Developing large rocklobsters, *Jasus edwardsii*, as a premium value-added product: Key sensory and biochemical characteristics of the flesh.

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ABSTRACT

The Southern Rocklobster, *Jasus edwardsii*, supports a commercial fishing industry worth $180 million AUD per annum, the majority of which is exported live to Asia. The current market demands for smaller rocklobsters can sometimes result in discounting of the larger individuals, a significant financial loss for the industry. Value adding of large rocklobster into processed product may help combat this loss; however, there is financial risk associated with the development of new products for new markets without first understanding the product variability. The aims of this thesis were to quantify raw product flesh characteristics using physical, biochemical and sensory approaches, determining the extent of variation in those characteristics, and finally to investigate the potential biological and post-harvest sources of that variation.

One of the initial requirements was the establishment of previously undefined key descriptors of sensory properties for raw rocklobster flesh, which were texture (chewiness and crunch), flavour (metallic, lobster and sweetness) and appearance (pinkness and translucency) (Chapter 2). These were tested using a combination of triangle tests and a hybrid descriptive test using a trained sensory panel. The trained panel found no significant difference in the texture, flavour or appearance of raw flesh between large and small rocklobster (Chapter 4). However, differences in the sensory descriptors of flesh translucency, pinkness and lobster flavour were significantly influenced by frozen storage of the product and the section of tail from which a sample was sourced (Chapter 4). Biochemically, these differences were largely associated with

variation in flesh adenylates, with AEC, IMP load, total adenylate pool and K value being identified as the key contributors.

Of all the potential sources contributing to variation in flesh biochemical properties, post-harvest factors such as 'batch' (i.e. rocklobsters processed on a single day) had a dominant influence (Chapter 3). The difference detected in flesh characteristics between batches was greater than any seasonal pattern such as moult stage. Biological variables such as rocklobster condition and shell colour had no significant influence on flesh properties (Chapters 3 & 4). White rocklobsters are currently discounted in the live export trade; however this does not appear to be necessary for value added product owing to the lack of significant differences to red rocklobsters across a range of biochemical parameters (Chapter 3). Rocklobster physical condition (which has previously been associated with prior stress) was not shown to affect flesh biochemistry or sensory properties (Chapter 4). This result was not expected and may reflect the potential recovery of rocklobsters sampled in this study prior to processing. These findings suggest that commercial rocklobsters, which have had similar recovery, are unlikely to show reduced sensory properties.

Recent commercial interest has focussed on holding rocklobster in tanks to provide year-round supply. As a result, the impacts of tank-holding and feeding on rocklobster flesh sensory properties were investigated (Chapter 5). Rocklobsters that were tank-held and fed for up to four months produced flesh with similar physical, biochemical and sensory properties to freshly caught rocklobster. Tank-holding therefore offers a viable solution

to operators wanting a year-round supply of fresh product from a resource which is subjected to a restricted fishing season.

A Japanese consumer panel was established to assess the greatest differences in flesh properties as detected by the trained sensory panel. The Japanese consumer panel assessed raw flesh from fresh, short and long-term frozen storage treatments (Chapter 4). This consumer panel detected similar differences in taste, texture and flavour as the trained panel, and whilst no significant overall preference was detected, half of the panellists showed a preference for rocklobster product that had been stored frozen for 18 months.

The findings from this research are useful for the commercial industry as they indicate that raw rocklobster flesh has little variation associated with discounting factors such as size and shell colour. Although the greatest variation in flesh biochemistry was seen with frozen storage, even long term storage produced rocklobster flesh properties which were favourable for some panellists. The commercially caught Southern Rocklobster appears to have raw flesh properties well suited for a value added product.

DECLARATION

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Michael Roberts

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CHAPTER ONE

General Introduction

The Southern Rocklobster, *Jasus edwardsii* supports a fishing industry in Australia with a net annual value of ~ $180m (Australian Southern Rocklobster Limited 2006). Almost 95% of the fishery's export is the live trade of whole rocklobsters. Large rocklobsters (above 1.5 kg) comprise approximately ~17% of the commercial fishery (calculated from Prescott et al. (1997)), and are often discounted by approximately $6 per kilogram to sell through the live trade market to Asia (Ferguson. A, *pers. comm.*). This discounting, below the price paid per kg for small rocklobster, equates to $4.9 million AUD lost annually for the combined fisheries of South Australia, Tasmania and Victoria. A new market direction of processed portions (value-adding) of large rocklobster may offer a solution to combat the required discounting. For value-adding of large rocklobster to be successful, there is a need to quantify any perceived variation in the flesh characteristics of the portioned product. The aims of this thesis were to quantifying product flesh characteristics using physical, biochemical and sensory approaches, determining the extent of variation in those characteristics, and finally to investigate the potential sources of that variation.

Biochemical indicators of flesh characteristics

Biochemical properties of flesh are routinely used to monitor changes in flesh characteristics associated with rigor mortis and tissue degradation during storage (Bremner 2003). Muscle nucleotides are of particular interest, as they have been associated with describing changes in rocklobster flesh characteristics post-mortem (Yamanaka and Shimada 1996). It was shown that with storage time, adenosine triphosphate (ATP) broke down into adenosine diphosphate (ADP), and then adenosine monophosphate (AMP). The further breakdown results in the production of inosine monophosphate (IMP), inosine and hypoxanthine, which are used to calculate a ratio called K value (Valle *et al.* 1996).

Yamanaka and Shimada (1996) identified K value as a useful indicator of freshness in rocklobster flesh.

Although this research will mainly focus on fresh product as appose to stored, it is important to establish the levels of ATP and related adenylate compounds, as these can vary in fresh rocklobster tissue and have been shown to change with prior stress (Speed *et al.* 2001). Specifically, abdominal muscle was sensitive to periods of emersion resulting in increased levels of muscle metabolites (lactate, glucose, ADP and AMP). There was also a difference between captive and wild rocklobster (muscle lactate and Arginine phosphate levels) possibly indicating energy usage related to stress in captive rocklobster.

Importantly, in addition to possible differences between wild and captive rocklobsters the variation within the wild populations remains unquantified. Flesh glycogen, moisture content and percent lipid have been used to characterise the nutritional condition of *J. edwardsii* from known areas of high and low shell growth (Musgrove 2001) and with the affects of starvation (McLeod *et al.* 2004). It is not known at what levels changes in these properties result in significant changes in sensory properties.

Sensory analysis

Recent rocklobster postharvest research has used flesh biochemical properties to investigate improved methods of post-harvest handling (Morris and Oliver 1999; Paterson *et al.* 2001; Paterson *et al.* 1997; Paterson *et al.* 2005). Changes in biochemical flesh properties are likely to be important for sensory characteristics of crustaceans. For example, Glutamic acid shows a synergistic effect with IMP or AMP

(as cited by Yamanaka and Shimada (1996)) to generate "umami" (a taste sensation of high importance to the Japanese consumer). In addition, Bremner (1988a) tested the sensory properties of Scampi, *Metanephrops* spp., with changes in adenylate flesh compounds and found that sensory panel acceptability did not significantly change over 8 days storage at 4°C. Despite significant nucleotide degradation with eight days storage, it was concluded that the strong positive scampi flavour was possibly enhanced by high flesh IMP levels. In addition, the flesh most likely had insufficient hypoxanthine to detract from overall acceptability.

Only 9 studies since 1978 have investigated both biochemical flesh properties and sensory characteristics for crustaceans (Table 1.1). With the exception of Bremner & Vieth (1980) and Bremner (1988b) who found no difference in sensory acceptability with frozen storage of rocklobster and scampi respectively, most of these studies have documented a loss of sensory acceptability with storage. In particular, ice-stored Scampi lost flavour acceptability after 13 days storage, which coincided with an increase in pH above 7.5 (Bremner 1985). Decreased sensory perception of odour and appearance has also been correlated with specific species of bacteria and conditions where they were linked to adverse odour characteristics of the tropical prawn (Chinivasagam *et al.* 1998). Zeng (2005) has since established correlations with decreased sensory perception of odour and appearance with total viable microbial counts, total volatile basic nitrogen, trimethylamine, and electronic nose results.

With the exception of Nelson *et al.* (2005), all previous studies have focussed on storage effects post processing. Nelson found no significant sensory differences between wild and cultured rocklobster, however, pre-processing practices may alter sensory properties. For example, stress prior to processing

alters adenylate level degradation responses with subsequent storage of finfish flesh (Thomas *et al.* 1999). Similarly in rocklobster, ATP,ADP and AEC have been shown to change in rocklobster flesh according to post harvest processes (Tod and Spanoghe 1997). Adenylates are reported to influence sensory properties of crustacea, for example, Scampi frozen stored for 12 months had less flavour, poorer texture and less overall acceptability than those stored 1-6 months. This corresponded with a decrease in total nucleotide pool after 6 months, characterised by IMP decrease and K value increase (Bremner 1988b). A similar increase in K-value and changes in IMP have been recorded for rocklobster flesh, although not in conjunction with sensory analysis (Yamanaka and Shimada 1996). It is therefore important to establish the link between adenylate levels experienced in rocklobster flesh with current commercial post-harvest practices and possible influences on the sensory properties of the flesh.

While the measurement of lobster biochemistry is important for detecting physiological changes in rocklobsters, evaluation of the processed product will ultimately depend on the sensory perception of the consumer market. Sensory perception of a product is based on a combination of flavour, texture, smell and conditioning. These perceptions are highly variable depending on individual taster's sensory sensitivity and personal preferences. So, the sensory properties of any product are dependent on both the product characteristics and the sensitivity and preferences of the taster. For this reason, sensory analysis is divided into two distinct methods. These are; (a) Descriptive Analysis, which focuses on sensory properties of the product in question; and (b) Consumer Analysis, which focuses on evaluating consumer responses to the product in question (Lawless and Heymann 1999). Consumer analysis is useful for locating or targeting a particular market demographic for a product. These analyses usually entail a simple survey, asking for a preference between samples, to identify the sensory properties the

taster liked and disliked. In contrast, a descriptive panel is often used to characterise a product based on sensory descriptive properties (Lawless and Heymann 1999). In essence a consumer panel gathers information mostly about the consumer preference, whereas the descriptive panel is focussed on the sample's properties. The descriptive panels are trained to use specific scales and compare two samples using a pre-determined set of indicators. Results obtained in descriptive panels are repeatable using other sufficiently trained panels and as such form a useful first step in finding differences for subsequent consumer panels to asses particular markets. Consumer tests, in contrast, are only relevant to the groups the panel represent.

Training a descriptive panel involves panellists learning to recognise specific intensities of a known standard for each sensory descriptor (e.g. lobster flavour). However, in the case of rocklobster, there are no samples known to differ in sensory description and therefore no standard product with which to train a panel.

Table 1.1 Summary of published literature on crustaceans combining biochemistry and sensory analysis of the flesh.

Reference	**Species**	**Treatment comparisons**	**Biochemistry**	**Cooked v Raw flesh**	**Panel composition**	**Sensory analysis used**
Bremner & Vieth (1980)	*Jasus edwardsii (previously called J. novaehollandiae)*	Live tailing v tailing after slush ice storage 1-48hrs, up to 40 weeks frozen storage.	Flesh pH, protein, potassium, driploss	cooked	18 Familiarity trials ran.	9 point Hedonic scale, colour, aroma, lobster flavour, off flavour, toughness, moisture, acceptibility
Bremner (1985)	Scampi: *Metanephrops andamanicus*	Storage of 17 days on ice	Flesh pH	cooked	12 untrained	Hedonic scales mandatory and free choice descriptive, Odour & Flavour
Bremner (1988b)	Scampi (Genus *Metanephrops): M. andamanicus, M. boschmai, M.australiensis*	Frozen storage (2, 6, 12mo) Whole scampi & tail section	Protein, wet weight, nucleotides	cooked	9 -16 untrained	Free choice hedonic scale, odour and flavour profiles
Bremner (1988a)	Scampi (Genus *Metanephrops): M. andamanicus,M. boschmai, M.australiensis*	Chilled storage (0, 4 & 8 days 4°C) Tail flesh	Protein, wet weight, nucleotides	cooked	16 untrained	Free choice hedonic scale, odour and flavour profiles

Yamanaka & Shimada (1996)	Japanese Spiny Lobster, *Panilurus japonicus*	Storage (0°C, 5°C, 20°C)	Nucleotides, amino acids	raw	15 panellists	Hedonic odour categories based on acceptable initial decomposition and advanced decomposition
Chini Vasagam et al (1998)	Tropical prawn, (Genus: *Penaeus): P. plebejus, P. erguiensis, P. esculentus/ semisulcatus, Metapenaeus bennettae*	Storage ice or ice slurry. 2 and 8 days.	Headspace volatiles.	raw	1 (experienced)	Hedonic odour categories for intensity for sulphidity and fruity.
Zeng *et al.* (2005)	Shrimp, *Pandalus borealis*	Storage, ice treatments	Proximate analysis, pH, water holding capacity, Total volatile basic nitrogen and trimethylamine	raw	6-9 trained	Appearance and smell combined in acceptability hedonic scale.
Nelson *et al.* (2005)	*Jasus edwardsii*	Tank-held (wet and dry feed) v wild caught	Fatty acids, Lipid	cooked	14 panellists (untrained)	Triangle tests
Roberts (2009), this study.	*Jasus edwardsii*	Tail section, rocklobster size, prior stress, frozen storage (times), tank-held v. wild caught.	Nucleotides, lipid content, moisture content, glycogen, lactate	raw	15-17 panellists trained and 16 consumer	Triangle test, descriptive hybrid test, hedonic preference (choice) test

The sensory attributes of rocklobster have not been defined. This presents some difficulty for the valid use of sensory analysis for this research. It is sometimes possible to train a panel on products other than those being tested, called reference samples (Lawless and Heymann 1999). For example, training a panel on the intensity of "crunch" may utilize a product such as celery as an end-point. However, the limitation of such training is the assumption that the variation in "crunch" within rocklobster flesh would rate on a scale that utilizes celery as an 'end point'. Determining an end point for a descriptive property, without knowing the variation within the product to be tested, may ultimately limit the panel's ability to detect a difference. Despite these recognized limitations, I have adapted sensory analysis methods (detailed in Chapter 2) to meet the need of investigating the variation in flesh characteristics that may be associated with production of a value-added product.

Rocklobster postharvest processing

Prior to the establishment of live trade, the global rocklobster industry was almost exclusively the export of frozen rocklobster tails (Montgomery and Sidhu 1972). The sensory properties of these products were studied and focused on the degradation of a frozen stored product, with limited research in Australia (*J. edwardsii:* formerly *J. novae-hollandiae:* Bremner and Veith 1980; Sidhu et al. 1974) and more extensively in South Africa (South coast Rocklobster *Panulirus gilchristi:* Coetzee and Simmonds 1988; Matta 1992; Nachenius et al. 1978; Wessels and Rudd 1976; Wessels et al. 1979). The latter work was key in establishing a reduction in rocklobster flavour with frozen storage (Matta 1992; Simmonds *et al.* 1992; Wessels *et al.* 1979). However the product

was always cooked. The cooking regime substantially changes flesh characteristics of rocklobster flesh, where over cooking was shown to relate to moisture loss (Coetzee and Simmonds 1988) and affect flesh texture "softness" (Simmonds *et al.* 1992).

Since the transition from tailing to live rocklobster export, very little research on sensory properties has occurred, with the exception of Norwegian trawled lobster species, *Nephrops norvegicus* (Gomez-Guillen *et al.* 2007; Lopez-Caballero *et al.* 2006). These papers assessed the ice-chilled storage life of raw flesh following different treatments, aimed at reducing melanosis. As a result, sensory analysis focused on the visual appearance and odour of flesh samples and did not assess flavour (Gomez-Guillen *et al.* 2007). These properties were rated to a scale based on 5 (very fresh) to 0 (very spoiled) and are not able to provide descriptive properties of raw crustacean flesh or the effects of ice chilled storage on flavour.

Factors affecting rocklobster flesh characteristics

There are a large number of potential sources of variation in flesh characteristics and ultimately sensory properties of fresh flesh. These can be categorised as either (a) biological (e.g. size or moult stage of rocklobster) or (b) post-harvest (e.g. stress, handling, storage and commercial diet). Biological variation is known to influence finfish flesh, where Atlantic salmon fillet fat content increased 12-13% during specific months (Morkore and Rorvik 2001). This may also be the case for rocklobster, as research shows that moult stage, which is seasonal in large rocklobster Ziegler et al. (2004), directly relates to flesh characteristics of Crustacea. Musgrove (2001) showed that the moisture content of rocklobster tail flesh decreases as moult stage progresses.

Further, supporting a possible interaction of moult stage with flesh properties, Wang et al. (2003) noted adenylate energy charge ratios change through moult stages of fresh water prawn *Macrobrachium nipponense*. It was thought that the adenylate ratio AEC may be a direct indicator of energy metabolic activity during the moult cycle (Wang *et al.* 2003). The adenylate energy values of Atlantic Salmon have also been shown to change with post-harvest stress (Thomas *et al.* 1999).

Stress events are measureable for rocklobster (Paterson and Spanoghe 1997). For example, stress is reflected with changes in haemolymph properties (Roberts 2001; Spanoghe 1996). Prior stress of rocklobster was also shown to influence flesh characteristics, where flesh from poor condition rocklobsters deteriorated quicker than from good condition rocklobsters (Boyd and Sumner 1973). This research indicates the likelihood of a causative link between the distinct biochemical changes within flesh associated with stress, and resulting sensory characteristics for rocklobster flesh.

Current industry practice for exporting live rocklobster is to hold them in recirculating tanks without feeding for up to two weeks. It is known that starved rocklobster use energy reserves during storage that can result in a reduction in lipid and glycogen within the flesh (McLeod *et al.* 2004). Diet during tank storage of rocklobsters may also influence flesh. Industry concerns also include the possibility that specific diet during tank-storage may taint the flavour of rocklobster flesh. It is the culmination of such industry concerns and the paucity of quantitative analysis of flesh changes within rocklobster that is the basis for this research.

Most recently, substantial industry effort has focused on the potential aquaculture of rocklobster, and the assessment of flesh characteristics likely to be produced by these methods (Nelson et al, 2005). In this case, a non-trained but experienced industry sensory panel was used to compare wild caught and tank-held (fed) rocklobster. Importantly (and in contrast to previous studies), sensory analysis was based on the properties of fresh product between treatments, rather than product sensory shelf life. The panel consensus resulted in no significant difference between treatments. However, voluntary comments provided a good starting point for establishing the key descriptors of fresh rocklobster flesh.

This study presents the unique approach of comparing biochemical differences in flesh due to biological and post-harvest handling, with the addition of sensory analysis. Characterising the product and comparing different biological and post-harvest treatments is important for addressing relevant industry concerns and identifying the potential product quality of a value added product. In this manner, the use of a descriptive sensory panel is therefore necessary to quantify differences in flesh parameters, as opposed to simply the acceptability of a product (which would be the outcome of using only a consumer panel). In order to analyse the sensory properties of flesh in this study (and in the absence of appropriate standards for descriptive analysis as described above), it was decided to develop a hybrid descriptive method to compliment standard triangle test methods (British Standard BS ISO 4120:2004). This was done in consultation with established food scientists at Regency Institute of TAFE SA (Chapter 2).

Finally, to maintain the relevance of this research to the commercial processing company, and off-set the costs of sourcing rocklobster, it was decided to process samples as they came through a private processing factory. As such, all samples processed were therefore subjected to variability of unknown industry practices pre-harvest and importantly reflect flesh quality expected in a commercial situation.

Research aims

The aim of this thesis was to quantify product flesh characteristics using physical, biochemical and sensory approaches, determining the extent of variation in those characteristics, and finally to investigate the potential sources of that variation. Each chapter follows a progression of ideas to assess possible biochemical and sensory variations in flesh of commercially harvested rocklobsters. Detailed chapter outlines are presented below.

Chapter 2

This chapter presents detailed methods for biochemical and sensory analysis of flesh samples that pertains to each chapter thereafter. Individual chapters contain only those methods specific to each experiment. A substantial amount of this chapter includes reviewing of established techniques for physiological, biochemical and sensory analysis and composition of a refined method. This includes;

- Development of a summarised table of existing definitions of moult staging (Table 1), along with photographic aids.

- Revised methods for glycogen and lactate analysis, driploss, and total lipid content
- The establishment of key sensory descriptors for rocklobster flesh
- Sensory panel selection process
- Justification for choosing appropriate sensory methods
- Summary of threshold tests for sensory panel
- Results from sensory panel training

Chapter 3

Within this chapter, I assess the biochemical variation of commercially harvested rocklobster over a period of two years. It was important to test a combination of processing and biological factors that could potentially influence biochemical properties of flesh. Specifically, this includes time within harvest season, moult stage, shell colour, and batch (individual processing day).

Chapter 4

Here, I present a comprehensive analysis of a number of potential sources of variation of sensory and biochemical properties of commercially processed *J. edwardsii* flesh. In addition, and of particular relevance to the rocklobster industry, was how these may translate to differences in consumer preferences. This chapter specifically addresses four

sources of variation using biochemical and sensory analysis that are of primary concern to rocklobster processors:

1. Variation in flesh characteristics within a rocklobster tail
2. Variation between rocklobster
    a. Rocklobster size
    b. Rocklobster prior stress
3. Stability of rocklobster flesh with frozen storage

The most significant variations detected in rocklobster flesh (frozen storage) were also assessed using a Japanese consumer panel.

Chapter 5

In order to match year-round supply demands of Southern Rocklobster (*J. edwardsii*) with the limitations of a six month fishing season, processors have started to hold rocklobster through the closed period of the commercial fishing season. The affect on both the biochemistry and sensory characteristics of flesh from these tank-held rocklobsters currently remains unknown. This chapter addresses the effects of tank-holding (both feeding and not-feeding) on biochemical properties of flesh and further investigates the resulting sensory properties of rocklobster that had been tank-held for four months (fed) vs. wild caught rocklobsters from the commencement of the following fishing season.

Notes on chapter style

Each research chapter in this thesis (Chapter 3 -5) presents original data and can be read as a separate, discrete study. Each chapter is preceded by a preamble that briefly describes the content of the chapter. Tables and figures are embedded within the text and all references are compiled at the end of the thesis, rather than at the conclusion of each chapter.