Evaluation of alternative processing technologies applicable to crustaceans

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2005/233 **Evaluation of alternative processing technologies applicable to crustaceans)**

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OBJECTIVES:

1. To determine a standard processing protocol for three selected alternative cooking method (steam, steam plus pressure and microwave cooking).
2. To investigate factors impacting on the uptake of water and anti browning agents during drowning of rock lobster correlated to weight recovery and melanosis development.
3. To evaluate the impact of alternative cooking methods, (microwave cooking, steam, and steam plus pressure) on weight recovery and melanosis rates.
4. To evaluate the sensory quality of rock lobster processed by alternative cooking methods in comparison to rock lobster processed using standard practise (boiling).
5. Optimisation of processing methods.

OUTCOMES ACHIEVED TO DATE

The proposed project has identified the processing parameters required to optimise rock lobster processing using atmospheric steam cooking to ensure increased weight recovery, reduced melanosis and improved post processing sensory quality.

The information arising from this proposed project enables processors to maximize their cooked weight recoveries whilst ensuring reduced melanosis through the use of the identified steaming protocol. This will lead to increased profitability and efficient use of the resource is possible through minimising costs of cooking and maximising financial returns due to improved yield and sensory appeal. The product will also be more competitive on the international market due to the improved sensory appeal and ability to reduce use of undesirable chemical treatments (sulphites).

KEYWORDS: **Rock lobster, processing optimisation, post harvest**

NON TECHNICAL SUMMARY

Prevention of discolouration or blackening in crustaceans can be achieved by chemical means (using antibrowning agents) or through physical means (deactivation of the enzyme by heating). However a combination of these factors may be more effective than using a single factor alone. This study looked at the effectiveness of existing processing technologies to address the need to ensure prevention of blackening whilst returning a good weight recovery. As rock lobster is a highly valued luxury item it is also important to ensure that the optimum sensory quality is maintained by which ever method is used. Therefore the aim of this project was to evaluate the ability of alternative processing methods to maintain or improve cooked western rock lobster quality whilst maintaining or improving weight recovery and ensuring the reduction of the incidence of blackening.

Western rock lobsters were subjected to a variety of processing treatments that investigated the impact of antibrowning agents on weight recovery and blackening in processed lobster. The treatments tested were: the use of ice in drowning; the ratio of lobsters to the volume of drowning solution; the length of the drowning period; and the influence of the concentration of antibrowning agents.

These experiments showed that the best combinations of factors to reduce blackening while maintaining weight recovery were:

1. Without anti-browning chemical being used then a drowning time of a minimum of 40 minutes with the drown ratio of 1 lobster per 2 litres of water should optimise weight recovery.
2. When using an antibrowning chemical, then it is recommended that a drown ratio of 1 lobster per 5 litres of iced antibrowning chemical solution for a minimum of 40 minutes should reduce blackening while maintaining improved weight recovery.

Western rock lobsters were also processed using a variety of cooking methods (boiling, microwave cooking, steam, and steam plus pressure) to investigate their impact on weight recovery and blackening rate; and sensory acceptability of processed rock lobster. The information from these experiments was then used to determine which combination of factors would deliver the best end product quality.

The investigation of alternative cooking methods showed that on the commercial scale there were some important quality issues with microwaved product that needed to be considered. These were: the uneven colour of the lobster shell after cooking; uneven flesh colour; and

burst membranes. In light of this it would appear that industrial cooking of whole lobsters using conventional microwave processes may not be a viable commercial process.

For all other processing methods (steam, steam plus pressure and boiling) it was noted that longer cook times resulted in greater reduction of blackening and a reduction in weight recovery. When comparing 'just-cooked' products, the highest recoveries were obtained from boiled lobsters closely followed by steamed products.

It was also shown that pressure steaming was able to reduce the development of blackening in lobsters while using much shorter cooking times than other methods (24 minutes using pressure +steam as opposed to 33 minutes using steam alone). However it also resulted in an increased weight loss (94% weight recovery on average). The maximum weight recovery (97%) and minimum blackening (0) was delivered by samples cooked using steaming at an endpoint equivalent to 33.5 minutes at 90 °C (steamed 'just right'). At this level of treatment NO lobster developed blackening when cooked by steaming. Thus it can be concluded that steaming delivers a better weight recovery in combination with reduction in blackening than pressurised cooking.

Any change to processing methods must take into consideration the impact of processing on the taste and texture of the product. Sensory testing showed that pressure cooking with steam was the least favoured method in terms of product acceptability while cooking with steam (no pressure) was the most favoured method closely followed by microwave cooking and boiling. In general, decreasing the amount of heat of the cooking process increased the acceptability of a product. However, the steamed 'just right' cooking protocol gave the best combination of reduction in blackening (0 black) and improved weight recovery (97%) along with the greatest acceptance by consumers.

The results of the study clearly showed that steaming was a more effective processing method for cooking lobster than the other treatments investigated. Steaming gave higher weight recoveries whilst delivering greater levels of blackening reduction and maintaining sensory quality. Therefore, based on these results it would appear that steaming offers the greatest potential for the industry to improve their processing methods.

The results of the study will be made available to the seafood industry and interested persons via a seminar to be held at the Centre of Excellence in Seafood, Science and Health in 2010. Interested parties can also contact the principal investigator for more information.

2.0 ACKNOWLEDGMENTS

This research was made possible through funding provided by the Fisheries Research and Development Corporation. The investigators would also like to acknowledge the active participation and involvement of the following individuals and companies in this research:

- Mr Ross Macgregor & Staff at Lobster Australia Pty Ltd
- Mr Stephen Hood of M. G. Kailis Ltd
- Mr Simon Warwick of Curtin University of Technology
- Mr Richard Stevens of the Western Australia Fishing Industry Council
- Mr Tony Gibson of the Western Rock Lobster Development Association; and
- Professor Bruce Phillips of the FRDC Rock Lobster Post Harvest Subprogram.

Without their assistance and input this project would never have started nor been completed as successfully as it was.

3.0 BACKGROUND

Melanosis (post processing blackening) and weight recovery are two major factors impacting on the profitability of processed western rock lobster. FRDC Project 2001/235 clearly demonstrated that the level and duration of heat input during processing is directly related to the level of weight loss and the incidence of melanosis in processed rock lobsters. The results also showed that current processing methods are not capable of reducing melanosis and improving weight recoveries.

Discussions were undertaken with the processors in the western rock lobster industry and they indicated a need for a study to evaluate the effectiveness of alternative cooking methods to the conventional batch boiling. It was thought that alternative cooking methods with a faster rate of heating may significantly improve the post harvest quality of lobsters (and other crustaceans) by delivering better sensory quality and increased weight recovery. If at the same time, they could contribute to a decrease or prevention of melanosis they would be of great value to the seafood processing industry. Systems that utilise steam, autoclave (steam and pressure) or microwave cooking have attributes that may deliver the desired outcomes.

The results would have a direct and dramatic impact. Given the scale of the West Australian rock lobster fishery, each percent improvement in weight recovery is the equivalent of fifty tonnes of rock lobster, or $1.4 million per season (based on a average price of $26 per kg, and a catch of 10,000 tonne (2005-2008)) (ABARE, 2009). As an average, 80% of this improvement will be returned to fishermen, representing an equivalent of $1.1 million in increased GVP. The project did not look at cooking methods and melanosis in the other rock lobster fisheries per se as the majority of the product in those fisheries is exported live (R. Stevens, pers.comm). However it is believed that the outcomes of the project maybe applicable to all the Australian rock lobster industry in the future.

4.0 NEED

It has been clearly identified by industry members that there is a need for improved and/or alternative processing methods for crustacean species in Australia. Developments in international trade and food standards indicate that a review of current and alternative processing methods is required. Any improvements in the yield and quality of the cooked products will result in a significant market advantage and increased profitability.

Initial studies focussed on western rock lobster as this is a high value market in which a significant portion of the catch is processed. It is proposed that further complementary projects could be initiated to extend this work to other species of crustaceans and other technologies over the next few years through the Australian Seafood CRC.

The western rock lobster industry turns over $250 to $300 million annually, with 70% of the catch currently marketed as processed product (ABARE, 2009). The major issues with western rock lobster cooking are weight recovery and melanosis reduction. Melanosis occurrence is related to cooking methods (Williams, Davidson, and Mamo 2005). Currently sulphites are widely used in the seafood industry as they provide an effective way to prevent melanosis but high levels of sulphites result in a negative impact on flavour and on health (McEvily and Iyengar 1992). Other antibrowning agents, such as Everfresh® (4-hexylresorcinol), have not found wide acceptance. For some decades, western rock lobster processors have attempted to refine their traditional cooking method (batch boiling), but to little avail as far as melanosis reduction is concerned. However, recent reports on the use of different cooking methods as alternatives to batch boiling indicate there are possibilities that would improve yields in cooked crustaceans. For example, when compared to boiling, Laitram Machinery Inc., reports typical yield increases of 2% for steamed homarid lobster. This information is confirmed by processors in Western Australia, with Ricciardi Seafood reporting a 2-3 % yield increase and a marked textural improvement in cooked prawns (Ricciardi Seafoods, 2000). A number of questions related to the impact of alternative cooking methods on weight recovery and melanosis rates for the western rock lobster needed to be investigated using a systematic approach based on the key baseline information gathered in FRDC project 2001/235 “Striking a balance between melanosis and weight recovery in western rocklobster (*Panulirus cygnus*)”.

5.0 OBJECTIVES

1. To determine a standard processing protocol for three selected alternative cooking method (steam, steam plus pressure and microwave cooking).

2. To investigate factors impacting on the uptake of water and anti browning agents during drowning of rock lobster correlated to weight recovery and melanosis development.

3. To evaluate the impact of alternative cooking methods, (microwave cooking, steam, and steam plus pressure) on weight recovery and melanosis rates.

4. To evaluate the sensory quality of rock lobster processed by alternative cooking methods in comparison to rock lobster processed using standard practise (boiling).

5. Optimisation of processing methods.

6.0 METHODS

The project focussed on western rock lobster as this is a high value market in which a large portion of the catch is processed, that is cooked, frozen or "tailed". Consideration was given to the variation that may exist between lobsters taken from different geographical locations, or at different times of the season. If not accounted for, these factors could have confounded experimental treatment effects. Therefore, as far as was practicable, all comparisons within experiments were made between lobsters from the same geographical region and catch history. Lobsters taken from the same catch and processed according to current practise were used as controls for each stage of the study. Gender, moult stage and weights, before and after treatment and cooking, were recorded for all lobsters utilised at each phase of the study. In order to characterise the development of melanosis, and measure variations between treatments, digital image analysis was used throughout the project to determine the rate and intensity of melanosis development occurring in processed lobsters as described by Williams, Davidson and Mamo, 2005.

OBJECTIVE 1:

The aim of this objective was to determine a standardised processing protocol for each alternative cooking method (steam, steam plus pressure and microwave cooking) based on the thermal deactivation parameters of polyphenoloxidase (polyphenoloxidase) as determined in FRDC 2001/235 (Williams, Davidson, and Mamo 2005).

Objective 1: Methodology

The first step in the process was to acquire and install the infrastructure and capital components required to carry out the study, i.e. the cookers and pilot plant facility, in Fremantle WA.

In this study, four pieces of equipment were used to cook lobsters and compared.

- *Boiler*: the gas fired pilot boiler developed for FRDC Project 2001/235 was used for all boiling trials. The stand alone system is capable of cooking 50 kgs of lobster held in two 25 kg aluminium wire baskets (Figure 1)

Figure 1: Pilot boiler and ice slurry bath

- *Microwave*: A commercial microwave oven (Panasonic NE-1880) with a capacity of 44 Litres was used in this study. The microwave runs at 1800 W and uses 4 magnetrons arranged to give top and bottom energy feed. Wave dispersers optimise the distribution of the microwaves so that the food is heated evenly without needing to use a turntable. This is essential to enable recording of temperature changes during cooking (Figure 2).

Figure 2: Panasonic NE1880 microwave oven

- *Steamer*: The steamer used for this project is a diesel fired cabinet steamer routinely used by Fremantle Octopus, Blamey Court, O'Conner, WA for cooking octopus (Figure 3)

Figure 3: Steamer loaded with four trays of lobster prior to cooking

- *Pressure steamer*: a Franke programmable pressure steamer (FS1/1P-15) was utilised for these trials. The steamer uses saturated steam under 0.98 atmosphere pressure to reach 119°C within the chamber. It is capable of holding 6 lobsters on a single tray or 12 lobsters on double trays (Figure 4).

Figure 4: Franke Pressure steamer

Once the apparatus was commissioned, trials were conducted to establish standard methodologies for cooking lobsters, for each of the selected processes.

From the findings of FRDC project 2001/235 it was established that a process lethality equivalent to 36.11 minutes at 90°C is required to deactivate polyphenoloxidase in western rock lobsters (Williams, Davidson, and Mamo 2005). Lethality is defined as the total heat input over time in a processing system. The process lethality is the lethality required to completely deactivate a given enzyme at a given temperature. For any given process the variation in the time taken to process the lobster and the maximum temperature reached

during processing will determine the lethality that is achievable using that process. Processing at atmospheric pressure is limited to the maximum temperature of boiling water (100 °C). Such processes include boiling, microwaving and steaming. The application of pressure enables much higher temperatures to be reached. For example; when one atmosphere of pressure is applied in a retort system a maximum temperature of 121 °C is possible. The pressure steamer used in this study was able to achieve a maximum temperature of 119 °C using a pressure of 0.98 atmospheres. This means that the lethality achievable in a pressure steamer will be much higher and will be achieved in a shorter time frame.

Lethality is calculated in a twostep process. In step 1 the z value is determined. z is the temperature change required to decrease the time necessary to destroy 90% of the enzyme activity by a factor of 10 (Toledo 1991). In FRDC 2001/235 the z value for polyphenoloxidase in western rock lobster was determined to be 16 °C.

In the second step of the process, the z value is then used to calculate the lethal rate (L) for the enzyme of interest. The lethal rate is a criterion commonly used in thermal processing technology to evaluate the efficacy of a process. In essence, it measures the lethal effect of heat on micro-organisms (or enzymes in the case of this study) at a given temperature. The lethal rate converts the minutes at the product temperature to the equivalent number of minutes at the reference temperature necessary to achieve the same degree of inactivation (Scott and Weddig, 1998).

The formula used is:

$$\mathrm{L} = 10^{\left(\frac{T - T_r}{Z}\right)}$$

where T_r is the reference temperature (90°C), T is the product temperature To calculate the total accumulated process lethality requires the integration of the lethal rate over time (Toledo, 1991) using the following equation:

$$F_r = \sum L_T \Delta T$$

The reference process lethality value derived in FRDC Project 2001/235 was used as the working standard for all processing methods. Therefore, a “standard” method for each processing technology could be defined as the combination of processing parameters which

consistently produced a lethality value equivalent to 36.11 minutes at 90°C in lobsters at the end of processing. By standardising the definition of cooking in this manner, comparison of the effectiveness of the different technologies to be tested at later phases of the project (Phase 3) was possible. Temperatures, process time, cook mass and distribution of product was monitored for every trial.

Grade A lobsters (up to 450g) from a single catch were used in each trial. All lobsters were weighed before and after cooking to allow determination of weight recovery. A set number of lobsters in each cook load had thermocouple inserted into the tail muscle mass at the base of the head while a second thermocouple was attached to the exterior of the carapace to enable measurement of the temperature of the immediate external environment and assess the uniformity of heat distribution. Probed lobsters were then distributed throughout the cook load to ensure measurement of any variations in the cooker profile. Fibre-optic probes were used for the microwave trials to prevent arcing and electrical interferences. The thermocouples were connected to a Datataker DT850 (Hinco Ltd) and laptop computer to enable real-time integration of the time-temperature profiles and therefore real-time monitoring of lethality. Sufficient replicates were carried out for each method to establish the consistency of the standard processing parameters for each method of cooking. Multivariate statistics were used to establish experimental designs and the subsequent data analysis.

OBJECTIVE 2

This phase of the study was run concurrently with Objective One to ensure reduction of downtime during the commissioning of the processing equipment. The aim was to investigate the influence of factors likely to impact on the uptake of water and antibrowning agents during drowning of rock lobster and to study their correlation to associated weight recovery and melanosis development.

Several issues had been identified in FRDC Project 2001/235 with respect to the use of antibrowning agents during drowning that need to be clarified for future development (Williams, Davidson, and Mamo 2005). These were:

1. The ratio of the weight of lobsters to the volume of the drowning solution.
2. The temperature of the drowning solution.
3. Length of drown period.

It was anticipated that upon completion of this phase of the project, it would be possible to identify which combination of these factors would achieve the best results in term of weight recovery and melanosis development after a standard cooking period of 20 minutes in boiling

water and hence, define a single standard protocol to be used for the drowning of lobsters throughout the remainder of the project.

Objective 2: Methodology

Two antibrowning agents (4-hexylresorcinol (4_HR) and citric acid) were tested at two concentrations, as determined in FRDC Project 2001/235 (87ppm & 10ppm, 4_HR and 2.5mg/ml & 1.5mg/ml citric acid) (Williams, Davidson, and Mamo 2005). Matched control lobsters were drowned in fresh water at the same ratio, temperature and time required for each trial. Each agent and concentration was evaluated at two different temperatures (ambient and iced water), two different drowning ratios of lobsters to drown solution volume (1 lobster per 2 litres and 1 lobster per 5 litres) and three different drown periods (20, 30 and 40 minutes). The trials were conducted in duplicate with 10 Grade A (450g) lobsters in each trial. After drowning in antibrowning agent solutions, a sub sample of lobsters was taken and frozen in the raw state. Uptake of antibrowning agents was later determined using HPLC analysis of the raw flesh. All remaining lobsters were cooked for 20 minutes in boiling water followed by 20 minutes cooling in iced water (as per FRDC Project 2001/235 (Williams, Davidson, and Mamo 2005)). All lobsters were weighed before and after drowning, and before and after cooking to allow determination of agent uptake and weight recovery. After processing lobsters were kept frozen until the extent, intensity and rate of melanosis development could be evaluated using digital image analysis. These parameters were determined following the standard methodology developed in FRDC Project 2001/233 (Williams, Davidson, and Mamo 2005). Multivariate statistics was used for experimental design and analysis.

OBJECTIVE 3

The aim of this objective was to evaluate the impact of alternative cooking methods, (microwave cooking, steam, and steam plus pressure) on weight recovery and melanosis rates. For each of the three cooking methods (microwave cooking, steam, and steam plus pressure) lobsters were subjected to different temperature-time profile cooking protocols, that span the required lethality determined in FRDC project 2001/235. Control lobsters were processed using the conventional processing protocol (20 minutes in boiling water followed by a 20 minutes cooling period in iced water) to enable comparison of the different experimental treatments with “commercial practice”. The purpose of this design was to establish the most effective set of parameters for each method to deliver increased weight recoveries and decreased melanosis.

Objective 3: Methodology

Grade A lobsters were taken from the previous day's catch and held in a flow through seawater system at ambient temperature until required. The number of lobsters for each cook load was defined by the outcomes of phase 1 of the project. Lobsters were drowned in fresh water at the optimum temperature-time-mass ratio combination determined in phase 2. After drowning, 5 lobsters in each cook load (1 for microwave cooking) were probed as per the methodology detailed in phase 1 of this study. Probed lobsters were then distributed throughout the cook load according to the findings of phase 1. The weights of the non-probed lobsters in each cook were recorded before and after drowning, and after the cooling period following the cooking procedure. Each cook was carried out to a predetermined lethality value. A range of lethality values spanning the calculated process lethality (from FRDC Project 2001/235) was achieved. A gradation from severely undercooked to severely overcooked lobsters resulted. After removal from the cooker, the lobsters were immediately placed into an ice slurry and held there for 20 minutes prior to washing, draining, packing and freezing. The probes remained in situ whilst the lobsters were cooled, but were removed immediately prior to packing and freezing. All trials were conducted in triplicate. Multivariate statistics were used for experimental design and analysis of data.

OBJECTIVE 4

The aim of this phase was to evaluate the post production sensory quality of rock lobster processed by alternative cooking methods in comparison to rock lobster processed using standard practise (boiling).

Sensory testing was used to evaluate the impact of the alternative processing methods in comparison to the standard boiling method with respect to consumer preference for colour, flavour and texture. This was done as it is important to ensure that any change to current processing practices does not have a negative impact on the perceived quality of the product. The data generated by the study enabled comparison of the effectiveness of the different processing methods in improving and/or maintaining acceptability of processed rock lobster.

Objective 4: Methodology

A consumer panel of 44 regular seafood consumers was recruited from the population at Curtin University. The panel was made up of 11 males and 32 females from diverse ethnic backgrounds. Sensory evaluation of acceptance of lobsters processed in phase 3 of this project was conducted using unstructured linear rating scales. Data was analysed using one way ANOVA and Principal Component Analysis.

OBJECTIVE 5

The aim of this phase of the study was to identify the optimal methods for processing crustaceans. The outcomes of the project are made available to all members of the seafood industry through this final report and other presentations. This will aid in understanding of the applicability and capabilities of the alternative technologies and ensure maximal uptake of appropriate technology by the crustacean processing industries.

Objective 5: Methodology:

Data generated in the proceeding phases of the study was subjected to optimisation statistical analytical methods to identify the processing parameters and method that are most effective in reducing melanosis formation while improving weight recovery and sensory quality. Extension to the industry was provided through meetings and conference presentations. The final report will be available from the FRDC for those who wish for more detailed information.

7.0 RESULTS/DISCUSSION

The Agreement between Curtin University of Technology and FRDC was finalised in July 2005. The equipment for the pilot plant (boiling system) was brought down from MG Kailis (Dongara, WA) and set up in the leased factory space in Rous Head, Fremantle.

OBJECTIVE 1:

To determine the standard processing protocol for three alternative cooking method (steam, steam plus pressure and microwave cooking)

The first stage of the project was to establish the processing methodologies and data recording systems for each of the cooking methods to be evaluated.

a) Microwave oven:

Since the microwave oven was the first system commissioned the work began on this method first. The fibre-optic data logger (Luxtron m600 Fluoroptic Thermometer) was used to record the internal temperature of lobsters during cooking (Figure 1).

Figure 5: Lobster fitted with fibre-optic probes inside the microwave oven prior to cooking

Several tests were performed to establish the correct methods of inserting the fibre-optic probes so that accurate internal temperatures would be recorded while ensuring that the fragile probes would not be damaged. The lethality was calculated using the equations and values derived in FRDC Project 2001/233

Figure 6 and Figure 7 show typical temperature and lethality profiles that were achieved in microwave cooking of lobster.

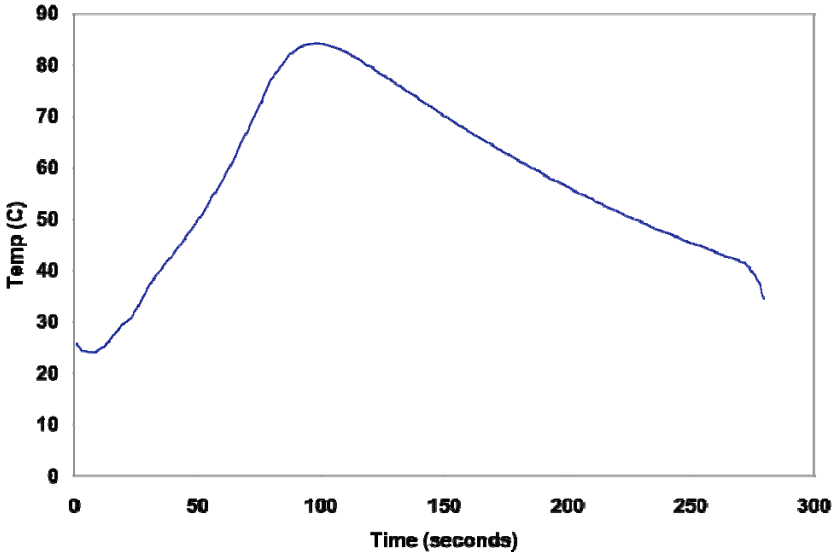

Figure 6: Thermal profile of lobster using microwave cooking

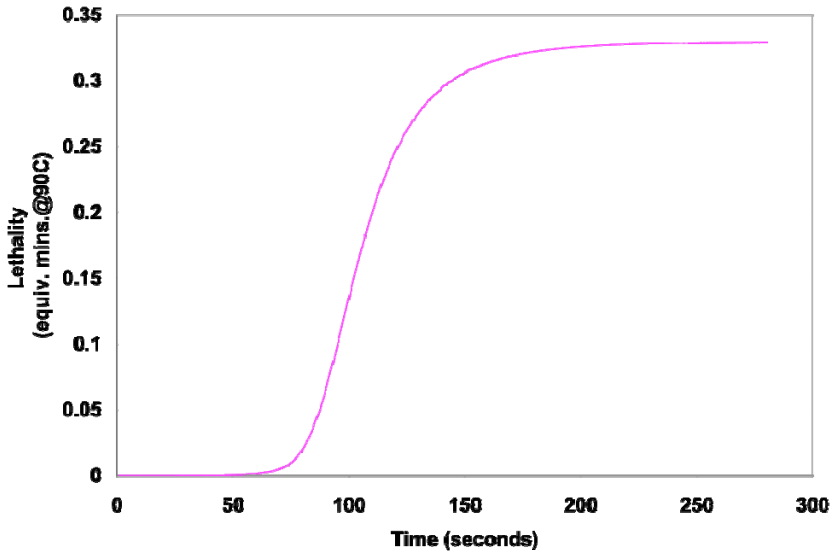

Figure 7 : Lethality profile of lobster using microwave cooking

The profiles measured indicate that the internal temperature of lobsters reached 60 ºC within 90 seconds after initiation of heating. The rise in temperature produced by microwaves is faster than that which can be achieved using conventional boiling. Previous work done in FRDC 2001/233 revealed that the boiling of lobsters required at least 8 minutes for the temperature to reach comparable values. The total period required to complete cooking was between 1 and 1.5 minutes, when using the commercial microwave cooker set on the “high” setting. Variation in cooking period appeared to be dependent on the size of the lobster. The overall heat input was considerably lower than that achieved by boiling as the time span was

so much shorter. However in order to investigate a possible influence of microwaves directly on the enzyme polyphenoloxidase, and to establish a possible distinction from the heating effect of microwaves the study was extended to include in-vitro tests, using rock lobster hemolymph (phase 3).

b) Steamer

The next set of trials was to establish the cooking protocols using the steamer. The steamer has a capacity to hold 18 trays with 12 lobsters each. However, in order to reduce costs, it was loaded with only 4 trays each holding 3 rows of 3 lobsters, as shown in Figure 8.

Figure 8: a close-up of the loaded trays with probed lobsters

An internal core body temperature of 60 ºC was recorded in lobsters after 10 minutes of cooking. This is comparable to boiling. Initial trials revealed that cooking to a lethality greater than a heat input equivalent to 36 minutes at 90 ºC will prevent melanosis when steaming is used. However, this overcooking also resulted in an average weight loss of -7 % which is slightly more than the current weight loss achieved in commercially boiled lobster (approx. -5 %). The work carried out to address Objectives 3 and 4 evaluated the impact of steaming on weight recovery, melanosis and sensory quality.

c) Pressure steamer

The procedures for using the pressure steamer were also developed. The pressure steamer delivers saturated steam at a temperature in excess of 115 ºC. It was thought that this may offer the benefits of steam in terms of weight recovery while reaching a higher temperature over a shorter period of time and thus reducing melanosis. The initial trials used a series of

overcooks to enable evaluation of cooking time and temperatures. These cooks were then used to establish the protocols for this processing method. None of the lobsters exhibited melanosis when cooked to a lethality greater than a heat input equivalent to 36 minutes at 90ºC which was determined as the required lethality by Williams, Davidson, and Mamo (2005). Typical temperature and lethality profiles are shown in Figure 9 and Figure 10. When steamed under pressure the internal temperature in rock lobster s reached much higher values, and hence greater lethality, when compared to similar cooking periods using other methods.

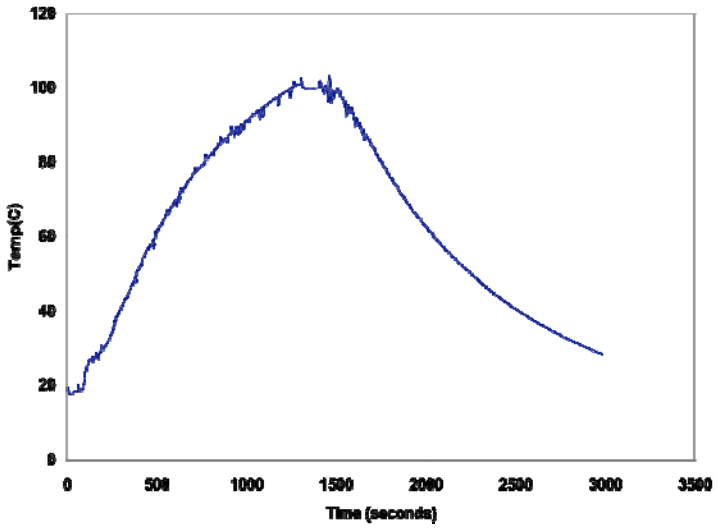

Figure 9: thermal profile in lobsters cooked using pressurised steam

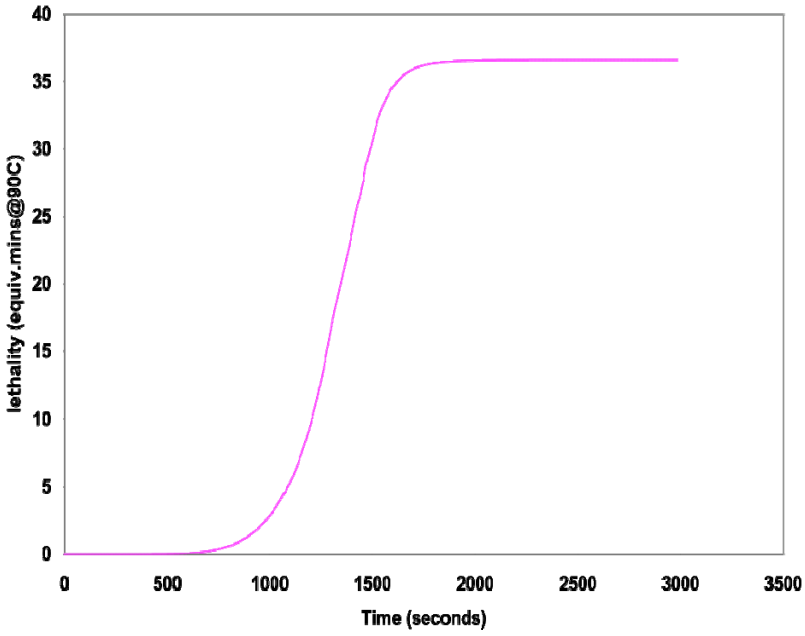

Figure 10: Lethality profile in lobsters cooked using a pressurised steamer

OBJECTIVE 2:

To investigate factors impacting on the uptake of water and anti browning agents during drowning of rock lobster

Once the boiler was commissioned, work began on the second phase of the project. Four factors were to be assessed using a multi-factorial experimental design (Table 1):

- Drowning bath temperature (i.e., drowning in iced water versus ambient water)
- Ratio of the number of lobsters to the volume of drowning solution (1 lobster per 2 litres vs. 1 lobster per 5 litres, assuming each lobster ≈450 gm)
- Drowning period (20, 40, or 60 minutes)
- Concentration of antibrowning agents (control vs. two concentrations of citric acid)

Table 1: Multi-factorial experimental design

Concentration of citric acid	Ratio of lobsters to drown volume (lobster : litres)	Ice level		Drown time (minutes)		
Control (0 ppm)	1:5	no ice	iced	20	40	60
	1:2	no ice	iced	20	40	60
1.5 ppm	1:5	no ice	iced	20	40	60
	1:2	no ice	iced	20	40	60
2.5 ppm	1:5	no ice	iced	20	40	60
	1:2	no ice	iced	20	40	60

It had been originally proposed to use 4-Hexylresorcinol (4_HR) and citric acid as antibrowning agents in this phase of the study. A preliminary study was conducted to establish a method to detect and measure the concentration of these antibrowning agents in lobster flesh. These studies showed that the presence of 4_HR could effectively be detected in lobsters that were injected with a solution of 4_HR. However, that compound could not be detected in the flesh of lobsters that had been drowned in a solution of 4_HR. This held true no matter what the concentration of the solution used. The implications of this finding were that 4_HR is possibly incapable of penetrating the lobster during drowning. When this result was discussed with the FRDC Rock Lobster Post Harvest Subprogram Steering Committee in February 2006 it was recommended by the Committee that 4_HR should be discarded from this study and only citric acid used. FRDC 2001/233 had shown that citric acid retards melanosis development in western rock lobster.

For every cook utilised in this phase of the study two lobsters had thermocouple probes inserted in their flesh to measure the internal and external temperature-time profile of the cook. The data was then used to calculate the process lethality for each cook. Typical temperature time profiles and lethality curve are presented in Figure 11 & Figure 12, respectively. Each cook was made up of a total of 36 size A lobsters (sized at approx 450g).

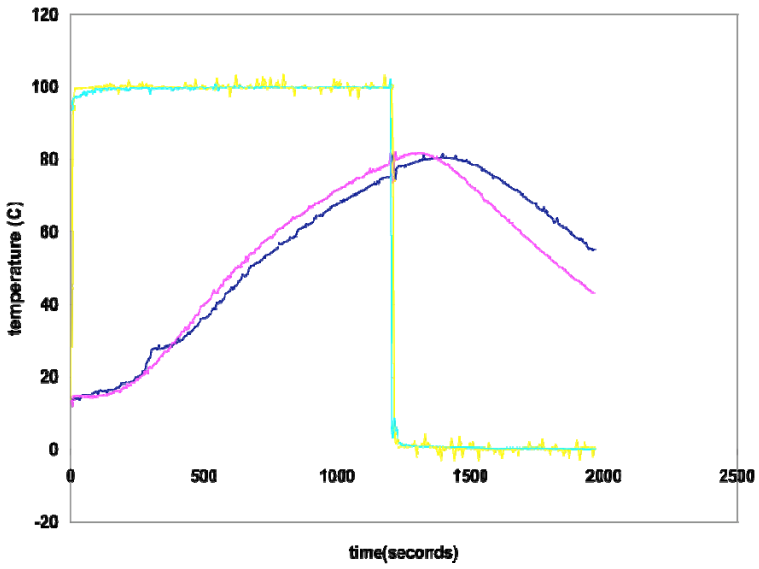

Figure 11: Temperature-time profile for boiled lobster

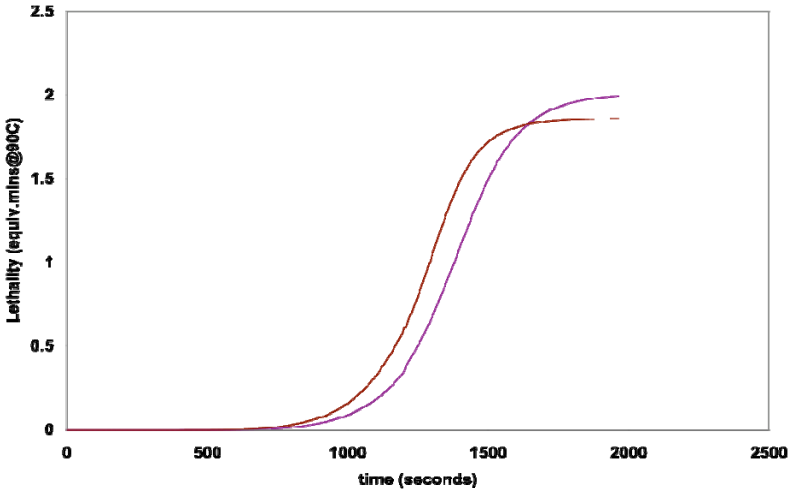

Figure 12: Lethality profile for boiled lobster

The influence of drowning treatments on weight recovery

Upon completion of the trials the data was analysed using the SPSS Statistical package. (SPSS 2008). From the descriptive statistics presented in Table 2 several trends were identified and the General Linear Univariate Analysis of Variance method was used to assess how the factors interacted to impact on weight in processed lobster. From Table 1 it can be

seen that the factors: citric acid concentration; drown ratio; and drown period all had a significant impact on the overall weight recovery ($p<0.05$).

Table 2: Descriptive statistics of weight change by drown treatments

Concentration of citric acid	Ratio of lobsters to drown volume (lobster : litres)	Ice level	Drown period (minutes)	Mean	Std. Deviation	N
Control (0 ppm)	1:5	no ice	20 minutes	2.55	3.13	18
			40 minutes	2.74	4.32	20
			60 minutes	2.89	5.64	20
			Total	2.73	4.45	58
		iced	20 minutes	-0.56	6.38	17
			40 minutes	3.26	2.26	20
			60 minutes	3.04	5.34	20
			Total	2.04	5.09	57
		Total	20 minutes	1.04	5.15	35
			40 minutes	3.00	3.41	40
			60 minutes	2.96	5.42	40
			Total	2.39	4.77	115
	1:2	no ice	20 minutes	1.34	6.24	16
			40 minutes	4.54	6.06	20
			60 minutes	4.27	3.44	20
			Total	3.53	5.42	56
		iced	20 minutes	2.09	4.42	20
			40 minutes	4.13	3.20	20
			60 minutes	4.12	4.49	20
			Total	3.45	4.12	60
		Total	20 minutes	1.75	5.24	36
			40 minutes	4.34	4.79	40
			60 minutes	4.20	3.95	40
			Total	3.49	4.77	116
	Total	no ice	20 minutes	1.98	4.81	34
			40 minutes	3.64	5.28	40
			60 minutes	3.58	4.67	40
			Total	3.12	4.94	114
		iced	20 minutes	0.87	5.49	37
			40 minutes	3.69	2.77	40
			60 minutes	3.58	4.90	40
			Total	2.76	4.66	117
		Total	20 minutes	1.40	5.17	71
			40 minutes	3.67	4.19	80
			60 minutes	3.58	4.75	80
			Total	2.94	4.79	231

Concentration of citric acid	Ratio of lobsters to drown volume (lobster : litres)	Ice level	Drown period (minutes)	Mean	Std. Deviation	N
1.5 ppm	1:5	no ice	20 minutes	-1.53	5.78	21
			40 minutes	0.94	5.37	23
			60 minutes	0.43	4.06	21
			Total	-0.02	5.16	65
		iced	20 minutes	-0.41	4.81	19
			40 minutes	-1.82	6.72	20
			60 minutes	1.31	4.85	20
			Total	-0.31	5.60	59
		Total	20 minutes	-1.00	5.30	40
			40 minutes	-0.34	6.12	43
			60 minutes	0.86	4.43	41
			Total	-0.16	5.36	124
	1:2	no ice	20 minutes	2.74	3.87	20
			40 minutes	3.54	4.77	19
			60 minutes	3.66	3.65	20
			Total	3.31	4.06	59
		iced	20 minutes	-1.59	8.29	20
			40 minutes	3.24	3.55	20
			60 minutes	0.61	6.60	20
			Total	0.75	6.65	60
		Total	20 minutes	0.57	6.75	40
			40 minutes	3.39	4.13	39
			60 minutes	2.14	5.49	40
			Total	2.02	5.64	119
	Total	no ice	20 minutes	0.55	5.34	41
			40 minutes	2.12	5.21	42
			60 minutes	2.01	4.15	41
			Total	1.56	4.94	124
		iced	20 minutes	-1.02	6.76	39
			40 minutes	0.71	5.89	40
			60 minutes	0.96	5.73	40
			Total	0.23	6.15	119
		Total	20 minutes	-0.21	6.09	80
			40 minutes	1.43	5.56	82
			60 minutes	1.49	4.99	81
			Total	0.91	5.59	243

Concentration of citric acid	Ratio of lobsters to drown volume (lobster : litres)	Ice level	Drown period (minutes)	Mean	Std. Deviation	N
2.5ppm	1:5	no ice	20 minutes	-3.61	6.34	20
			40 minutes	-3.15	6.58	20
			60 minutes	-3.04	6.48	20
			Total	-3.27	6.36	60
		iced	20 minutes	0.54	3.70	20
			40 minutes	-0.42	5.87	20
			60 minutes	2.13	2.30	20
			Total	0.75	4.28	60
		Total	20 minutes	-1.53	5.53	40
			40 minutes	-1.78	6.31	40
			60 minutes	-0.45	5.47	40
			Total	-1.26	5.76	120
	1:2	no ice	20 minutes	0.18	4.90	20
			40 minutes	-1.09	5.77	20
			60 minutes	2.17	4.14	20
			Total	0.42	5.08	60
		iced	20 minutes	-3.76	6.89	21
			40 minutes	-0.97	3.93	19
			60 minutes	1.83	6.45	20
			Total	-1.01	6.30	60
		Total	20 minutes	-1.84	6.25	41
			40 minutes	-1.03	4.90	39
			60 minutes	2.00	5.35	40
			Total	-0.30	5.74	120
	Total	no ice	20 minutes	-1.71	5.91	40
			40 minutes	-2.12	6.20	40
			60 minutes	-0.44	5.98	40
			Total	-1.42	6.02	120
		iced	20 minutes	-1.66	5.92	41
			40 minutes	-0.68	4.96	39
			60 minutes	1.98	4.78	40
			Total	-0.13	5.43	120
		Total	20 minutes	-1.69	5.88	81
			40 minutes	-1.41	5.63	79
			60 minutes	0.77	5.52	80
			Total	-0.78	5.76	240

Concentration of citric acid	Ratio of lobsters to drown volume (lobster: litres)	Ice level	Drown period (minutes)	Mean	Std. Deviation	N
Total	1:5	no ice	20 minutes	-0.99	5.82	59
			40 minutes	0.21	5.93	63
			60 minutes	0.10	5.90	61
			Total	-0.21	5.88	183
		iced	20 minutes	-0.12	4.94	56
			40 minutes	0.34	5.65	60
			60 minutes	2.16	4.36	60
			Total	0.81	5.08	176
		Total	20 minutes	-0.57	5.40	115
			40 minutes	0.27	5.77	123
			60 minutes	1.12	5.27	121
			Total	0.29	5.52	359
	1:2	no ice	20 minutes	1.43	5.02	56
			40 minutes	2.31	6.02	59
			60 minutes	3.37	3.80	60
			Total	2.39	5.06	175
		iced	20 minutes	-1.13	7.05	61
			40 minutes	2.19	4.15	59
			60 minutes	2.19	6.01	60
			Total	1.06	6.05	180
		Total	20 minutes	0.09	6.27	117
			40 minutes	2.25	5.15	118
			60 minutes	2.78	5.04	120
			Total	1.72	5.62	355
	Total	no ice	20 minutes	0.19	5.56	115
			40 minutes	1.23	6.04	122
			60 minutes	1.72	5.21	121
			Total	1.06	5.64	358
		iced	20 minutes	-0.65	6.13	117
			40 minutes	1.26	5.03	119
			60 minutes	2.17	5.22	120
			Total	0.94	5.59	356
		Total	20 minutes	-0.23	5.85	232
			40 minutes	1.24	5.55	241
			60 minutes	1.95	5.21	241
			Total	1.00	5.61	714

Table 3: Analysis of Variance. Identification of significant treatment effects on weight recovery

Source	Mean Square	F	Sig.
concentration	774.45	28.57	**0.00**
ratio	364.69	13.46	**0.00**
iced	4.35	0.16	0.69
Drowning period	273.73	10.10	**0.00**
conc * ratio	27.81	1.03	0.36
conc * iced	113.79	4.20	**0.02**
conc * Drowning period	37.95	1.40	0.23
ratio * iced	230.98	8.52	**0.00**
ratio * Drowning period	27.08	1.00	0.37
iced * Drowning period	27.08	1.00	0.37
conc * ratio * iced	144.56	5.33	**0.01**
conc * ratio * Drowning period	25.76	0.95	0.43
conc * iced * Drowning period	5.26	0.19	0.94
ratio * iced * Drowning period	41.23	1.52	0.22
conc * ratio * iced * Drowning period	56.94	2.10	0.08

**significant differences indicated in red text.*

From Table 3 it can be seen that citric acid concentrations had a significant impact on weight recovery for lobsters ($p < 0.001$). The control lobsters that were not treated with citric acid recorded a higher weight recovery when compared to lobsters subjected to citric acid treatments. Treated lobsters recorded a significant decrease in weight recovery when citric acid concentration was increased. This trend is associated to a linear regression ($r^2 = 0.99$), as illustrated in Figure 13.

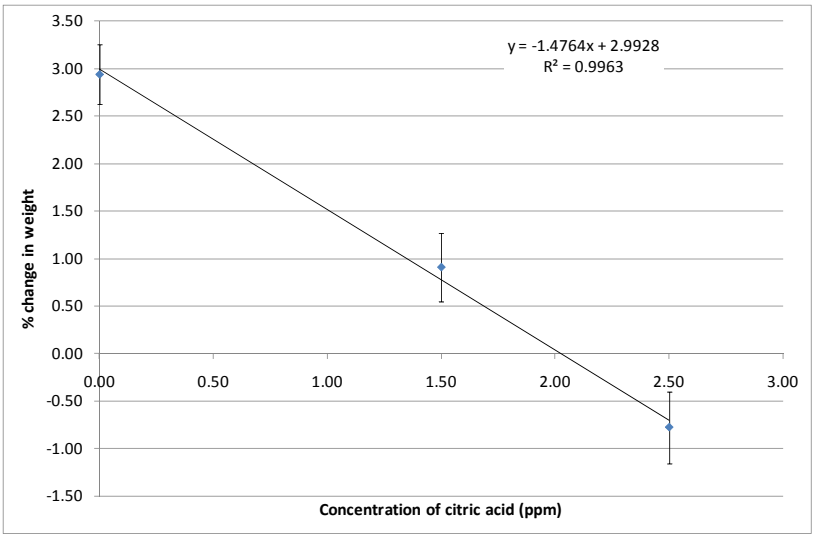

Figure 13 : Impact of citric acid concentration on weight recovery (x ± SEM)

The drown ratio of number of lobsters per volume of water also had a significant influence on weight recovery, when no ice was added to the drown bath. From Figure 14, and Table 2, it

appears that a higher weight recovery can be expected when lobsters are drowned at a drowning ratio of 1 lobster per 2 litres of water irrespective of the citric acid concentration.

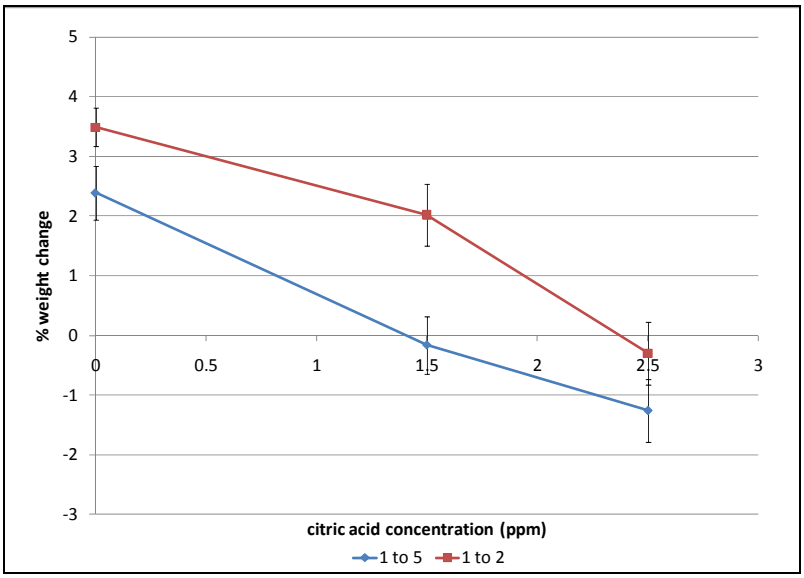

Figure 14: Impact of drowning ratio on weight recovery (un-iced) (x ± SEM)

As far as the length of the drown period is concerned, the results indicate that increasing the drowning time from 20 minutes to 40 minutes resulted in a significant increase in weight recovery (-0.23% loss increased to 1.24% gain) (Table 2, Total). Extending the drown period from 40 minutes to 60 minutes was reflected by another increased weight recovery (1.24% gain compared to 1.94 % gain at 60 minutes) but this trend was however not statistically significant at the 0.05 level.

Adding ice to the drowning solution did not resulted into significant changes to weight recovery (p= 0.689), when considered as an isolated factor. However a significant influence of 'icing" was identified when such treatment was combined with experimental treatments. The results indicate a significant influence on weight recovery associated firstly with the interaction between icing and citric acid concentration (p=0.015); and secondly with the interaction between icing and drown ratio (p =0.004); thirdly with the interaction between icing, drown ratio and citric acid concentration (p= 0.005).

Scrutiny of the data in Table 2 reveals that lobsters drowned in iced citric acid solutions recorded a lower weight yield (average 0.048% gain) when compared to the control group (average 2.76% gain). There was also a marked decrease in weight recovery corresponding with an increasing citric acid concentration (1.5 ppm = 0.23% gain and 2.5 ppm = -0.13% loss). The trend was consistently observed across all treatments. As a confirming fact, lobsters drowned in an iced solution at the low drown ratio (1:2) returned a higher weight

recovery when compared to lobsters drowned in iced water at the higher ratio (1:5) (1:2 iced = 3.45% gain, 1:5 iced = 2.04 % gain).

However it is interesting to note that lobsters drowned at a high acid concentration (2.5ppm) in combination with icing and a high drown ratio (1:5) went against the overall trends described above, to return a significantly higher weight recovery when compared to the low ratio drown (1:5 ratio =0.7518% compared to 1:2 ratio = -1.0135%) (Figure 15).

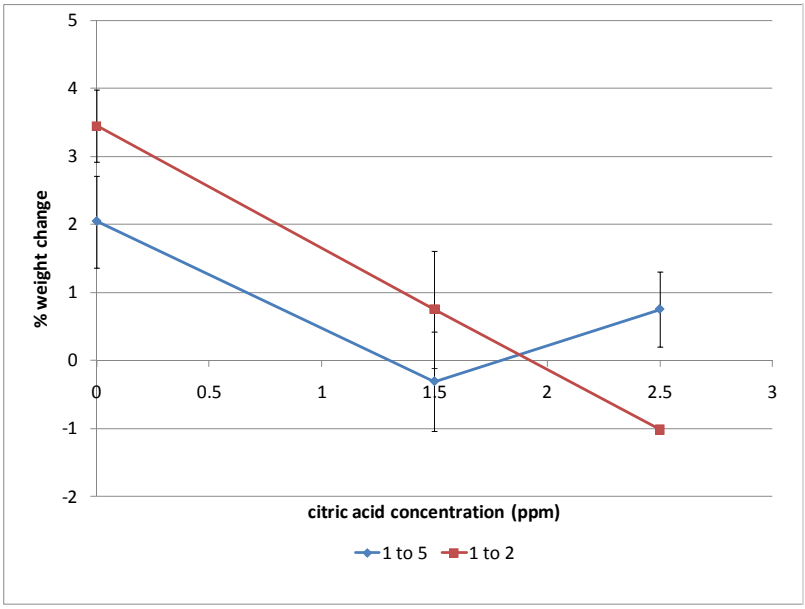

Figure 15: impact of icing in combination with citric acid treatment and drowning ratio (x ± SEM)

Overall weight recoveries were optimised in the absence of citric acid when using a drown time of 40 minutes and a drowning ratio of 1 lobster per 2 litres of water. Icing can be used if desired as it did not significantly impact on weight recovery in the absence of citric acid. In the presence of citric acid the best return is given by a combination of icing, high drown ratio (1:5) and high citric acid concentration (2ppm). Under these condition melanosis incidence was reduced and a better weight recovery was achieved (1:5 ratio =0.7518% iced)

The influence of drowning treatments on the development of melanosis in cooked lobsters

The General Linear Model of Multivariate Analysis was used to identify significant influences of the studied treatments in relation to melanosis development. From Table 4 it can be seen that only the concentration of citric acid and the drowning ratio exerted significant independent effects on the development of melanosis ($p<0.001$)

Table 4: Multivariate analysis of the impact of factors on melanosis development

Source	Dependent Variable	Mean Square	F	Sig.
Concentration of antibrowning agent	Area 40 mins	18.64	11.73	**0.00**
	Area 3hr	81.02	10.83	**0.00**
	Area 24hr	185.58	11.11	**0.00**
	intensity	85722.99	14.29	**0.00**
	rate	0.00	10.01	**0.00**
ratio	Area 40 mins	40.09	25.22	**0.00**
	Area 3hr	234.42	31.34	**0.00**
	Area 24hr	343.24	20.54	**0.00**
	intensity	25710.74	4.29	**0.04**
	rate	0.00	15.63	**0.00**
iced	Area 40 mins	2.41	1.51	0.22
	Area 3hr	0.29	0.04	0.85
	Area 24hr	24.51	1.47	0.23
	intensity	14068.53	2.35	0.13
	rate	0.00	1.67	0.20
Drown time	Area 40 mins	1.47	0.93	0.40
	Area 3hr	13.83	1.85	0.16
	Area 24hr	30.59	1.83	0.16
	intensity	9930.18	1.66	0.19
	rate	0.00	1.79	0.17
conc * ratio	Area 40 mins	4.41	2.78	0.06
	Area 3hr	2.65	0.36	0.70
	Area 24hr	0.12	0.01	0.99
	intensity	7511.00	1.25	0.29
	rate	0.00	0.15	0.86
conc * iced	Area 40 mins	0.11	0.07	0.94
	Area 3hr	3.11	0.42	0.66
	Area 24hr	8.95	0.54	0.59
	intensity	4805.84	0.80	0.45
	rate	0.00	1.07	0.34
conc * drowntime	Area 40 mins	2.67	1.68	0.15
	Area 3hr	13.25	1.77	0.13
	Area 24hr	36.72	2.20	0.07
	intensity	8321.88	1.39	0.24
	rate	0.00	1.81	0.13
ratio * iced	Area 40 mins	4.83	3.04	0.08
	Area 3hr	0.34	0.05	0.83
	Area 24hr	6.37	0.38	0.54
	intensity	12171.52	2.03	0.16
	rate	0.00	0.52	0.47

Source	Dependent Variable	Mean Square	F	Sig.
ratio * drowntime	Area 40 mins	2.72	1.71	0.18
	Area 3hr	9.77	1.31	0.27
	Area 24hr	22.94	1.37	0.25
	intensity	15238.67	2.54	0.08
	rate	0.00	1.81	0.17
iced * drowntime	Area 40 mins	1.51	0.95	0.39
	Area 3hr	8.64	1.16	0.32
	Area 24hr	4.62	0.28	0.76
	intensity	4570.44	0.76	0.47
	rate	0.00	0.09	0.92
conc * ratio * iced	Area 40 mins	0.71	0.45	0.64
	Area 3hr	0.17	0.02	0.98
	Area 24hr	1.24	0.07	0.93
	intensity	382.18	0.06	0.94
	rate	0.00	0.26	0.77
conc * ratio * drowntime	Area 40 mins	2.19	1.38	0.24
	Area 3hr	15.30	2.05	0.09
	Area 24hr	22.90	1.37	0.24
	intensity	13233.70	2.21	0.07
	rate	0.00	0.91	0.46
conc * iced * drowntime	Area 40 mins	0.75	0.47	0.76
	Area 3hr	4.77	0.64	0.64
	Area 24hr	13.46	0.81	0.52
	Intensity	5658.15	0.94	0.44
	Rate	0.00	2.14	0.08
ratio * iced * drowntime	Area 40 mins	0.42	0.27	0.77
	Area 3hr	0.89	0.12	0.89
	Area 24hr	4.39	0.26	0.77
	intensity	1186.12	0.20	0.82
	rate	0.00	1.21	0.30
conc * ratio * iced * drowntime	Area 40 mins	2.13	1.34	0.25
	Area 3hr	7.60	1.02	0.40
	Area 24hr	17.36	1.04	0.39
	intensity	3853.78	0.64	0.63
	rate	0.00	1.13	0.34

An examination of the descriptive statistics presented in Table 4 reveals that an increase of the citric concentration exerted a positive effect on melanosis with the higher concentration delivering a reduced area of melanosis in cooked lobsters ($p<0.001$) (Table 5). Similarly, an increase of the drowning ratio from 1:2 to 1:5 was also associated with a decrease in the formation of melanosis ($p<0.001$) (

Table 6).

Table 5: Descriptive statistics of melanosis development Versus Citric acid concentration

Source	Antibrowning agent concentration	N	Mean	Std. Deviation	Std. Error
Area 40 minutes	control	230	1.04	1.31	0.09
	1.5 ppm	243	0.50	1.02	0.07
	2.5 ppm	240	0.58	1.49	0.10
	Total	713	0.70	1.31	0.05
Area 3hr	control	230	2.82	2.64	0.17
	1.5 ppm	243	1.75	2.49	0.16
	2.5 ppm	240	1.78	3.19	0.21
	Total	713	2.10	2.83	0.11
Area 24hr	control	230	4.81	3.98	0.26
	1.5 ppm	243	3.23	3.71	0.24
	2.5 ppm	240	3.16	4.67	0.30
	Total	713	3.72	4.20	0.16
Intensity	control	230	158.28	63.15	4.16
	1.5 ppm	243	136.67	77.98	5.00
	2.5 ppm	240	119.30	89.88	5.80
	Total	713	1.04	1.31	0.09
Rate	control	230	0.50	1.02	0.07
	1.5 ppm	243	0.58	1.49	0.10
	2.5 ppm	240	0.70	1.31	0.05
	Total	713	2.82	2.64	0.17

Table 6: Descriptive statistics of melanosis development by drown ratio

source	Drown ratio	N	Mean	Std. Deviation	Std. Error
Area 40 mins	1:5	359	0.46	0.98	0.05
	1:2	354	0.94	1.53	0.08
	Total	713	0.70	1.31	0.05
Area 3hr	1:5	359	1.53	2.32	0.12
	1:2	354	2.69	3.16	0.17
	Total	713	2.10	2.83	0.11
Area 24hr	1:5	359	3.01	3.76	0.20
	1:2	354	4.43	4.50	0.24
	Total	713	3.72	4.20	0.16
Intensity	1:5	359	131.86	82.66	4.36
	1:2	354	143.81	75.70	4.02
	Total	713	137.79	79.45	2.98
Rate	1:5	359	0.00	0.00	0.00
	1:2	354	0.00	0.00	0.00
	Total	713	0.00	0.00	0.00

Variations of the drowning period exerted no significant influence on melanosis development in boiled lobsters. Similarly, adding ice to the drowning bath had no significant impact on the level of melanosis development. There were also no significant interactions between any of the parameters measured.

Recommendations

From these results the following recommendations can be made:

1. Should a processor not wish to use anti-browning additives then an increase in the drowning period of lobsters to a minimum of 40 minutes should be recommended in combination with adjusting the drowning ratio to 1 lobster per 2 litres of water. Icing the water is not necessary, although not detrimental. Implementing such protocol has proven to optimise weight recovery.
2. Should a processor decide to use citric acid as an antibrowning agent, then it is recommended that a drowning bath recording a concentration of 2.5ppm citric acid should be used, with a drown ratio of 1 lobster per 5 litres of solution and for a period of 40 minutes. Following such a process should optimise the reduction in melanosis development while maintaining improved weight recovery.

OBJECTIVE 3:

To evaluate the impact of alternative cooking methods, (microwave cooking, steam, and steam plus pressure) on weight recovery and melanosis rate

In this phase of the project, lobsters were exposed to a range of temperature-time protocols for each of the three cooking methods (microwave, steam, and steam plus pressure). The range of protocols spanned the required process lethality determined in FRDC project 2001/235.

Care was taken to ensure that a full range of under processed, just right and over processed lobsters was achieved when applicable. Each level was defined as follows:

- Under: the protocol will deliver a lobster with just cooked flesh and will have achieved lethality <20 (core temperature 65 °C). This level optimises weight recovery;
- Just right: the protocol will deliver a lobster with firm cooked flesh and have a achieved a lethality between 20 and 40;
- Over: the protocol will deliver a lobster that has reached lethality greater than 40. This level optimises prevention of melanosis.

As pressure steaming and steaming methods can be readily manipulated a range of cook lethalities were achieved for each processing method as shown in Figure 16 and Figure 17

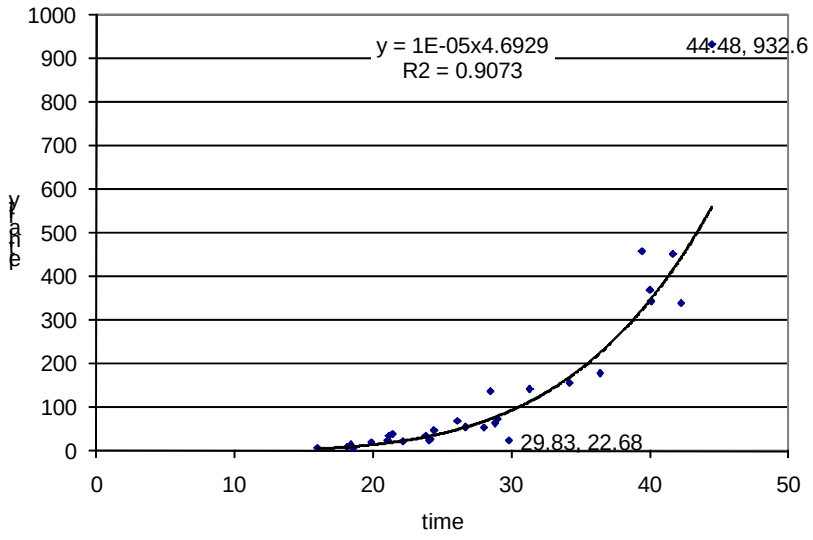

Figure 16: Cooking lethalities achieved in pressure steamed lobsters

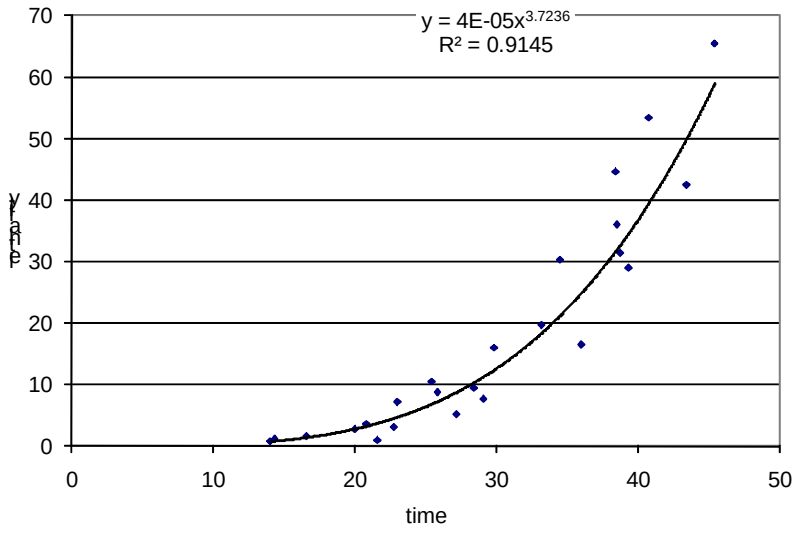

Figure 17: Cooking lethalities achieved in steamed lobsters

Some technical difficulties were encountered when conducting the microwave cooking tests. The lethality of the microwave trials averaged 1.39 (± SEM 0.31) with an average weight recovery of 99.1% (± SEM 0.94). However, several factors influenced the determination of the cooking period required to achieve a specific lethality value which resulted in difficulties in accurately predicting lethality. These included:

- *The size/weight of the lobsters used in the microwave trials*. The influence of size variations was profound as only one lobster can be cooked at a time in the microwave oven and it was difficult to obtain a representative number of lobsters within a sufficiently narrow size range to control for size variations.
- *The rate and continuation of heating*. The temperature rose very rapidly when using the microwave and continued to rise after heating had ceased so that it was difficult to ensure that a specific level of lethality had been reached.
- *Inaccuracies in thermal probe placement*: Fibreoptic probes were used to record the changes in temperature during cooking for safety reasons. However they cannot be bent around to accommodate the variations in lobsters and considerable care had to be taken in their placement to prevent them being fractured. Unfortunately this made it difficult to ensure that the probe was centred in the muscle mass at the base of the cephalothorax in every lobster.

Therefore it was decided to cook lobsters of an equal size from one catch to a lethality equivalent to that achievable by the control boiling method. Comparison of the weight recovery and melanosis development would enable assessment of any differences between microwaves and the control method. Pressure steamed and steamed cooks were grouped by

average lethality to enable ease of comparison. Control lobsters were processed using the conventional cooking protocol (20 minutes in boiling water followed by 20 minutes cooling in iced water) to enable comparison of the different experimental treatments with "commercial practice".

Table 7 details the descriptive statistics for the length of the cooking period and the lethality achieved for each of the grouped processing methods. It shows that the grouped treatments have similar lethalities and cook times in the under cooked (including boiled and microwave) grouping, but as cook time increases the lethalities achieved become more divergent. The higher lethality achieved in the pressure steamed products at similar cook times to other processes is due to the higher processing temperatures achieved due to the application of pressure.

Table 7: Descriptive statistics for cooking period vs lethality achieved by treatment group

	Cook time			Lethality		
Processing method	**Mean**	**Std. Deviation**	**Std. Error of Mean**	**Mean**	**Std. Deviation**	**Std. Error of Mean**
pressure over	33.26	7.49	0.78	255.71	241.76	25.21
steam over	42.80	3.79	0.47	66.67	10.91	1.36
pressure just right	24.27	4.44	0.62	29.56	8.35	1.16
steam just right	37.89	3.57	0.29	33.49	7.85	0.63
pressure under	19.42	4.33	0.78	10.94	5.79	1.02
steam under	24.92	7.59	0.39	6.36	5.24	0.27
boil	20.00	0.00	0.00	4.56	2.49	0.26
microwave	4.56	4.37	1.65	1.39	0.68	0.26

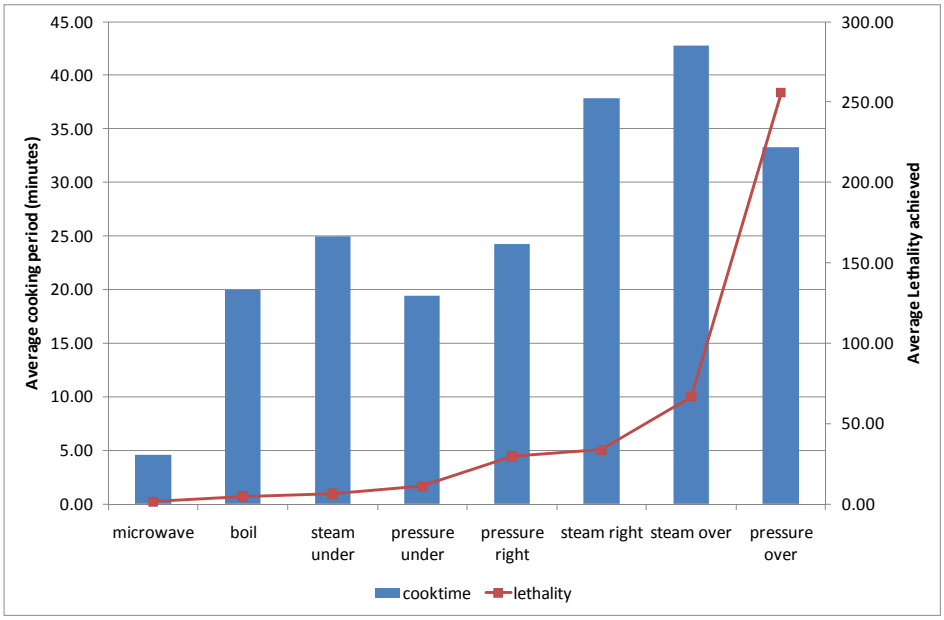

Figure 18: Comparison of cook time and lethality achieved by treatment

Figure 18 clearly demonstrates that pressure steaming achieves a higher lethality in the same or shorter cooking times when compared to other processes. The process has potential to produce energy savings for a processor when processing large volumes of lobster. However further investigation was required into how pressure processing would impact on weight recovery and sensory quality.

Table 8 presents the descriptive statistics for percentage weight change and lethality for the different processing methods, while Figure 19 shows how the weight change varies between the different levels of lethality across treatments.

Table 8: Descriptive statistics for weight change and lethality by treatment

	Average % weight change			**Average lethality**			
Processing method	*Mean*	*Std. Dev*	*SEM*	*Mean*	*Std. Dev.*	*SEM*	**N**
pressure under	-5.26	12.30	2.17	10.94	5.79	1.02	32
pressure right	-5.25	6.79	0.94	29.56	8.35	1.16	52
pressure over	-8.19	5.99	0.62	255.71	241.76	25.21	92
steam under	-1.72	6.31	0.32	6.36	5.24	0.27	386
steam right	-4.72	5.37	0.43	33.49	7.85	0.63	154
steam over	-6.02	6.36	0.79	66.67	10.91	1.36	64
boil	1.81	5.76	0.61	4.56	2.49	0.26	90
microwave	0.09	2.49	0.94	1.39	0.68	0.26	7

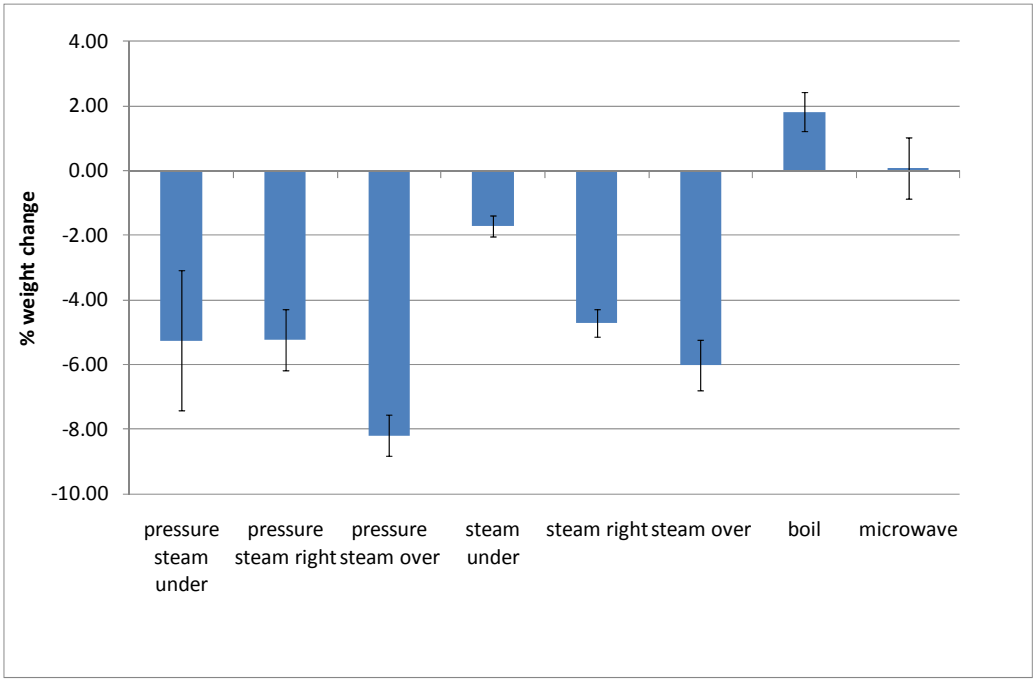

Figure 19: Percent weight change over processing treatments

The lethality obtained using the control method (boiling) averaged 4.56 (± SEM 0.26). The lethality achieved was considerably lower than the calculated lethality required to deactivate polyphenoloxidase (36 mins at 90 C, Williams, Davidson & Mamo 2005). However as it was desirable that all boiled lobsters were processed to a standard method that optimised weight recovery this was not considered to be a drawback. The average weight recovery of the boiled lobsters was 101.8% (±SEM 0.61).

Figure 19 and Table 7 suggest that for each processing method, as the lethality increases the weight loss increases i.e. more weight is lost during longer cooking periods. It is clear from Figure 19 that steam cooking resulted in better weight recovery than using pressurised steam cooking at comparable levels of lethality.

For each processing method the goal set was to maximise the weight recovery and minimize the melanosis. Figure 20 shows that for all methods increasing the lethality resulted in decreased melanosis and increased weight loss, i.e. the lower the lethality value, the larger the weight recovery while higher lethality values resulted in lower rates of melanosis.

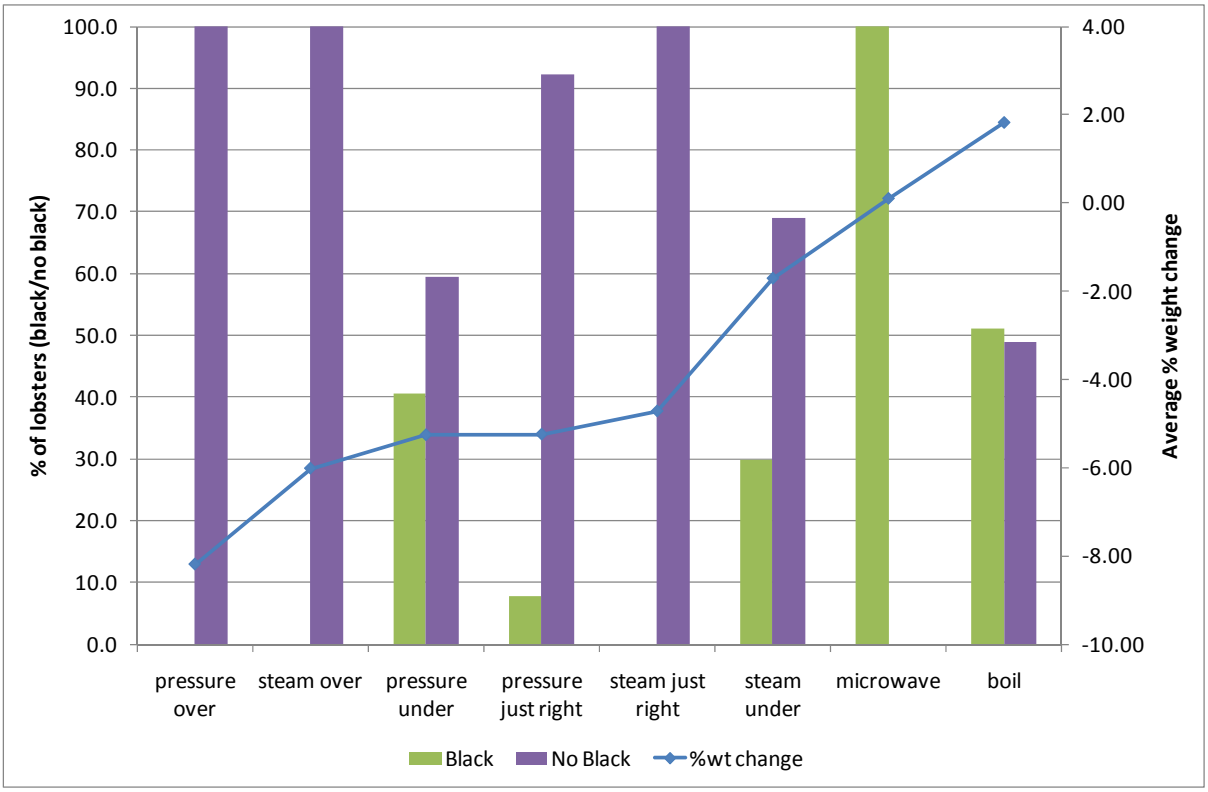

Figure 20: Comparison of weight loss and melanosis development when using different treatments at comparable lethalities

However, the final goal set in this phase was to identify the optimum process and associated processing parameters that would maximise the weight recovery and minimize melanosis.

Comparison of steaming, boiling and pressure steaming methods (Figure 20) showed that the maximum weight recovery and minimum melanosis was delivered by samples treated with steaming at levels near to the calculated lethality value of 36 min at 90 °C i.e. the 'steam just right' category. This category has lobsters steamed at lethality levels equivalent to an average lethality of 33.5 minutes at 90 °C. At this level of treatment NO lobster developed melanosis when cooked by steaming. In comparison lobsters cooked using pressure steaming at a comparable lethality level (average lethality 29.6 minutes at 90 °C) had a 7% loss due to melanosis development. This same trend was observed when comparing the under cooked lobsters for both processing methods. A higher proportion of lobsters showed melanosis development when cooked by pressurised steam methods that when cooked using atmospheric steaming. In addition, while both methods delivered complete prevention of melanosis in the overcooked category, the steamed lobsters recorded a lower weight loss than the comparable pressurised product. As the catch history of the lobsters was controlled for in the experimental design these variations are most probably due solely to the cooking parameters. Thus it can be concluded that steaming delivers a better weight recovery in combination with reduction in melanosis development than pressurised cooking, or boiling under the conditions examined. It is also important to note that this has been achieved WITHOUT the use of undesirable chemical additives such as sulphiting treatments.

One of the objectives of this project was to evaluate the impact of microwave processing on lobsters in terms of appearance, blackening and eating quality. Figure 20 shows that melanosis did not decease when lobsters were heated at low lethalities using microwaves. The review of literature had suggested that further to their heating effects, microwaves could exert an additional effect on the actual enzyme responsible for the processes of melanisation, and hence confound the results of the cooking trials. This was deemed worthwhile of further study since while the impact of convection heating on polyphenoloxidase activity is known, the impact of microwave heating on polyphenoloxidase activity had never been determined. A need to evaluate the effect of microwave heating on polyphenoloxidase in lobster haemolymph was identified and this particular piece of work was carried out as a research project by Mr Simon Warwick, a Masters student in the Food Science and Technology Program at Curtin University of Technology. The specific aim of this work was defined as an evaluation of "*The effect of microwave heating on polyphenoloxidase activity in the haemolymph of western rock lobster*"

Baseline polyphenoloxidase activity in haemolymph exposed to microwave heat to reach selected temperatures was compared with baseline polyphenoloxidase activity in unheated

haemolymph. The % relative activity was calculated and is plotted in Figure 21 (Warwick 2007).

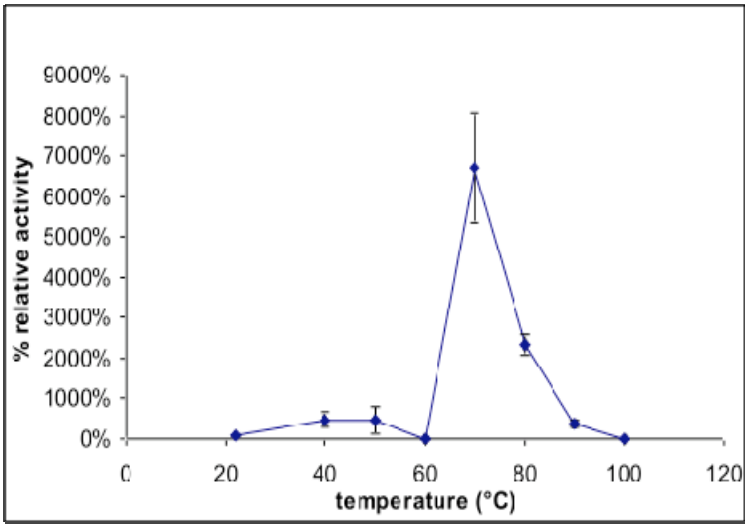

Figure 21: Baseline relative polyphenoloxidase activity during microwave heating (mean SEM, n = 8) (Warwick 2007)

As the haemolymph was heated to 40 °C and 50 °C, there was no significant change in baseline polyphenoloxidase activity ($P>0.05$). At 60 °C however, there was a significant drop in the level of polyphenoloxidase activity ($P<0.05$) (Warwick 2007). The decrease in polyphenoloxidase activity suggests that enzyme deactivation induced by heating was markedly greater than any heat activation of the inherent polyphenoloxidase (Warwick 2007). As the haemolymph is heated to 70 °C there is a considerable increase in the baseline polyphenoloxidase activity ($P<0.05$) (Figure 21) (Warwick 2007). The polyphenoloxidase activity was approximately 67 times greater than that measured in unheated haemolymph (Warwick 2007).

However polyphenoloxidase activity is a balance between temperature-induced activation and temperature deactivation (Williams, Mamo, and Davidson, 2003). The rapid and significant rise in polyphenoloxidase activity indicates that the heat-induced activation far exceeds the deactivation processes that occur at this temperature (Warwick 2007). Microwave heating to 70 °C may also activate the prophenoloxidase or other forms of polyphenoloxidase activity (such as that in the haemocyanin) and/or increase the concentration of polyphenoloxidase in the haemolymph plasma due to a disruption of the haemocytes (Williams et al., 2003).

A significant baseline polyphenoloxidase activity remained when haemolymph was heated to 80 °C ($P<0.05$) but polyphenoloxidase activity dropped as the temperature reached 90 °C and

was not significantly different to the initial polyphenoloxidase activity (Figure 21) (Warwick 2007). At 100 °C no baseline polyphenoloxidase was detected (Warwick 2007).

Figure 22 shows the percent relative baseline activity of polyphenoloxidase when heated in a water bath (Williams et al 2003) which follows a pattern of temperature rise similar to the one recorded with microwave heating. However, a comparison of the effect of microwave heating (Figure 21) with heating in a water bath (Figure 22) shows that microwave heating caused greater activation of polyphenoloxidase-like activity at almost all temperature points (Warwick 2007). The 100 °C point was the exception since at this temperature point both heat processes had no activation effect on polyphenoloxidase activity. Williams et al (2003) reported an increase in baseline polyphenoloxidase activity of approximately 350 % at 70 °C when compared to the initial baseline polyphenoloxidase activity. However microwave heating showed a mean increase of 6,700 % in baseline polyphenoloxidase activity at 70 °C. Therefore heating lobster haemolymph in a microwave oven to 70 °C increases the baseline polyphenoloxidase activity by almost 20 fold when compared to heating in a water bath to the same temperature.

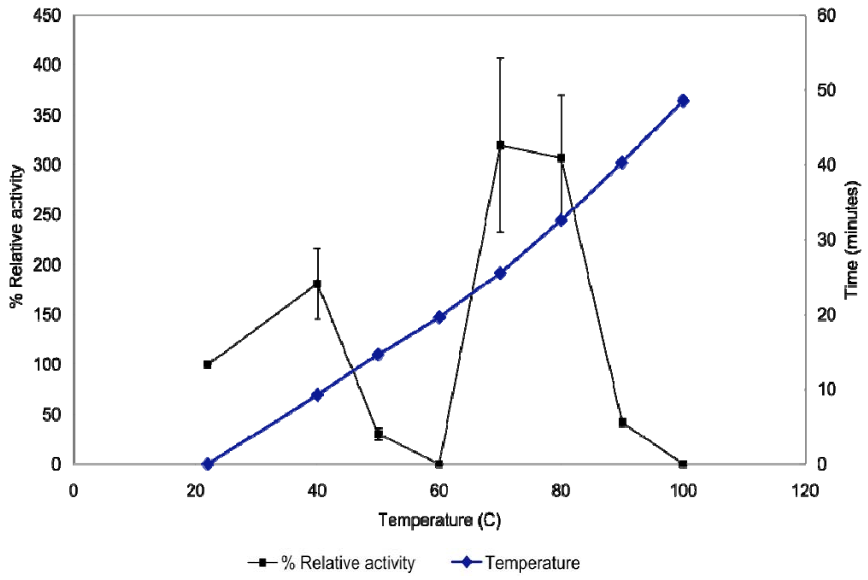

Figure 22: Baseline relative polyphenoloxidase activity in western rock lobster hemolymph under unsteady state heating conditions (mean ± SEM, n= 8) (Williams et al. 2003)

The differences in activity may be explained by the fact that microwave energy has the capacity to break weak bonds such as hydrogen, hydrophobic or polar bonds (Rodriguiez-Lopez et al. 1999). Breaking these weak bonds on the prophenoloxidase or haemocyanin molecules could accelerate the conformational changes of the enzyme, which in turn could exposes the active sites of these proteins to phenolic substrates resulting in a greater level of enzyme activity.

To measure total polyphenoloxidase activity, trypsin was added to the haemolymph *in vitro*. Trypsin cleaves a peptide chain between a threonine residue and an arginine residue from the prophenoloxidase (Söderhäll and Cerenius, 1998). This exposes the active site to substrate, activating the prophenoloxidase, and allows for the maximum available polyphenoloxidase activity (i.e. total polyphenoloxidase activity) to be measured. Trypsin also acts by proteolysis on haemocyanin to produce polyphenoloxidase activity (Terwilliger, 1999; Lee, Lee, and Söderhäll, 2004).

Total relative polyphenoloxidase activity was measured at the predetermined temperatures under microwave heating (Figure 23). There was no significant difference between the total polyphenoloxidase activities measured at 40 – 70 °C when compared to the initial total polyphenoloxidase activity ($P>0.05$) (Warwick 2007). However the increase in total polyphenoloxidase activity recorded between 50 and 60 °C was significantly different to the initial polyphenoloxidase activity ($P<0.05$) (Warwick 2007). This may be due to a more optimal conformation change at 60 °C of the prophenoloxidase and other polyphenoloxidase-like proteins that provides more efficient catalysis of the substrates (Warwick 2007).

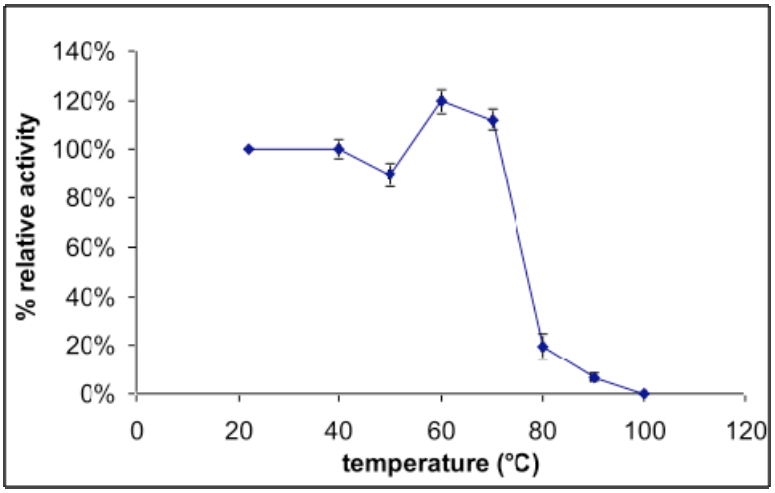

Figure 23: Total relative polyphenoloxidase activity during microwave heating (mean SEM, n = 8) (Warwick 2007)

When the haemolymph was heated above 70 °C there was a rapid decrease in the total polyphenoloxidase activity (Figure 23) (Warwick 2007). There was no detectable polyphenoloxidase activity at 100 °C suggesting that all forms of polyphenoloxidase activity were completely deactivated at this temperature (Warwick 2007). Total polyphenoloxidase activity was much greater than that found in baseline activity even at temperatures that provided considerable heat-induced activity.

Figure 24 shows the total polyphenoloxidase activity when heated in a water bath. A comparison of the patterns presented in Figure 23 and Figure 24 suggests that the type of heating had little impact on the total polyphenoloxidase activity level in lobster haemolymph (Warwick 2007).

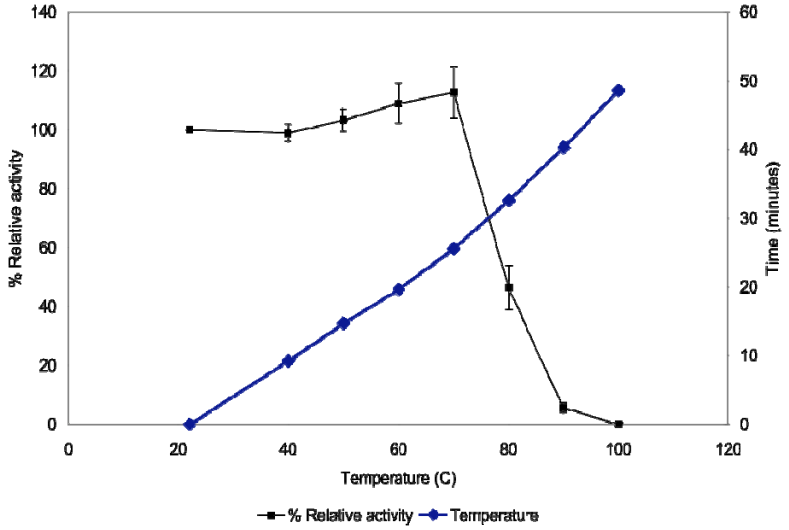

Figure 24: Total relative polyphenoloxidase activity in western rock lobster haemolymph under unsteady state heating conditions using a water bath (mean ± SEM, n=8) (Williams et al, 2003)

Based on these results it could be anticipated that an increase in melanosis would result from the greatly increased baseline polyphenoloxidase activity levels associated with microwave cooking. However when the results of the microwave cooking trials of whole lobster were evaluated using digital image analysis, the occurrence of blackening in lobsters cooked by microwave oven was comparable to that in lobsters processed by traditional methods.

Lobsters cooked by microwave oven recorded a weight recovery of 102% after cooling and draining. Every lobster was fitted with optical probes and so some loss of fluid would have occurred through the punctured membrane in the cooking process but despite this, a weight increase was recorded over the whole process of drowning, cooking, and cooling.

A thorough visual examination of the lobsters cooked in the microwave oven after cooling revealed quality issues. These were:

1. The colour of the lobster shell;
2. The colour of the flesh colour
3. The integrity of membranes.

1. Colour of lobster shell after cooking.

As can be seen in Figure 25, the colour of lobster shells after microwave cooking was very uneven and patchy, with some portions of the shell maintaining the natural dark red colour of the uncooked lobster shell.

Figure 25: Cooked lobster showing patchy shell colour after microwave cooking

The discolouration of the shell was consistent for all lobsters except for those who were heated to higher internal temperatures, resulting from extended cooking periods. All lobsters that displayed discoloured shells were however completely cooked, according to the criteria of this study, and did not develop any blackening of the tail meat (Figure 26).

2. Flesh colour of lobsters cooked in microwave oven

Figure 26: internal appearance of cooked lobster with discoloured shell.

A visual examination of the flesh of these lobsters indicated that it was white and appeared juicy. However, a closer examination revealed that some areas of the tail meat appeared to be underdone, suggesting technical issues with uneven cooking (see Figure 26). Furthermore, the hepatopancreas was disrupted in all cases which resulted in yellow staining of the flesh

when the lobsters were cut in half sagitally. Such yellow discoloration of the flesh could constitute a processing problem under commercial conditions.

3. Disrupted membranes

Longer cook periods improved shell colour but increased the incidence of ruptured membranes. Figure 27 clearly shows that the membrane between the cephalothorax of the lobster and the abdomen has ruptured during the cooking process. In comparison, under conventional cooking conditions (boiling) that particular membrane usually appears white, turgescent and firm to the touch.

Figure 27: lobster with ruptured membrane

Anecdotally, the flesh of lobster could by microwave oven is very sweet and juicy. However from the issues identified in this study it seems unlikely at this stage that microwave cooking could be a viable method for the production of industrially cooked lobster. Consideration of mixed processing methods, such as steam and microwave in conjunction, may however be of value.

CONCLUSIONS:

The prevention of melanosis whilst maintaining weight recoveries in cooked lobster products has been an issue that has plagued the lobster processing industry since its inception. The use of alternative cooking methods was thought to be a possible method of managing these conflicting problems. This study was undertaken to evaluate new and existing technology for use in the lobster industry.

The use of microwaves in processing foods is a relatively recent and innovative technology however, as has been identified in this study, there is issues with its use as a commercial

cooking method. Overall the issues were due to the fact that lobsters are not homogeneous and present significant problems due to their variable heat penetration characteristics. It is possible that in the future a combination of technologies that include microwaves maybe used to process lobsters in order to take advantage of shortened cooking times. However such a technology is not currently available.

The final goal set in this phase was to identify the optimum process and processing parameters that would maximise the weight recovery and minimize melanosis. Comparison of steaming, boiling and pressure steaming methods showed steaming has the greatest potential to deliver a good weight recovery whilst delivering a reduction in melanosis however it did require a longer cook time to do so. Unfortunately this phase of the study did not identify a faster more effective way to cook as had been proposed.

OBJECTIVE 4:

To evaluate the post production sensory quality of rock lobster processed by alternative cooking methods in comparison to rock lobster processed using standard practise (boiling)

In the fourth phase of the project sensory evaluation was used to determine which protocol delivered the best organoleptic qualities as judged by the consumer. Control lobsters were processed using the conventional cooking protocol (20 minutes in boiling water followed by 20 minutes cooling in iced water) to enable comparison of the different experimental treatments with "commercial practice". Microwaved lobsters were cooked long enough to deliver fully cooked flesh but no variations were attempted due to the difficulty in delivering an exact level of lethality for each lobster processed. Steamed and pressure steamed lobsters were cooked at three levels determined from the results of phase 3 of the project. Each level was defined as follows:

- Undercooked: the protocol will deliver a lobster with just cooked flesh and will have achieved lethality <20 (core temperature 65 °C). This level optimises weight recovery
- Just right: the protocol will deliver a lobster with firm cooked flesh and have a achieved a lethality between 20 and 40.
- Overcooked: the protocol will deliver a lobster that has reached lethality greater than 40. This level optimises prevention of melanosis

A focus group of 12 seafood lovers was recruited from staff at Curtin and from the local community with a view to discuss and identify factors that encouraged or discouraged consumption of seafood (in particular crustaceans such as lobster and prawns). The group agreed that consumption patterns depended on the occasion and the degree of preparation required. However fish always came first (variety, ease and comfort with preparation methods), shellfish or prawns were next. Lobster was eaten outside of the home by most people as they commented that they were unlikely to buy it and prepare it at home due to uncertainty as to how to prepare it and being afraid of ruining an expensive product. This fear was decreased in some measure when pre-cooked lobster was the product under consideration due to the greater ease of preparation.

When entertaining in the home, cooked lobster was considered a better buy by the majority of participants as it was considered easy to prepare and thus considered less risky. However, those participants who felt they were comfortable with preparing lobsters said that they were more likely to buy an unprocessed lobster and prepare it themselves as they felt the taste and

texture were then superior. Lobster was deemed superior to prawns in that you got more meat with minimum fuss. The fact that lobsters of larger size are available was also counted as a definite plus when catering for crowds.

Lobster was always perceived as a special occasion food regardless of the eating environment and as such, was unlikely to be bought except on celebratory occasions. This was in part related to cost and also uncertainty as to preparation & presentation methods (the 'fear factor'). Participants commented that restaurants typically made dishes too fussy and disguised the lobster to such an extent that many people were in fact quite unfamiliar with the natural taste of cooked lobster flesh. The status symbol associated with lobster consumption at a business dinner or event was also identified.

The group was used to determine the characteristics deemed to be important to consumers for analysis in the sensory trial and it follows that:

1. Shell colour was not a major issue for the participants but it was felt that darker red was better in a cooked lobster and uneven colouration was very undesirable. Pale colours were thought to reflect a lack of freshness as it was thought that the product had been in the freezer for too long.

2. Any form of discolouration of the flesh was looked on unfavourably. Participants agreed that lobster flesh must be bright white at all times. Black and grey colours promoted a more negative response from the participants than pink or yellow tinged flesh.

3. In terms of texture, participants looked for a firm springy bite to lobster flesh with a small amount of moisture. Lobster flesh must NOT be soft or mushy. Muscle structure should hold together but not be tough, rubbery, stringy, or ropey. No residue should be left on the teeth surface.

4. The ideal flavour was described as mild and subtle oceanic flavours, a fresh sea taste with a level of sweetness. The flavour was perceived as being a rich full taste but not strong. Strong fishy odours were identified as a frequently occurring negative odour/flavour associated with lobster. Other minor variations were: metallic, iodine, bitterness, musty and earthy. Tasteless and watery lobster was equally undesirable.

On the basis of the focus group discussion it was decided to serve all sample pieces used in the sensory evaluation without the shell, as flesh characteristics were deemed to be the most

important parameters in determining quality. Panellists were asked to assess colour, texture, flavour and overall acceptability.

A total of 44 panellists were recruited from staff and students at Curtin University plus several community members. Smokers and those with food allergies or health conditions were excluded from the trials. There were 11 males and 32 females with an age distribution of: 22 between 21-30 years; 10 between 30-40 years; and 6 over 40 years. 18 participants were from Asia, 15 were Australian, 9 were born in Europe and 2 came from Africa/Middle East. All panellists were frequent seafood eaters with a preference for crustaceans.

Panellists were asked to taste 6 pieces of lobster flesh and compare them for preference of colour, texture, flavour and overall preference using an unstructured anchored line scale. The trial was replicated on two separate days with the same panellists to control for judge effects. There were a total of 8 treatments (as shown in Table 9) to be evaluated so an incomplete balanced block design was used to ensure that each treatment was tasted by the same number of panellists.

Table 9: Treatments to be analysed

Treatment	Code used in data analysis
Boiled	Boiled
Steamed: under	ST under
Steamed: over,	ST over
Steamed: just right	ST right
Pressure steamed: under	ST+P under
Pressure steamed: over	ST+P over
Pressure steamed: just right	ST+P right
Microwave	MW

Sample presentation was fully randomised to ensure that order effect and halo effects were controlled for. The sensory laboratory at Curtin University was used to ensure that environmental factors and sample presentation were controlled. Controlling for all these factors means differences in the consumers' perceptions arise from the treatments and not the presentation or environment in which the test was conducted.

Data was statistically analysed using the SPSS Statistical package (SPSS 2008). The descriptive statistics for the sensory scores by process are given in Table 10. From this it can be seen that there is considerable variability in the acceptance of the different processing methods (range 27.075 to 67.543).

Table 10: Descriptive statistics for sensory scores by process

	Process	Mean	Std. Deviation	N
Overall Acceptability	control (boil)	59.81	22.46	44
	steam +under	67.54	24.51	41
	steam+ right	63.99	20.45	37
	steam + over	54.98	25.51	41
	pressure + under	55.09	22.78	38
	pressure + right	42.64	24.62	39
	pressure + over	27.08	22.12	40
	microwave	60.38	21.77	39
	Total	53.97	25.97	319
Colour	control (boil)	74.13	17.22	44
	steam +under	74.54	16.82	41
	steam+ right	55.20	18.55	37
	steam + over	47.70	25.44	41
	pressure + under	51.76	23.00	38
	pressure + right	34.67	21.91	39
	pressure + over	22.69	19.54	40
	microwave	61.00	21.69	39
	Total	53.05	26.62	319
Taste	control (boil)	54.11	23.40	44
	steam +under	62.25	27.01	41
	steam+ right	65.59	20.79	37
	steam + over	59.43	27.86	41
	pressure + under	61.28	22.61	38
	pressure + right	48.47	21.93	39
	pressure + over	31.67	26.18	40
	microwave	57.21	23.22	39
	Total	54.90	26.06	319
Texture	control (boil)	64.39	19.70	44
	steam +under	60.35	25.15	41
	steam+ right	62.79	21.83	37
	steam + over	54.84	27.33	41
	pressure + under	56.82	26.90	38
	pressure + right	46.63	23.52	39
	pressure + over	26.18	24.81	40
	microwave	60.84	22.04	39
	Total	54.16	26.53	319

Correlation analysis of the sensory characteristics evaluated in this study revealed a number of significant trends. Firstly the type of process had a highly significant ($p<0.001$) impact on the level of acceptability (Table 11). It also influenced the perception of sensory characteristics i.e. colour, taste and texture ($p<0.001$, Table 11). Secondly, it can be seen that

overall acceptability is also influenced by the perception of the individual sensory characteristics (P<0.001).

Table 11: Correlation Matrix of sensory acceptability

		Process	Overall Acceptability	Colour	Taste
Overall Acceptability	Pearson Correlation	-.278**			
	Sig. (2-tailed)	.000			
Colour	Pearson Correlation	-.433**	.521**		
	Sig. (2-tailed)	.000	.000		
Taste	Pearson Correlation	-.186**	.784**	.363**	
	Sig. (2-tailed)	.001	.000	.000	
Texture	Pearson Correlation	-.255**	.788**	.464**	.677**
	Sig. (2-tailed)	.000	.000	.000	.000

In order to elucidate the differences between treatments and the impacts on consumer acceptance a Spidergram of the average results for each treatment and characteristic was developed as shown in Figure 28. The spidergram illustrates the differences between treatments in acceptability of the sensory characteristics which were measured with values equal to 100 corresponding to "liked extremely" and values equal to 0 to "disliked extremely". Treatments that scored values less than 50 were ranked as "disliked".

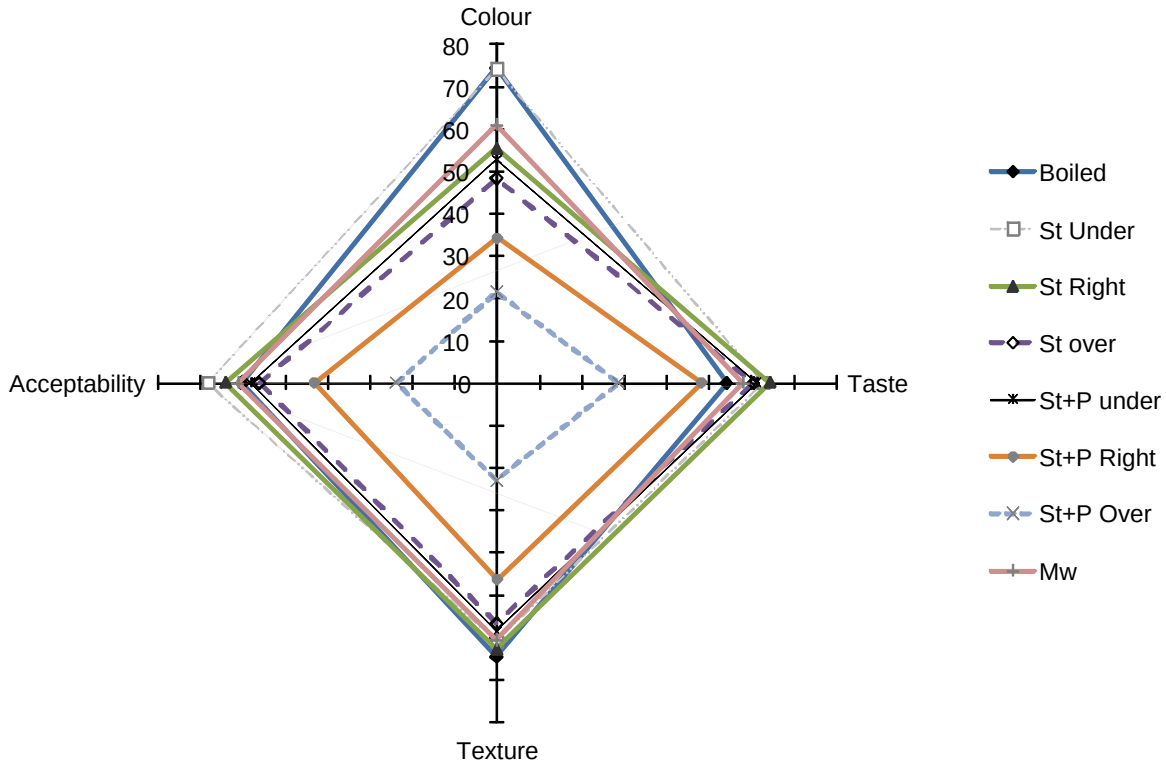

Figure 28: Spidergram of preference differences between treatments

From Figure 28 it can be observed that boiling, microwaving and steaming gave very comparable textural characteristics (scores of 64.3, 60.8 and 60.3 respectively). The texture of 'over pressurised steamed' and 'just right pressurised steamed' products were disliked by everyone (26.2 and 46.6 respectively). Evaluation of taste shows that pressure steamed products were the least acceptable (average = 47.1) while steamed (average 62.4) and microwave (57.2) products recorded the highest preference values. Even when over-cooked the steamed products were rated more highly (59.4) for taste than the other cooking methods. The control method of boiling was rated lower for taste (54.1) than all steamed samples but better than 'over' and 'just right' pressure steamed products. Flesh colour was significantly better for boiled (74.1) and underdone steamed (74.5) products when compared to other treatments. All other cooking methods gave comparable flesh colour (range of 47.7 to 61.0) with the exception of pressure steamed 'just-right' and pressure steamed 'over' products that recorded markedly lower values (34.7 and 22.7 respectively).

Principle Component Analysis of the sensory data was used to develop an Internal Preference Bi-plot for consumers' overall preferences versus processing methods. The corresponding Internal Preferences Map for lobsters processed by the selected 8 different methods is presented in

Figure 29. Each arrow represents the direction and strength of one consumer's preference while each square represents a cooking method as indicated in the legend. This enables clustering of the consumers by preference and identification of preference groupings.

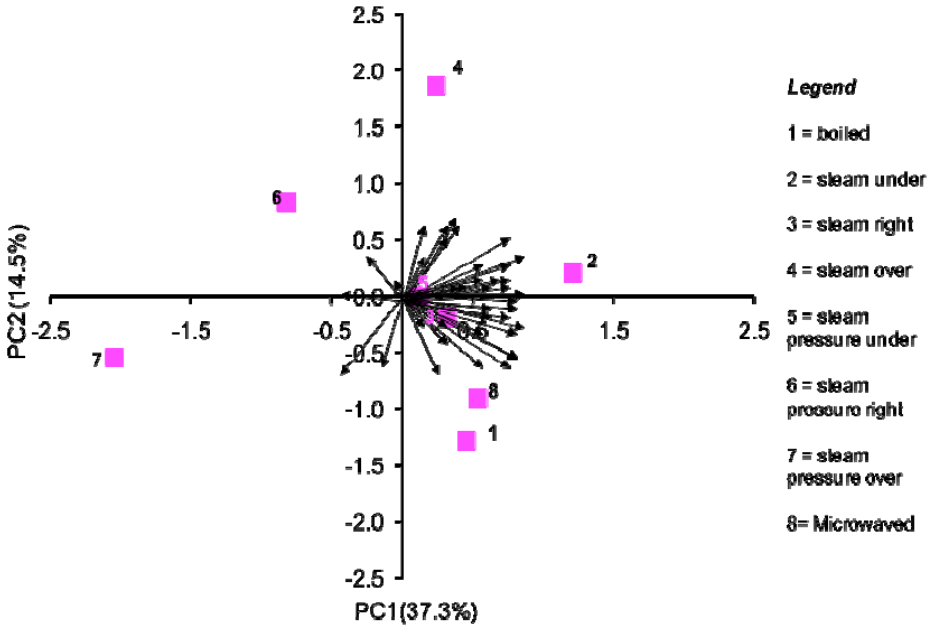

Figure 29: Internal Preference Map for lobsters processed by 8 different methods

From

Figure 29 it appears that very few consumers (5 out of 44) liked pressurised steamed products in the 'just right' or 'over' cooked categories (treatments 6 & 7 respectively). Comments by a large proportion of consumers about these samples indicated that they were perceived to be 'mushy' in texture and very strongly flavoured. All other treatments were described as acceptable to the majority of customers.

Six panellists expressed an equal overall preference for 'over' steamed lobsters (treatment 4) and 'under' pressure steamed lobsters (treatment 5). Eighteen showed a preference for boiled, 'just right' steamed and microwave cooked lobsters (treatments 1, 3, & 8 respectively). The remaining 15 panellists had a preference for 'under' steamed lobsters (treatment 2).

With the establishment of the Internal Preference Bi-plot for consumers' overall preferences versus processing methods, it is postulated that the groupings of treatments by consumers is based on the fact that different treatments may correspond to very similar textural and flavour characteristics of the product. From this study, it appears that in terms of overall acceptability, pressure cooking with steam was the least favoured method while cooking with steam (no pressure) was the most favoured method closely followed by microwave cooking and boiling. Based on the results of this work it would appear that cooking with steam offers promising potential for the industry in its aim to improve processing methods.

8.0 OBJECTIVE 5: OPTIMISATION OF PROCESSING METHODS.

The aim of this project was to evaluate the potential of alternative processing methods to increase weight recovery whilst reducing the incidence of melanosis in cooked western rock lobster. Based on the results generated by this study several recommendations can be made to optimise processing of western rock lobster.

Consideration of the use of antibrowning agents during drowning showed that on the basis of the experimental work with citric acid:

1. Should a processor not wish to use anti-browning additives then an increase in the drowning period of lobsters to a minimum of 40 minutes is recommended in combination with adjusting the drowning ratio to 1 lobster per 2 litres of water. Icing the water is not necessary, although not detrimental. Implementing such process should optimise weight recovery.

2. Should a processor decide to use citric acid as an antibrowning agent, then it is recommended that they use a drown ratio of 1 lobster per 5 litres of 2.5 ppm citric acid as a drowning bath for a period of 40 minutes. Following such a process should reduce melanosis development while maintaining improved weight recovery.

The incidence of melanosis development in microwaved product was equivalent to that of the control method (boiling) at similar lethalities. However, examination of the microwaved lobsters after cooling showed further quality issues that need to be considered. These were:

- The uneven colour of the lobster shell after cooking;
- Uneven flesh colour; and
- Disrupted membranes.

In view of this it would appear that industrial cooking of whole lobsters using a conventional microwave oven may not be a viable process. However its use in combination with steaming may be an option to consider for future studies.

When investigating weight recovery and melanosis rates in other processing methods it was noted that longer cook time resulted in greater reduction of melanosis. However this was offset by a reduction in weight recovery regardless of the method used. When comparing ‘just-right’ products, the highest recoveries were obtained from boiled lobsters closely

followed by steamed products. Lobsters cooked by boiling gave a weight recovery of 102% after cooling and draining, whilst steamed lobster gave a weight recovery of 98% when cooked to a similar lethality ('under').

Investigation of the impact of processing methods on melanosis showed that

- The use of pressure steaming reduced the development of melanosis in lobster flesh using markedly shorter cooking duration than other methods. However it also resulted into an increased weight loss (94% weight recovery on average).
- The maximum weight recovery (97%) and minimum melanosis (0) was delivered by samples treated with steaming at levels near to the calculated lethality value of 36 min at 90 °C i.e. the 'steam just right' category. This category has lobsters steamed at average lethality levels equivalent to 33.5 minutes at 90 °C. At this level of treatment NO lobster developed melanosis when cooked by steaming. Thus it can be concluded that steaming delivers a better weight recovery and reduction in melanosis development than pressurised cooking, or boiling under the conditions examined.

Any change to processing methods must take into consideration the impact of processing methods on consumer acceptability. The focus groups consulted in this study found that flesh colour, flavour and texture are the determinants of overall acceptability for a lobster product. The results of the sensory evaluation clearly suggested that pressure cooking with steam was the least favoured method in term of product acceptability while cooking with steam (no pressure) was the most favoured method closely followed by microwave cooking and boiling (Figure 30). Figure 30 also clearly shows that, in general, decreasing the lethality of the cooking process increases the acceptability of a product. However it is interesting to note that steamed products with lethality in the 'just right' or 'under' categories were the most preferred products even though their lethality exceeded that of the boiled or microwaved products. In conjunction with this, the steamed 'just right' cooking protocol gave the best combination of reduction in melanosis (0 black) and weight recovery (97%). Thus it can be concluded that steaming provides the best processing methods for cooking of western rock lobster.

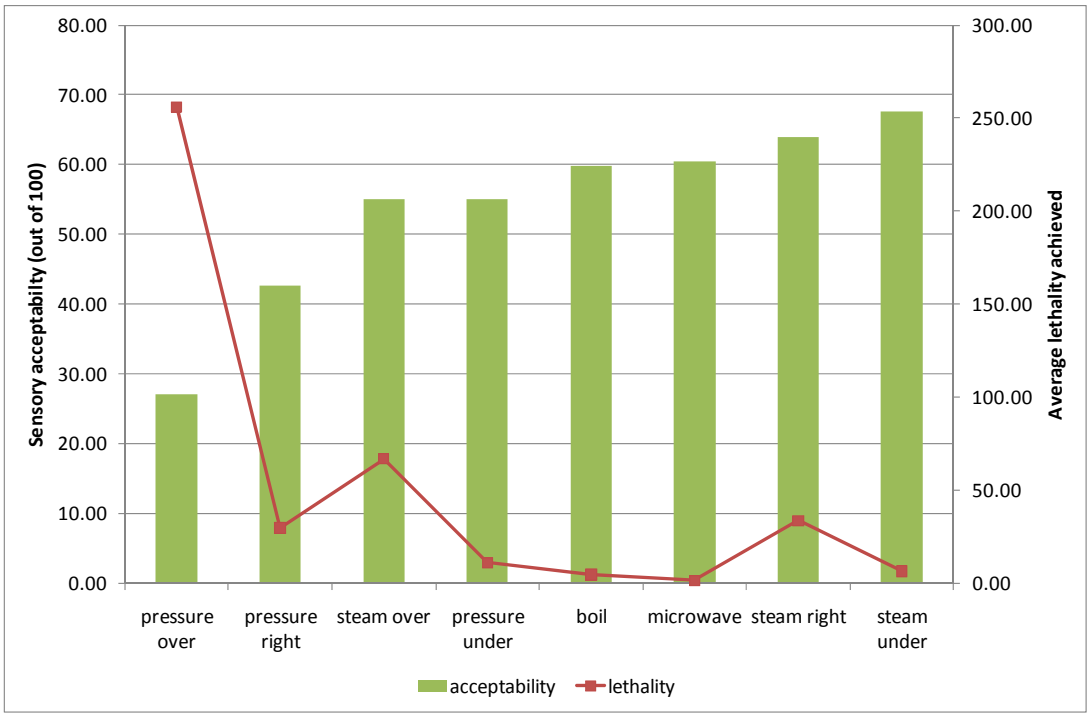

Figure 30: Comparison of sensory acceptability with lethality achieved

In summary, melanosis development and weight recovery are significant factors in determining the effectiveness of a processing technique for rock lobsters. Prevention of melanosis development can be achieved by chemical means (using antibrowning agents) or through physical means (deactivation of the enzyme by heating). However a combination of these factors may be more effective than using a single factor alone. A limitation of this study was that it was not possible to investigate the application of the antibrowning agents in conjunction with cooking technologies. However future researchers may choose to investigate the synergistic effects of antibrowning agents, drowning times and ratios with the optimised cooking methods identified here.

In investigating the effectiveness of existing processing technologies this study looked at the need to ensure prevention of melanosis whilst returning a good weight recovery. As a rock lobster is a highly valued luxury item it is also important to ensure that the optimum sensory quality is maintained by which ever treatment is selected.

The results of the study clearly showed that steaming was a more effective processing method for cooking lobster than the other treatments investigated. Atmospheric steaming gave higher weight recoveries whilst delivering greater levels of melanosis reduction and maintaining sensory quality. Therefore, based on these results it would appear that atmospheric steaming offers the greatest potential for the industry to improve their processing methods.

9.0 BENEFITS AND ADOPTION

The provision of clear recommendations for optimising weight yield and reduction of melanosis through the use of the identified steaming protocol will enable processors to make informed decisions about processing protocols and infrastructure investment. The combination of processing technologies will enable the processor to reduce wastage and losses thus maintaining the financial return on a limited catch. Steaming also offers advantages in reduced energy costs, lowered carbon emissions during operation and lowered ecological impact though decreased water demand and waste production.

Using the identified steaming methods will enable production of a product with maximal sensory acceptability, minimal weight loss and decreased use of undesirable chemical treatments (sulphite treatments). This in turn should enable the western rock lobster industry to be more competitive on the international market and increase its level of market penetration.

The transformation sector of the rock lobster industry will benefit of the findings of the project. The results will also benefit other crustacean processors dealing with similar issues as it provides an example for determining the direction of future research activity.

10.0 FURTHER DEVELOPMENT

The project has clearly identified an optimised steaming protocol for processing western rock lobster. However the project was unable to systematically investigate how the optimised protocol synergistically interacts with antibrowning agents, drowning times and drowning ratios to further improve the weight recovery of cooked western rock lobster whilst retaining prevention of melanosis development. Investigation of this by future researchers may offer an opportunity to further improve the return to the processing industry on this high value catch.

11.0 PLANNED OUTCOMES

The proposed project has identified the processing parameters required to optimise rock lobster processing using atmospheric steam cooking to ensure increased weight recovery, reduced melanosis and improved post processing sensory quality.

Technical information on the processing of rock lobster by steaming has been developed so that processors are able to make informed decisions based on scientific fact. The information arising from this proposed project achieves the following outcomes:

1. Processors are able to maximize their cooked weight recoveries whilst ensuring reduced melanosis through the use of the identified steaming protocol,

2. Increased profitability and efficient use of the resource is possible through minimising costs of cooking and maximising financial returns due to improved yield and sensory appeal,

3. The product will be more competitive on the international market due to the improved sensory appeal and ability to reduce use of undesirable chemical treatments (sulphites).

All participants in the commercial fishery (i.e. both processors and fishers) should benefit through the realization of increased profitability.

12.0 CONCLUSION

In investigating the effectiveness of existing processing technologies this study looked at the need to ensure prevention of melanosis in western rock lobster whilst returning a good weight recovery. As a rock lobster is a highly valued luxury item it is also important to ensure that the optimum sensory quality is maintained by which ever treatment is selected.

Melanosis development and weight recovery are significant factors in determining the effectiveness of a processing technique for rock lobsters. Prevention of melanosis development can be achieved by chemical means (using antibrowning agents) or through physical means (deactivation of the enzyme by heating). However a combination of these factors may be more effective than using a single factor alone.

Consideration of the use of antibrowning agents during drowning showed that on the basis of the experimental work with citric acid:

1. Should a processor not wish to use anti-browning additives then an increase in the drowning period of lobsters to a minimum of 40 minutes is recommended in combination with adjusting the drowning ratio to 1 lobster per 2 litres of water. Icing the water is not necessary, although not detrimental. Implementing such process should optimise weight recovery.

2. Should a processor decide to use citric acid as an antibrowning agent, then it is recommended that they use a drown ratio of 1 lobster per 5 litres of 2.5 ppm citric acid as a drowning bath for a period of 40 minutes. Icing is preferable for this treatment. Following such a process should reduce melanosis development while maintaining improved weight recovery.

Investigation of the differences between cooking technologies (boiling, atmospheric steaming, pressurised steaming and microwaving) showed that the maximum weight recovery and minimum melanosis was delivered by samples treated with atmospheric steaming at average lethality levels equivalent to 33.5 minutes at 90 °C. At this level of treatment NO lobster developed melanosis when cooked by steaming. Atmospheric steaming gave higher weight recoveries whilst delivering greater levels of melanosis reduction and maintaining sensory quality. Therefore, based on these results it would appear that atmospheric steaming offers the greatest potential for the industry to improve their processing methods.

A limitation of this study was that it was not possible to investigate the application of the antibrowning agents in conjunction with cooking technologies. However future researchers

may choose to investigate the synergistic effects of antibrowning agents, drowning times and ratios with the optimised cooking methods identified here.

RECOMMENDATIONS:

1. Longer drowning times with low water to lobster ratios (one lobster per two litres of water) result in greater weight recoveries and lower rates of melanosis;
2. Application of anti-browning agents during drowning under iced conditions may improve weight recovery and reduce melanosis; and
3. Steaming is the preferred method for processing western rock lobster as longer cook times using steam will reduce melanosis while still maintaining a good weight recovery and high consumer acceptance.

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14.0 APPENDIX 1: INTELLECTUAL PROPERTY

NIL

15.0 APPENDIX 2: STAFF

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