Electronic cooking end point determination and the effectiveness of alternative cooking methods for crustacea

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By

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OBJECTIVES:

(1) To develop a device which will determine the end-point of cooking for crustaceans by:
(a) developing a durable sensor for measuring the thermal centre of the crustacean
(b) determining crustacean protease deactivation temperature curves

(2) To confirm that the endpoint for cooking is determined by protease deactivation by:
(a) confirmation trials of several species, sizes and cooking rates
(b) determining the effects on possible melanosis development, sensory and textural quality and yields against a chosen reference such as farmed prawns

(3) Evaluate alternative cooking, processing and handling conditions for prawns.

(4) Build 10 prototypes of the device for industry to trial.

(5) Extend results to industry through workshops, publications and the media.

(6) Optional: To further develop the cooking end point device for two other crustacean species with methods subject to the outcomes of the first two objectives.

NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED

- Thermal deactivation curves for the key spoilage processes for prawns have been determined.
- A meter for monitoring cooking processes for crustaceans has been developed.
- Alternative cooking processes for prawns have been evaluated against those specified by the meter. Ten prototypes are in service with the industry.
- An extensive dissemination process has resulted in considerable industry interest in obtaining the meters.
- The feasibility of extending the instrument for cooking of other crustaceans has been demonstrated.
- Negotiations with a company over commercialisation and manufacture of the meters are in progress

A prawn cooking meter and self-centring thermocouple clip has been successfully developed for monitoring the cooking of prawns. This cooking meter provides a much needed control tool for ensuring reliable and consistent quality required of modern quality assurance programs.

The design of the prawn cooking meter relies upon the fact that enzymes that discolour and soften the flesh of cooked prawns are a major cause of quality loss. Ideally, cooking should destroy these enzymes, but experience shows there is typically not enough control over the

cooking step on vessels and in processing factories to bring this about. Simple methods of timing cooking do not take account of the complex factors that can influence the rate of product heating such as size and quantity of prawns, cooker efficiency etc. This results in variable quality product, which can exhibit mushiness and discoloration including black-spot (melanosis) and autolysis.

This problem has been solved by developing a meter (Objective 1) that actually monitors the heat put into a prawn in the cooker and signals the end-point of cooking when the product is cooked enough to destroy the target enzymes, without the over-cooking that might otherwise cause toughness and weight loss. The progress of the cook is tracked by fitting a prawn typical of the batch into a robust clip, also developed in this project. The clip places a temperature sensor in the thermal centre of the tail of the prawn. The cooking end-point used by the meter is calculated from the thermal destruction rates of the enzymes that are achieved at particular temperatures. These were determined in *in vitro* experiments using extracts from several prawn species.

The use of the meter was tested in a number of confirmatory trials (Objective 2) where the prototype of the meter was used to successfully cook prawns of several species and size, and was, as long as the cooker approached boiling temperatures, independent of the performance of various kinds of prawn cookers used.

The meter was used to monitor a number of alternative cooking techniques (Objective 3). Of these, most interest was in sub-boiling or simmering of prawns. However, after cooking trials, this practice cannot be recommended. It fails to reach the threshold temperatures necessary to denature the enzymes that cause softening, discoloration and black spot. The underlying algorithm in the meter requires the prawns to warm significantly above the temperatures reached by simmering. Perhaps a higher sub-boil temperature can be used, as the final temperature, even in boiling prawns, is typically in the order of 90-95^{o}C. Industry interest in steam tunnels was considered in passing by the project team, but trials were not undertaken. There appears to be no reason why this technology would not be suitable.

After the meter validation trials, ten prototype meters were manufactured and tested by industry with favourable results (Objective 4). These tests used a number of species under commercial conditions with cooperation of processors of both farmed and wild prawns in Queensland and Western Australia. Important feedback was obtained on the design features needed in a commercial model of the meter.

Dissemination of the results to companies participating in the trials was rapid. In addition, two workshops were held for prawn farmers in south and north Queensland (Objective 5). A workshop manual and training video have been prepared. The successful development of the prawn cooking meter has also been widely promoted in trade magazines and general media. Negotiations are in progress with a company wishing to manufacture and market the meters.

The cooking meter was tested on four other types of crustaceans (Objective 6) namely yabbies, redclaw, western rock lobsters and sand crabs. Suitable algorithms have been developed for all four species. Its use proved relatively straightforward for freshwater crayfish, which are of similar size and morphology to prawns, and the same self-centering clip could be used. However, further work is required to develop a practical temperature sensor clip for use with rock lobsters and crabs.

KEYWORDS:
processing, cooking. prawn, shrimp, lobster, crustaceans, crayfish, redclaw, temperature; enzyme de-activation, spoilage, meter, monitor.

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BACKGROUND:

Shrimp/prawns are one of the major seafood commodities in world commerce, with 2,773,000 tonnes being traded in 1996. Australia is a relatively minor player in this market, with an export volume of only 9,525 tonnes, and a domestic trade of 18,011 tonnes. While the volume is small, Australian product competes in the high quality end of the market and is a significant player in that niche.

There is no cause for complacency. Throughout Asia, the adoption of quality management programs incorporating the Hazard Analysis and Critical Control Point (HACCP) principles, often in combination with ISO 9002 quality assurance, has given Asian producers much greater control over their processing, resulting in marked improvement in product quality and presentation. Competition in our export and domestic markets is increasing.

In the Australian Seafood Industry Quality Assurance project, process specifications for cooking prawns were identified as a subject needing special attention. The control measures used are extremely primitive, and reflect the handed down experience of earlier generations rather than any systematic approach to the process itself. Examination of codes of practice set down in recent years reveals there is no agreement about how prawns should be cooked in order to maximise the quality outcome.

The general method of cooking prawns is to immerse them in salted boiling water. The end point of cooking varies from operator to operator, but can be either a given time after the prawns have returned to the boil or when a certain proportion of prawns begin to float. Under these circumstances, the effectiveness of the cooking process depends on:

- the judgement of the operator
- whether the product was chilled or at ambient temperature before cooking
- the species, condition, and size of the prawn
- the performance of the different cookers used by the industry.

Black spot (melanosis) is probably the most visible quality defect in prawns. The role of the enzyme polyphenoloxidase in development of melanosis is well understood, and there has been much research over the years in controlling black spot in raw prawns using a variety of inhibitors, such as metabisulphite and more recently with products such as Everfresh (2,4-hexylresorcinol). Rather than relying on these chemical treatments for cooked prawns, the cooking process itself should be adequate to deactivate the polyphenoloxidase enzyme, and hence there has been considerable interest over the years in the thermal stability of the melanosis-producing enzyme system.

Proteolysis, enzymatic softening of cooked prawns, can also occur if cooking is inadequate. If enzymes remain active after cooking, digestive enzymes called proteases break down the coloured digestive gland of prawns and then discolour and damage the texture of the meat. Other crustaceans such as crabs and lobsters also suffer from this problem, and consequently attention has been focused on the thermal denaturation of the various enzymes involved.

The application of adequate heat input to deactivate the enzyme systems is essential. The temperature must be raised above that necessary to denature the enzyme (inactivation threshold) and be maintained there long enough to destroy the enzyme systems. At present there is no consistently applied method of determining when the prawns are sufficiently cooked. One of the reasons for this is that simply applying a standard cooking time to all batches of prawns fails to take into account factors such as, prawn temperature, size, cooker design and efficiency. Similarly, using floatation as an indicator method is subject to error due to the changing moult stage of the prawns.

The only truly objective way to measure the heat uptake in any practical sense, and thus avoid any errors, is to monitor and integrate the temperature of the prawn itself during the cooking process. Although inserting a thermocouple into a prawn during cooking might sound impractical, coupling such a sensor to a purpose built cooking meter makes it possible to apply the principles of canning sterilisation to the prawn cooking process to ensure that the prawn becomes hot enough for long enough to "kill" the enzymes responsible for product spoilage. Information about the thermal stability of target enzymes can be programmed into the meter to directly control cooking operations in a processing factory, delivering reliable and consistent quality product.

NEED:

To date there is no consistent, simple means of determining the end point for cooking of crustaceans. It is impossible to establish a broadly applicable time-based cooking regimen that will optimise yield and quality, because prawns vary substantially in size and morphology, and the cooking equipment used by industry varies in power, capacity and performance.

Processors use several different methods of determining the end point of cooking, and there is no systematic information on the optimum method for prawns of different species and size to produce best quality, yields and shelf life. In fact, while it is rarely admitted, many processors encounter problems related to quality, appearance, weight-loss, excessive saltiness, toughness and blackening of prawns after cooking.

A device that tracks and integrates the internal temperature of a prawn in the batch is the most practical way to account for the diversity of factors that impact on cooking rate. The device would identify the exact end-point of cooking required to inactivate key enzymes responsible for loss of quality and alert the operator when the process is complete.

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METHODS:

Location of temperature probe

It was decided that it would be best to locate the probe in the abdomen or tail for the following reasons:

- The head of a prawn is easily damaged and can break away from the abdomen during handling and cooking.
- Location of a probe in the head could allow leaching of the enzymes and lead to higher internal temperatures in the head.

To find the most appropriate site for positioning the sensor, probes were inserted into several different positions in the tail, the prawns were immersed in heated water (75, 80, and 85^{o}C) and temperatures monitored for each position. The positions used were:

- mid-point of the flesh between segments 1 & 2.
- one quarter through the flesh between segments 1 & 2 on left side.
- one quarter through the flesh between segments 1 & 2 on right side.
- mid-point of the flesh between segments 4 & 5.
- one quarter through the flesh between segments 4 & 5 on left side.
- one quarter through the flesh between segments 4 & 5 on right side.

Protease deactivation curves

The mathematical model used as software in the meter was drawn from that used in thermal retort processing (canning), except that instead of applying it to bacterial destruction, it was applied to protease deactivation. This was done using *in vitro* studies of extracts from the hepatopancreas. The first step was to derive a suitable unit of activity to fit the enzymology of prawns. This involved many cooking trials and analyses.

Preparation of Hepatopancreas Extract

Live prawns were brought to the laboratory from the east and west coast fisheries. Chilling under ice killed the prawns. The cephalothorax (head) was severed from the abdomen (tail), and the carapace was removed from the head. The tissue surrounding the hepatopancreas was excised, and the hepatopancreas itself was removed. The hepatopancreases from 6 to 8 prawns were pooled and homogenised in a hand held blender with a volume of tris buffer equal to 4, 20, 40, and 400 times the weight of the organs.

The homogenate was spun at 45,000 g. for 30 minutes at 5^{o}C. The supernatant was removed, and 1 ml aliquots tested for protease activity using the spectrophotometric method of Jensen *et al.* (1980) using azocasein (1.7g/l) as the substrate.

- One unit of activity was defined as that required to produce an increase of 0.01 absorbance/hr at 366 nm under standard assay conditions.
- The 1:400 dilution gave absorbance values between 0.6 and 0.8, the optimum range for the method, so this was used as the standard assay.

Mechanical Texture Analysis

Mechanical assessment of texture was performed using a modified Lee-Kramer shear cell attached to a Model 1130 Instron Universal Testing Machine.

A mounting block was inserted into the shear cell to hold a plug of prawn meat and two 3 mm shear blades, driven by a 1kN force at 20mm/min, penetrated the meat perpendicularly to the direction of the surface muscle fibres and across the grain of that surface. The Instron was interfaced with a Data Systems Adaptor that had a sample rate of 18.2 pts/s that plotted the compression chart. The derived chart was divided into two sections identified as muscle and connective tissue (collagen) according to the method of Moller (1980).

A sample of tail meat was cut from 10 prawns from each cooking treatment. Measurements were made of the load at peak height in kN, and the total combined energy to shear a plug of cooked prawn meat. Both these measurements were adjusted for weight of sample.

Taste Panel Assessment

The best way to assess food quality is to taste it. The sensory unit at the Centre for Food technology (CFT) is the most experienced seafood assessment group in Australia, and sensory analysis was an important tool in testing the effectiveness of the cooking processes used. The assessment sheets used by the taste panels are presented in Appendix 1.

Tasters were supplied with a whole sample from each cooking treatment on storage day 0 and day 4 or 6. Tasters were asked to rate several sensory parameters of the samples using standard rating test procedures (AS2542.2.3). They were also asked to rate the overall acceptability of the product. Numerical scores of 0 and 100 were assigned to all scales on the questionnaire, with 0 representing the left-hand end (= none) and 100 the right hand end (= very much) of the characteristic labelled on the scales. Results were analysed using one way analysis of variance (ANOVA) and pairwise comparison of means for those attributes that showed a significant ($p<0.05$) difference between cooking treatments. Product characteristics were profiled with standard descriptors for the flavour, texture and odour of samples.

Visual assessment (Demerit points)

Chilled cooked prawns were stored at $\pm$ 2^{o}C for up to 6 days. The appearance of the prawns directly after cooking and after subsequent storage was assessed drawing on a demerit score system developed by Chinivasagam *et al.*, (1996). The discolouration of the hepatopancreas and gills, firmness of the head attachment to the tail and the development of melanosis were rated 1 to 4 over the storage period. The assessment sheets used by the visual assessment panel are presented in Appendix 2.

Each of the four characteristics was broken down into four levels of deterioration and the number of prawns within each appearance level was recorded. Summary scores were then weighted by multiplying the number of prawns within each rating by the demerit score particular to that rating and dividing by the total number of sample prawns assessed for each cooking treatment

Melanosis

The development of black spot on the margins of the shell (melanosis) is perhaps the best-recognised form of enzymic spoilage. Often prawns are dipped in chemical agents such as metabisulphite and/or "Everfresh" to prevent melanosis. Visual examination of prawns in the post-cook storage period will identify any residual melanosis activity.

Yield

The yield or “recovery” measures the amount of weight lost in the cooking process, and subsequent storage. Fluid loss can result from undercooking leading to cell destruction by proteases, and also from overcooking, which causes loss of water holding capacity of the structural proteins that make up the flesh.

Processing Treatments

The major field experiments were conducted during March and June 1999, at a prawn farm in S.E Queensland and in July and November 1999 at a prawn farm located in Nth Queensland Experimentation was conducted on Black Tiger (*P. monodon*), Banana (*Fenneropenaeus. merguiensis*) and Brown Tiger (*P. esculentus*) prawns.

Prawns were cooked using either experimental cooking treatments or commercial practices. A total of 150 prawns were removed from each cooking treatment and returned to the laboratory for chemical and physical analysis. Cooked samples were analysed for residual protease activity and were stored for 6 days at chilled temperatures for assessment of shelf life and sensory parameters.

Cooking Treatments

Washed and graded prawns were placed into cooking baskets, weights recorded, and cooked in individual gas powered cookers in boiling salt water (≅ 3.0% salt). During each cook the initial and final temperatures, return to boil time and total cooking time were recorded. The cooking treatments applied during these trials were cooking till the target temperature of 80°C had been attained for 1, 2 or 3 minutes, until one third of the prawns floated or the method currently in use by the factory.

Temperature Monitoring

Internal temperature of the prawns was monitored through T-type thermocouple probes inserted into both the tail meat and head of the prawns and attached to a datalogger. Thermocouples were held in place with elastic bands to prevent separation of product and probe during cooking.

Protease activity tests

Quantitative analysis of protease activity was done according to the method of Dulley & Grieve (1975).

As described above, samples were prepared by severing the cephalothorax from the abdomen and excising the tissue surrounding the hepatopancreas. The hepatopancreatic extract was homogenised with an equal weight of tris buffer and centrifuged for 30min at 45,000 g.

Test samples (1.0 ml), diluted to 1:400, were incubated with a 1ml aliquot of azocasein (0.5%) at 37°C for 60min and the reaction terminated with 10% TCA. solution. Test samples were filtered and the optical density of the clear filtrate was determined in a spectrophotometer at 366nm.

A control was performed for each test sample by adding 10% TCA solution before incubation. For a blank, the test sample was substituted with tris buffer.

The azocasein assay was optimised by preparing hepatopancreatic extract from live prawns, homogenised with a volume of tris buffer equal to 4, 20, 40 and 100 times the weight of the organs and determining protease activity as above. The optimised dilution rate for hepatopancreas extracts was used in all further enzyme assays.

Post cooking residual enzyme activity was determined from composite samples of the hepatopancreas from 6 prawns with 5 replicates (unless otherwise noted in text), totalling 30 prawns sampled from each cooking treatment. Samples were diluted 1:40 with Tris buffer and protease activity was determined as above.

RESULTS / DISCUSSION:

Because of the prospective patent and licensing requirements of the prawn cooking device, confidentiality of the information and formulae developed by this project needs to be maintained. For this reason only a limited amount of data has been presented in this final report. A full disclosure of all data will be released to the successful tenderer. The order of presentation for this section will follow the order of the objectives:

Objective 1

To develop a device which will determine the end point of cooking for crustacea by:

(a) Developing a durable sensor for measuring the thermal centre of the crustacea
(b) Determining crustacean protease deactivation temperature curves

Sensor Probe Development

There was no significant difference in temperature between any of the positions used, so the position in the flesh between 1 & 2 was chosen as the thickest and therefore most secure site for sensor positioning. A second factor supporting this decision was the observation that insertion of a thermocouple into the cephalothorax disrupted the structure of the hepatopancreas, allowing enzymes to escape and resulting in lower recoveries of hepatopancreas extract.

In an attempt to obtain a correction factor relating head and tail temperatures, prawns with thermocouples inserted in head and tail were immersed in laboratory water baths held between 90 and 100^{o}C. The results were not typical of a commercial cooker, and therefore were used only for this purpose.

Temperature measurements were analysed by analysis of variance. Data from the optimal cooks and one minute longer or shorter than the optimum gave the following relationship:

$$\text{head temperature} = 1.1606 * \text{body temperature} - 14.254 \quad (r^2 = 0.9653,\ p<0.001)$$

The close agreement between body and head temperatures in the ranges used in cooking can be seen by inserting a body temperature of 85^{o}C, which results in a calculated head temperature of 84.5^{o}C.

A contractor was employed to design and build a clip that could position the probe in the desired position without significantly damaging the prawn.

Protein Deactivation Curves

Hepatopancreas extracts were prepared from the following:

- western king prawns *(Penaeus latisulcatus)*
- brown tiger prawns (west and east coasts) *(Penaeus esculentus)*
- eastern king prawns *(Penaeus plebejus)*
- black tiger prawns *(Penaeus monodon)*
- banana prawns (*Fenneropenaeus merguiensis)*
- Endeavour prawns *(Metapenaeus endeavouri)*

Hepatopancreas extracts were exposed to cooking temperatures of 70, 75, 80, 85, and 90^{o}C for up to 6 minutes and the residual protease activity measured.

The enzyme activities in the raw extracts varied from 1170 to 5680 units/ml. To overcome this variability in initial values and provide a common starting point for comparison of heat stability, the absolute activity figures for each extract were converted to a percentage of the original raw activity for each extract.

While it was difficult to obtain more than one live sample for most of these species, three batches of farmed *P.monodon* were investigated for heat stability.

Three interesting factors were immediately apparent:

- The absolute activities of small raw *P. monodon* were twice that of the other prawns, but the enzymes were far more easily destroyed than those of the others.
- Analysis of the percentage inactivation of protease activity in extracts at four different temperatures showed no significant difference between chilled small *P. monodon*, and large *P. monodon*, and large *P. monodon* that had been frozen.
- The thermal conditions for deactivation of prawn proteases were similar to those for spanner crabs, sand crabs, and western rock lobsters. This entails holding at or above 80^{o}C for more than 2 minutes.

Objective 2

To confirm that the end point for cooking is determined by protease deactivation by:

(a) Confirmation trials using several species, sizes and cooking rates.

(b) Determining the effects on possible melanosis development, sensory and textural quality, and yields against a chosen reference such as farmed prawns.

Wild harvested king prawns (*P. plebjus*)

A batch of 12kg of small eastern king prawns was cooked on board a trawler fishing in Moreton Bay. Of 14 prawns monitored for temperature change:

- Four did not attain the goal of a cephalothorax temperature above 80^{o}C for 2 minutes.
- Recovery of the hepatopancreatic extract was minimal due to leaching from damage caused by insertion of the thermocouple into the cephalothorax.
- While the temperature in the body was lower than that in the head, this difference was negligible.

Farmed black tiger prawns (*P. monodon*) Trial 1

A commercial batch of 15kg of prawns were cooked at a prawn farm and four further 5kg batches were cooked in the CFT pilot plant.

Five cooking treatments were compared:

- Internal head temperature of lowest temperature prawn remains above 80^{o}C for 120 seconds (120s>80).

- Internal head temperature of lowest temperature prawn remains above 80ºC for 180 seconds (180s>80).
- Internal head temperature of lowest temperature prawn remains above 80ºC for 60 seconds (60s>60).
- Cook until one third of prawns float (1/3Float).
- The commercial cooking method used by the farm.

Parameters measured after cooking were yield, residual protease activity, mechanical texture measurement, and sensory characteristics. The prawns were then stored for 6 days and then reassessed for residual protease activity, mechanical texture measurement, and appraisal using demerit scores.

The main observations from the temperature readings were:

- There was considerable variability in temperatures between prawns in a batch, which reflected differences in size.
- There was more thermal inertia in the commercial (15kg) cook. It took longer to return to the boil after the prawns were put into the boiling water and remained hotter longer after boiling ceased.
- The 1/3 float method cooled more rapidly after the boil.

Protease activity after the commercial cooking treatment was high and remained so after 6 days storage. The lethal rate (L) values (see below) for the prawns that took less time to heat up and cool down (1/3 float) were much lower than for the other treatments, and this was reflected by higher residual protease activities. Melanosis in the 1/3 float treatment was significantly higher than the others immediately after cooking.

Storage for 6 days after cooking resulted in significant reduction in protease activity, but that in the 1/3 float treatment remained high enough to cause deterioration. This was reflected in significantly poorer scores for melanosis. The 1/3 float prawns were also scored higher for moistness after 6 days storage.

Farmed black tiger prawns (*P. monodon*) Trial 2

This trial was repeated with prawns from the same farm. The time/temperature parameters were a little higher, but the trends were similar.

Pooling the results from the two trials showed the following:

- Cooking yields showed no significant differences between treatments or trials.
- Residual protease activities were higher in trial 2, but treatment trends were similar.
- Residual protease activity in the 1/3 float was sufficient to cause deterioration.
- The 1/3 float treatment resulted in melanosis and deterioration in appearance.
- Keeping the prawns in boiling water until the head temperature is above 80ºC for 2 minutes gives the firmest texture.

Farmed banana prawns (*F. merguiensis*) Trials 1 & 2

Trials were carried out at a large prawn farm in central Queensland using the farm's equipment and staff. The company was interested in evaluating and possibly changing its cooking procedures at this time, so this exercise provided an opportunity to experiment on a large commercial scale.

The cooking treatments used were similar to those used in the trials on farmed black tiger prawns, with three differences:

- In place of the 1/3 float system, the operator waited until all the prawns floated, as evidenced by a decrease in weight of the basket in the boiler,

- A shorter 30 second boil was also assessed,
- Due to the logistics of harvesting there was a fairly long, variable period of chilled storage prior to cooking.

The results were more variable than those from the black tiger trials, and it was difficult to find statistically significant differences. Despite this, similar trends were observed, that can be summarised thus:

- Deterioration due to enzyme action occurred in the head in the chilled storage period (up to 6 hours) prior to cooking.
- There was a tendency to rely on the judgement of the operator rather than timers etc. in controlling the cooking process. This introduced inconsistencies, and the residual enzymic activity in prawns from these treatments was higher than that in more controlled processes with the exception of the 30 second cook, which was obviously way too short.
- There was a heavy reliance on metabisulphite rather than thermal denaturation to control melanosis, so that black spot could not be relied upon as an indicator of spoilage.
- With the exception of the 30 second cook, no differences were detected between treatments in sensory, textural and yield data for the period immediately after cooking. The evidence suggests that the boiling time can be increased without any significant loss of quality or yield.
- Deterioration began to occur in all treatments during the chilled storage period after cooking. This was evident in decreased scores for ease of peeling, fibrousness, moistness, prawn flavour, sweetness, and overall acceptability.

A mathematical model to control prawn cooking

The trials described above provide graphic evidence of the inadequacies of existing methods used to control cooking. It was obvious that there was a need to develop a system that could take account of the vagaries of raw material, equipment, and operator judgement.

The thermal retort model was an obvious choice, but first it would be necessary to specify an appropriate algorithm which could then be programmed into an electronic temperature integrator. For a discussion of the underlying principles and methodology behind deriving the algorithm, the reader is referred to Brown, (1991). This was done in a series of cooking trials using brown tiger prawns (*P. esculentus*) and results in a formula of the form:

$$L = \log^{-1} [(T-T_{ref})/z]$$

This allows the effectiveness of a given heat process (lethal rate = L) using a given temperature T to be compared with that at a reference temperature T_{ref} using the thermal death time constant *z*.

So for example, for a reference temperature T_{ref} = 121.1^{o}C, and *z*=10C^{o}, L at T= 111.1^{o}C will be 0.1. This means for a process with *z*=10C^{o}, 1 minute exposure to 111.1^{o}C is as effective as 0.1 minutes at 121.11^{o}C.

In the first trials, the sensor in the clip was inserted into a prawn of median weight for the batch and normal thermocouples were also inserted into five other prawns. L values were calculated from when the internal temperature reached 60^{o}C. Samples were taken over the calculated L value range 1.2-1.8 and analysed for the normal chemical and physical parameters. A number of facts emerged:

- L values after cooling were higher than those immediately after cooking.

- There was no significant difference between L values calculated from head temperatures and body temperatures.
- There was no consistent trend for reduction in protease activity as L value was increased, possibly trends were obscured by variations in size and condition of the raw material. To improve this, the clip was inserted in the largest prawn in the batch in all subsequent trials.

In the next series of cooking trials, potentially damaging residual protease levels (> 50 units) underscored the importance of good grading and the need to have L values >1.5. There were no obvious effects on yield from overcooking, so a margin of overcooking may be advisable to allow for inconsistencies in grading. Even for milder conditions such as sub-boiling at 85ºC, there was no significant difference in the final L values calculated from the time of immersion or the time the temperature reached 60ºC.

This meant that the clip could be inserted in the largest prawn in the batch, cooking could be timed from the time of immersion, and no allowance need be made for conversion between head and body temperatures.

Objective 3
Evaluate alternative cooking, processing, and handling conditions for prawns.

Yield, or the potential loss of weight in the cooked product is a significant issue to prawn processors. In discussions with one major processor of wild prawns, one strategy proposed that we investigate simmering the prawns at sub-boiling temperatures to increase yield. While longer cooking times may be required, the presumed benefit was that adverse weight loss and textural changes would not occur. A number of sub-boiling cooking trials were conducted using the cooking meter on a range of prawn species.

The target temperature chosen was 85ºC, remembering that it was earlier found that prawn proteases must be heated above 80ºC for 2 minutes to deactivate them. Even so, the prawns did not heat up fast enough to denature the key enzymes when simmered in this manner, and the combined lower temperatures and lack of agitation proved ineffective. This is not to say that simmering cannot be applied to prawns, but that the method should be approached with caution. Further investigation of sub-boil cook temperatures of approximately 90°C to 95°C may be warranted.

A simmering water temperature of 85°C, while above the 80ºC target temperature, recommended earlier, did not prevent autolysis and/or melanosis in the cooked prawns. When the prawns were placed into the sub-boiling water, the initial temperature increase was not as fast as in boiling water, and the product was subjected to lower temperatures (between 40° C to 60° C) for longer at the beginning of the cooking period. Obviously, up to a point, enzyme activity increases with rising temperature. This may encourage the conversion of precursors into active enzymes, hence increasing the activity levels recorded after the cook. It may also promote the development of melanosis. In the sub-boiling conditions, there is no natural agitation of the product from movement of the cooker water, which leads to a slower rate of heat transfer to the bulk of the prawns.

There was no melanosis recorded for the tiger and king prawns from the sub-boil cooks whereas the endeavour prawns showed increasing melanosis over the four days of chilled in ice storage in ice. Simmered banana prawns developed melanosis during post-cook storage in ice.

The quality of all species of sub-boiled prawns was lower than boiled prawns of the same species by day four of chilled storage. This was noticeable for the head and gill demerit scores of the tiger and king prawns, indicating the protease remaining after the cook was causing loosening of the heads. The post cooking yields for sub-boiled prawns were slightly higher than the boiled prawns, although this difference between the cooking methods was not maintained over four days of chilled storage as the post storage weights of all of the samples increased, possibly due to absorption of drip water from the ice.

Comparison of sensory ratings of the simmered and boiled prawns showed that trained seafood tasters were not able to discern differences between the cooking treatments. When the products were directly compared using a triangle test, only the endeavour prawns showed treatment differences. These prawns were described as having a strong flavour taint, which was more apparent in the boiled samples. The taster comments showed that both the boiled and sub-boiled endeavour prawns had a strong iodine / chemical flavour.

The king prawns simmered to an L value of 1.7 had no residual protease activity, and the temperature records from this cooking showed that the core temperature of the product reached over 90^{o}C during the cook.

O b j e c t i v e 4
Build 10 prototypes of the device

Ten meters were built and distributed for commercial evaluation. A draft best practice manual has also been written (Appendix 3).

Table 1. Commercial trials of the prawn cooking meter.

Establishment	Location	Species	Comments
Seafarms Pty Ltd	Cardwell, QLD	Banana	Comments indicate that it is felt the clip would slow the cooking operation. It was felt that this could diminish as practice is gained. The biggest benefit of the meter was felt to be the definable cooking times for AQIS. The process manager was happy with the appearance of the product that was cooked using the meter.
M.G Kailis	Learmonth, W.A	Western King Prawns Endeavour Prawns Grooved Tiger Prawns	The prawn cooking meter was believed to offer better control over the cooking operation and confidence by staff, management and AQIS of cooked quality. The meter and clip were thought to be easy to use but the buttons were awkward when wearing gloves. The processing manager believed the product cooked with the meter had improved taste and texture.
Gold Coast Marine Hatcheries	Woongoolba, QLD	Black Tiger Prawns	The meter and clip have been used on the premises before commercial trials. Cooking staff believe the meter and clip appear easy to use and that the meter will have benefits in producing standard cooked quality.
Clarence River Fisherman's CO-OP	Iluka N.S.W	Eastern King Prawns	As catches were significantly lower than usual, a minimum number of cooks were performed. Commercial and meter cooks were monitored. No residual protease was recorded in either sample.
Great Barrier Reef Tuna	Cairns QLD	Black Tiger Prawns	Commercial cooks were significantly variable in time and L value from meters. Cooking techniques (non boil) used at this establishment may have interfered with the effectiveness of the cooking meter. Due to proximity to end of season, meter was not left for appraisal.
SeaRanch Mossman Mill	Mossman QLD	Black Tiger Prawns	The processing manager at SeaRanch felt the prawn thermocouple and clip needed practice to perfect the use of. The prawn-cooking meter was believed to assist with the development of HACCP plans for the factory. The greatest benefit of the meter was felt to be the objective, scientific basis to indicate when the prawns were cooked, which would reduce variability in final product when different operators were cooking the prawns.

Table 1 summarises the results of evaluation by the companies who tried out the meter. In general, the operators found that using the meter to regulate cooking times resulted in products that were at least as good, and in many cases superior to their normal commercial practice. The clip used to position the sensor did, however present some problems and one operator found that the meter itself was difficult to operate while wearing gloves. It should be remembered however that this was a prototype and these problems will be rectified by the manufacturer in the commercial unit.

We have had numerous enquiries about when a commercial unit will be available, which indicates that there is a real need for the instrument. Discussions with industry suggest that rather than using the meter on every cook, they would use it to characterise their cooker performance

Objective 5
Extend the results to industry through workshops, publications and the media

There has been considerable stakeholder involvement throughout this project. A steering committee provided valuable input and data collection and evaluation were done in commercial plants.

Once the final design and prototype construction was completed, a very extensive program of dissemination was put in place.

The meter was officially launched by the Queensland Minister for Primary Industries, Mr Henry Palaszczuk at Parliament House in Brisbane. This resulted in intense media interest viz.

Newspaper articles

- The Australian
- Regional Queensland Press
- The London Times

Radio Interviews

- *3AW Morning Show*
- *Radio Newcastle*
- *Radio National Innovation Hour*
- *The Country Hour*

Television

- *ABC Nightly News*

This media coverage set the scene for more targeted extension activities. There are two "products" to be marketed from this project, the theoretical concept, and the meter itself. Whilst it may be possible for the operator to use the meter, by slavishly following the instructions, maximum benefits will accrue if the meter is included in a fuller Quality Assurance program, and that requires understanding of the concepts.

The best way to "sell" the package is through hands on experience. The meter was demonstrated to an appreciative audience at the exhibition that accompanies the annual convention of the Australian Institute of Food Science and Technology. It was also demonstrated to the conference of the Australian Prawn Farmers Association in Cairns where it excited the interest not only of the delegates but also the caterers.

With the cooperation of the Bribie Island Aquaculture Research Centre, The Queensland Seafood Industry Association, and APFA, several workshops were organised in regional areas. Notification was sent to each prawn farm and secretaries of the trawl committees in Queensland. Meters were set up in a plant, and operators from the surrounding area were invited to attend. At these workshops technical details were kept to a minimum and the emphasis was on hands on experience. A discussion was then conducted on how the meter might be incorporated into quality assurance systems. Participants were encouraged to direct the discussion to their own situation.

Once the 10 prototypes were available, CFT staff took them to commercial plants and trained operators in their use. These are currently in use, providing a period of extensive evaluation.

Objective 6

Optional. To further develop the end point cooking device for two other crustacean species with methods subject to the outcomes of the first two objectives.

The experimental work done in Objective 1 laid out the methodology and equipment necessary to develop the instrument. This methodology has now been extended to four other species:

- redclaw *Cherax quadricarinatus*
- yabbies *Cherax tenuimanus*
- western rock lobsters *Panulirus cygnus* and
- sand crabs *Portunus pelagicus*

The model works for all four species, provided the unique coefficients derived from the deactivation curves for each species are used in the algorithm. The final design for the meter incorporates a facility for resetting the algorithm, so the same meter can be used with several different crustacean species.

The centring clip used to position the temperature probe is suitable for small crustaceans such as prawns, yabbies scampi and redclaw, but for larger animals with tougher shells such as lobsters and sand crabs, a different, purpose built clip should be designed.

BENEFITS:

The outcomes of this project directly benefit prawn farmers and fishers, the processing, wholesale and retail sectors of the industry and the end consumer. How often do we hear complaints about mushy prawns, loose heads, off smells?

Whether prawns are cooked on the vessel, in factories or on the farms, problems related to quality, appearance, weight loss, excessive saltiness, toughness and blackening frequently surface further along the distribution chain. This results in returns, disputes, financial loss and dissatisfaction. At $16/kg, rejection of 100kg of product could cost $1,600 directly, and much more in loss of goodwill. The price of a cooking meter is minimal in comparison!

Accurate process control is the outstanding benefit that will result from use of this meter. An accurate, unambiguous signal that the end point of the cooking process has been reached will assure consistently good quality and reduce wastage and financial losses right along the distribution chain.

The principle behind the meter applies to other crustaceans. Already progress has been made here with freshwater crayfish, and further development will see the device used in factories cooking other commercially significant crustacean species such as rock lobsters and crabs.

A note of caution is in order. The meter is a tool that looks at one critical step in the process. For maximum benefit, its use must be built into a quality assurance program. The prawns must still be packaged, stored and transported properly before and after cooking, or spoilage

will still occur. If careful attention is paid to quality at every step, the whole chain, fishers, farmers, processors, retailers and consumers will benefit.

FURTHER DEVELOPMENT:

Intellectual property is obviously of prime importance to this project. It is expected that negotiations will soon be completed on manufacture and commercialisation of the meters. Hopefully this will see them become widely available for sale to seafood processors. The successful manufacturing company would also be a likely partner in any further application of the device in other crustacean fisheries.

The preliminary work on other crustacean species in this project has paved the way for further development of the device for cooking lobsters and crabs. For example, the recently funded FRDC project “Striking A Balance Between Melanosis and Weight Recovery In Western Rock Lobsters” has identified prevention of black spot development as a significant issue for the western rock lobster industry.

A cooking meter for lobsters is an ideal vehicle for applying the findings of that project. Suitably programmed, the electronic meter has the potential to minimise losses due to under-cooking and inadequate deactivation of significant enzymes in lobsters and crabs, and to prevent over-cooking and subsequent weight loss from occurring.

To do this requires a practical method of reproducibly locating a sensor in the thermal centre of large crustaceans during cooking. A suitable temperature sensor for large lobsters and crabs would be very different to the clip that has been developed here for prawns. There are several issues that make its design entirely different such as carapace thickness, animal size etc and different designs will need to be tested before a robust "fool-proof" one is found and wider scale testing with lobsters and crabs begins. A stainless steel prawn-style clip for lobsters would be similar in dimensions to the biggest lobster cooked and much too awkward to use. A whole new design concept is needed.

The output from the meter at present merely activates an alarm. It could equally be used as a controller in an automated process. It might for example, turn off a cooker and activate a crane, lifting the basket out of the cooker and depositing it in an ice slurry. There is no reason why algorithms could not be developed for other food processing operations such as the steam blanching of vegetables.

PLANNED OUTCOMES:

This has been an extremely successful project in meeting its objectives, and has been warmly welcomed by the industry. It has applied good science and technology to a pressing industry problem, and come up with a practical solution. The commercialisation of the instrument is the next logical step to complete the process.

The demonstration that time and temperature can be quantifiably integrated by a single instrument and the results applied directly to prevent a series of significant biochemical spoilage processes has encouraged a renewed interest by the industry in evaluating their current processing practices.

Repeated inquiries from within Australia and overseas indicates that there will be a strong worldwide demand for meters.

CONCLUSIONS:

Objective 1

To develop a device which will determine the end-point of cooking for crustaceans by:

- *developing a durable sensor for measuring the thermal centre of the crustacean*
- *determining crustacean protease deactivation temperature curves.*

Inactivation curves have been determined for key enzymes that cause deterioration in a range of prawn species. This data has been programmed into an electronic meter. A robust clip has been developed to hold a durable temperature sensor in the thermal centre of a representative prawn during the cooking process. The instrument transmits a signal when an adequate cooking process has been achieved.

Objective 2

To confirm that the endpoint for cooking is determined by protease deactivation by:

- *confirmation trials of several species, sizes and cooking rates*
- *determining the effects on possible melanosis development, sensory and textural quality and yields against a chosen reference such as farmed prawns.*

The efficacy of using the meter to control the cooking process has been confirmed using a range of sizes and species of prawns.

Objective 3

Evaluate alternative cooking, processing and handling conditions for prawns.

Control by the meter has been benchmarked against several other commonly used control indicators and has proven more reliable in ensuring deactivation of the key enzyme systems. For example, applying the algorithm derived from deactivation studies shows the simmering systems used by industry are inadequate to deactivate proteolytic enzymes, higher temperatures need to be used.

Objective 4

Build 10 prototypes of the device for industry to trial.

Ten prototype meters have been built and distributed for evaluation by producers in Queensland, New South Wales and Western Australia. They have proven extremely popular with the participants.

Objective 5

Extend results to industry through workshops, publications and the media.

A comprehensive extension program has been undertaken. First recipients of the results were those companies that participated directly in the project. Workshops were then run to reach a wider audience. The project attracted wide media interest, and TV spots and photo opportunities were staged, even to the extent of featuring the Minister for Primary Industries. QDPI and FRDC have signed a letter agreement with Seafood Innovations to investigate the feasibility of incorporating a new clip design with the prawn-cooking meter. If the feasibility is positive, Seafood Innovations Ltd will enter into a formal commercialization and licensing agreement with QDPI and FRDC. The outcome of the feasibility should complete before June 2004.

Objective 6

Optional: To further develop the cooking end point device for two other crustacean species with methods subject to the outcomes of the first two objectives.

The experimental approach and the concepts developed from the prawn studies were successfully applied to four other crustacean species, two fresh water, and two marine.

There is no reason to suppose that it could not be used in cooking other crustaceans such as bugs, scampi, and other species of lobsters and crabs. The final meter design makes provision for resetting the algorithm for this purpose.

REFERENCES:

Brown, K. L. (1991)
Principles of heat preservation in *Processing and Packaging of Preserved Foods* p.1-14 Blackie, Glasgow & London.

Chinivasagam, H. N., Bremner, H.A., Thrower, S. J., & Nottingham, S.M. (1996)
Spoilage pattern of five species of Australian prawns: deterioration is influenced by environment of capture and mode of storage. J. Aquatic Food Product Technol. **5** (1) :25-49

Jensen, S.E., Fecycz, I.T., Stemfeg, G.W., and Campbell, J.N. (1980)
Demonstration of a cell associated inactive precursor of an exocellular protease produced by *Pseudomonas aeruginosa*. Microbiology 26: 87-93.

Moller, A.J. (1980)
Analysis of Warner-Bratzler shear pattern with regard to myofibrillar and connective tissue components of tenderness. Meat Sci. 5:247-260.

APPENDIX 1 INTELLECTUAL PROPERTY

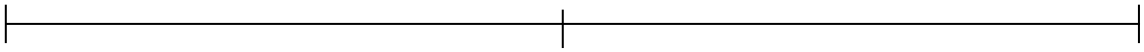
QDPI and FRDC have signed a letter agreement with Seafood Innovations Ltd to investigate the feasibility of incorporating a new clip design with the prawn-cooking meter. If the result is positive, Seafood Innovations Ltd will enter into a formal commercialization of the instrument and licensing agreement with QDPI and FRDC. The outcome of the feasibility study should be completed before June 2004.

APPENDIX 2. STAFF EMPLOYED ON THE PROJECT

Steven Slattery	Senior Seafood Technologist
Brian Paterson	Senior Research Scientist
Darren Leighton	Technical Engineering Officer
Jacqui Edwards	Research Scientist
Stephen Thrower	Principal Scientist

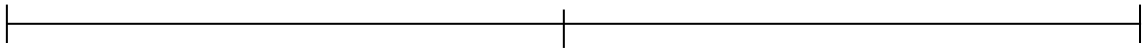
APPENDIX 3 EXAMPLES OF LINE SCALES USED IN THE QUESTIONNAIRE.

How much do you like or dislike the odour of sample 222?



Dislike extremely (0) | neither like nor dislike (50) | Like extremely (100)

How much fresh typical prawn flavour is there in sample 222?



None (0) | Strong (100)

NOTE: on all scales the consumers only see the verbal anchors and NOT the numerical values shown in brackets.

APPENDIX 4 EXAMPLE OF A DEMERIT POINT ASSESSMENT SHEET

Demerit Evaluation of Cooked Prawns

Cook _____

Storage _____

HEAD	Rating	Nº Affected
Firmly		
Slightly drooped or		
Loose / Membrane	3	
Very loose or		

MELANOSIS		
No		
Slight blackening of head or shell		
Head black / moderate blackening of tail	3	
Extensive blackening to head and tail	4	

GILLS		
Normal / No	1	
Gills visible / Slight grey	2	
Dark grey	3	
Severe blackening of	4	

HEPATOPANCREAS		
Not	1	
Slightly visible but complete / White to off white	2	
Visible /Slight greenish grey	3	
Distinctly visible / burst or ruptured / dark	4	

COMMENTS

TECHNICAL INSTRUCTIONS MANUAL

FOR

PRAWN COOKING METER

prepared for

THE FISHERIES RESEARCH & DEVELOPMENT CORPORATION

DPI QLD

1.0 PHYSICAL DESCRIPTION

On front of the meter there are 3 buttons:

ON/OFF
START
STOP/RESET

The meter can be either in normal mode or in setup mode.
These buttons have different actions in normal mode to setup mode.

Beside the buttons are 3 LED's.

ON	- power indicator
COOKING	- indicates meter is in a cooking cycle
OK	- indicates cooking cycle is completed

These LED's flash at approximately once per second, and if the COOKING or OK LED is on, then it will alternate with the power LED.
At the top of the meter is a 2 x 16 LCD display for messages.
In the top end of the meter are 2 connectors, one for the thermocouple probe, and one for external interfaces.
In the bottom end of the meter is a removable panel covering the battery holder.

2.0 MESSAGE DISPLAYs

The 2x16 LCD shows a range of messages, depending on the state the meter is in.

2.1 INTRODUCTION SCREEN

When the meter is first turned on the message:

```
FRD-C-FT Cooker
System/Probe OK
```

appears.
This message appears for approximately 3 seconds and then the screen goes to the resting state.

2.1 RESTING STATE SCREEN

The resting state screen shows:

```
TARGET L=2.10
Prawn -> Clip
```

The "TARGET L" is the user set value for the total calculated L's.

If the "START" button is pressed then the meter goes into cooking mode and the screen changes to the cooking cycle screen.

If the ON/OFF button is pressed then the meter will turn off.

The ON LED will flash.

2.3 COOKING CYCLE SCREEN

When the meter is in cooking mode the "COOKING" LED will flash, the “ON” LED will go off, and the screen will first show:

```
Clip -> Basket
Basket -> Cooker
```

This will stay on the screen until the probe temperature reaches 35 degrees.

Once these conditions have been met, then the cooking cycle screen will change to:

```
Cooking for 1:30
L=1.3400
```

where the amount of time the cooking cycle has been running for is shown and the running total of calculated values of "L" is shown and the current probe temperature is also shown.

Once the value of "F90" exceeds the set value of "L" then the cooking cycle is complete and the screen changes to the cooking completed screen, and the "COOKING" and “OK” LEDs goes alternate.

At any time the cooking cycle can be terminated by pressing the "STOP/RESET" button.

The ON/OFF button is disabled in this mode.

2.4 COOKING COMPLETED SCREEN

Once the cooking cycle is completed the “COOKING” and "OK" LEDs alternate and the internal piezo sounder beeps approximately every 2 seconds. The screen also changes to:

```
COOKED 00:26 ago
L= 1.9212 T=85o
```

This indicates how long ago the cooking cycle completed in minutes and seconds and the current probe temperature, along with the calculated total value of L, the time taken to complete a cook and the current probe temperature.

An internal relay is activated to the closed position at this stage. If the external alarm is attached then it will be activated.

Pressing the “STOP/RESET” button turns off the internal relay and also the “COOKING” LED also stays off.

The meter will stay in the cooking completed mode until the "STOP/RESET" button has been pressed again.

The "ON/OFF" and "START" buttons are disabled in this mode.

2.5 LOW BATTERY INDICATOR

At any time if the battery voltage drops below approximately 2.6V then a "B" in the bottom right of the screen indicates that the batteries are getting flat and should be replaced.

```
Cooking: 01:30
F90 = 0.0234    B
```

2.6 PROBE DAMAGED / PROBE HEATING TOO FAST

If during the cooking cycle the probe is heated more than 45 ºC in 2 seconds then a “check probe” error is shown on the screen.

If the probe temperature reaches more than 104ºC (a broken probe simulates this condition) then the “check probe” error is also shown during a cook cycle.

The “check probe” error occurs only during the cook cycle and looks like:

```
Cooking for 0:15
n.b. Check Probe
```

2.7 SETUP SCREENS

The following are the screens in setup mode:

```
SETUP
F90:1.7
```

user selectable total of calculated values of "L" - ranges from 1.7 - 2.5 in 0.1 steps

```
SETUP
Z = 17.0
```

user selectable value for "Z" in the DPI equation - ranges from 24.0 to 31.0 in 0.5 steps

```
SETUP
C 0oC: 1
```

probe calibration value at 0 degrees - ranges from 0 to 15

```
SETUP
C 100oC: 244
```

probe calibration value at 100 degrees – ranges from 235 to 244

```
SETUP
Calibrate?
```

allows user to enter the calibration mode - see calibration section.

3.0 NORMAL MODE

The normal operating mode is where the meter is monitoring a cooking cycle. in this mode the buttons do the following:

3.1 ON/OFF BUTTON

RESTING MODE: Turns meter off
COOKING MODE: Disabled
COMPLETED MODE: Disabled

3.2 START BUTTON

RESTING MODE: Starts cooking cycle (entry into setup)
COOKING MODE: Disabled
COMPLETED MODE: Disabled

3.3 STOP RESET BUTTON

RESTING MODE: Allows entry into setup mode
COOKING MODE: Stops cooking cycle
COMPLETED MODE: Exits completed mode

4.0 SETUP MODE

The user can enter the setup mode (5 x "STOP/RESET" + 1 x "START") and change the variables for the DPI equation.

To enter setup mode:

Go into RESTING MODE
Press "STOP/RESET" 5 times
Press "START" 1 time

The screen changes to the setup mode.

In this mode the buttons do the following:

4.1 ON/OFF BUTTON

Advances to the next changeable variable:

FINAL F90
Z VALUE
CALIBRATION AT 0 DEGREES
CALIBRATION AT 100 DEGREES
CHANGE FROM CALIBRATE AT 0 DEGREES TO 100 DEGREES

4.2 START BUTTON

The "START" button increases the variables by the following

F90	by	+ 0.1
Z	by	+ 0.5
Cal 0 degrees	by	+ 1
Cal 100 deg	by	+ 1

If the screen is showing:

```
SETUP
Calibrate?
```

pressing the "START" button takes the meter into calibration mode.

4.3 STOP RESET BUTTON

The "STOP/RESET" button decreases the variables by the following

F90	by	- 0.1
Z	by	- 0.5
Cal 0 degrees	by	- 1
Cal 100 deg	by	- 1

4.4 CALIBRATING THE TEMPERATURE PROBE

Once the calibration mode has been entered (5 x "STOP/RESET" + 1 x "START", then advance to "Calibrate" then press "START") the first screen will look like:

```
SETUP
0oC-R:70
```

(n.b. example while at room temp)

Place the probe in an ice slurry at 0 degrees and the raw value should settle at around 1 once the probe has finished cooling.

Pressing "ON/OFF" changes the screen to:

```
SETUP
100oC-R:1
```

(n.b. example while still in ice)

Now put the probe in boiling water (100 degrees) and the raw value should settle at around 244.

Pressing "ON/OFF" now saves all of the variables and calibration settings.

5 EXTERNAL CONNECTORS

5.1 PROBE CONNECTOR

The probe goes into the meter via the 3 pin connector.
The pin assignments are as follows:

1 - probe positive
2 - probe negative
3 - not used

5.2 EXTERNAL INTERFACE CONNECTOR

The external interface connector is the 8 way connector at the top of the meter.
The pin assignments are as follows:

1. 0V
2. regulated 5V
3. relay normall open
4. not used
5. relay common
6. reserved
7. reserved
8. not used.

N.B. if an external 5V is being used it must be regulated to +/- 0.5VDC @ 100mA. If the voltage falls out of this range then the internal relay may be damaged.
The external 5V is not a battery charger, but it can be used instead of the internal battery.

N.B. If the internal relay is being used then it can only be used to switch up to 24V at 100mA. i.e to switch high current loads this relay must be used to switch a high current relay.

6.0 BATTERY HOLDER

The batteries to run the meter are 2xAA Alkaline batteries.
The batteries must be Alkaline or the meter life will be severely diminished.

The battery holder is under the cover at the bottom of the meter. To remove the cover press the two clips - located at the bottom sides of the case- inwards. the cover should then pop off revealing the black battery holder (small lid to unclip to reveal the batteries)

When the battery holder cover is removed, care should be taken not to damage the rubber seal, as this will compromise the IP65 rating on the case.

APPENDIX 6 WORKSHOPS AND OTHER EXTENSION ACTIVITIES

QLD and NSW Prawn Cooking Workshops

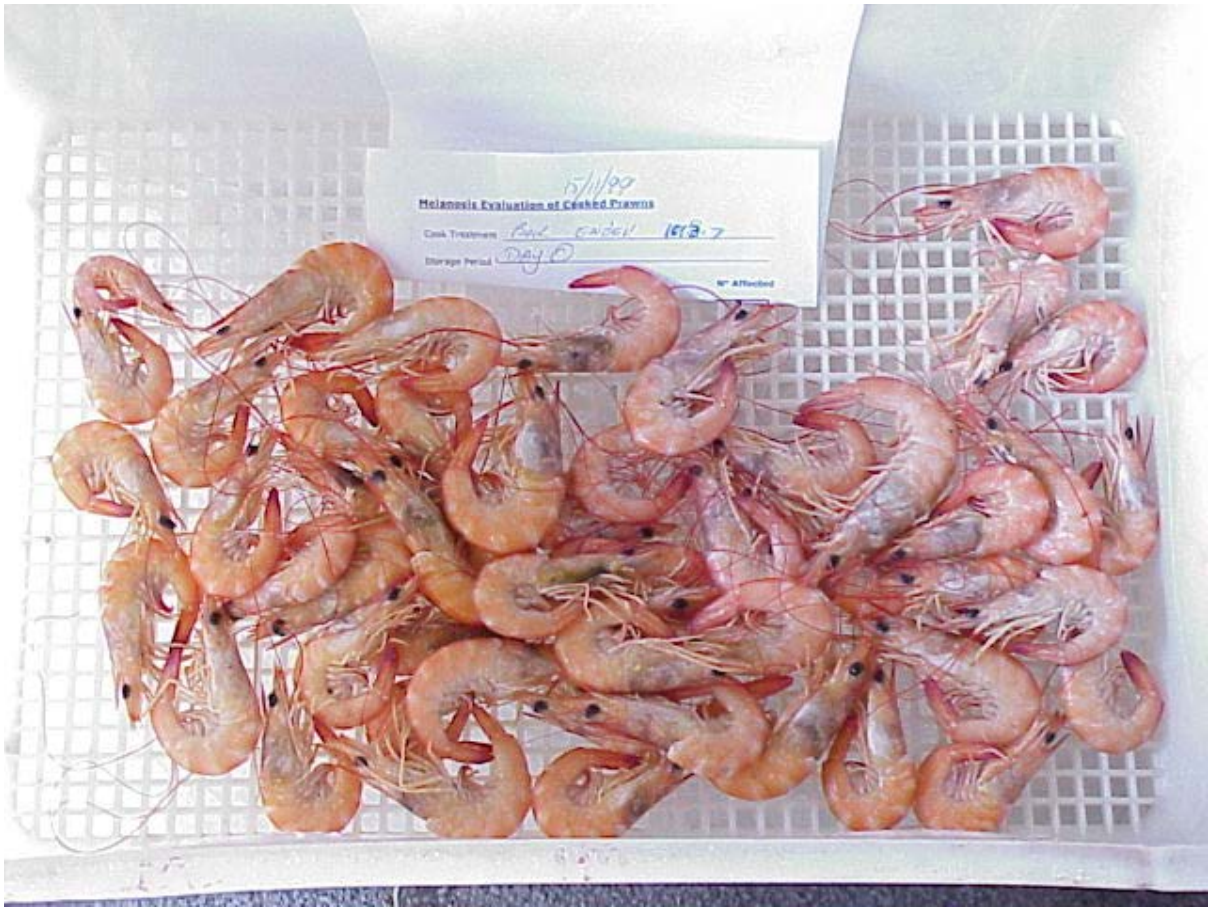
"USING THE PRAWN COOKING METER"

HELD AT AMAGRAZE CONFERENCE ROOM, CENTRE FOR FOOD TECHNOLOGY, 19 HERCULES STREET, HAMILTON Q 4007, 9:00 - 2:00 PM, WEDNESDAY, JUNE 20TH, 2001

Attendees
Gold Coast Marine Hatcheries
Trulove prawn farm

Qld Prawn Farm	Bundaberg Qld 4670
Tru Blu Prawn Farm	Palmers Island NSW 2463
Fortune	Yamba NSW 2464
Croxway Pty Ltd	Robertson Qld 4109
NCQ Seafood Pty Ltd	Ballina NSW 2478
Searle Aquaculture	Palmers Island NSW 2463
Ausfarm	Carlton NSW 2218

Workshop held to coincide with APFA meeting August 2001 Cairns



Prawns cooked by the prawn cooking device being stored for visual evaluation

Demonstration of prawn cooking device at APFA conference.

Prawns with thermocouples attached being cooked by boiling in a commercial prawn cooker.

A boiled southern rock lobster cooked using the cooking device formula.