Dry** | 250 | 2 | | "squished" Dorsoventrally compressed, firm to tough texture, Best flavour etc of 4, 4A and 4B |
| **VP Dry** | 300 | 2 | | "Squished" Dorsoventrally compressed, very tough texture, flavour is fine, slightly dry |
| **VP Dry** | 600 | 5 | | "squished" Flavour fine a bit dry, maybe salty |

| | | | | |
|---|---|---|---|---|
| **VP Water** | 600 | 5 | | Not squished, round and juicy, Flavour fine, slightly saltier |

**Sensory results (average of 2 panellists (not chefs)**

| Packaging | Pressure (Mpa) | Time | Appearance* | Odour* | Texture* | Flavour* | Acceptability* |
|---|---|---|---|---|---|---|---|
| **Within 4 hours** | | | | | | | |
| **Control** | **0** | **0** | **9.05** | **9.2** | **9.4** | **10.4** | **10.2** |
| **VP Dry** | **250** | **2** | **9.8** | **9.75** | **8.75** | **10.95** | **10.95** |
| **VP Dry** | **300** | **2** | **9.6** | **9.4** | **13.75** | **11.8** | **10.4** |
| **VP Dry** | **600** | **5** | **9.25** | **9** | **9.2** | **9.4** | **9.8** |
| **VP Water** | **600** | **5** | **9.95** | **8.35** | **9.55** | **10.8** | **11.15** |

- **Dislike extremely is 0 like extremely is 14.8**

**Shelf-life Results**

| Packaging | Pressure (Mpa) | Time | Any further storage treatment | Time after HPP | Micro results (TPC/g) |
|---|---|---|---|---|---|
| | **250** | **2** | **no** | **17 days** | **$9.4 \times 10^7$** |
| | **300** | **2** | **no** | **17 days** | **$5.6 \times 10^4$** |

**Photos**

**Photo of flattening following dry HPP treatment (left) compared to control (right).**

### 5.6.3 Discussion and Next Steps

The results were compromised by a lack of sufficient samples. However flattening of prawns when packed dry then HPP treated needs attention, in water no flattening was noticed. HPP did not appear to impact on ease of peeling (and hence on meat recoveries). HPP at 250, 300 and 600 Mpa did not affect comparative flavour (especially if not flattened). Texture was affected, but this may be a result of the flattening. At 17 days there was a difference in the TPC/g at between 250 and 300 Mpa, indicating some shelf-life extension with increased pressure, but insufficient samples were tested.

Next steps suggested were to HPP treat whole and peeled cooked prawns at 600 Mpa for 5-8mins in liquid (maybe flavoured sauce) and do extended shelf–life and sensory testing (up to 45 days).

## 5.7 Marron

### 5.7.1 Product Information

**F**resh live Marron, anaethesised, vacuum packed in water, left chilled.

### 5.7.2 Results

**Sensory and Quality Results**

| Packaging | Pressure (Mpa) | Time | Meat Yield | Pre-Cooking | Cooking method | Post cooking assessment |
|---|---|---|---|---|---|---|
| **Within 4 hours** | | | | | | |
| **Control** | 0 | 0 | Not easy to peel<br>Meat: 35.26%<br>Rest (claws not peeled, shell and guts etc): 64.22%<br>Loss: 0.52% | | Pan fried | Fresh, meaty, tender, can smell dam organics |
| **VP in Water** | 200 | 2 | Meat (claws peeled): 43%<br>Rest: 57%<br>Loss: 0% | Internals not smashed, removed meat easily, needed some cracking of shell, knuckles moved but didn't quite fall out. Has finer texture than others | Pan fried | Sweet crunchy, delicate subtle flavour, claw meat very sweet, |
| **VP in Water** | 350 | 2 | Meat: 42.83%<br>Rest Claws peeled):57.72%<br>Loss:+0.55% | Feels firmer, came out slightly easier, knuckles give way so total meat removed | Pan fried | Texture is better, very good, sweetness is better, no dam water, , subtle as in delicate, peppery, bites the tongue (but not zingy), pleasant experience, |
| **VP in Water** | 500 | 2 | Meat: 49.04%<br>Rest (claws peeled):49.79%<br>Loss: 1.17% | Cooked appearance, some adhering to joints, came out of tube very easily, with no need to take edges away | Pan fried | Firmer, stringier, too frim, gelatinous, overdone. |

**Sensory results (2 panellists) Panellist 1 in normal, Panellist 2 in italics, Panellist 3 in red**

| Packaging | Pressure (Mpa) | Time | Appearance* | Odour* | Texture* | Flavour* | Acceptability* |
|---|---|---|---|---|---|---|---|
| **Within 4 hours** | | | | | | | |
| **Control** | 0 | 0 | 9, *5* | 10.6, *9.3* | 10.7, *10.5* | 10.7, *9.9* | 10.7, *10.6* |
| **VP in Water** | 200 | 2 | 11, *11.5* | 10.6, *11* | 11.6 | 6.1, *9.2* | 10.1, *10.6*, |
| **VP in Water** | 350 | 2 | 12.2, *9.8* | 11.5, *10.2* | 12.3, *11* | 11.6, *10.6* | 11.8, *11.9* |
| **VP in Water** | 500 | 2 | 11, *7.8* | 11.5, *8.4* | 11.6 | 9.4, *10.2* | 10.1, *11.2* |

- **Dislike extremely is 0 like extremely is 14.8**

**Photos**

Meat extraction from marron following HPP

### 5.7.3 Discussion and Next Steps

HPP of marron resulted in enhanced meat recovery (35-49%0 and improved flavour (dam organics smell was removed). 250 and 350 Mpa did not result in the whitening/cooked/appearance but this was noticed at 500 Mpa. Further work on marron is advised.

## 5.8 Raw Finfish Fillets

### 5.8.1 Product Information

Frozen Bluespot Emporer fillets, thaw, divide and re-vacuum packed, store chilled.

### 5.8.2 Results

**Sensory and Quality Results**

| Packaging | Pressure (Mpa) | Time | Yield | Pre-Cooking | Cooking method | Post cooking assessment |
|---|---|---|---|---|---|---|
| **Within 4 hours** | | | | | | |
| **Control** | **0** | **0** | **na** | **Normal raw** | **Pan fry** | **Soft delicate** |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | **fillet, can detect free organics in odour** | | |
| **VP dry** | **200** | **2** | **na** | **Has appearance of normal raw fillet, odour OK** | **Pan fry** | **Slightly tougher texture, bland, fibrous, dry** |
| **VP dry** | **350** | **2** | **na** | **White, tough texture, looks cooked, odour OK** | **Pan fry** | **Flavour bland but acceptable, very rubbery texture, not acceptable.** |
| **VP dry** | **500** | **2** | **na** | **White, very tough texture, looks cooked, odour OK** | **Pan fry** | **Flavour bland but acceptable/or off flavour, very rubbery texture, not acceptable.** |

**Sensory results (2 panellists)**

| **Packaging** | **Pressure (Mpa)** | **Time** | **Yield** | **Appearance *** | **Odour *** | **Texture *** | **Flavour *** | **Acceptability *** |
|---|---|---|---|---|---|---|---|---|
| **Within 4 hours** | | | | | | | | |
| **Control** | 0 | 0 | na | 8.7 | 10.6 | 9.9 | 10.4 | 11.3 |
| **VP dry** | 200 | 2 | na | 10.7 | 10.6 | 10.7 | 11 | 11.9 |
| **VP dry** | 350 | 2 | na | 10.7 | 10.6 | 9 | 8.3 | 9.3 |
| **VP dry** | 500 | 2 | na | 10.7 | 10.6 | 8 | 7.8 | 8.9 |

- **Dislike extremely is 0 like extremely is 14.8**

**Shelf-life Results**

| **Packaging** | **Pressure (Mpa)** | **Time** | **Any further storage treatment** | **Time after HPP** | **Micro results (TPC/g)** |
|---|---|---|---|---|---|
| **VP Dry** | **200** | **2** | **no** | **17 days** | **$3.2 \times 10^8$** |
| **VP Dry** | **350** | **2** | **no** | **17 days** | **$2.7 \times 10^8$** |
| **VP Dry** | **500** | **5** | **no** | **17 days** | **$1.1 \times 10^8$** |

**Photos**

**Whitening of fillets following HPP treatment (compared to control).**

### 5.8.3 Discussion and Next Steps

The whitening and loss of flavour of the raw fillets precluded any further work on this product. Shelf-life extension was not observed.

## 5.9 Cooked Finfish

### 5.9.1 Product Information

Fresh Atlantic Salmon, Painted Sweetlip and Barramundi fillets. Filleted and vacuum packed on 16 January 2017, samples cooked by sous vide (40 mins at 50 C) on 16 January 2017. HPP treated (600:8 minutes) on 17 January 2017. Samples opened and pan fried on 23 January 2017.

### 5.9.2 Results

**Sensory and Quality Results**

| Packaging | Pressure (Mpa) | Time | Pre-Cooking | Cooking method | Post cooking assessment |
|---|---|---|---|---|---|
| **Within 3 day.** | | | | | |
| **SALMON** | | | | | |
| | 0 | 0 | Liquid around fillet is slightly red, colour light orange, slightly softer texture | Pan fry | All good |
| | 600 | 8 | Liquid around fillet in VP is white, more solid, light orange, slightly firmer | Pan fry | All good Very little difference, mybe HPP slightly tougher, slightly |

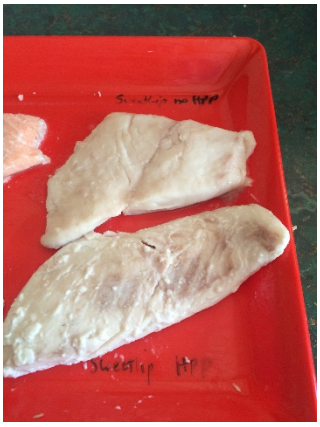
| | | | | | |
|---|---|---|---|---|---|
| | | | texture | | less flavour |
| **SWEETLIP** | | | | | |
| | 0 | | Liquid around fillet is colourless, colour texture similar | Pan fry | |
| | 600 | 8 | Liquid around fillet in VP is white, more solid, similar colour/texture | Pan fry | No difference |
| **BARRAMUNDI** | | | | | |
| **Skin on** | 0 | 0 | Liquid around fillet is pink, some white patches, similar colour/texture, skin no difference | Pan fry | No difference |
| | 600 | 8 | Liquid around fillet in VP is white, more solid, similar colour/texture | Pan fry | |
| **Skin off** | 0 | 0 | Liquid around fillet is pink, similar colour/texture | Pan fry | No difference |
| | 600 | 8 | Liquid around fillet in VP is white, more solid, and a lot of liquid, similar colour/texture | Pan fry | |

**Shelf-life Results**

| Packaging | Pressure (Mpa) | Time | Day 3 (TPC/g) | Day 7 (TPC/g) | Day 14 (TPC/g) | Day 21 (TPC/g) | Day 28 (TPC/g) | Day 35 (TPC/g) |
|---|---|---|---|---|---|---|---|---|
| **Salmon** | 0 | 0 | $2.7 \times 10^4$ | $7.3 \times 10^5$ | | | | |
| | 600 | 8 | <10 | 120 | 880 | <10 | 20 | |
| **Sweetlip** | 0 | 0 | $2.8 \times 10^4$ | $2.7 \times 10^6$ | | | | |
| | 600 | 8 | 20 | <10 | 70 | | 110 | |
| **Barramundi** | 0 | | 600 | $5.3 \times 10^5$ | | | | |
| | 600 | 8 | 40 | 80 | 30 | 40 | 120 | 70 |

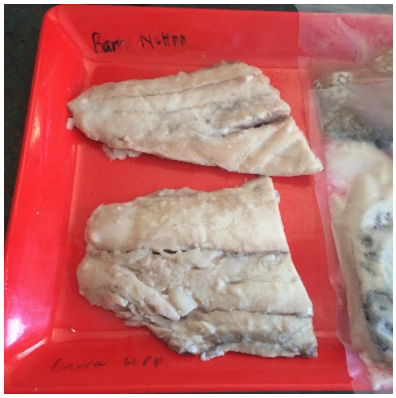
**Photos**

**Salmon before and after cooking**



**Sweetlip before and after cooking**

**Barramundi before cooking**



**Barramundi after cooking**

### 5.9.3 Discussion and next Steps

There is a clear opportunity for extending the shelf-life of cooked fin fish products by HPP. Flavour and/or appearance was not affected.

## 5.10 Octopus and Squid

### 5.10.1 Product Information

Raw Frozen Octopus and raw frozen squid, thawed, and vacuum packed dry.

### 5.10.2 Results

**Sensory and Quality Results (octopus)**

| Packaging | Pressure (Mpa) | Time | Appearance/taste etc after HPP |
|---|---|---|---|
| **Within 4 hours** | | | |
| **VP dry** | 200 and 500 | 2 and 5 | No impact at 200 so put through again at 500. Some tenderising (better than 500 only) so need to look at higher pressures (eg 600) |
| **VP dry** | 500 | 5 | Rubbery, very tough |

**Sensory and Quality Results (squid)**

| Packaging | Pressure (Mpa) | Time | Appearance/taste etc after HPP |
|---|---|---|---|
| **Within 4 hours** | | | |
| **VP dry** | 250 | 2 | Firm texture#, best flavour of the three, but all taste really good. |
| **VP dry** | 350 | 2 | Soft texture, very easy to skin, cuttle just dropped out, ink all stayed intact, did not go everywhere. |
| **VP dry** | 500 | 2 | Firm texture, denatured protein so looks slightly different. |

**# texture varies but may be due to individual size and sample of different squid.**

**All very easy to peel.**

**Shelf-life Results (next set of trials) (Octopus)**

| Packaging | Pressure (Mpa) | Time | Any further storage treatment | Time after HPP | Micro results (TPC/g) |
|---|---|---|---|---|---|
| **VP** | 600 | 5 | no | 15 days | <10 |
| **VP** | 600 | 8 | no | 15 days | 300 |
| **VP** | 600 | 5 | no | 22 days | 3200 |
| **VP** | 600 | 8 | no | 22 days | 1500 |
| **VP** | 600 | 5 | no | 29 days | 410000 |
| **VP** | 600 | 8 | no | 29 days | 1700 |

### 5.10.3 Discussion and Next Steps

There appears some opportunity to further explore HPP for octopus and squid to increase chilled shelf-life and assist with tenderising. However, at the moment supply is an issue, therefore no need to explore other value-added options.

## 5.11 Cooked Crab Meat

### 5.11.1 Product Information

Vacuum packed, cooked crab meat.

### 5.11.2 Trials

Description of Trials

Trial 1: 6 December 2017: fresh cooked crab meat, vacuum packed. Three treatments 0, 500 Mpa (for 5 mins), 600 Mpa (for five minutes). Sensory assessment at 4 and 24 hours.

Trial 2: 8 December 2017: fresh cooked crab meat, vacuum packed, four treatments: 500 psi (3 mins), 500 Mpa (5 minutes), 600 Mpa (5 minutes), 600 Mpa (8 minute). Weekly TPC and informal sensory.

Trials 3: 18 December 2016 fresh cooked crab meat, vacuum packed. Two treatments 600 Mpa for 8 minutes and 600 Mpa for 10 minutes. One sample of 600 Mpa for 8 minutes held on ice for 5 weeks, the others held in refrigerator.

### 5.11.3 Results

**Sensory and Quality Results**

**Trial 1:**

| **Packaging** | **Pressure (Mpa)** | **Time** | **After Treatment** |
|---|---|---|---|
| **Within 4 hours** | | | |
| **6** | 0 | | Good flavour, colour |
| | 500 | 5 | Good flavour, colour |
| | 600 | 5 | Good flavour, colour |
| **After 24 hours** | | | |
| **6** | 0 | | Good flavour, colour |
| | 500 | 5 | Good flavour, colour |
| | 600 | 5 | Good flavour, colour |

**Notes: no difference in flavour between treatments, no difference in colour between treatments. No change in flavour/appearance after 24 hours.**

**Trial 2: TPC results from samples treated on 7/12/2016**

| **Packaging** | **Pressure Mpa)** | **Time** | **TPC/g results** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Day 2 | Day 8 | Day 15 | Day 29 | Day 36 | Day 43 (1) | Day 43 (2) |
| **VP** | 500 | 3 | 2100 | | 1100 | Est 50 | 36 x $10^6$ | 29 x $10^6$ | 35 x $10^6$ |
| **VP** | 500 | 5 | 870 | 660 | 810 | 4400000 | 33 x $10^6$ | 86 x $10^6$ | 110 x $10^6$ |
| **VP** | 600 | 5 | 850 | | 1100 | 120000 | 290 x | 360 x | 580 x |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $10^6$ | $10^6$ | $10^6$ |
| **VP** | 600 | 8 | 160 | 150 | 700 | 6200 | 2 X $10^6$ | 46 X $10^6$ | 50 X $10^6$ |

**Listeria not detected in 25 g in all day 2 samples.**

**Listeria, Coagulase positive Staphylococcus and Salmonella not detected in Day 36 600: 8 mins samples.**

**Informal sensory assessment on Day 35, no difference in taste between Day 35 samples (600/8 minutes) and Fresh Day 4 samples.**

**Trial 3 TPC and other results from samples treated on conducted on 10/1/2017**

| **Packaging** | **Pressure (Mpa)** | **Time** | **TPC/g results** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Day 3 | Day 5 | Day 7 | Day 14 | Day 21 | Day 28 | Day 35 |
| **VP (ice for 10 days then fridge)** | 600 | 8 | 4800 | | 5700 | 7800 | 2500 | 5.1 x $10^5$ | 4 x $10^6$ |
| **VP (ice)** | 600 | 8 | | | | | | | 32 x $10^6$ |
| **VP** | 600 | 10 | 2500 | | 7100 | 3000 | 1400 | 1.5 x $10^6$ | 6.4 x $10^5$ |
| **VP** | 0 | 0 | | 3.7 x $10^5$ | 3.7 x $10^5$ | | | | |

**Listeria, Coagulase positive Staphylococcus and Salmonella not detected in Day 35 600: 8 mins samples kept on ice.**

### 5.11.4 Discussion and Next Steps

The HPP results in extension of shelf-life of the cooked crab meat. Shelf-life of at least three weeks is possible when compared to around 5 days for an untreated control. HPP cooked crab samples were given to key chefs, and subsequently the product was a finalist in the ABC WA Delicious Awards (see packaging below).


## 5.12 Cooked Whole Crabs

### 5.12.1 Product Information

Cooked whole crabs, sharp points filed then vacuum packed dry.

### 5.12.2 Results

**Sensory and Quality Results**

| Packaging | Pressure (Mpa) | Time | After Treatment Appearance and Sensory | Sensory (Day 21) |
|---|---|---|---|---|
| | | | | |
| VP Dry | 0 | | As normal | Not tasted |
| VP White | 500 | 8 | Crabs are squashed and cracked following HPP | Flavour and appearance all good |
| VP Pink | 600 | 8 | Crabs are squashed and cracked following HPP | Flavour and appearance all good |

**Microbiological Results**

| Packaging | Pressure (Mpa) | Time | TPC/g | | |
|---|---|---|---|---|---|
| | | | Day 21 | Day 28 | Day 35 |
| VP (white) | 500 | 2 | 60 | 1400000* | ND |
| VP (pink) | 600 | 2 | 80 | 13000* | 29000 |

*all Day 28 samples Listeria ND/25g, Salmonella ND/25g, Coagulase Positive Staphylococcus <100/g.

**Photos**

**Whole crabs "squashed" and cracked after HPP treatment.**

### 5.12.3 Discussion and Next Steps.

Shelf-life extension of whole cooked crabs is achieved, and flavour and flesh appearance unaffected. However, whole crab shells were squashed and cracked following HPP treatments. Meat extraction was not improved.

## 6 Conclusions

HPP treatment of a number of different seafood products has been trialled and much new knowledge gained.

In summary, and following consultation with the producers, the following products will likely be further investigated: cooked chilled crab meat (extended shelf-life), cooked chilled finfish (extended shelf-life), marron (meat extraction), abalone (meat extraction and tenderising), Akoya oysters (shucking), mussels (shucking and new mussel in sauce products with extended shelf-life), cooked prawns (cooked prawn in sauce product with extended shelf-life). Octopus and squid could be further investigated to tenderise and extend shelf-life in chilled products, however supply is an issue for those products at the current time.

The activity also resulted in a general increase in knowledge and interest about HPP in the WA seafood industry.

Unfortunately a planned second set of more intensive, rigorous and statistically valid trials had to be cancelled due to the HPP operation becoming non-operational in March 2018.

## References


Balasubramaniam, V.M., Sergio I. Martínez-Monteagudo, and Rockendra Gupta. 2015. "Principles and Application of High Pressure–Based Technologies in the Food Industry." *Annual Review of Food Science and Technology* 6 (1): 435-462. doi: doi:10.1146/annurev-food-022814-015539.

Briones-Labarca, V., M. Perez-Won, M. Zamarca, J. M. Aguilera-Radic, and G. Tabilo-Munizaga. 2012. "Effects of High Hydrostatic Pressure on Microstructure, Texture, Colour and Biochemical Changes of Red Abalone (Haliotis Rufecens) During Cold Storage Time." *Innovative Food Science & Emerging Technologies* 13: 42-50. doi: http://dx.doi.org/10.1016/j.ifset.2011.09.002.

Campus, Marco. 2010. "High Pressure Processing of Meat, Meat Products and Seafood." *Food Engineering Reviews* 2 (4): 256-273. doi: 10.1007/s12393-010-9028-y.

Christensen, Line Bach, Maria Befring Hovda, and Tone Mari Rode. 2017. "Quality Changes in High Pressure Processed Cod, Salmon and Mackerel During Storage." *Food Control* 72, Part A: 90-96. doi: http://dx.doi.org/10.1016/j.foodcont.2016.07.037.

Cruz-Romero, M., J. P. Kerry, and A. L. Kelly. 2008. "Changes in the Microbiological and Physicochemical Quality of High-Pressure-Treated Oysters (Crassostrea Gigas) During Chilled Storage." *Food Control* 19 (12): 1139-1147. doi: http://dx.doi.org/10.1016/j.foodcont.2007.12.004.

Cruz-Romero, M., M. Smiddy, C. Hill, J. P. Kerry, and A. L. Kelly. 2004. "Effects of High Pressure Treatment on Physicochemical Characteristics of Fresh Oysters (Crassostrea Gigas)." *Innovative Food Science & Emerging Technologies* 5 (2): 161-169. doi: http://dx.doi.org/10.1016/j.ifset.2004.01.002.

Elamin, Wael Mohamed, Johari Endan, Yus-Aniza Yusof, Rosnah Shamsudin, and Anvarjon Ahmedov. 2015. "Effect of High Pressure Processing on Sensory and Physical Attributes of Malaysian Shrimps and Mud Crabs." *2015* 14 (2): 6. http://asrjetsjournal.org/index.php/American_Scientific_Journal/article/view/1033.

Hsu, Chiao-Ping, Hsiao-Wen Huang, and Chung-Yi Wang. 2014. "Effects of High-Pressure Processing on the Quality of Chopped Raw Octopus." *LWT - Food Science and Technology* 56 (2): 303-308. doi: http://dx.doi.org/10.1016/j.lwt.2013.11.025.

Huang, Hsiao-Wen, Sz-Jie Wu, Jen-Kai Lu, Yuan-Tay Shyu, and Chung-Yi Wang. 2017. "Current Status and Future Trends of High-Pressure Processing in Food Industry." *Food Control* 72, Part A: 1-8. doi: http://dx.doi.org/10.1016/j.foodcont.2016.07.019.

Hughes, Brianna H., Neil J. Greenberg, Tom C. Yang, and Denise I. Skonberg. 2015. "Effects of Rigor Status During High-Pressure Processing on the Physical Qualities of Farm-Raised Abalone (Haliotis Rufescens)." *Journal of Food Science* 80 (1): C40-C48. doi: 10.1111/1750-3841.12717.

Hughes, Brianna H., L. Brian Perkins, Tom C. Yang, and Denise I. Skonberg. 2016. "Impact of Post-Rigor High Pressure Processing on the Physicochemical and Microbial Shelf-Life of Cultured Red Abalone (Haliotis Rufescens)." *Food Chemistry* 194: 487-494. doi: http://dx.doi.org/10.1016/j.foodchem.2015.07.144.

Hurtado, J. L., P. Montero, and J. Borderías. 2001. "Chilled Storage of Pressurized Octopus (Octopus Vulgaris) Muscle." *Journal of Food Science* 66 (3): 400-406. doi: 10.1111/j.1365-2621.2001.tb16117.x.

Jo, Yeon-Ji, Kyung-Hun Jung, Mi-Yeon Lee, Mi-Jung Choi, Sang-Gi Min, and Geun-Pyo Hong. 2014. "Effect of High-Pressure Short-Time Processing on the Physicochemical Properties of Abalone (Haliotis Discus Hannai) During Refrigerated Storage." *Innovative Food Science & Emerging Technologies* 23: 33-38. doi: http://dx.doi.org/10.1016/j.ifset.2014.02.011.

Kaur, Barjinder Pal, Neelima Kaushik, P. Srinivasa Rao, and O. P. Chauhan. 2013. "Effect of High-Pressure Processing on Physical, Biochemical, and Microbiological Characteristics of Black Tiger Shrimp (Penaeus Monodon)." *Food and Bioprocess Technology* 6 (6): 1390-1400. doi: 10.1007/s11947-012-0870-1.

Kingsley, David H., Susan E. Duncan, Linda A. Granata, Amanda Salinas-Jones, George J. Flick, Dianne M. Bourne, and Virginia C. Fernandez-Plotka. 2015. "High-Pressure Processing with Hot Sauce Flavouring Enhances Sensory Quality for Raw Oysters (Crassostrea Virginica)." *International Journal of Food Science & Technology* 50 (9): 2013-2021. doi: 10.1111/ijfs.12852.

López-Caballero, ME, M Pérez-Mateos, JA Borderías, and P Montero. 2000. "Extension of the Shelf Life of Prawns (Penaeus Japonicus) by Vacuum Packaging and High-Pressure Treatment." *Journal of Food Protection* 63 (10): 8.

Ma, Lei, and Yi-Cheng Su. 2011. "Validation of High Pressure Processing for Inactivating Vibrio Parahaemolyticus in Pacific Oysters (Crassostrea Gigas)." *International Journal of Food Microbiology* 144 (3): 469-474. doi: http://dx.doi.org/10.1016/j.ijfoodmicro.2010.10.037.

Matser, Ariette M., Dick Stegeman, Jeroen Kals, and Paul V. Bartels. 2000. "Effects of High Pressure on Colour and Texture of Fish." *High Pressure Research* 19 (1-6): 109-115. doi: 10.1080/08957950008202543.

Motarjemi, Yasmine, Gerald Moy, and Ewen Todd. 2014. "27.9 High Pressure Processing." In *Encyclopedia of Food Safety*. Elsevier.

Rode, Tone Mari, and Maria Befring Hovda. 2016. "High Pressure Processing Extend the Shelf Life of Fresh Salmon, Cod and Mackerel." *Food Control* 70: 242-248. doi: http://dx.doi.org/10.1016/j.foodcont.2016.05.045.