

**EXTENDING THE HIGH QUALITY
SHELF LIFE OF
SEAFOOD PRODUCTS**

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OBJECTIVES:

1. Conduct market research and industry discussions to assess species and markets where opportunities may exist.
2. Develop package types to suit various target species.
3. Ascertain microbiological soundness of the concept, products and species which are the suggested targets eg. scallops, prawns, fish.
4. Use industry partners in development of products.
5. Conduct joint investigations on safety and shelf life with the marketing and processing sector and determine industry standards.

NON TECHNICAL SUMMARY:

Most seafood in chill storage at 4°C will last only a few days. The shelf life of any seafood product is dependent on the initial levels of bacteria present. Modified atmosphere packaging (MAP) technology can extend the shelf life of seafood. MAP is extensively applied to seafood in Europe and the United Kingdom. So far little interest has been shown by the Australian seafood industry yet it is already used extensively in Australia to package meat, poultry, pasta and fruit and vegetables. MAP uses a combination of carbon dioxide and other gases which is flushed into a pack containing the food. The pack is then sealed and the 'modified' atmosphere retards the growth of oxygen-loving spoilage bacteria.

The research project '*Extending the high quality life of seafood*' funded by the Fisheries Research & Development Corporation (FRDC) and undertaken by the Centre for Food Technology shows that MAP technology can double the shelf life of fresh seafood under Australian conditions. The initial quality of the seafood must be high and contain low microbial counts for this to be achieved. The following recommendations are made based on the findings of this research.

An industry standard should be applied to raw seafood that is to be packed in modified atmosphere: the raw seafood must contain less than 10,000 bacteria per gram.

It is essential that Australian companies establish quality assurance programs before they produce any MAP products to ensure this standard can be met routinely.

The research team conducted a market study with supermarket buyers, chefs, caterers and restaurateurs, shelf life trials, tracked microbial growth and physical and chemical changes, and conducted consumer acceptability tests that looked at the taste, texture, appearance and smell of the MAP seafood.

The researchers during this project applied a storage "abuse" temperature of 4°C to encourage the growth of *Clostridium botulinum* if and when present. Even higher temperatures than this are common for many consumer and retail storage facilities.

The research applied MAP to four different types of seafood products: saucer scallops, broadbill swordfish cutlets, Atlantic salmon portions and rainbow trout fillets.

A lower cost alternative to large automated MAP equipment was used in the research. The seafood was packed on an impermeable tray and sealed with transparent plastic film which retained the moisture and enhanced the appearance of the product. The tray was then placed in an outer master bag that was partly evacuated then filled with carbon dioxide. The carbon dioxide was then absorbed through the plastic film surrounding the product to exert its beneficial effect on the product's shelf life.

An industry workshop was conducted at the Centre on 25 June 1998 to disseminate the findings. General findings and conclusions from the MAP research include:

- > market research identified strong commercial interest in MAP seafood products from major retailers and the food service sector; with small or single-serve retail packs having potential in some supermarkets while bulk packs could be sold to supermarkets' 'fresh counters' and the food service sector
- > producers would need to provide guidelines to seafood buyers on how MAP seafood can be used and sold safely
- > some potential exists to extend MAP to cooked and other value-added seafood
- > *Clostridium botulinum*, the pathogenic microbe responsible for botulism, was not identified in any seafood tested. These bacteria can grow in carbon dioxide-rich conditions at temperatures greater than 4°C but other researchers have found that seafood contaminated with this particular pathogen did not become toxic until the seafood was very noticeably 'off' (Reddy et al, 1997).

Specific results for the individual species are as follows.

Saucer scallops (*Amusium balloti*) placed in vacuum skin packs (covered with a gas permeable membrane and placed in a barrier bag outer flushed with 100% CO₂ atmosphere) gained an additional six days of shelf life at 4°C. This is virtually double the shelf life obtained when stored in air at 4°C.

Broadbill swordfish cutlets placed in vacuum skin bulk packs (covered with a gas permeable membrane and placed in a barrier bag outer flushed with 100% CO₂ atmosphere) displayed a slow increase in microbial counts during MAP storage at 4°C. This type of MAP is feasible for short term storage of the product

Broadbill swordfish cutlets placed in modified atmosphere flushed impermeable lidded retail packs stored at 4°C achieved double the shelf life from four to nine days when the initial quality of the product was high and microbial counts were less than 10,000 bacteria per gram.

Atlantic salmon fillets present in modified atmosphere flushed impermeable lidded retail packs achieved double the shelf life from three to five days when the initial bacterial counts were less than 10,000 bacteria per gram. When the initial bacterial count was lowered to 1000 bacteria per gram, a 13 day shelf life in MAP at 4°C was possible.

Rainbow trout fillets packed in modified atmosphere flushed impermeable lidded retail packs more than doubled the shelf life when initial bacterial counts were less than 10,000 bacteria per gram the MAP stored trout was acceptable for nine days compared to three days under normal air storage. When the starting microbial count was less than 1000 bacteria per gram a 14-day shelf life in MAP at 4°C was achieved.

KEYWORDS: Modified atmosphere packaging, seafood, shelf life extension

BACKGROUND

The packaging of seafood in modified atmosphere (MAP) is widely used in Europe and the UK, but has not been applied effectively in Australia. The active component in MAP is carbon dioxide which can inhibit the growth of spoilage bacteria. Packs with a high void volume in relation to the weight of the product are required for the CO₂ levels to be effective. One important consideration is that when temperature become higher than that of a chiller the conditions present in MAP can encourage botulism. Because of this potential health risk the initial quality of the product needs to be high standard and have low microbiological loads. The adoption of Quality Assurances principals for the processing line is imperative before product can to be packed in a modified atmosphere.

There is now a potentially safer and less costly alternative to large automated MAP equipment, which combines the effectiveness of CO₂ with the safety and appeal of vacuum skin packaging results in a more compact attractive pack. The process involves packing the seafood on an impermeable tray and sealing it with a transparent plastic film which retains the moisture and enhances the appearance of the product. The film used is gas permeable, but is moisture proof. These packs can then be placed in an outer master bag (often within a cardboard box) which is partly evacuated and then filled with CO₂ which is absorbed through the film to exert its beneficial effect. Recent trials at CFT have shown this to be a promising approach with prawns (FRDC Project 91/100).

Unlike other complex procedures used to produce modified atmosphere packs, the equipment involved is sufficiently portable to be transported in a station wagon to commercial factories. In this way, the process can be demonstrated and packaging trials done in cooperation with commercial processors. The master pack in its elementary form need only be a large plastic bag which can be clipped at the neck after filling with the gas mixture.

NEED

The high quality shelf life of most seafood in chill storage is relatively short, being only a few days. This short period does not allow sufficient time for receipt; distribution and display to ensure the restaurateur or consumer can obtain it at its best. Many of the high quality characteristics are depleted in the marketing and distribution chain. Therefore extension of this high quality life is required to improve the standard of product reaching the consumer.

Just to keep its place in the markets the industry requires products of higher standard for both the domestic and export markets. Time and again studies have shown that consumers require convenient well presented packs of seafood that do not smell out the bag, car or kitchen and that are easy to prepare free of bones or shell without much waste.

There is a strong interest in the application of MAP technology to improve seafood quality and shelf life. Our feedback through AUSEAS, NSC, packaging and equipment manufacturers, and clients suggests that there is a deficiency in knowledge of the type of modified atmosphere to use and the most appropriate methods of application.

From our experience and knowledge, and considering the need for a simple practical application of this technology, we believe that the major development emphasis should be placed on vacuum skin packaging in CO₂ master packs. This is apparent from our discussion with industry contacts. It is necessary to consider the wide range of potential package types, sizes, materials and even the information presented on the package and to focus on those most likely to succeed.

Discussion during the past few years with industry and packaging companies indicates that their market research need not be duplicated but that there are technical areas of marketing of these products which are not well covered. These aspects involve the technical characteristics of the products and the packaging requirements that must be met in order to stand a chance of success in the marketplace.

PROJECT OBJECTIVES

- > Conduct market research and industry discussions to assess species and markets where opportunities may exist.
- > Develop package types to suit various target species.
- > Ascertain microbiological soundness of the concept, products and species which are the suggested targets eg. scallops, prawns, fish.
- > Use industry partners in development of products.
- > Conduct joint investigations on safety and shelf life with the marketing and processing sector and determine industry standards.

METHODS

The definition of high quality life is the time when a taste panel does not identify any significant differences from the initial high quality. Keizer (1995) declares that this term does not show adequate relation with the quality perception by consumers. Trained taste panels can be more discerning than many consumers. These panels are more effective in determining the practical storage life or the time during which the stored product is still acceptable to the consumer. Some researchers contend that MAP itself can reduce high quality life (Haard 1997, personal communication).

In conducting this project it became apparent the goal of this work, as perceived by processors, was to principally extend shelf life to a point where a product then became unfit for human consumption. This attitude has grave risks when the technology applied encourages the growth of pathogens. A compromise was decided upon which determined that shelf life had ended when the total bacterial count was greater than 1,000,000 bacteria per gram or the overall quality scores from the taste panel dropped below 50%. This standard incorporates both aspects of quality and safety.

Marketing

Information and data were collected on the MAP seafood in Australia and overseas through literature searches and industry discussions. In the literature the terms MAP and Controlled Atmosphere Packaging (CAP) are sometimes wrongly used interchangeably. Genuine CAP is quite expensive to produce. In the review of overseas markets the term CAP is sometimes used in this report Packaging Experiments

Raw Material

Scallops were purchased from Fishmac Pty Ltd in Bundaberg while other species were supplied free by participating companies. The scallops had been stored in refrigerated seawater (RSW) on board the capture vessel. They were then unloaded at the processing factory and shucked the same or following day. Initial samples were sent chilled to the laboratory while later material was obtained direct from the processing line. The scallops were placed in plastic trays and sealed under a permeable membrane using a Trigon "Intact" skin packaging system Model RM 331-C (Trigon Engineering Ltd, New Zealand). These packs were then placed in impermeable barrier bags which were flushed with 100% CO₂ gas and heat-sealed. The bulk packs were then stored in a cold room at

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4°C until unpacked which occurred at regular intervals. Individual skin packs from these removed for testing, also at regular intervals. Swordfish cutlets were also packed in large trays using this procedure.

An alternate packing style involved product placed in impermeable plastic trays that were evacuated and then flushed with a modified atmosphere before an impermeable lid was heat sealed on top. This tray style is the one most commonly used by processors in the Northern Hemisphere. The lidding machine was an experimental model built by Trigon Engineering and was made available by the company for this project. Swordfish, salmon and trout were packed using this equipment. Initially the pH, microbial flora, gas concentrations and physical appearance were evaluated for stored packs for the initial trials and then later in conjunction with sensorial appraisal.

Microbiological Evaluation

The microbiological properties of the raw materials, those stored under aerobic and MAP conditions, and sometimes under aerobic conditions following MAP treatment were evaluated through a series of trials. A storage temperature of 4°C was used throughout for these trials. The fresh seafood was received directly from the processing plant on the arrival of the fishing boats or samples were transported to the laboratory and tested within 24 hours. The total bacterial counts of some frozen scallops were also evaluated.

Sample preparation

The test sample was prepared by aseptically subsampling 10 g from several seafood portions and transferring it into sterile stomacher bag. The subsample was diluted 1:10 with 0.1% peptone diluent. The mixture was then homogenised for 60 seconds using a Colworth Stomacher 400.

Total bacterial count

The total bacterial count (TPC) were carried out by the surface spread method (Australian Standard, 1991b) using nutrient agar. The plates were incubated at 25°C for 3 to 4 days

Bacterial isolation and identification

Twelve representative colonies were recovered from each set of the total bacterial count plates. Each culture was purified by streaking on a nutrient agar plate and incubated at 25°C for 48 hours. An isolated colony was picked from the incubated streaked plate and transferred on to nutrient agar slope and incubated at 25°C for 24 to 48 hours.

Colony appearance description was taken from colonies grown on the streaked plate.

Preliminary grouping of bacterial isolates was obtained from 24-hour cultures using nutrient agar slopes. The following tests were performed:

- > the motility test by the hanging drop method (Skerman 1967)
- > Gram stain reaction and bacterial morphology by the Gram stain method (Skerman 1967)
- > oxidase reaction using oxidase detection strip (Disposable Products Pty Ltd, Adelaide South Australia)
- > catalase reaction using 3% w/v H₂O₂ solution based on the method of Skerman (1967) and Topley and Wilson (1926)
- > the differentiation of oxidative and fermentative production of acid from glucose by Gram negative bacteria was tested by Hugh and Leifson method (1953), with tubes incubated at 25°C for 7 to 10 days and for Gram positives using media as described in Skerman (1967).

The Gram negative isolates were grouped according to the test reactions, colony and bacterial morphologies. Representative isolates from each group were classified to generic level using Microbact 24E test kits and criteria as described in Shewan *et al.* (1960). The Gram positive isolates were classified according to Sneath *et al.* (1986).

Anaerobic count

Anaerobic counts were done by the surface spread method (Australian Standard, 1991b) using reinforced Clostridial agar (Oxoid). The plates were incubated anaerobically at 30°C for 10 days in an anaerobic jar charged with hydrogen and carbon dioxide gases using Gas-Pak Plus (Beckton Dickinson).

A new method was used to determine anaerobic counts was done by the surface spread method (Australian Standard, 1991b) using a modified Differential Clostridial Media (DRCM) with the addition of polymyxin B sulphate. The plates were incubated anaerobically at 30°C for 10 days in an anaerobic jar charged with hydrogen and carbon dioxide gases using Gas-Pak Plus (Beckton Dickinson). This media is selective for gram +ve anaerobic rods and cocci. A further step was pasteurisation of a sample to grow the heat-activated spores of anaerobic gram +ve spore formers on this media (**Pasteurised DRCM**).

H₂S positive bacterial count

Total count for hydrogen disulphide (H₂S) producing organisms was estimated by the pour plate method (Australian Standard, 1991a) using iron agar of Gram *et al* (1987), when set, the agar was overlaid with the same agar. The plates were incubated aerobically at 25°C for 3 days.

Coliforms/Escherichia coli count

E. coli/coliforms bacteria were tested (in Trial 3) by the triplicate tube method (Australian Standard, 1987) using lauryl tryptose broth, the initial presumptive tests were incubated at 30°C for 48 hours.

Demerit Assessment

The appearance of the product in the packs before and after opening and the odour and, when not presented to taste panel for assessment, the taste and texture were rated using the demerit point system. A number of descriptive parameters were scored on sheets designed specifically for each product. Copies are present in Appendix 3. The accumulated scores were calculated and these and the individual parameter scores were analysed for significant difference using analysis of variance.

Sensory Analysis

Preparation

The seafood was placed in individual foil dishes, covered with a foil lid and held in a 5°C refrigerator until cooked (within 30 minutes). Samples were cooked in a fan forced electric oven at 200°C for six minutes and served as soon as possible after this time (less than 10 minutes).

Sensory evaluation

A total of ten tasters (eight male, two female) assessed samples a product at 12 sessions over two trials (6 per trial) using a standard rating test (AS2542.2.3, 1988). Order of tasting of treatments was balanced across the panel. Samples were served to tasters in

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individual booths illuminated with white light (daylight equivalent). Purified water was freely available for palate cleansing prior and during tasting.

Tasters identified and rated the colour, odour, flavour and texture characteristics on unstructured graphic line scales. Overall acceptability of the scallop was also rated, and tasters were given the opportunity to record additional descriptors and add any general comments about the samples. Lists of descriptors used and comments made about them are in Appendix 4. Data was collected directly into computers using an integrated software package, Compusense five ver. 2.2 (Compusense Inc, Canada) to present a standard rating test (AS 2542.2.3 1988).

For the purpose of analysis the two trials were used as replicates and they were combined into eleven treatments. This makes no adjustment for session effects which is not possible with the design of the experiment. The taste panel scores for various parameters were based on a range from poor or none to extreme with a scale of 100. The terms used are listed below.

Overall quality	Very poor (0) to Very good (100)
Fishy odour	None (0) to Very strong (100)
Meaty odour	None (0) to Very strong (100)
Muddy odour	None (0) to Very strong (100)
Other odour	None (0) to Very strong (100)
Free moisture	None (0) to A lot (100)
Colour (intensity of)	Very pale (0) to Very bright (100)
Moistness	Very dry (0) to Very moist (100)
Firmness	Very soft (0) to Very firm (100)
Flakiness	None (0) to Very flaky (100)
Fibrousness	None (0) to Very fibrous (100)
Typical flavour intensity	None (0) to Very strong (100)
Meaty flavour	None (0) to Very strong (100)
Sweet flavour	None (0) to Very strong (100)
Muddy flavour	None (0) to Very strong (100)
Other flavour	None (0) to Very strong (100)
Overall quality	None (0) to Very strong (100)

RESULTS

An industry workshop was conducted at CFT on 25 June 1998 to disseminate the findings of this project and a copy of the program is present in Appendix 6

Map Market Evaluation

The marketing research involved a literature search on the applications of MAP in overseas markets and interviews with the trade in Australia. The research has identified the need to change the direction of the technical research and has identified strong commercial interest in the project. There are opportunities for commercial involvement of supermarkets, seafood processors, chefs and caterers in 1997.

Primary research was carried out in November and December 1996 in Queensland, Victoria and New South Wales, involving face-to-face interviews with seafood category managers from Woolworths, Franklins and Coles. Interviews were also conducted with seafood processors, caterers and chefs in each state. In Brisbane, interviews were conducted with other food companies using MAP, and with gas and packaging companies. Table 1 outlines the number of interviews conducted in each state with each trade group.

Table 1. Sample size of industry interviews

Trade group	Queensland	New South Wales	Victoria
Supermarkets	3	2	4
Chefs (hotels and restaurants)	4	5	1
Caterers	2	2	1
Processors	16	6	6
Other packaging companies, researchers, gas companies and other food companies using MAP	6	5	2
Total	31	20	14

Overseas Trends in Map Seafood

Use of MAP in food/seafood industry

United Kingdom

It is estimated that the UK is the largest user of MAP in Europe with 40 per cent market share (Day, 1990). MAP is used in a wide range of industries in the UK. It has the greatest penetration in the meat industry where the technology was first applied. The first commercial use of MAP in the UK was in 1979 by the supermarket Marks and Spencer in packaging meat. Use of MAP in the UK has been developed and driven by the supermarket chains. MAP is used in the UK to pack carcass meat, cooked meat, meat products, poultry, fish and shellfish, fresh vegetables and fruit, ready meals, dairy products, dried foods, bakery products and fresh pasta (MSI, 1996).

France

The French market is the second largest in Europe with 25 per cent market share (Day, 1993). The development of MAP in the French market has been slower than in the UK. In France MAP has been driven by the packaging and gas companies. MAP is mainly being used with new products and therefore its market growth is linked to the launch of new food products. The main foods packed in MAP in France include vegetables, cooked and cured meats, bakery products, sliced cheeses, fresh meat and fish (MSI, 1994).

Germany

In Germany there has been a low level of development of MAP. Initially MAP was mainly used on fish, prepared salads and pizzas. However, MAP fresh pasta has been very successful in German supermarkets and in 1995 there were plans to release a range of chilled deli salads in MAP (Neubacher, 1995). In 1995 an Icelandic company (Fisco of Reykjavik) started exporting bulk and retail MAP fish to Germany for sale through a supermarket chain. This fish has an additional 2 to 4 days shelf life if packaged at the source it is caught and kept to 0°C. The fish is no older than 3 to 4 days prior to it being packed. The types of seafood packed in MAP includes redfish, saithe, cod, salmon, plaice, haddock, catfish, Greenland halibut and trout (Scudder, 1996). MAP fish is sold in retail packs from 300 g to 1 kg. Bulk MAP fish of 5 kg which is then packed into polystyrene boxes is also sold to supermarkets for sale in the wet fish counter sections of supermarkets (Scudder, 1996). In 1996 the Danish seafood company Abba released five new chilled peeled shrimp products in CAP onto the German market. The range includes two cold water and three warm water shrimp species sold in the pack on its own as well as in a garlic and parsley sauce. The packs are 125 g and have a shelf life of six weeks. The range has been selling in France since autumn of 1995 (Anon, 1996).

United States

In contrast to Europe and the UK, MAP technology is still in its infancy in the United States (US). It is reported that there have been isolated uses of MAP for 10-20 years in the US. Packaging companies in the US have been reluctant to promote MAP to the

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seafood industry due to the lack of standards in the seafood processing sector (pers. comm. Maskell, 1996). In this respect the US industry is similar to the Australian industry. In the last few years M-TEK INCORPORATED (a packaging company) in the US has assisted two seafood processors to set up MAP operations. In the US the main problems faced in the seafood industry are the lack of quality seafood and lack of control over the "cold chain" (pers. comm. Maskell, 1996).

Market size for MAP seafood in overseas markets

United Kingdom

The MAP market in the UK has reached the mature stage of the product life cycle which contrasts with Australia which is still in the introductory phase (Day, 1992). The major supermarkets such as Sainsbury sell seafood in three areas; wet fish counter, prepackaged section (chilled MAP/CAP) and a frozen pack section (-30°C). In the chilled MAP/CAP section boneless fish fillets and steaks are being sold as well as crumbed, battered, sauced and spiced seafood. It is reported that consumers fully accept MAP/CAP products and perceive they are of higher quality than frozen products (Williams, 1995).

The total retail market in the UK in 1995 for MAP was 2,310 million packs. It is forecast that in 1996 the total market will increase by 5 per cent (MSI, 1996). In 1995 the UK market for fish and shellfish was 0.4 million tonnes valued at £2,307.8 million (A\$5,184 million). The fastest growing segments of the seafood industry are salmon and shellfish. It is estimated that 17 per cent of all fresh fish is packed in MAP, 66 per cent is other packed and 17 per cent unpacked. Fish and shellfish represented 9 per cent or 210 million packs of the total MAP market in the UK (MSI, 1996). The market share for each food type is presented in Table 2.

Table 2. Segmentation of the UK MAP retail market by food sector 1995

Product	Volume (million packs)	% of total
Carcase meat	718	31
Cooked meat & meat products	346	15
Snack food	244	11
Fish & shellfish	210	9
Fresh fruit & vegetables	161	7
Ready meals	140	6
Dairy products	117	5
Dried food	117	5
Poultry	117	5
Fresh pasta	71	3
Bakery products	46	2
Others	23	1
Total	2,310	100

Source: Trade and MSI estimates

In addition to the retail packs for MAP there is also a substantial market for bulk packs. In 1995, as presented in Table 3, the bulk MAP market in the UK was 1.55 million tonnes. In 1996 it has been forecast that the total market would grow by 6 per cent (MSI, 1996). Fish and shellfish represented 12 per cent of the bulk market at 186,300 tonnes. Fish is placed in MAP for distribution purposes to eliminate wastage and unnecessary handling and then sold loose in the wet fish section of the supermarket. In 1996 the fish and shellfish MAP market was expected to grow by 5 per cent to 195,600 tonnes (MSI, 1996).

Table 3. Segmentation of the UK MAP bulk market by food sector 1995

Product	Volume (1'000 tonnes)	% of total
Cooked meat & meat products	465	30
Poultry	434	28
Fresh fruit & vegetables	372	24
Fish & shellfish	186	12
Carcase meat	92	6
Total	1,550	100

Source: Trade and MSI estimates

France

The market for MAP fish and shellfish in France is substantially smaller than in the UK. In 1994 as presented in Table 4, the retail market for MAP products in France was estimated to be 1,390 million packs. The MAP seafood segment represents 83 million retail packs or 6 per cent of the total MAP market. It has been predicted that the retail market for MAP will grow by 10 to 11 per cent per year from 1995 to 1999 (MSI, 1994).

Table 4. Segmentation of the French MAP retail market by food sector 1994

Product	Volume (million packs)	% of total
Cooked meat & meat products	278	20
Others delicatessen products	209	15
Fresh fruit & vegetables	209	15
Bakery products	209	15
Dairy products	153	11
Fish & shellfish	83	6
Fresh pasta	83	6
Carcase meat	56	4
Snack food	42	3
Poultry	42	3
Other	26	2
Total	1,390	100

Source: Trade and MSI estimates

Factors affecting demand/use of MAP

United Kingdom

The main factors affecting the development of the MAP market in the UK include:

- > Changing eating habits.
- > Changing lifestyles.
- > Need for assurances of product safety.
- > Need for extending the shelf life of foods.
- > Development of other packaging technologies.
- > Use of centralised distribution facilities (MSI, 1996).
- > Driven by supermarkets.

Australian consumers in common with British consumers are demanding fresh foods and those free from additives and preservatives. There is also a change in lifestyle with more women working and spending less time preparing meals. The area in which the UK market differs from Australia's is control over temperature. However, in both markets, there is a need for longer shelf life to facilitate distribution. At the present time, fresh seafood sold in supermarkets in Australia is delivered daily by processors to individual stores. There are no centralised packaging and distribution facilities in Australia for

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seafood as is the case in the UK. The supermarkets in the UK have developed the MAP market. In Australia supermarkets are just starting to expand and to improve their seafood sections. These factors have resulted in limited use of MAP seafood and other foods in Australia.

Germany

The major factors affecting the development of MAP in Germany are lack of retailer commitment and lack of temperature/quality control. In Germany most supermarkets lack the technology to store and display MAP products at the correct temperature. In response to this, some processing firms are providing supermarkets with refrigerated cabinets to maintain the temperature and therefore the quality of MAP seafood (Neubacher, 1995). The seafood industry is actively developing the quality and temperature controls required for high quality MAP seafood.

United States

The US market has been slower than Europe to adopt MAP for the following reasons:

- > Europeans shop more frequently than Americans.
- > Higher refrigerated-foods awareness and acceptance in Europe.
- > Total system/quality approach for MAP technology in Europe.
- > Higher prices of food in the EC market place.
- > The European food market is driven by retailers, while in the US it is driven by packers/consumers. Large supermarket chains in Europe are dedicated to high quality refrigerated foods (Day 1990). Many of these factors which differentiate the US and European markets also apply to Australia.

Distribution of MAP seafood

United Kingdom

The retail market for fresh fish in the UK is valued at \$2.6 billion (Williams, 1995). In 1992 the main outlets for fresh fish were fishmongers (40 per cent), supermarkets (34 per cent), market stalls/vendors (14 per cent) and other outlets (12 per cent). The number of fishmongers in the UK is declining due to competition from supermarkets. Fresh fish counters were introduced in supermarkets in the mid 1980s. There are approximately 550 fresh fish counters in the UK (Williams, 1995). The use of CAP, where fish is packed in nitrogen flushed packs, has been a major boost to supermarkets. Approximately 2,150 supermarkets in the UK handle CAP seafood. The shelf life on average is extended an extra 1.5 to 2 days held at 0°C.

Supermarkets in the UK have highly developed cold-chain systems (Williams, 1995). More retail space is being devoted to chilled foods at the expense of frozen and shelf stable foods. Retail sales of food are concentrated in the hands of Sainsbury, Tesco, Safeway, Asda, Gateway, Waitrose and Marks and Spencer. These supermarkets account for over 50 per cent of all food sales and over 80 per cent of chilled food sales (Day, 1992).

Regulatory Requirements

European Community

In January 1997 all MAP food sold in the European Union must be labelled "packaged in a protective atmosphere" (MSI, 1996). This may affect sales of MAP products, as previously consumers may not have been aware of the use of a modified atmosphere and therefore the labelling may change their perception of the product's freshness.

United States

Chiller cabinets in the US fluctuate between 7°C to 10°C. In the US, certification of the use of MAP is controlled by the National Maritime Fisheries Service which requires that

fish be packed no later than five days after it is caught, sold within 10 days and kept at 3°C or lower until it is sold (Rose, 1992).

Australian Market for MAP Seafood

Seafood consumption trends

Consumption of seafood in Australia is one of the lowest in the developed world. In 1990/91 total annual seafood consumption per head in Australia was 12.06 kg, an increase of 20 per cent over 13 years. Seventy-seven percent of the consumption was fish (PA Consulting, 1992).

Use of MAP in food/seafood industry

MAP is used on meat, poultry, salads, pasta and bacon in Australia. The only foods using retail packs of MAP are salads and pasta. All other foods using MAP are sold in bulk form. There is no confirmed use of MAP seafood in Australia.

A good example of commitment to quality in the use of MAP is Harvest Freshcuts. The retail MAP salads sold by Harvest Freshcuts through supermarkets are characterised by temperature control, testing for microbial contamination, control of the quality of raw material and automation (Biggs, 1995). Harvest Freshcuts would be a good model for seafood processors contemplating the use of MAP to emulate.

Safeways and Coles in Victoria are buying poultry in bulk and selling it through the delicatessen counter. A poultry company has been using MAP since 1986 and approximately 20 to 30 per cent of their product is MAP. Safeways and several chefs have also had experience in buying MAP bacon in bulk (MAP interviews, 1996).

One exporter of tuna produced gas flushed tuna for export to Germany. However, this enterprise ceased due to a limited supply of raw material. The Victorian government provided an export grant to Kallis and France (seafood processor) to build a MAP machine. Coles sold retail MAP packs produced using this equipment. The product, however, failed to sell and was withdrawn. These are the only known uses of MAP seafood in Australia (MAP interviews, 1996).

Potential market size for MAP seafood

The potential market for MAP fish fillets in bulk form in the supermarket sector is approximately 2,460 tonnes per year. At an average wholesale price of \$8.50 per kg the bulk market for MAP fish fillets is valued at approximately \$21 million per year. Supermarket seafood category managers perceive MAP seafood to fish fillets which are a volume seller. (MAP Interviews, 1996). The potential market size for retail packs in MAP sold through the supermarkets is approximately 200 kg per week for all types of seafood (MAP Interviews, 1996).

The potential market size for retail packs in MAP sold through the supermarkets is approximately 200 to 8,500 kg per week with an upper value of \$96,000 per week for all types of seafood. (MAP Interviews, 1996)

Market segments

There is potential for MAP seafood in bulk and retail packs. The retail packs have potential in some supermarkets, while the bulk packs could be sold to supermarkets and the food service sector.

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The food service sector rather than supermarkets may have the greatest potential for MAP seafood, as out-of-home consumption of seafood is increasing while in-home consumption of seafood has fallen since 1977. In 1977 the average frequency of in-home consumption of fish and seafood was 1.55 meals per household per week. By 1990/91 it had fallen to 1.08 meals per household per week. Out-of-home consumption of fish increased by 1.49 kg per capita from 1977 to 1990/91. Consumption of other seafood increased by 0.77 per capita (PA Consulting Group, 1992).

The dominant place of purchase of fresh and frozen seafood for in-home consumption is specialist retail fish shops, with 32 per cent market share in 1990/91. From 1977 to 1990/91, supermarkets gained an increased share of this market. In 1977 only 7 per cent of fresh and frozen seafood was sold by supermarkets. In 1990/91 their share had increased to 17 per cent (PA Consulting Group, 1992).

Growth in the quantity and value of seafood sold by supermarkets in Australia will continue to increase, as all major supermarkets are expanding the number of stores selling seafood. According to Woolworths in Queensland, there are 11 stores with seafood sections. By mid 1998 there will be 70.

Supermarkets are gaining market share in the in-home consumption segment of the seafood market. The overall trend, however, is for an increasing proportion of seafood to be eaten out. The foodservice market may represent the major user of MAP seafood.

Factors affecting demand / use of MAP

Factors affecting the demand for and use of MAP seafood in Australia are:

- > Quality and availability of raw material.
- > Storage/transport.
- > Temperature control.
- > Lack of innovation and technology uptake.
- > Cost.
- > Safety concerns over using vacuum skin packaging (VSP) or MAP for seafood.
- > Education and training.
- > Consumer/buyer resistance.

Seafood sold on the domestic market is generally of a lower quality than seafood that is exported. Prices paid for seafood in Australia are lower than those obtained on the export market, which in turn affects quality. Fishers supplying high quality seafood for export to Japan, on average, obtain \$1 to 1.50 per kg more than domestic suppliers (MAP Interviews, 1996). As a result the quality of seafood available on the domestic market may be unsuitable for MAP. According to reports on the European market, fish is from 3 to 7 days old prior to being placed in MAP (Scudder, 1996 and pers. comm. Day, 1996).

Seafood sold through supermarkets in Australia is delivered on a daily basis to each store by seafood processors. The fish is delivered on ice in a polystyrene box. Some seafood processors do not use refrigerated trucks. Supermarkets' refrigerators are kept at 0-1°C. Temperatures in the seafood cabinets where fish is displayed, however, can fluctuate significantly. Lack of temperature control in seafood cabinets is reported to be a problem in the United States too (Rose, 1992). A poultry company using bulk MAP report that at 0-1°C they can achieve 21 days shelf life. Due to the lack of a cool chain and handling problems shelf life is reduced to 14 to 15 days (MAP Interviews, 1996). Should MAP be applied properly to seafood, an extended shelf life may only be achieved up until it is displayed in the seafood cabinets in the supermarkets.

An additional issue or barrier to the commercialisation of MAP seafood is the lack of technical knowledge and innovation in the industry. Several seafood processors reported difficulties using VSP seafood. This would indicate that many seafood processors would

be unsuitable for using the more complex MAP process. Most of the people interviewed were unfamiliar with MAP despite the fact it has been applied to seafood in Europe and to other foods in Australia for over 10 years (MAP Interviews, 1996).

The cost of using MAP may not be viable, considering the lower prices paid for seafood on the domestic market. Initially, processors will have higher labour and packaging costs and will need to monitor their quality and handling procedures. Although some buyers indicated they would pay a premium for MAP seafood, others would not.

Several packaging companies are also advising the seafood industry not to use VSP or MAP. Concerns relate to the possible dangers of botulism which may occur in an anaerobic environment. These concerns and failures with VSP and MAP in the seafood industry have slowed its development. (MAP Interviews, 1996)

There is a need for training and education of seafood processors and retailers who decide to use this technology. There may be potential abuses of the technology with some operators attempting to use poor quality seafood, using the maximum shelf life projections, freezing MAP seafood if it doesn't sell and failing to control temperatures (MAP Interviews, 1996). It was reported that a store manager from Marks and Spencer (UK supermarket) had a high level of knowledge of MAP and how to treat the products (pers. comm. Rooney). To be successful, supermarkets and seafood processors would need to undergo considerable training on how to manage MAP seafood.

There is also a need to educate the trade and consumers about the characteristics of MAP. Several chefs were concerned that MAP seafood may have an off-smell similar to vacuum packing and that it wasn't really fresh as it had a long shelf life. In addition there may be a need to educate consumers if a retail pack of MAP seafood were sold. Some industry people said consumers wouldn't buy a retail pack of MAP, as they would think it was processed. To successfully commercialise MAP seafood, education of users would be required (MAP Interviews, 1996).

Pricing

Bulk packs of MAP seafood are likely to be more price sensitive than retail packs. The food service sector is less price conscious than supermarkets. There were varying opinions from potential buyers as to their willingness to pay a premium for MAP seafood. Many in the food service sector (chefs and caterers) were willing to pay a premium. Fifty cents per kg was the maximum premium one caterer would pay for MAP seafood (MAP Interviews, 1996).

Category buyers of seafood for supermarkets were more concerned with price. According to one buyer, price would be one of the major obstacles to the commercialisation of MAP. Several buyers were willing to pay a premium for bulk MAP seafood, while others were not. According to one buyer, seafood processors' costs would be reduced if they used MAP. The premium one buyer cited he would pay for bulk MAP seafood was \$0.25 to 0.50 per kg, providing the shelf life was guaranteed. (MAP Interviews, 1996)

A retail pack of MAP seafood was considered to be a convenience product and therefore price was not seen to be important. Seafood processors expected a premium of 15 to 40 per cent for a retail pack of MAP seafood. The suggested maximum price per retail pack was thought to be \$10 (MAP Interviews, 1996).

Species preferences

The preferred species nominated by the trade for inclusion in the trial work of this project varied from state to state. Presented in Table 5 are the seafood species in order of preference nominated by each state.

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Table 5. Species preferences for MAP trial

Queensland	New South Wales	Victoria
<i>Fish fillets</i> (sweetlip, coral trout, red snapper, flake, trevally, mullet)	<i>Fish fillets</i> (flake, blue eye, John dory, orange roughy, snapper, whiting, flathead, silver dory, ocean trout, red fish, bream, ling, reef fish)	<i>Fish fillets</i> (blue grenadier, trevally, orange roughy, flathead, flake)
<i>Prawns</i>	<i>Atlantic salmon</i>	<i>Scallops</i>
<i>Crabmeat</i>	<i>Crabmeat</i>	<i>Squid</i>
<i>Scallops</i>	<i>Tuna</i>	<i>Octopus</i>
<i>Lobster</i>	<i>Cooked prawns</i>	
<i>Mussels</i>		

There was also interest in applying the MAP technology to whole fish, cooked seafood, crustaceans and marinated and crumbed seafood (MAP Interviews, 1996). There may be opportunities for a follow up project to investigate whole fish and value added seafood. Value added seafood is increasingly prevalent in supermarkets in the UK and Europe (Day, 1990).

Packaging preferences

There is interest in retail and bulk packs of MAP seafood. However, there appears to be greater demand and potential for a bulk pack. Bulk packs range in size from 2 to 20 kg. The most frequently requested bulk pack size for MAP seafood was 5 kg. Bulk packs of MAP poultry in Australia are 12 kg (MAP Interviews, 1996). In Europe, seafood is being MAP in 5 kg lots which are then placed in polystyrene boxes (Scudder, 1996).

There was limited interest in a retail pack. One supermarket chain was interested in buying a retail pack of MAP seafood immediately, while other supermarkets said a retail pack would be used in the future. The recommended retail pack sizes were 7 cm by 5 cm and 5 cm by 11 cm, ranging from 350 to 500 g. (MAP Interviews, 1996)

Perceived commercial benefits

The trade perceived MAP seafood would provide a range of advantages. Presented below are the main points raised:

- > Avoid price fluctuations.
- > Reduce supply fluctuations.
- > Fresh instead of frozen seafood.
- > Reduced wastage and need of discounting stock when initially MAP.
- > Increased shelf life - hold stock over weekend.
- > Convenience for consumers in stores with no seafood section.
- > Supply country stores and north Queensland.

(MAP Interviews, 1996)

MAP seafood was perceived to have the ability to assist processors and buyers to avoid supply fluctuations. The extended shelf life would enable processors to sell fresh seafood when prices increased and to avoid the daily lows and highs of supply (MAP Interviews, 1996). Many of the chefs also saw MAP as a way to obtain and store fresh seafood and therefore reduce their reliance on frozen seafood. At the present time, some chefs freeze seafood if their supply exceeds their immediate requirements. Chefs also thought that processors may be less likely to freeze seafood and therefore more fresh would be available on the market if MAP were used (MAP Interviews, 1996).

Although the level of wastage by chefs and caterers was reported to be low, supermarkets frequently discount seafood to reduce their wastage. According to one seafood

supermarket buyer, they can lose up to \$5 per kg if an over-order occurs and the product has to be marked down. MAP seafood was perceived as a way to reduce their wastage. With the extended shelf life offered by MAP, supermarkets would have increased time in which to turnover seafood. However it does need to be emphasised to industry that MAP is not a waste management system. This attitude could cause many potential hygiene and food safety problems.

MAP could help reduce the number of deliveries required by seafood processors and enable supermarkets to hold seafood over the weekend for sale on Monday. Another potential benefit of MAP was the ability for supermarkets to deliver and sell fresh seafood to country supermarkets and those located in north Queensland (MAP Interviews, 1996). Retail packs of MAP seafood were perceived to offer a convenience to consumers shopping in stores which do not have a seafood counter section (MAP Interviews, 1996).

Shelf life expectations

The preferred shelf life for MAP seafood was 7 to 10 days. The expectations after unpacking master bags were a shelf life of 2 to 4 days (MAP Interviews, 1996).

Technical considerations

The issues raised by industry which need to be taken into account to ensure the research is relevant and commercially viable were:

- > Safety/handling practise - best practice (storage / transport procedures).
- > Stacking within bag and bags on top of each other.
- > Use bulk and retail packs used by processors and supermarkets.
- > Allow commercial participation (use raw material which is of domestic quality, packaging supplies).
- > Educate and train commercial partners and other industry people during the project.(MAP Interviews, 1996).

Map Seafood Product Evaluation

Introduction

The marketing component of the project "Extending high quality shelf-life of seafood products" has involved establishing a communication link with industry through issues of the MAP newsletter and sending product samples to industry for evaluation and comment.

Four newsletters were sent to supermarket buyers, caterers, seafood processors, chefs, consultants and government personnel to keep those people who expressed an interest in the project informed of its progress and the results

To continue to obtain industry feedback and involvement in the project, three samples of MAP seafood were sent to chefs, supermarket buyers and caterers. The MAP seafood, which was assessed by respondents, included scallops, salmon and swordfish. This report sets out the results of the surveys conducted on MAP salmon and swordfish in November 1997.

Objectives

1. Use industry partners in the development of products.
2. Conduct joint investigations on safety and shelf life with the marketing and processing sector and determine industry standards.

Methodology

Information was collected by means of questionnaires which were sent together with sample packs of modified atmosphere packaged salmon and swordfish to chefs, supermarket buyers and caterers in Brisbane, Sydney and Melbourne.

Table 6 shows that 12 people were sent questionnaires in November 1997. All questionnaires were returned. However, three respondents assessed the MAP salmon and swordfish after the specified deadline. Responses from these people were only included for preferred pack sizes, preferred form in which they buy salmon and swordfish, factors affecting purchase and shelf life of the swordfish or salmon that they buy. In addition, one supermarket buyer failed to return the questionnaire for salmon. Two other supermarket buyers did not answer all of the questions. One supermarket buyer did not cook the salmon or swordfish. Therefore, there were no responses to the questions relating to the products' characteristics after cooking. Respondents were given a list of instructions with the survey. To ensure consistency, respondents were asked to open and sample the MAP seafood between the 10 and 12 November 1997. As a result, the MAP salmon and swordfish were between 6 and 8 days old when assessed.

The questionnaire consisted of open ended, multiple choice and Likert scale questions. The Likert scale ranged from 5 to 1. Five was very important, or very appealing, or very satisfied or much better. At the other end of the scale, was one, representing not very appealing, or not very satisfied or much worse.

Table 6 Number and Type of Respondents

Type	Number
Caterers	2
Supermarket buyers	4
Chefs (hotels)	6
Total	12

Findings

Map Salmon

Market size for fresh salmon

Supermarket buyers reported that they sold between 1 000 and 2 000 kilograms of fresh salmon each week. Caterers reported that they used between 300 and 500 kilograms of fresh salmon. The quantity of fresh salmon used by chefs varied considerably, ranging from 6 kilograms to 200 kilograms per week. However, most chefs stated that they used between 20 to 30 kilograms per week.

Potential market size for MAP salmon

Eight of the nine respondents said they would prefer to buy MAP salmon instead of fresh salmon. However, one respondent preferred MAP salmon for fillets and would continue to buy whole salmon and clean it in house.

Chefs estimated that they would use between 10 and 30 kilograms of MAP seafood each week. Supermarket buyers indicated they could sell all their fresh salmon using MAP. On this basis the potential market for MAP salmon through each of the three major supermarkets is 1 000 to 2 000 kilograms per week.

Demand for MAP salmon could be limited by the following:

- > buyers' lack of willingness to pay more for MAP salmon
- > lack of value for extending the high quality shelf life of salmon

- > preference for using whole fish to control own portion sizes and freshness
- > concerns by some that the smell, taste and texture of MAP salmon was inferior to the salmon they bought.

Purchasing factors

Factors which affected decision to buy the fresh salmon were product characteristics (smell, appearance, texture), consistent supply and to a lesser extent shelf life.

As highlighted in Table 43, the most important characteristics to chefs were fresh salmon's texture, followed by appearance, smell, shelf life and consistent supply. Chefs were least concerned about packaging and using their existing supplier.

Caterers required fresh salmon which had a good appearance, smell and texture. Of least importance were price and packaging and the use of an existing supplier.

Supermarket buyers considered the appearance of fresh salmon to be most important, followed by smell, packaging, consistent supply and shelf life. Of least importance to supermarket buyers was price.

Table 7 Scores for factors affecting the purchase of fresh salmon¹

Attribute	Sector scores														
	Chefs					Caterers					Supermarket buyers				
	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
Smell	4	1	1	-	-	2	-	-	-	-	2	1	-	-	-
Appearance	5	1	-	-	-	2	-	-	-	-	3	-	-	-	-
Texture	6	-	-	-	-	2	-	-	-	-	1	2	-	-	-
Price	3	2	1	-	-	-	-	2	-	-	1	1	1	-	-
Packaging	-	3	2	1	-	-	-	2	-	-	2	1	-	-	-
Consistent supply	4	2	-	-	-	1	-	1	-	-	2	1	-	-	-
Self life	4	2	-	-	-	-	2	-	-	-	2	1	-	-	-
Current supplier	1	2	2	-	1	-	1	-	1	-	2	-	1	-	-
Total	27	13	6	1	1	7	3	5	1	-	14	6	2	1	-

¹ 5 very important, 1 not very important. Two respondents who assessed the MAP swordfish after the specified date have been included in this table

Product assessment

Form

Table 8 shows that most respondents bought salmon fresh. Two supermarket buyers and a caterer said they bought both fresh and frozen salmon.

Table 8. Form in which salmon¹ bought (multiple responses)

Respondent	Frozen	Fresh
Chefs	-	6
Caterers	1	2
Supermarkets	2	3
Total	3	11

¹ Two respondents who assessed the MAP swordfish after the specified date have been included in this table.

Smell

Respondents were asked to rate the smell of MAP salmon prior to and after cooking. They were also asked to compare uncooked and cooked MAP salmon with the fresh

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salmon they usually bought. As outlined in Table 9, most respondents rated the smell of MAP salmon prior to it being cooked and after it was cooked to be either a five or a four. The average score dropped to a four when MAP salmon was compared with the smell of the fresh salmon they currently bought.

Table 9. Assessment scores for the smell of MAP salmon

Respondent	Component scores																			
	Raw odour					Raw odour compared with usual product					Cooked odour					Cooked odour compared with usual product				
	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
Chefs	2	2	-	1	-	2	1	1	1	-	2	1	2	-	-	-	3	1	1	-
Caterers	1	1	-	-	-	-	2	-	-	-	1	1	-	-	-	-	1	-	1	-
Supermarkets	1	-	-	-	-	-	1	-	-	-	1	-	-	1	-	1	-	-	1	-
Total	4	3	-	1	-	2	4	1	1	-	4	2	2	1	-	1	4	1	3	-

Appearance

The appearance of the MAP salmon was assessed prior to cooking and after cooking. Respondents were also asked to compare the MAP salmon with the fresh salmon they usually bought, both before and after cooking. Table 10 shows that MAP salmon was rated at five or four for appearance prior to cooking, compared with salmon they usually bought. The rating fell to a four or a three when respondents compared the cooked MAP salmon with the cooked salmon they usually bought.

Table 10. Assessment scores for the appearance of MAP salmon

Respondent	Component scores																			
	Raw odour					Raw odour compared with usual product					Cooked odour					Cooked odour compared with usual product				
	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
Chefs	2	2	1	-	-	2	2	1	-	-	2	2	1	-	-	-	3	2	-	-
Caterers	2	-	-	-	-	-	2	-	-	-	1	1	-	-	-	-	1	1	-	-
Supermarkets	1	-	-	-	-	-	1	-	-	-	2	-	-	-	-	-	-	2	-	-
Total	5	2	1	-	-	2	5	1	-	-	4	3	1	-	-	-	4	5	-	-

Texture

Respondents were asked to assess the MAP salmon's texture after it was cooked and compare it with the texture of salmon they usually bought. As presented in Table 11, the texture was rated a five or a four by all respondents. However, when compared with the salmon they usually bought, the rating for texture dropped. Most rated it a four or a three for texture.

Table 11. Assessment scores for the texture of MAP salmon

Respondent	Component scores									
	Texture after cook					Texture after cook compared with salmon usually bought				
	5	4	3	2	1	5	4	3	2	1
Chefs	2	3	-	-	-	-	3	1	-	1
Caterers	1	1	-	-	-	-	1	1	-	-
Supermarkets	2	-	-	-	-	1	-	1	-	-
Total	5	4	-	-	-	1	4	3	-	1

Shrinkage

Respondents were asked to assess the shrinkage (water loss) of the MAP salmon when they cooked it and compare it with the fresh salmon they usually bought. Overall, the amount of shrinkage was rated satisfactory.

Table 12 shows that all respondents rated the shrinkage of the MAP salmon as either a five or a four. The scores dropped when respondents compared it with the shrinkage of the fresh salmon they usually bought. Most respondents rated it as either a four or a three.

Table 12. Assessment scores for the shrinkage of MAP salmon

Respondent	Attribute scores									
	Shrinkage					Shrinkage compared with salmon usually bought				
	5	4	3	2	1	5	4	3	2	1
Chefs	1	4	-	-	-	-	3	2	-	-
Caterers	1	1	-	-	-	-	1	1	-	-
Supermarkets	1	1	-	-	-	1	-	1	-	-
Total	3	6	-	-	-	1	4	4	-	-

Taste

Respondents were asked to rate the taste of MAP salmon and then rate its taste as it compared with salmon they usually bought.

As presented in Table 13, most respondents rated the taste of MAP as a five or a four. However, when they compared it with the taste of the salmon they usually bought, the scores dropped. Most respondents gave it a three for taste.

Table 13. Assessment scores for the taste of MAP salmon.

Respondent	Attribute scores									
	Taste					Taste compared with salmon usually bought				
	5	4	3	2	1	5	4	3	2	1
Chefs	2	2	-	1	-	1	2	1	-	1
Caterers	-	2	-	-	-	-	-	2	-	-
Supermarkets	2	-	-	-	-	1	-	1	-	-
Total	4	4	-	1	-	2	2	4	-	1

*Packaging**Pack size*

Ten of the twelve respondents said the MAP packaging was convenient to store and handle. Two chefs did not consider the MAP packaging suitable for storage or handling. One chef said the plastic trays could not be stacked, as the film was not strong enough. The other said the plastic film would be easily punctured and required a knife to open. As outlined in Table 14, the preferred form in which to buy MAP salmon was by weight.

Table 14. Preference frequency for form in which to buy MAP salmon¹.

Respondent	Weight	Number of cutlets
Chefs	5	1
Supermarkets	1	2
Caterers	1	1
Total	7	4

¹ Two respondents who assessed the MAP swordfish after the specified date have been included in this table.

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These have been broken down into pack by weight and pack by number of pieces. The preferred pack weights were 1 to 2 kg, 2 to 3 kg and 5 kg. The four respondents who nominated a preference for buying MAP salmon by number preferred 1 to 2 cutlets per pack followed by 7 to 10 cutlets.

Price

Table 15 shows that most respondents were willing to pay the same or less for MAP salmon than they paid for fresh salmon. Noone said they were willing to pay more.

Table 15. Frequency for price willing to pay for MAP salmon compared with price paid for fresh salmon.

Respondent	More than current price	Same as current price	Less than current price
Chefs	-	2	3
Caterers	-	1	1
Supermarkets	-	2	-
Total	-	5	4

Table 16 shows that four of the nine respondents said they were willing to pay between \$19 and \$24 per kilogram for MAP salmon. However, most respondents nominated prices lower than \$19 per kilogram. Other prices nominated by respondents included from \$11 to \$15 per kilogram. The prices listed in the survey were seen by these respondents as being above the current market value of fresh salmon.

Table 16. Price willing to pay for MAP salmon.

Respondent	\$19 to 20 per kg	\$21 to 22 per kg	\$23 to 24 per kg	Other
Chefs	1	1	-	3
Caterers	-	1	1	-
Supermarkets	-	-	-	2
Total	1	2	1	5

The data suggests that most respondents were not prepared to pay more for extended high quality shelf life of seafood. Only two (chefs) of the nine respondents were prepared to pay more for it. Most respondents were not prepared to pay more because they perceived that an adequate supply of fresh salmon was available. Other reasons included, no added value to the consumer and the taste was not quite right.

Shelf life of existing product

As presented in Table 17, most respondents reported achieving 4 to 5 days shelf life with the fresh salmon they bought. The additional 5 days of high quality shelf life provided by MAP was not valued by most respondents.

Table 17. Shelf life of fresh salmon¹.

Respondent	1 to 2 days	2 to 3 days	4 to 5 days
Chefs	1	2	3
Caterers	-	1	1
Supermarkets	1	-	2
Total	2	3	6

¹ Two respondents who assessed the MAP swordfish after the specified date have been included in this table.

*MAP swordfish**Market size for fresh swordfish*

Supermarket buyers said they used between 20 and 500 kilograms of swordfish each week. One caterer said they did not buy swordfish weekly. Another said they used between 300 and 500 kilograms of fresh swordfish per week. Several hotel chefs said they used between 50 and 100 kilograms of fish fillets each week. Most hotel chefs said they use 10 kilograms of swordfish each week. One hotel chef said they used 20 to 30 kilograms of snapper, coral trout and salmon per week.

Potential market size for MAP swordfish

Eight of the nine respondents said they would prefer to buy MAP swordfish to their existing swordfish or fish fillets. One respondent did not prefer the MAP swordfish, stating that they did not believe the quality was the same nor the shelf life as long as that of fresh swordfish. This respondent reported off odours when he opened the pack. He was the only respondent to report this problem.

Only four hotel chefs estimated how much MAP swordfish they may use. They stated between 10 and 20 kilograms each week as their potential usage of MAP swordfish. One supermarket buyer said they did not know how much they would use, while the other would not buy it because of the off odours. The caterers also said they did not know how much MAP swordfish they would use.

Demand for MAP swordfish would be limited by the following:

- > buyers' lack of willingness to pay more for MAP swordfish
- > unwillingness to pay for technology which extends the high quality shelf life of swordfish
- > concerns over the safety of eating MAP swordfish as sashimi
- > swordfish is not perceived to be popular with consumers
- > achieving the right portion sizes
- > consistent quality and supply.

Several respondents made favourable comments about the quality (texture and taste) of the MAP swordfish and the packaging.

Purchasing factors

As highlighted in Table 18, the most important factors when purchasing swordfish or fish fillets were smell, appearance and texture. Of least importance were shelf life and obtaining product from their current supplier. Chefs considered the product's smell, appearance and texture to be the most important factors, followed by packaging and consistent supply. Of lesser importance to chefs were price, shelf life and obtaining product from their current supplier.

Table 18. Factors affecting the purchase of fresh swordfish.

Attribute	Sector scores*														
	Chefs					Caterers					Supermarket buyers				
	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
Smell	5	1	-	-	-	1	1	-	-	-	3	1	-	-	-
Appearance	4	2	-	-	-	1	1	-	-	-	4	-	-	-	-
Texture	5	-	1	-	-	1	1	-	-	-	2	1	1	-	-
Price	2	3	1	-	-	-	1	1	-	-	2	-	1	1	-
Packaging	5	1	-	-	-	-	1	-	1	-	2	1	1	-	-
Consistent supply	4	2	-	-	-	-	-	1	-	1	2	1	1	-	-
Shelf life	2	3	1	-	-	-	1	1	-	-	2	1	1	-	-
Current supplier	-	3	2	-	1	-	-	-	2	-	2	-	2	-	-
Total	32	15	5	-	1	3	6	3	3	1	19	5	7	1	-

* 5 very important, 1 not very important

Extending the high quality life of seafood

The most important factors to the caterers were the product's characteristics including smell, appearance and texture. Of least importance were consistent supply and obtaining product from their current supplier. Supermarket buyers considered the appearance of the swordfish or fish fillets to be the most important factor followed by smell, texture, packaging, consistent supply and shelf life. Of lesser importance were price and obtaining seafood from their existing supplier.

*Product assessment**Form*

As outlined in Table 19, most respondents buy swordfish or fish fillets fresh. Only one hotel chef and supermarket buyer purchased swordfish and fish fillets both fresh and frozen.

Table 19. Form in which swordfish bought (multiple responses).

Respondent	Frozen (number)	Fresh (number)	Have not bought
Chefs	1	5	1
Caterers	-	2	-
Supermarkets	1	4	-
Total	2	11	1

Smell

Respondents were asked to rate the smell of the MAP swordfish prior to it being cooked and compare its smell, with the smell of the swordfish or fish fillets they normally bought. They were also asked to rate the smell of MAP swordfish after it was cooked and to compare its smell with the smell of cooked swordfish or fish fillets they usually bought.

As outlined in Table 20, the smell of the MAP swordfish rated well at each stage from the uncooked sample to comparing it with the cooked smell of the product they usually bought. Most respondents rated the smell of the MAP swordfish at five or four. The score given by chefs fell when they compared the smell of cooked MAP swordfish with the smell of cooked swordfish or fish fillets they usually bought.

Table 20. Assessment of the smell of MAP swordfish.

Respondent	Attribute scores																			
	Raw odour					Raw odour compared with usual product					Cooked odour									
	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
Chefs	2	3	-	-	-	1	4	-	-	-	2	3	-	-	-	-	4	1	-	-
Caterers	2	-	-	-	-	-	2	-	-	-	1	1	-	-	-	1	1	-	-	-
Supermarkets	1	-	-	-	1	-	1	-	-	-	1	-	-	-	-	1	-	-	-	-
Total	5	3	-	-	1	1	7	-	-	-	4	4	-	-	-	2	5	1	-	-

¹ One respondent did not cook the swordfish. Their rating was only included prior to cooking.

Appearance

Respondents were asked to assess the appearance of MAP swordfish prior to cooking and compare it with the appearance of uncooked swordfish or fish fillets they usually bought. They were also asked to assess the cooked MAP swordfish and compare it with the cooked appearance of the swordfish or fish fillets they usually bought.

Table 21 shows that the appearance of the MAP swordfish was satisfactory to all respondents. The average score was a five or a four across all categories. The scores fell when respondents compared the MAP swordfish with the swordfish or fish fillets they usually bought. Overall, the scores given by all respondents were lower for the appearance of cooked MAP swordfish when it was compared with the cooked appearance of swordfish or fish fillets they usually bought.

Table 21. Assessment of the appearance of MAP swordfish.

Respondent	Attribute scores																			
	Precook Appearance					Precook Appearance compared with product usually bought					Cooked Appearance ¹					Cooked Appearance compared with product usually bought ¹				
	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	4	3	2	1
Chefs	2	3	-	-	-	2	3	-	-	-	3	2	-	-	-	1	3	1	-	-
Caterers	2	-	-	-	-	2	-	-	-	-	2	-	-	-	-	1	-	1	-	-
Supermarkets	1	-	1	-	-	-	1	-	-	-	1	-	-	-	-	-	-	1	-	-
Total	5	3	1	-	-	4	4	-	-	-	6	2	-	-	-	2	3	3	-	-

¹ One respondent did not cook the swordfish. Their rating was only included prior to cooking.

Texture

Respondents were asked to assess the texture of MAP swordfish as well as to compare it with the texture of the swordfish or fish fillets they usually bought.

Table 22 shows that most respondents rated the texture of MAP swordfish as a five. Two chefs rated the texture of the swordfish as a three. When compared with the swordfish they usually bought most respondents rated the texture of MAP swordfish as a four.

Table 22. Assessment of the texture of MAP swordfish.

Respondent	Attribute scores									
	Texture after cooking					Texture after cooking compared with swordfish usually bought				
	5	4	3	2	1	5	4	3	2	1
Chefs	2	1	2	-	-	1	3	1	-	-
Caterers	1	1	-	-	-	1	1	-	-	-
Supermarkets	1	-	-	-	-	1	-	-	-	-
Total	4	2	2	-	-	3	4	1	-	-

Shrinkage

Respondents were asked to assess shrinkage (water loss) after they cooked the MAP swordfish and compare it with the shrinkage of swordfish or fish fillets they usually bought.

As presented in Table 23, shrinkage was not seen to be a problem by most respondents. Shrinkage was rated by most to be satisfactory with scores of five or four.

Table 23. Assessment of the shrinkage of MAP swordfish.

Respondent	Attribute scores									
	Shrinkage					Shrinkage of swordfish usually bought				
	5	4	3	2	1	5	4	3	2	1
Chefs	1	3	1	-	-	-	4	-	1	-
Caterers	1	1	-	-	-	-	2	-	-	-
Supermarkets	1	-	-	-	-	1	-	-	-	-
Total	3	4	1	-	-	1	6	-	1	-

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Taste

Respondents were asked to assess the taste of the MAP swordfish and compare it with the taste of swordfish or fish fillets they normally bought.

As outlined in Table 24, most respondents were satisfied with the taste of MAP swordfish and indicated that the taste was better than the taste of the swordfish or fish fillets they normally bought.

Table 24. Assessment of the taste of MAP swordfish.

Respondent	Attribute scores									
	Taste					Taste of swordfish usually bought				
	5	4	3	2	1	5	4	3	2	1
Chefs	3	-	1	1	-	2	2	-	1	-
Caterers	1	1	-	-	-	1	-	1	-	-
Supermarkets	1	-	-	-	-	-	-	-	-	-
Total	5	1	1	1	-	3	2	1	1	-

Packaging

Pack size

Respondents were asked to state how they would prefer to buy MAP swordfish, by weight or by number of cutlets. They were also asked to specify their preferred pack size for MAP swordfish. As outlined in Table 25, there was no preference for weight over number. An equal number of respondents stated that they would buy MAP swordfish by weight and by number.

Table 25. Preferred form in which to buy MAP swordfish¹ (multiple responses).

Respondent	Weight	Number of cutlets
Chefs	4	3
Supermarkets	3	2
Caterers	-	2
Total	7	7

¹ Three respondents who assessed the MAP swordfish after the specified date have been included in this table.

Tables 26 and 27 show a range of pack sizes. There was no consistent preference for the number of cutlets in a pack. However, chefs tended to prefer 5 kilogram packs of MAP swordfish. Supermarket buyers stated that they had a need for both retail and bulk packs. Some seafood is sold in retail packs to consumers. Bulk packs would be unpacked and displayed in the seafood counter.

Table 26. Preferred pack size (by weight) to buy MAP swordfish¹.

Size	Chefs	Supermarket buyers	Caterers
250 to 500 g	-	-	-
1 to 2 kg	-	1	-
2 to 3 kg	-	-	-
5 kg	3	-	-
10 kg	1	-	-
Over 10 kg	-	-	-
Other	1	1	-
Total	5	2	-

¹ Three respondents who assessed the MAP swordfish after the specified date have been included in this table.

Table 27. Preferred pack size (by number) to buy MAP swordfish¹.

Amount	Chefs	Supermarket buyers	Caterers
1 to 2 cutlets	1	1	-
3 to 4 cutlets	-	-	1
5 to 6 cutlets	1	-	-
7 to 10 cutlets	1	-	-
Other	-	-	1
Total	3	1	2

¹ Three respondents who assessed the MAP swordfish after the specified date have been included in this table.

Price

As presented in Table 28, respondents' opinions varied as to whether they would pay more, less or the same as they pay for fresh swordfish or fish fillets.

Both supermarket buyers said they would pay the same price for MAP swordfish as they pay for fresh swordfish.

Responses from hotel chefs were more diverse. However, most wanted to pay less for MAP swordfish than they pay for fresh swordfish.

Table 28. Price willing to pay for MAP swordfish in relation to swordfish fillets usually bought (multiple responses).

Respondent	More than present price	Same as present price	Less than present price
Chefs	1	2	3
Caterers	2	1	1
Supermarkets	-	2	-
Total	3	5	4

As outlined in Table 29, the price ranges presented in the survey were considered by most respondents to be too expensive. Four chefs said they would pay market value for MAP swordfish which they said was between \$14 to \$16 per kilogram. The supermarket buyers were also of the opinion that the MAP swordfish price ranges were too high. One buyer said they were willing to pay between \$9 and \$10 per kilogram for MAP swordfish steaks.

Only caterers appeared willing to pay above market price. Both said they would pay between \$20 and \$21 per kilogram for MAP swordfish.

Table 29. Price willing to pay for MAP swordfish.

Respondent	\$18 to 19 per kg	\$20 to 21 per kg	\$22 to 23 per kg	Other
Chefs	-	1	-	4
Caterers	-	2	-	-
Supermarkets	-	-	-	2
Total	-	3	-	6

Shelf life of existing product

Table 30 shows that five of the eleven respondents said they were willing to pay more for extended shelf life.

Extending the high quality life of seafood

Table 30. Responses to the question "Are you willing to pay more for extended high quality shelf life¹".

Respondent	Yes	No
Chefs	3	3
Caterers	1	1
Supermarket buyers	1	3
Total	5	6

¹ Three respondents who assessed the MAP swordfish after the specified date have been included in this table.

Reasons given by respondents who said they would pay more included convenience; reduced spoilage; and ability to provide fresh, top quality seafood to customers.

Reasons given by respondents who were unwilling to pay more for extended shelf life were:

- > always turnover product quickly
- > not convinced the MAP swordfish is of high quality and fresh
- > seafood should be of good quality anyway
- > customers would feel ripped off
- > prefer to buy fresh fish regularly
- > cost would be too high
- > there is an abundant supply of fresh fish available.

As outlined in Table 31, most respondents said they had 2 to 3 days' shelf life for the fresh swordfish or fish fillets they usually bought. Most supermarket buyers said they achieved 4 to 5 days shelf life for fresh swordfish or fish fillets.

Table 31. Shelf life of fresh swordfish/fish¹ fillets usually bought.

Respondent	1 to 2 days	2 to 3 days	4 to 5 days
Chefs	1	4	1
Caterers	-	2	-
Supermarket buyers	1	-	3
Total	2	6	4

¹ Three respondents who assessed the MAP swordfish after the specified date have been included in this table.

The marketing component of the FRDC funded project entitled "Extending high quality shelf-life of seafood products" has involved establishing communication channels with industry to maintain their input and direction to the project and educating industry on modified atmosphere packaged (MAP) seafood.

To achieve these objectives, MAP newsletters have been sent at irregular intervals to industry, to inform them of the results from the project and to provide information on MAP seafood. Three newsletters have been sent. In addition, two separate product assessments have been conducted with industry.

In March 1997, MAP scallops that had been stored for three days were sent to supermarket seafood managers, caterers and chefs in Brisbane, Sydney and Melbourne for

assessment. These were sampled at a range of times from four to ten days. The average score for "appearance" was 4.1 for a 1 to 5 scale. One supermarket stated that the product packaging was excellent while others rated it as good. One individual stated that MAP scallops had better flavour and were tenderer than the scallops currently being purchased. Another had the opinion that the flavour was of fresh scallops. The results were that MAP scallops were appealing with no difference detected between these and scallops currently purchased in terms of texture, flavour and smell. The average score for "overall quality" was 4.3 for a 1 to 5 scale. The quality of MAP scallops was considered high to very high and the price paid for these would depend on cost and availability. One negative aspect pertinent to MAP products was that the drip loss was obvious.

In November 1997 a sample of MAP salmon and swordfish were sent to industry for assessment. The findings from industry's assessment of the MAP salmon and swordfish are presented in this report. The MAP salmon and swordfish samples were sent to twelve people, including chefs, supermarket buyers and caterers in Brisbane, Sydney and Melbourne. They were sent a questionnaire and set of instructions on how to evaluate the MAP salmon and swordfish. Respondents were asked to open and assess the MAP salmon and swordfish when it was between 6 and 8 days old.

Information was collected from respondents about how much MAP salmon and swordfish they would buy and if they preferred the MAP product to the salmon and swordfish they usually bought. For both the MAP salmon and swordfish, eight respondents said they preferred it to the salmon and swordfish they usually bought. Supermarket buyers said they potentially would replace all the salmon they currently sell with MAP salmon. Supermarket buyers said they sold between 1 000 and 2 000 kilograms of fresh salmon each week. Supermarket buyers said they bought approximately 20 to 500 kilograms of swordfish each week. One supermarket buyer would not buy the MAP swordfish. The other could not estimate the amount of MAP swordfish they would use.

Chefs said that they would potentially use between 10 and 30 kilograms of MAP salmon each week. Four of the chefs said they would potentially use between 10 and 20 kilograms of MAP swordfish each week. The caterers did not provide estimates of the amount of MAP salmon or swordfish that they would use.

In buying salmon and swordfish, the factors which respondents said were the most important were smell, texture and appearance. Of lesser importance were shelf life and consistent supply. The salmon and swordfish were rated on a five-point scale for smell, appearance and texture. Five represented very appealing, very satisfied or much better and one represented not very appealing, not very satisfied or much worse. Both the salmon and the swordfish averaged scores of five and four for smell, appearance and texture. The scores for both products tended to fall by one point to a four or a three when industry were asked to compare the MAP salmon and swordfish's smell, appearance and texture with the smell, appearance and texture of the salmon and swordfish they usually bought.

Most respondents were very satisfied or satisfied with shrinkage (water loss) for both the MAP salmon and swordfish. However, the scores dropped for both products when respondents were asked to state if the shrinkage was much better or worse than the salmon and swordfish they usually bought. Most respondents were also satisfied with the taste of MAP salmon and swordfish. However, again the scores fell when respondents were asked to compare it with the taste of the salmon and swordfish they usually bought.

Most respondents said the MAP packaging was convenient to store and handle. The preferred pack sizes for salmon were 1 to 2 kg, 2 to 3 kg and 5 kg. Chefs had a preference for MAP swordfish in 5-kilogram packs. Supermarket buyers liked both bulk and retail packs.

Extending the high quality life of seafood

Most respondents wanted to pay either the same or less for MAP salmon and swordfish as they pay for fresh salmon and swordfish. This response should have been anticipated given the question. Only three respondents, two caterers and one chef, said they were willing to pay more for MAP swordfish than they pay for swordfish. For the MAP salmon, most respondents said they would pay between \$11 and \$15 per kilogram. For the MAP swordfish, most of the chefs said they would pay between \$14 and \$16 per kilogram. One supermarket buyer said they would pay between \$9 and \$10 per kilogram for MAP swordfish.

The respondents' reaction to price was related to a perceived lack of value from high quality shelf life extension of seafood. In response to the question "Are you willing to pay more for extended high quality shelf life?", seven of nine respondents said no for the MAP salmon and six of the eleven respondents said no for the MAP swordfish. More respondents appeared willing to pay more for shelf life extensions for MAP swordfish than for MAP salmon.

The survey results suggest a few barriers to the adoption and use of MAP in the seafood industry. There is a lack of interest in paying more for MAP seafood products and an unwillingness to pay for the cost of extending the shelf life of certain seafood (salmon). Although the scores for all product attributes (smell, appearance, texture, taste and shrinkage) were high, the scores consistently fell by at least one point when respondents compared the MAP seafood with the seafood they usually bought. It may be beneficial to conduct blind assessments with industry to identify any real difference between MAP seafood and fresh seafood currently bought. The results of this research would assist in providing direction for future research and in educating the seafood industry.

Conclusion

MAP salmon and swordfish appear to have market potential provided they are offered for sale at a price similar to the price of fresh seafood. MAP swordfish would appear to have greater potential, as some respondents were willing to pay more for this product than for the swordfish they usually bought. The scores given for the product's characteristics, including smell, appearance, taste, texture and shrinkage, were favourable. However, the scores fell when respondents compared the MAP seafood with the seafood they usually bought. Consideration should be given to conducting blind industry assessments of MAP seafood and fresh seafood to determine if these differences are real or perceptual. This information would provide direction to the research and assist in promoting MAP to the seafood industry.

Newsletters

Newsletters reporting the results of trials have been distributed to participants listed on the contact sheet present in Appendix 5.

Industry Collaborators

A number of companies offered to collaborate on this project. Their participation ranged from the supply of raw material, access to raw material, information about product specifications, sample appraisal to market contacts. A list of all the contacts made and their pertinent information has been presented in this report in Appendix 7.

Industry Visits and Contacts

A number of industry visits were conducted to observe MAP of non-seafood products being processed or to discuss involvement in the project.

Steggles Limited

Toongarra Rd Wulkuraka Ipswich 4305

Contact: Jason Oldaker

Steggles routinely MAP whole broiler chickens for their distant customers and will be packing chicken pieces in the future. They use a MAP machine supplied by the Oakland company of New Zealand. This company installs the packers and supplies the barrier bags at a contract price, which avoids the capital outlay normally, associated with new machinery.

Harvest Freshcuts Pty Ltd

79 Tile St Wacol 4076

Contact: Rob Munton

This company contract packs for Woolworths using equipment from a French manufacturer. They have a confidentiality agreement which prohibited close study of the machinery. Discussions mainly involved the control of raw material quality and handling. This company spends a large amount of time and money in research and development and provided seed stock of the specific types of salad vegetables intended for MAP to the growers. The packing of vegetables does not involve the addition of carbon dioxide or oxygen, only nitrogen to maintain positive pressure.

A Geelong scallop company

A company was currently undergoing registration for ISO certification and a major exporter of southern scallops to Europe were initially eager to become involved in the project. They were to send samples in August for evaluation prior to any packing trials. If there was little difference in the microbial flora to that of the northern species then storage trials would have begun after the appraisal of the raw material.

Satellite Seafoods

17E Quay St Bundaberg 4670

Contact: Bruce Trewavas

This factory was having difficulty with the marketing of spanner crabs and on occasion picks the meat for local sale. If the demand for this product increased there was the possibility of including this company with storage trials. The company also markets tuna and swordfish.

Pioneer Seafoods

17 Dawson Rd Gladstone 4680

Contact: Barry Young

This company had been contacted previously about participation in the project but did not show any interest. They were concentrating on processing scallops and live reef fish. After a visit to the factory where a vacuum skin packaging machine was operating a second invitation was offered. With this equipment, the large new factory currently in operation and the geographic location this establishment would have been a good prospect for processing MAP reef fish. Art Laudani (Fresh seafood category manager for Woolworths Supermarkets Queensland) did buy produce from this company and visited to seek involvement in the project. If and when trials are completed he wants to test market MAP fish in the Gladstone shop.

Scarborough Trawler Seafoods

Box 519 Redcliffe 4020

Contact: Ric Morgan

Extending the high quality life of seafood

This company was one of the few that returned the questionnaire about processing conditions. The completion and return of this questionnaire was a prerequisite for participation in the project. Samples were obtained from the cutting line and tested. The bacterial levels were high for MAP so some evaluation and cleaning improvements of the work area was carried out. The data for this exercise is present further on in the report. An independent processing environment necessary for producing MAP at this factory was not available so no further work was carried out.

Fortuna Seafoods

PO Box 933
Mooloolaba Qld 4557
17 Production Av Kawana Estate
Contact: Steve Hall

This company exports long-line caught tuna and broadbill swordfish to Japan via Sydney. There was some value-adding already occurring with tuna and swordfish cutlets being vacuum packed and frozen for domestic sales. The company has the vacuum skin packaging equipment which would be required for MAP and has been encouraged by Art Laudani of Woolworths to become involved in the project. The information supplied on the questionnaire about the capture and processing conditions indicated that this company could successfully produce MAP seafood. The company was contacted for further information discussion centred about possible products that could be the basis of experiments. While tuna was the main commodity processed the colour changes that MAP can induce in this fish it was decided that swordfish would be the first species to conduct storage experiments on.

Nortas Pty Ltd

100-104 Mornington Rd
Mornington
Tas 7018
Contact: Ashley McCoy

This company declared an interest in participating in MAP trials and as the processing in the salmon aquaculture industry can be highly controlled good quality raw material could be expected. This and the fact that many of the wild capture industry had trouble meeting quality standards made salmon a most suitable candidate for experimentation. Samples were appraised. Ongoing difficulty with quality required a factory visit to sample extensively the sites for contamination.

Goulburn River Trout Pty Ltd

Goulburn Valley Highway
PO Box 69
Alexandra 3714
Contact: Hugh Meggett

This company became interested in MAP through the contact established with the Aquaculture CRC. This company is one of the largest trout producers in Australia, is new and is trying to produce a variety of products. A visit to the factory was conducted in conjunction with a salmon factory visit.

Quality Appraisals And Improvements

Samples of fish were obtained from one of the local processors to determine the quality of seafood being produced. These were tested for total count of bacteria, the number of H₂S producers and presence of coliforms. The fresh whole gutted fish contained a total

of 1,700 cfu/g and no H₂S producers or coliforms while the fillets contained a total of 114,800 cfu/g, 396 cfu/g for H₂S producers and no coliforms.

The counts obtained were much too high to use for MAP. To assist the processor in improving the quality of the product a further visit to the factory was planned. This visit was carried out to identify some sources of contamination and to train the processor in methods of cleaner handling of seafood. Swabs were obtained from the cutting table before and after filleting of fish. These and tissue samples from the fillets were evaluated for the bacterial load. The following table contains the different bacterial counts tested.

Table 32. Microbial counts from the processing site and progressive samples taken during processing.

Sample No.	Site	Total log count (cfu)	H ₂ S producer log count (cfu)	Coliform log count (cfu)
1	Swab of cutting table at start	2.69/cm ²	0.30/cm ²	0/cm ²
2	Swab of cutting table at start after hosing with town water	2.78/cm ²	0.78/cm ²	<0/cm ²
3	Fillet after some cutting of fish	3.87/g	1.65/g	<1/g
4	Swab of table after some cutting of fish	2.48/cm ²	1.0/cm ²	<0/cm ²
5	Water holding fish used for washing cutting table	3.88/ml	1.65/ml	0/ml
6	Water from basin downstream of fish used for washing knife	4.11/ml	2.32/ml	0/ml
First 2% chlorine wash of table				
7	Swab of cutting table at start after chlorine	1/cm ²	<0/cm ²	<0/cm ²
8	Fillet after holding water (sample 5) used to clean fish and table	3.28/g	1.90/g	<1/g
Second 2% chlorine wash of table				
9	Swab of table after several fish cut and chlorinated water used to wash	1.18/cm ²	<0/cm ²	<0/cm ²
10	Fillet after cutting handled by cutter	4.02/g	2.08/g	<1/g
11	Town water supply (NHMRC advisory std <100cfu/ml and no coliforms)	2.22/ml	<0/ml	<0/ml
12	Fillet (same as 10) after 15 minute soak in town water but handled by cutter	3.39/g	1.70/g	<1/g

Samples number 3 and 10 from the fillets were tested for chlorine residue. None was found but 0.5ppm was present in the town water. The result show that the cutting bench and wash water were sources of bacterial contamination (samples 1, 2 & 4). The counts in the fillets (samples 3, 8 & 10) while high do not mean that they were unfit for human consumption. This would have to be much higher, for example above 1,000,000cfu/g. We use this level as a bench mark for the end of shelf life. The count however does increase the risk of contamination by toxin producing bacteria which can grow under MAP conditions. It would be ideal to start with counts between 100 and 1,000. This is the level achieved by the beef industry.

Hosing down of the work site with town water while clean (sample 11) it is insufficient to remove accumulated bacteria (sample 1, 2 & 4). These are then transferred to the fillet (sample 3). The holding water the uncut fish are kept in (sample 5) is another source (especially of coliforms which come from the gut) and should be flushed frequently. One problem was that the fish were in the sink that received fresh water and this flowed over the fish and into the next sink (sample 6). A higher count was present downstream of the fish (sample 6) yet this was presumed to be clean and used to wash the knife. The water from the sink containing the fish (sample 5) was used to wash the cutting surface. None of this water should be used to clean the cutting surface or equipment.

Extending the high quality life of seafood

The application of 2% chlorine will reduce the amount of contamination from the table and knives (samples 7 & 9). As the table shows washing the cutting table with chlorinated water (samples 7 & 9) will remove bacteria deposited during cutting. The count present in sample number 10 (a fillet) appears to have been contaminated from the hands of the person cutting the fish but as no swabs were taken this can not be proven. After washing in town water for 15 minutes the load has been significantly reduced (sample 12). It would be prudent for the fish cutter to scrub hands frequently during processing. There was no chlorine residues detected in the fillet cut on the chlorine-cleaned bench. The data indicates that chlorine rinses of the bench and equipment can reduce the amount of bacteria present in the fillets and leave no residue in the flesh.

Another factory was sampled for prospective MAP trials. Skin off filleted fish samples held for 24hrs at 2°C with ice packs (ice in plastic bags) before a total bacterial count of 1,112,500 cfu/g, 312,500 cfu/g H₂S producers and coliforms present at 0.1 cfu/g were identified. These levels are too high to start storage trials utilising this raw material. Some improvements in handling were required before any MAP could be carried out with this company.

Fortuna Seafoods

Three samples received from the factory were sampled and stored in air for three days at 4°C. The average pH was 6.25, the total bacterial count was 50,000 cfu/g and the H₂S producers count was 114 cfu/g. After three days these changed to 6.3, 24,363,000 cfu/g and 35,408 cfu/g respectively.

These initial counts were too high for use in a storage trial and the three-day storage shows there is very little shelf life possible. A visit to the factory was planned to identify the sources of contamination and to develop practices which could be used to improve the quality of the raw material. The use of chlorine for preparing the loading and cutting tables was demonstrated. Table 33 contains the bacterial counts for a number of sites sampled in the processing line.

Table 33. Microbial counts from the processing site and progressive samples taken during processing.

Sample No.	Site	Total log count cfu/g
1	Swab of end of loading table at start before hosing with town water	4.39/cm ²
2	Swab of loading table at start after dirty practices and hosing with town water	1.8/cm ²
3	Swab of loading table after cleaning with chlorine	0/cm ²
4	Swab of skin surface of second tuna down table	1.26/cm ²
5	Swab of loading table after several fish	2.92/cm ²
6	Piece of second tuna after cutlets produced	5.29/g
7	Swab of skin surface of swordfish	2.42/cm ²
8	Swab of cutting table during cutting of swordfish	3.04/cm ²
9	Swab of swordfish loin	5.17/cm ²
10	Swab of cutting table after cutting of swordfish cutlets	3.0/cm ²
11	Swab of cutting table after cutting table cleaned	2.43/cm ²
12	Swab of outlet table under fillet board	0/cm ²
13	Swordfish sample from trial sample A	5.03/g
14	Swordfish sample from trial sample B	5.08/g

The tables used for cutting the loins and cutlets carried a reasonable load of bacteria which indicates that the contact from the fish can lead to cross contamination of successive fish. The levels on the surface of the loins after removal from the frame was very high and has led to the high total counts observed in the cutlets. The belly cavity is the most likely source of contamination considering the low counts on the surface of

various fish. The cutter touches this area while the loins are excised and is thus spreading the bacteria onto the cut surfaces. At the next sampling sterile samples of flesh will be taken to determine levels of bacteria in the flesh in undamaged, damaged areas and those close to the gut lining.

A number of strategies have been developed to reduce the bacterial load of the cutlets. The capture vessel will cease to use carpets to lie fish on during the cruise and replace it with a sterilisable sealed foam rubber mat. The use of seawater ice will continue but the belly cavity of the fish will be swabbed with a chlorine solution before ice storage. The fish will be swabbed again with chlorine when the fish are cleaned on the loading table at the factory. Chlorine will be used to clean all surfaces and a piece of paper towel will be placed under each fish during cutting which will be disposed of before the next fish arrives. The knives and gloves of the cutter will be washed between and during the cutting of each loin.

Satellite Seafoods

Satellite Seafoods is another company that processes swordfish as a by-catch of a long-line operation. After the final trial of swordfish failed due to poor quality a sample was obtained for evaluation. Procedures developed during the previous trials were recommended for the preparation of samples by this processor. The microbial evaluation found 1,260 cfu/g for the total bacterial count, 0 cfu/g for the H₂S producers and coliform counts and 25 cfu/g for Gram +ve anaerobes while the mean total demerit score was 9. This quality was the best of any seafood evaluated so far by this project and storage trials were commenced directly.

Nortas Pty Ltd

A batch of 15 salmon fillet pieces in the size range 170-190g was received for evaluation of quality. The process at the factory was stated as the following. Fish were harvested and brought to the factory, gutted and gilled, stored overnight for rigor to extinguish and filleted. The fillets were then stored overnight to allow easier removal of pin bones. The next day samples were prepared for shipment. Samples arrived at the laboratory on the Tuesday. This indicated a two-day storage delay before appraisal.

Three pieces were sampled on each day for total count, hydrogen disulphide producers, gram positive anaerobes, spore producing gram positive anaerobes, coliforms, pH and sensory attributes using demerits. A copy of the demerit sheet used for salmon is present in Appendix 3. Table 34 shows the data obtained from the salmon pieces.

Table 34. Data collated from appraisal of salmon pieces stored at 4°C.

Parameter	Storage time (days)			
	0	1	2	3
pH	6.58	6.94	6.20	6.33
Log total plate count	4.60	4.90	5.01	5.11
H ₂ S producer log count	2.10	2.58	2.67	2.77
Coliform log count	2.02	2.16	2.23	2.09
Anaerobic log count	0	0	0	0
Raw drip score	0	0	0	0
Colour score	1	1	1.25	2
Flesh appearance score	0	0.50	0.42	0.58
Raw odour score	0.50	0.50	0.50	1.20
Cooked drip score	0.42	0.50	0.70	0.58
Cooked odour score	1.17	1.50	3.67	4.50
Flavour score	1.67	2.33	3.17	3.50
Texture score	0.17	0.67	0.83	1.20
Moisture score	0.00	0.50	1.42	1.08
Total demerit scores	4.92	7.50	11.95	14.65

There was some variability in the bacterial counts between samples. The log total count rose to rejection level within two days of storage due to the high bacterial count of the samples when they arrived at the laboratory. The hydrogen disulphide producers were present in slightly higher numbers than the coliforms. Both of these groups were only a minor component of the total count. There were no anaerobic bacteria present. The history of the fish was investigated and it was identified that the fish supplied had been stored for four days before cutting. This allowed growth of microbes to high levels which then contaminated the cutlets when the fillets were cut. More samples produced using better handling practices and of a fresher nature were requested. When these arrived they were tested as before (Table 35).

Table 35. Data collated from appraisal of second sample of salmon pieces stored at 4°C

Parameter	Storage time (days)		
	0	1	4
pH	6.32	6.24	6.28
Log total plate count	5.08	5.03	8.39
H ₂ S producer log count	2.85	2.38	4.81
Coliform log count	2.25	2.99	4.75
Anaerobic log count	0	0	5.91
Pasteurised anaerobic log count	0	0	0
Raw drip score	1	0	0.25
Colour score	1	1.25	2
Flesh appearance score	0	0.42	0.33
Raw odour score	0.33	0.50	1
Cooked drip score	0.17	0.42	0.67
Cooked odour score	2.50	2.50	4.5
Flavour score	3.17	2.67	3.83
Texture score	0.17	0.33	1.08
Moisture score	0.83	1.83	1.83
Total demerit scores	2.83	9.92	15.49

As the initial bacterial counts were still too high to start MAP storage some processing changes were required to reduce these counts. After consultation with the Production Manager some cleaning of belly and skin areas with a chlorine solution and separation of the cutting lines was implemented. A new sample of pieces and two whole fish were received for testing. One of the whole fish had not been washed with chlorine while the second had been scrubbed both externally and in the belly cavity with the chlorine solution. Table 36 shows the data obtained from the whole fish.

Table 36. Microbial counts from swabs taken from various sites of two whole gutted salmon

Treatment Surface Position on body of swap site	Unwashed				Washed			
	Outside head	Belly cavity tail	Outside head	Belly cavity tail	Outside head	Belly cavity tail	Outside head	Belly cavity tail
Log total plate count/cm ²	0.78	0.60	2.49	2.67	0	0.78	0.30	0.93
H ₂ S producer log count /cm ²	0	0	1.40	1.38	0	0	0	0
Coliform log count/cm ²	0	0	0	0	0	0	0	0
Anaerobic log count/cm ²	0	0	0	0	0	0	0	0
Pasteurised anaerobic log count/cm ²	0	0	0	0	0	0	0	0

As expected bacteria were present on the surface and in the belly cavity of the unwashed fish. The belly cavity lining is a reservoir for bacteria which readily spreads onto fillets when they are cut. The simple procedure of scrubbing this area and the outside of the fish with a chlorine solution has reduced numbers by a log factor of two. If this procedure is incorporated into the normal processing line then good quality fillets should be produced.

The next sample did not have low bacterial counts so a treatment stage was needed to reduce counts after filleting. A dip in 1% potassium sorbate is the most commonly used method for reducing the bacterial load of seafood. Samples of freshly killed and gutted salmon were sent to the laboratory overnight for a dipping experiment. Salmon were sampled to provide counts of bacteria present on the outer surface and within the gut cavity. The fish were then dipped for one or three minutes in a 1% potassium sorbate solution and left to drain for five minutes. Swabs were taken beside the sites previously sampled then the fish were stored in a brine/ice slurry for 24 hours. After this time the fish were drained and swabs taken close to the earlier sites. The swabs were evaluated for total numbers of bacteria, H₂S producers and coliforms. Table 37 shows the log count per cm² for each treatment.

Table 37. Log counts of spoilage bacteria on salmon.

Dip time (min)	Treatment	Total log count cfu/cm ²	H ₂ S producer log count cfu/cm ²	Coliform log count cfu/cm ²
1	pre-dip	1.37 ^{bc}	0.02	-0.04
3	pre-dip	1.15 ^c	-0.08	0
1	post-dip	1.59 ^{ab}	0.03	0
3	post-dip	1.2 ^{bc}	-0.04	-0.04
1	24hr brined	1.34 ^{bc}	0	-0.04
3	24hr brined	1.83 ^a	0	0

^{abc} Different letters signify significant differences between treatments ($P < 0.05$)

The only significant differences present was between the sampling position with the belly cavity containing the higher count per cm². There was a significant interaction ($P < 0.05$) between the dip time and treatment but there was no consistent trend evident. Later samples supplied by the factory still contained large numbers of bacteria. To identify the source of contamination a visit to the factory was organised. The report to the company follows.

Factory Visit

Summary

- > Low numbers of bacteria on HOGG salmon and fillets can be achieved with due attention to processing operations.
- > Washing of HOGG fish with water sprays before and after storage in ice is strongly recommended.
- > A short treatment with potassium sorbate can be included between evisceration and grading with minimal disruption to the processing line.
- > A system should be established so that the holding trough, filleting boards, trimming boards, pin boning boards, portioning boards, knives and weighing scales are frequently cleaned during processing to minimise the risk of bacterial contamination.
- > A system for routine washing and sanitising of baskets and other process items would help maintain low bacterial numbers. Investigation of options for this operation is strongly encouraged.

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Product Quality

The microbial counts of the portions supplied to the CFT microbiology laboratory have been moderate to high. Table 38 shows the counts for key microbial groups for all samples delivered to Brisbane and the shelf life obtained.

Table 38. Salmon portion counts for all deliveries to the laboratory.

Date	Total log count cfu/g	H ₂ S producer log count cfu/g	Coliform log count cfu/g	Air storage days at 4°C till log count > 6.0 cfu/g
13 May 1998	2.81	0	0	5
26 February 1998	4.07	-	-	not stored
19 February 1998	3.61	2.34	1.34	not stored
4 November 1997	4.27	0.40	1.0	3
7 October 1997	2.67	0	0	> 10
25 September 1997	4.60	2.85	2.26	2
9 September 1997	4.60	2.10	2.02	2

The reason for visiting the factory was to confirm the main sites of contamination so that improvements to the processing line could be recommended with an understanding of the existing conditions.

The fact that low counts for all types of bacteria were achieved for one shipment of portions to the laboratory indicates that improvements could be made to the processing line. When the normal processing line supplied the portions, the counts were moderate to high and as the table shows did not lead to good shelf-life times when stored at 4°C. Normal storage temperature for food should be between 0 and 2°C but this higher temperature is used to encourage the growth of *Clostridium botulinum* so that it can be identified in samples when present. This is still considered an abuse temperature but unfortunately many processors, shippers, retailers and supermarkets hold seafood at much higher temperatures. Using this temperature during the storage trials provides an insight into what quality the consumer would normally receive. Seafood is considered not fit for consumption when the total log count is greater than 6.0 cfu/g. This count or the sensory attributes are used in this project to signify the end of shelf life.

Survey Methods

Numerous sites within the factory were sampled using the swab technique and salmon portions from the end of the processing line were shipped to the laboratory for enumeration of bacteria present. Swab samples taken from selected sites on the processing line can give an indication of where contamination occurs. Swabs remove bacteria from a fixed surface area. In this case a sterile template was placed over a surface exposing a 9 square centimetres of that surface. It was repeatedly wiped using cotton wool wrapped about a stick that was then placed in a 9.2mL sterile peptone solution.

The samples were returned to the laboratory where small volumes were poured onto agar plates containing selective media. The plates were incubated for several days to promote the growth of bacterial colonies. Each colony that grows represents an individual microbe present in the original swab and is called a Colony Forming Unit (cfu). The counts are then converted to the number of bacteria per square centimetre (cfu/cm²). When a piece of flesh is sampled 10g is macerated with 100mL of peptone solution to provide a count. This leads to big differences between the numbers obtained from surface swabs and from flesh samples.

A number of different types of bacteria were selected for enumeration. While the total count is used to determine the end of shelf life, the H₂S producers are the bacteria responsible for production of off-fish odours and flavours and the coliforms usually

indicate that contamination from the gut of fish has occurred. Psychrotrophs are bacteria that grow well at low temperatures.

Processing line experiments

Factory samples

The use of foot baths, hairnets and protective clothing are very good tools to reduce the contamination of food material from human and external sources and their use throughout the factory was a sign of good hygiene being practiced. Unfortunately the fish themselves can be a great source of bacterial contamination. Swabs are used for site evaluations rather than flesh samples because they provide a real time evaluation time. Delays in transport and handling will lead to some microbial growth in flesh samples. The amount of bacteria present on work surfaces can be highly variable because one fish may wipe off the bacteria deposited by the previous fish and contaminate a clean surface. Counts generally increase as the day progresses because of the amount of product being processed. The samples taken should be viewed as a snapshot of the bacteria present at only one time as the counts could increase later in the day. Samples were taken after the first shift when staff had morning tea. Figure 1 following shows a flow chart of the salmon processing line with the corresponding sample number used in Table 42 and the sites for possible contamination identified.

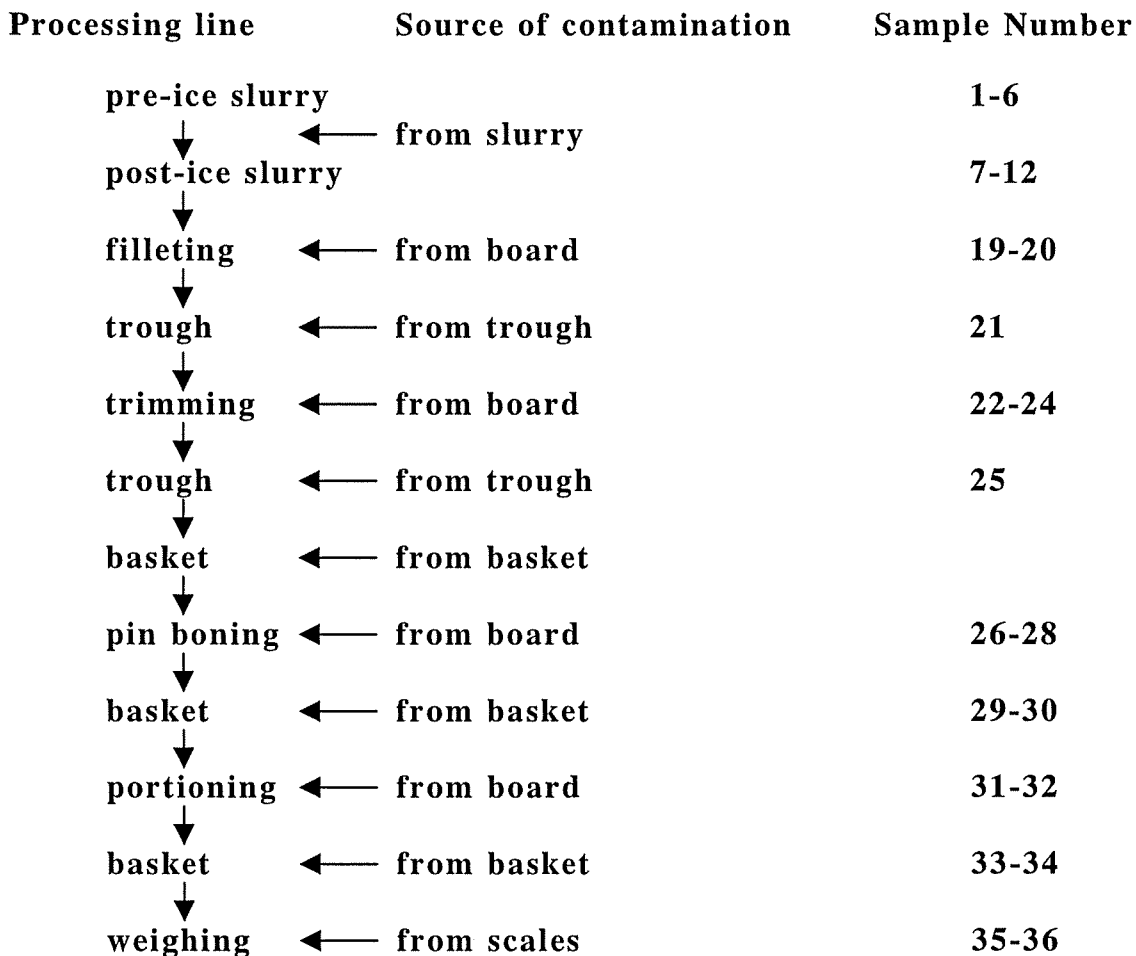


Figure 1. Flow chart of salmon processing line.

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From our work with salmon, a surface log count of 2.24 cfu/cm² (an apparently low number) can reflect a flesh log count of 4.07 cfu/g (a moderate number and one too high for MAP or good shelf life). Table 39 shows the various counts obtained from swabs taken at the factory.

Table 39. Microbial Counts from factory sampling swabs.

Sample number	Site	Total log count	H ₂ S producers cfu/cm ²	Coliforms cfu/cm ²
Gutted and graded, pre slurry				
1	outer surface fish 1	5.03	0	0
2	belly cavity fish 1	4.13	0	0.48
3	outer surface fish 2	3.41	0	<1
4	belly cavity fish 2	4.00	0	0.85
5	outer surface fish 3	4.50	0	0
6	belly cavity fish 3	2.57	1	0
Ice slurried fish in filleting room				
<i>normal treatment 24 hr in ice</i>				
7	outer surface fish a	1.30	0.60	0
8	belly cavity fish a	1.70	0	0.30
9	outer surface fish b	0	0	0
10	belly cavity fish b	1.48	0	0
11	outer surface fish c	0	0	0
12	belly cavity fish c	1.30	0	0
<i>post sorbate 48 hr in ice</i>				
13	outer surface fish 1	1	0	0
14	belly cavity fish 1	1.78	0	0
15	outer surface fish 2	<1	0	0
16	belly cavity fish 2	1.85	0	0
17	outer surface fish 3	1.70	0	0
18	belly cavity fish 3	2.20	0	0
Filleting table				
19	Middle cutting board (1 hr use)	3.42	2.0	0
20	Edge of cutting board (1 hr use)	3.18	1.28	0
21	Trough of filleted fish	2.0	0.48	0
Trimming table				
22	Meat side fillet1	1.78	0	0
23	Meat side fillet2	1.78	0.30	0
24	Meat side fillet3	3.21	2.04	1
25	Trough of filleted fish before pinning	2.04	0	0
Pin-boning table				
26	Pin-boned & skinned fillet a	1.60	0.48	0
27	Pin-boned & skinned fillet b	2.45	0	0
28	Pin-boned & skinned fillet c	1.48	0	0
29	Basket side holding boned & skinned fish	1.30	0	0
30	Basket bottom holding boned & skinned fish	2.53	1	0
Portioning table				
31	Portion cutting board	2.65	0.60	0.30
32	Portion cutting board	1.70	0	0
33	Basket bottom holding portions	1.70	0	0
34	Basket side holding portions	0	0	0
35	Scale pan centre	2.26	0.30	0
36	Scale pan edge but not side	3.77	2.46	0.85
37	Smoking Racks	0	0	0
38	Smoking Racks	0	0	0

The counts from gutted and graded salmon, as shown by this study (sample numbers 1-6 in 39) and previous shipments, can be very high. The fish were brought to the factory

ungutted in large numbers in ice slurry before cleaning. The washing after gutting has not been sufficient to reduce high counts on some individual fish (1 & 5). More thorough washing of the surface and belly cavity is required. When these fish are stored in an ice slurry again there is opportunity for contamination of any fish with low counts, especially if there is a lengthy storage time (I was told fish could be present in the slurry for up to two days). This encourages the growth of cold loving species of bacteria (psychrotrophs). The total count ranged from 50 to 100% for portions.

While the counts obtained for fish unloaded at the filleting table were low (7-12), the counts obtained from the filleting board (19 & 20) indicate that previous fish still retained high counts. The application of a 2% potassium sorbate dip before ice slurry storage for 48 hours restricted the counts of bacteria (13-18) to that of untreated fish stored for 24 hours. The conveyor took 30 seconds to lift gutted fish onto the grading table.

The inclusion of a dip tank with fish removal by the conveyor would minimise or eliminate any delay in the processing line. Alternately, the fish could be dipped after grading. This treatment will ensure that all fish leaving the grading line will have lower bacterial counts and thus better shelf life. The treatment of whole fish leads to minimal chemical residues whereas the dipping of fillets can lead to residues of 500mg/kg.

The handling of fillets during and after filleting will spread bacteria from the skin side to the board and the newly exposed flesh. The filleting board should be cleaned and sanitised more frequently than the present hourly clean and possibly with chlorine or other chemical solution. I would recommend after a maximum of five fish. Because bacteria have been deposited on the surface of the trough (21 & 25) the flesh side of any clean fillets easily becomes contaminated (22-24).

After trimming fillets are placed into baskets and then removed for pin boning. The constant reuse of baskets during processing without cleaning (29, 30, 33, 34) helps spread bacteria further between these stages. A cleaning system for baskets and utensils should be investigated to minimise contamination of and re-contamination from processing items such as baskets, boards, knives etc. Washing of fillets occurred only during the pin boning stage and even this was insufficient to reduce counts (26-28). The portioning board counts (31-32) show that bacteria have been transferred to the freshly cut surfaces of the portions. The extremely high bacterial count on the scale (35-36) shows the importance of effective and regular cleaning of all surfaces that come in contact with fish.

The smoking racks, while containing remnants of flesh, did not contain any bacteria when sampled. The presence of a suitable growing media for bacteria for long periods of time could lead to contamination if repeatedly used for cold smoking.

Salmon Portions

Following the factory survey a batch of salmon portions were sent to the laboratory in Brisbane on 19 February and the counts can be seen in Table 38. No *E. coli* were found in salmon portions or swabs. The similarity between the counts of individual portions indicates that the source of microbial contamination has occurred at an earlier stage of processing and that handling has spread bacteria evenly over all portions.

To further improvements to the processing line a comparison of three treatments for cut salmon portions was carried out. Six portions of salmon were dipped in freshwater, six portions were dipped in 40ppm chlorinated water while another six were dipped in 2% potassium sorbate for two minutes. The microbial count and sensory demerits were appraised for the different treatments. The data obtained is present in Table 40.

Table 40. Microbial count and demerit scores for salmon portions dipped in fresh water, 40ppm chlorinated water or a 2% solution of potassium sorbate.

Measurement	Water dip	40ppm Cl ₂ dip	Potassium sorbate dip
pH	6.34 ^a	6.25 ^b	6.31 ^{ab}
Log total plate count (cfu/g)	3.0	3.2	3.0
Log count range (cfu/g)	2.2-3.8	2.0-4.9	2.2-3.7
Raw drip score	0.7	0.8	1.2
Colour score	1.7	1.4	1.4
Flesh appearance score	0.8	0.7	0.8
Raw odour score	0.8	0.3	0.6
Cooked drip score	0.6	0.5	0.7
Cooked odour score	1.7	1.7	2.3
Cooked flavour score	1.8	2.3	2.8
Texture score	0.8	0.9	0.8
Moisture score	0.4	0.6	0.5
Total demerit scores	9.1	9.1	11.1
Sorbic acid residue (mg/kg)	-	-	560

^{abc} Different letters signify significant differences between treatments ($P < 0.01$)

Statistical analysis of the results identified only one parameter with significant differences. While there were significant differences between the treatments for pH this would have little influence on shelf life. The acid conditions of the two chemical dips led to only a slight reduction in pH. The two chemical dips did not result in a reduction in the total bacterial log count. This result is partly due to the large variability between portions for log count. As suggested previously the act of washing is as important as the presence of chemicals. The high residues obtained for sorbate treatment indicate that this procedure should **NOT** be applied to fillets or portions where the muscle tissue is exposed. There were no sensory or aesthetic differences between treatments so a dip in chlorinated water is an acceptable alternative to a dip in fresh water.

One aspect not investigated was the effect of water running over fillets during processing. If a short dip is effective then a wash of longer duration should be more effective in reducing initial bacterial counts. Prior to the packaging of the salmon for the second taste panel trial a new chemical treatment was appraised using Chlorine dioxide. The treatments involved a storage treatment using a concentration of 20ppm (mg/kg), a spray application using a concentration of 500ppm and a control of no chemical. For effective action by the chemical the fish were hosed down to remove the natural layer of slime. Table 41 shows the mean surface and flesh counts obtained for all samples taken.

Table 41. Microbial Counts from factory sampling swabs prior to storage.

Treatment	Surface	Total log count (cfu)	Units
freshly gutted fish	belly cavity	2.98	cm ²
freshly gutted fish	outer surface	1.91	cm ²
deslimed fish	belly cavity	3.01	cm ²
deslimed fish	outer surface	0.12	cm ²
deslimed/sprayed/stand 5min	belly cavity	2.05	cm ²
deslimed/sprayed/stand 5min	outer surface	1.82	cm ²
fillet portion		2.77	g

The desliming did appear to reduce surface counts while the chemical spray should have continued this trend. The data obtained for samples 13 to 18 not support this. The bacterial loads of fillets from the cutting line were low however. The fish were then stored for 24 hours in ice slurry before sampling. Table 42 shows the bacterial counts.

Table 42 Microbial Counts from factory sampling swabs after 24-hour storage.

Treatment	surface	Total log count (cfu)	Units
deslimed then 24hr ice-only slurry	belly cavity	2.10	cm ²
deslimed then 24 hr ice-only slurry	outer surface	0.72	cm ²
deslimed/spray/5min/24hr ice-only slurry	belly cavity	1.18	cm ²
deslimed/spray/5min/24hr ice-only slurry	outer surface	0	cm ²
after 24hr ice-only slurry	belly cavity	3.18	cm ²
after 24hr ice-only slurry	outer surface	0.48	cm ²
after 24hr 20ppm slurry	belly cavity	0.73	cm ²
after 24hr 20ppm slurry	outer surface	1.72	cm ²
deslimed/sprayed/24hr/deslimed/sprayed	belly cavity	1.34	cm ²
deslimed/sprayed/24hr/deslimed/sprayed	outer surface	0.73	cm ²
filleting board swab		2.07	cm ²
trimming board swab		3.76	cm ²
pin boning board swab		1.76	cm ²
flesh after filleting fish		3.27	g
flesh after trimming fish		3.58	g
flesh after pinboning fish		3.79	g
ClO ² and ice slurry		1.23	g
ice-only slurry		1.30	g

The chlorine dioxide was effective for both forms of treatment. Because of the need to automate the treatment the spray method of application was chosen for use during the next packaging trial.

Southern scallops

A sample of southern pecten scallop for MAP trials was to be supplied by a Geelong scallop company. The cost of shipment to the laboratory was paid for by the project but the sample was sent to Cairns due to an incorrect address change at the factory. Another sample was requested but this took a month to organise due to bad weather restricting fishing. This sample arrived 24-30 hours after shucking which started with a high total count of 125.900 cfu/g which went to 17,378,000 cfu/g within three days. A high proportion of bacteria was hydrogen disulphide producers while coliforms and anaerobes were also present. The data indicates that the scallops arrived in poor condition and it was not apparent what caused the loss in quality as no temperature probes were present. Another sample was obtained after much difficulty. It even took some time to get the processor to return a temperature probe (valued at \$300). On two separate occasions the investigator was told that it had been mailed that day. There was not much time left to conduct two trials before the end of the project so other processors were assisted. It would be expected that southern scallops would behave in a similar manner to saucer scallops if the quality was good.

Gouldburn River Trout Pty Ltd

Survey Methods

Numerous sites within the factory were sampled using the swab technique and salmon portions from the end of the processing line were shipped to the laboratory for enumeration of bacteria present. Swab samples taken from selected sites on the processing line can give an indication of when contamination occurs. Swabs remove bacteria from a fixed surface area. In this case a sterile template was placed over a surface exposing 9 square centimetres of that surface. It was repeatedly wiped using cotton wool wrapped about a stick that was then placed in a 9.2mL sterile peptone solution.

Extending the high quality life of seafood

The samples were returned to the laboratory where small volumes were poured onto agar plates containing selective media. The plates were incubated for several days to promote the growth of bacterial colonies. Each colony that grows represents an individual microbe present in the original swab and is called a Colony Forming Unit (cfu). The counts are then converted to the number of bacteria per square centimetre (cfu/cm²). When a piece of flesh is sampled 10g is macerated with 100mL of peptone solution to provide a count. This leads to big differences between the numbers obtained from surface swabs and from flesh samples.

A number of different types of bacteria were selected for enumeration. While the total count is used to determine the end of shelf life, the H₂S producers are the bacteria responsible for production of off-fish odours and flavours and the coliforms usually indicate that contamination from the gut of fish has occurred. Psychrotrophs are bacteria that grow well at low temperatures.

Factory samples

Table 43 shows the mean microbial counts obtained from swabs taken at the factory.

Table 43. Mean microbial counts from factory sampling swabs.

Site surface counts (cfu/cm ²)	Total log count	H ₂ S producer log count	Coliform log count	Psychrotroph log count
large trout cut gut in	2.59	1.15	0	2.34
whole small trout belly cavity	3.05	1.70	0	2.42
whole small trout skin surface	1.90	0	0	1.60
crate side	<1	0	0	<1
crate bottom	<1	0	0	<1
flesh counts (cfu/g)				
raw fillet	5.67	2.51	1.94	5.56
smoked	4.79	<1	<1	4.72
smoked 1 week later	<2	<1	<1	<2

From our work with salmon, a surface log count of 2.24 cfu/cm² (an apparently low number) can reflect a flesh log count of 4.07 cfu/g (a moderate number and one too high for MAP or good shelf life). While the total count is used to determine the end of shelf life, the H₂S producers are the ones responsible for off-fish odours and flavours and the coliforms usually indicate contamination from the gut of fish. No *E. Coli* were found in any samples or *Listeria* found in the smoked samples.

The surface bacteria on fillets and whole gutted fish were high yet no coliforms were identified. This is unexpected as counts from the flesh identified the presence of coliforms. The extremely high surface count for the lining of the belly cavity suggests that there may have been insufficient washing of the gutted fish. These high belly cavity counts were present for both batches of trout. When fish are stored in ice slurry bacteria can spread to other fish. High numbers at this site also allows the bacteria to penetrate into the flesh more rapidly than through the skin and can be accelerated by cuts and tears made during cleaning. The high flesh count obtained for one of the smoked trout may have developed this way as the hot smoking process generally kills most surface bacteria. The high flesh count in fillet A shows that there is a definite need for more washing throughout the processing line and/or changes to the chilling operation.

At this stage smoked trout, with the exception of one sample, appear to be suitable for MAP processing. It is suggested that a storage trial on this product be carried out in the near future. Results also indicate there is some need to improve the processing environment and reduce bacterial counts before other products could be used for MAP.

Temperature during transport

A datalogger recorded the internal temperature of a box of trout dispatched on 23 February to Sam's Seafood. The internal temperature remained between 7 and 10°C during shipment. The batch of trout sent for the dipping experiment that accompanied this shipment had a temperature of 14°C upon arrival. For general shipment of fresh seafood temperatures between 0 and 2°C are required to be maintained. The internal temperatures of both samples dispatched would encourage bacterial growth. It is suggested that more efficient packaging and coolants be used to reduce bacterial spoilage and increase shelf life.

Evaluation Of Chemical Treatments For Seafood

The cleaning of fish prior to processing is a key aspect in achieving low microbial counts at the start of MAP storage. In most situations plenty of running water is all that is needed but when this is not effective due to long periods of storage a chemical treatment may be appropriate. Chlorine is the most commonly used cleaning agent in the seafood industry but there are drawbacks to its use. Individuals can develop sensitivities and prolonged exposure can result in dermatitis.

Citrox

A batch of salmon was sent to the laboratory to evaluate the effect of the chemical Citrox, also labelled as Fish Fresh (14W), on the bacterial count. The dipping of fillets in 2% Citrox for 10 minutes was not suitable for salmon fillets. Table 44 shows the counts obtained using this treatment.

Table 44. Total counts for salmon dipped in 2% Citrox for 10 minutes.

Type Treatment	Flesh counts		Surface counts	
	Before dip	After dip	Before dip	After dip
Units	cfu/g	cfu/g	cfu/cm ²	cfu/cm ²
Mean	4.07	3.26	2.24	2.41
Change	reduction by 15.60% or log 0.81		increase by 146% or log 0.16	

Protein denaturation at the surface occurred immediately after immersion in the solution reducing the visual quality of the salmon. This is due to a dip pH of 2.7, indicating that the chemical is mainly acid. The capacity to reduce bacterial count was inconclusive. Normally a reduction in count by a factor of log 2 is required. The treatments only reduced the count figure by ten for the flesh count and unexpectedly increased the surface count.

A batch of trout sent one week later to the CFT laboratory was also used to evaluate the effect of the chemical Citrox on the bacterial count. The data presented in Table 45 shows the reduction in bacterial numbers on the surface and in the flesh of the trout.

Table 45. Total counts for trout dipped in 2% Citrox for 2 minutes.

Sample Treatment	Flesh total count		Surface total count	
	Before dip	After dip	Before dip	After dip
Units	cfu/g	cfu/g	cfu/cm ²	cfu/cm ²
Mean	3.966	2.929	2.639	2.170
Change	reduction to 9.2% or log 1.037		reduction to 34.1% or log 0.469	

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The application of 2% Citrox for 2 minutes reduced bacterial numbers at most by a factor of 10. Effective treatments need to reduce numbers to a 100th of the original. One aspect of the treatment was that the fillets exhibited a blanched immediately after contact with the dipping solution due to protein precipitation. Blanching occurred because of the acidic nature of the dipping solution (pH of 2.7). A blanched appearance also developed immediately after immersion of salmon in the solution, thus reducing the visual quality of the product. The capacity of Citrox to lower bacterial counts was inconclusive. The treatment only reduced the log count figure by one for the salmon flesh count. Trout fillets dipped for 2 minutes only showed minor reductions in bacterial counts and still exhibited the bleached appearance. This chemical treatment does not appear to be suitable for salmon or trout and has a negative effect on the products visual appearance.

OxSil

A number of alternate chemical treatments are available, one of which is called OxSil FP50. This treatment is certified as safe for food, contains 500g/L hydrogen peroxide and 840mg/L colloidal silver and reported to be effective against bacteria, virus and fungi.

A comparison of a 2% solution of OxSil with a 2% solution of chlorine was conducted using filleting boards that had been use to process several fish. The boards were rinsed in fresh water but not scrubbed to retain high numbers of bacteria. Three different sites were tested for bacterial counts. A 3x3cm square was swabbed and the swab placed in a peptone solution before plating. The surfaces were then sprayed with either chemical, left to stand for 5 minutes then rinsed with clean water. The position adjacent to the previous sample site was then tested. Table 46 reports the mean bacterial counts before and after cleaning for three separate trials.

Table 46 Treatment of fish cutting boards with chemicals.

Pretreatment log count (cfu/cm ²)	Log count after 2% OxSil (cfu/cm ²)	Log reduction after 2% OxSil (cfu/cm ²)	Log count after 2% Chlorine (cfu/cm ²)	Log reduction after 2% Chlorine (cfu/cm ²)
3.81	2.95	0.86	3.06	0.76

Chlorine can be quite effective in destroying most bacteria. Sykes (1970) claims that "100ppm hypochlorite solution will kill 10⁴ *Bacillus subtilis* var *niger* within one hour and a buffered solution at pH 7.0 will carry out the same killing activity within five minutes". The data above shows that while the chlorine solution was effective in destroying bacteria the OxSil was more efficient in destroying more than 80% of the bacteria present. This is however not close to the 2 log counts required to ensure clean surfaces and raw materials.

Chlorine Dioxide

This chemical was compared with OxSil P F50 using freshly harvested rainbow trout. A batch of 5 gutted rainbow trout was given a rinse of chemical by direct placement in a ClO₂ 100 ppm dip or dipped in a 600 ppm solution of OxSil PF50. Another batch of 5 fish was deslimed by hosing and then sprayed using a ClO₂ solution of 500 ppm or a 600 ppm solution of OxSil PF50. The fish were left to stand for 10 minutes in a cold room before swabs for bacteria were taken from the belly cavity and outer surface of each fish. The fish was then stored at 2°C for 20 hours before sampling again. The swabs were placed into peptone water and returned to the laboratory for enumeration of bacteria present. The effectiveness of each treatment was statistically analysed for significant differences in bacterial log counts. The mean total counts for five rainbow trout exposed to the two chemicals by either being dipped or sprayed are present in Table 47.

Table 47. Microbial counts of rainbow trout treated with two chemicals.

Treatment	Site	Total log count (cfu/cm ²)*
Prior to treatment	inside	2.73 ^{ab}
Prior to treatment	outside	2.29 ^b
Spray CLO ₂ 500 ppm 10 minutes later	inside	2.24 ^b
Spray CLO ₂ 500 ppm 10 minutes later	outside	2.55 ^b
Dip CLO ₂ 100 ppm 10 minutes later	inside	1.81 ^b
Dip CLO ₂ 100 ppm 10 minutes later	outside	2.03 ^b
Spray OxSil 600 ppm 10 minutes later	inside	1.97 ^b
Spray OxSil 600 ppm 10 minutes later	outside	2.12 ^b
Dip OxSil 600 ppm 10 minutes later	inside	1.45 ^b
Dip OxSil 600 ppm 10 minutes later	outside	2.99 ^a
Spray CLO ₂ 500 ppm 20 hours later	inside	2.98 ^a
Spray CLO ₂ 500 ppm 20 hours later	outside	2.17 ^b
Dip CLO ₂ 100 ppm 20 hours later	outside	2.18 ^b
Dip CLO ₂ 100 ppm 20 hours later	inside	2.20 ^b
Spray OxSil 600 ppm 20 hours later	inside	2.48 ^b
Spray OxSil 600 ppm 20 hours later	outside	2.63 ^{ab}
Dip OxSil 600 ppm 20 hours later	inside	2.21 ^b
Dip OxSil 600 ppm 20 hours later	outside	1.94 ^b

* Means followed by a different letter are significantly different at the 5% level.

There were no significant differences between counts of trout from the different treatments, the site of sampling, between individuals from a particular treatment or after some storage time. The only difference present was between the interaction of site and treatment and this was for a limited number of treatments. The anticipated size of reduction in count was not achieved so an increase in concentration of either chemical may need to be investigated. One explanation for the limited success of the chemicals could be the apparent low levels of bacteria present on the fish prior to treatment and large individual variability.

Packaging Experiments

Gas Absorption

The first experiment conducted was one investigating the amount of CO₂ gas fresh caught Queensland saucer scallops (*Amusium balloti*) could absorb. Batches containing 5 and 10 scallops were placed in barrier bags which after evacuating and flushing with medical grade CO₂ were then sealed. The scallops and bags were weighed before and after flushing with gas. The volume of water the sealed bag displaced during complete immersion was then measured. The scallops were stored at 4°C with displacement measurements conducted over several days.

The graph present as Figure 1 in Appendix 8 shows the changes in volume of barrier bags containing different amounts of scallops. There was some loss of volume in the control bags (no scallops). This may have been due to changes in temperature from the initial filling to the refrigerated storage or to leaks through the seams of the barrier bags.

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When the change in volume of the control bags is compared with the changes when scallops are present the latter, during the initial part of storage, exhibited much larger reductions in volume. The more scallop meat present the higher the reduction from the original volume. Towards the end of the storage period there was little headspace left in some of the packets containing 10 scallops. There would be a lower amount of CO₂ absorbed by scallops covered by a gas permeable membrane than when in direct contact with the modified atmosphere. The packs containing 5 scallops averaged a 20% reduction in total volume after 45 hours while those containing 10 scallops averaged a reduction of 30%. These results show that the scallop has the ability to absorb large amounts of CO₂. Information provided by Seafood Technologies Pty Ltd indicated that a 40% headspace was required for the most efficient extension of shelf life.

Gas Mixtures

Access to a prototype packaging machine which produces product in a gas flushed tray sealed with an impermeable membrane became available in the second year of the project. A packaging experiment using Broadbill swordfish cutlets was carried out to determine the best packaging conditions for this tray method. Two pieces of swordfish of approximately 200g were placed in an impermeable tray with an absorbent pad (capacity 60 ml) placed on the bottom. A transparent, impermeable, antifog (hydrophobic), polymer film was placed as a lid to the pack and the chamber of the packaging machine evacuated. Two gas mixtures were flushed into the chamber after all air had been removed composed of either 100% carbon dioxide or a mixture of 55% carbon dioxide, 35% nitrogen and 5% oxygen. One pack of the latter also contained a sachet which released carbon dioxide when it came in contact with the drip. This sachet was in an experimental stage at the time of the experiments but it is hoped that it will become commercially available in the future. The lid was heat sealed after a two-second flush with the modified atmosphere. The microbial and visual quality was appraised after 11 days storage at 1°C. Table 53 shows the microbial counts obtained for the different conditions.

Table 53. pH, microbial counts and demerit scores collated from swordfish cutlets stored in MAP with different gases at 1°C.

Pack conditions	Start	100%CO ₂	56%CO ₂	56%CO ₂ +sachet
pH	5.97	5.93	6.07	5.89
Log total plate count	3.10	2.05	2.18	1.93
Hydrogen disulphide producer log count	0	0	0	0
Coliform log count	0	0	0	0
Anaerobic log count	1.40	0	0	0
Pasteurised anaerobes	0	0	0	0
Drip as a % of pack weight	-	5.03	0.84	-
Raw drip score	1.25	1.75	0.57	0.5
White muscle colour score	2.00	2.53	2.47	2
Red muscle colour score	2.25	3.00	2.83	2.4
Parasite score	0.00	0	0	0
Flesh appearance score	0.00	0	0	0
Raw odour score	0.25	2.00	1.83	1.75
Cooked drip score	1.00	1.25	0.63	0.25
Cooked odour score	0.50	1.67	1.38	1
Flavour	1.00	1.90	2.73	1.75
Texture	1.50	0	0.50	0
Total demerit scores	9.75	14.10	12.95	9.65

The packs filled with 100% carbon dioxide collapsed due to excessive absorption of carbon dioxide by the fish. The lower concentration carbon dioxide packs also exhibited some distortion but not as bad as the packs with a 100% carbon dioxide atmosphere. The one pack with the developmental sachet did not show signs of collapse. The absorption of drip by the sachet prevented any evaluation of drip loss. The raw drip score was lower for the sachet containing pack because the sachet absorbed the drip. It would be expected to be higher than the other packs containing 56% CO₂. There was no effect on pH by the treatments. The mean microbial counts for each treatment appear to be similar and lower than the starting count. The individual demerit parameter scores and totals for the packs containing 56% CO₂ were lower than those containing 100% but the pack containing the CO₂ generating sachet scored lowest.

As packs containing 100% CO₂ displayed some distortion due to excessive absorption by the product and the fact that these sachets will not be available commercially for some time, packs containing different mixtures of carbon dioxide and nitrogen were evaluated. There was no conclusive evidence in the literature for having oxygen present in the gas mixture so this gas was left out of any gas mixture experiments using lidded retail packs. Both swordfish cutlets and salmon pieces were obtained on the same day and packed in trays with impermeable lids after flushing with a mixture containing either 60% carbon dioxide and 40% nitrogen or 40% carbon dioxide and 60% nitrogen. The microbial and sensory data from the start and after 7 days storage at 4°C is present in Table 54.

Table 54 Comparison of two gas mixtures after 7 days MAP storage at 4°C.

Species % of CO ₂ applied	Swordfish			Salmon		
	Start	60	40	Start	60	40
Log total plate count	1.90	5.71	6.89	4.27	6.90	6.45
Psychrotropic log count	0.00	5.60	7.17	4.15	6.86	6.17
Hydrogen disulphide producers log count	0.00	3.62	5.21	0.40	5.54	5.05
Coliform log count	0	0	0	1	5.20	4.38
Anaerobic log count	0	0	0	0	0	0
Pasteurised anaerobic log count	0	0	0	0	0	0
Drip in tray as % of product	-	0.65	0.59	-	3.96	0.97
Normal muscle colour score	1	1.9	2	1.28	1.38	1.5
Flesh appearance score	0	0	0	0	0.45	0.43
Raw odour score	0	2.05	2	0.75	0.9	0.88
Total common demerit scores	1	3.95	4	2.03	2.73	2.81

There were no significant differences present between the two gas mixtures for any parameter. This suggests that either atmosphere is suitable for extending the shelf life of these two species of fish. There were differences between the species fish for coliform and anaerobic log counts with the salmon exhibiting higher levels. The lower ratio of carbon dioxide to nitrogen allows for a large amount of carbon dioxide to be absorbed by the fish tissue and yet prevents early distortion of the pack. The literature indicates that an ideal product to atmosphere ratio is greater than 1:1 and that the level of CO₂ should not fall below 40%. Using a mixture with only 40% CO₂ could lead to problems in packs with low atmosphere to product ratios and high initial microbial counts. Only one sized tray could be used in the machine available so lower concentration of CO₂ would only have been applied during this project if the size of the fish pieces were large and filled most of the tray.

Saucer Scallop Trials

As indicated in the original grant proposal scallops were the first subjects to be trialed in modified atmosphere packaging.

Trial 1

The first shelf-life experiment involved storage of freshly processed Queensland saucer scallops in air. The scallops are caught from trawlers and stored in refrigerated seawater until the vessel returns to port. This results in batches of scallops with storage ages of several days' difference. The scallops for this trial were kept in bulk and stored in air at 4°C. The total microbial count and count of hydrogen disulphide (H₂S) producers per gram was determined during storage and are present in Table 55.

Table 55. Microbial counts of scallops stored in air at 4 °C.

Storage time (days)	Total log count cfu/g	H ₂ S log count cfu/g
0	4.36	1.54
3	5.40	4.86
7	5.67	5.07
10	6.96	6.94

The initial count was moderate and but it was many days before the total count became excessive (>1,000,000cfu/g).

Trial 2

The second trial involved the shipment of freshly shucked scallops to the laboratory overnight. They were then packed in batches of 10 in shallow gas impermeable plastic trays and covered with a gas permeable layer of clear film which was shrink wrapped onto the base tray. Groups of 2 or 4 of these trays were then placed in non-permeable barrier bags, given a flush of CO₂ gas and heat-sealed. The bulk packs were then stored at 4°C and removed at regular intervals for testing or further storage in air. Two packs were tested each sampling time for pH, total microbial count and H₂S producers and data is present in Table 56.

Table 56. pH and microbial count of scallops stored in air and MAP at 4 °C during trial 2.

Storage days and (conditions)	pH	Total log count cfu/g	H ₂ S producer log count cfu/g
0 (fresh)	6.04	3.58	1.00
3 (3 Air)	6.21	4.43	2.40
3 (3 MAP)	5.99	3.61	2.18
6 (6 Air)	6.45	5.74	4.72
6 (6 MAP)	5.94	3.83	3.65
6 (3 MAP 3 Air)	6.07	4.30	3.88
9 (3 MAP 6 Air)	6.33	4.45	4.34
9 (6 MAP 3 Air)	6.15	3.78	3.28
10 (10 Air)	6.57	6.51	5.57
10 (10 MAP)	5.86	4.08	3.45
12 (6 MAP 6 Air)	6.28	4.73	4.58
13 (3 MAP 10 Air)	6.24	6.04	5.83
13 (10 MAP 3 Air)	6.18	3.72	3.61
13 (13 MAP)	5.99	4.08	4.00
16 (6 MAP 10 Air)	6.56	5.53	5.26
16 (10 MAP 6 Air)	6.4	4.99	4.86
16 (13 MAP 3 Air)	6.28	3.73	3.38
19 (13 MAP 6 Air)	6.41	4.96	4.90
20 (10 MAP 10 Air)	6.49	6.76	6.38
23 (13 MAP 10 Air)	6.52	5.78	5.03

Identification of spoilage organisms at these times was also carried out. Table 57 shows that there was a progressive drop in pH of scallops while they were exposed to the modified atmosphere in the bulk packs, except for the final storage time of 13 days. These samples exhibited levels of pH close to those that were present at the start of storage in MAP. The drop in pH was due to the absorption of CO₂ gas into the tissues of the scallops and the resulting formation of carbonic acid. After 13 days of this of storage the trays were removed from the bulk packs but kept within the individual shrink packs and left exposed to the air in the cold room. This caused a rapid increase in the pH of the scallops.

The bacterial load of the scallops followed some of the trends exhibited by the pH. The total plate count, unlike the pH, remained fairly stable while exposed to the modified atmosphere with only a slight increase over time. When the scallop trays were removed from the bulk packs and exposed to the air there were differences in growth depending on the time exposed to CO₂ gas. The trays kept in MAP for three days exhibited increased counts after three days in air and continued for the rest of this storage.

Those stored in MAP for 6 or more days exhibited reductions in bacterial load after three days in air. The numbers of bacteria then increased during the remaining time in air to approach the levels achieved by the scallops that were not exposed to CO₂ gas. The count of H₂S producers increased during the first 6 days in MAP then stabilised for the rest of this storage phase. When the scallops were removed from the MAP bulk pack after three days and exposed to air, the count increase in a similar manner to those not kept in MAP. Those kept for 6 days or more in MAP, after three days in air, exhibited a decrease from the level at removal that was then followed by an increase in numbers to levels similar to that present in scallops not exposed to MAP. The identification of individual microbes present was carried out and is present in Table 57. The behaviour of the microbial flora during this trial indicates that some initial exposure to the modified atmosphere is required before any benefit becomes apparent.

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Table 57. Bacterial flora of scallops during trial 2 storage at 4°C

Air (days)	MAP (days)	Total Log Count (cfu/g)	Others	Proportion of total count (%)													
				<i>Aerobacter</i>	<i>Alcaligenes</i>	<i>Flavobacterium</i>	<i>Stenohalobium</i>	Gram -ve	yeast	Others	<i>Kurtzia</i>	<i>Corynebacterium</i>	<i>Lactobacillus</i>	<i>Streptococcus</i>	<i>Staphylococcus</i>	<i>Micrococcus</i>	Gram +ve
0	0	3.58	0.0	0.0	0.0	16.7	0.0	16.7	0.0	0.0	0.0	8.3	0.0	0.0	41.7	33.3	83.3
3	0	4.43	0.0	0.0	16.7	41.7	0.0	58.3	0.0	0.0	0.0	0.0	0.0	0.0	8.3	33.3	41.7
6	0	5.74	0.0	0.0	0.0	66.7	0.0	66.7	0.0	0.0	0.0	0.0	8.3	0.0	0.0	25.0	33.3
10	0	6.51	0.0	0.0	0.0	45.5	0.0	45.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.6	54.6
0	3	3.61	0.0	0.0	0.0	25.0	0.0	25.0	8.3	0.0	0.0	16.7	0.0	0.0	25.0	25.0	75.0
3	3	4.30	0.0	0.0	0.0	8.3	58.3	66.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.3	33.3
6	3	4.45	0.0	0.0	0.0	16.7	75.0	91.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	8.3
10	3	6.04	0.0	0.0	0.0	50.0	33.3	83.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	16.7
0	6	3.83	0.0	0.0	0.0	8.3	16.7	25.0	0.0	0.0	0.0	8.3	0.0	8.3	25.0	33.3	75.0
3	6	3.78	0.0	0.0	0.0	8.3	58.3	66.7	0.0	0.0	0.0	0.0	0.0	0.0	8.3	25.0	33.3
6	6	4.73	0.0	0.0	0.0	8.3	83.3	91.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	8.3
10	6	5.53	0.0	0.0	0.0	16.7	50.0	66.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.3	33.3
0	10	4.08	0.0	9.1	0.0	27.7	45.5	81.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.2	18.2
3	10	3.72	0.0	0.0	0.0	0.0	75.0	75.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	25.0
6	10	4.99	0.0	0.0	0.0	16.7	83.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	10	6.76	0.0	0.0	0.0	50.0	41.7	91.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	8.3
0	13	4.08	0.0	0.0	0.0	0.0	72.7	72.7	0.0	0.0	0.0	9.1	0.0	0.0	0.0	18.2	27.3
3	13	3.73	0.0	0.0	0.0	0.0	63.6	63.6	0.0	0.0	0.0	0.0	0.0	9.1	9.1	18.2	36.4
6	13	4.96	0.0	0.0	0.0	0.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	13	5.78	0.0	0.0	0.0	16.7	8.3	25.0	0.0	0.0	0.0	0.0	75.0	0.0	0.0	0.0	75.0

The proportion of Gram -ve bacteria increased during MAP storage time while the trend for Gram +ve bacteria was to decrease during air storage.

Trial 3

The next trial was designed to investigate the minimum amount of exposure to the modified atmosphere required as well as the changes during longer term MAP storage. The microbial counts, pH and drip loss in packs is shown in Table 58.

Table 58. Microbial counts, pH and drip loss of scallops stored in air and MAP at 4°C during trial 3.

Storage days and (conditions)	Total log count (cfu/g)	H ₂ S producer log count (cfu/g)	Anaerobe log count (cfu/g)	pH	Drip as a % of pack weight
1 (1 Air)	3.72	0.95	2.00	6.18	-
1 (frozen 1 Air)	3.78	-	-	6.37	-
1 (5hr MAP)	3.76	0.00	2.00	6.21	-
1 (1MAP)	3.69	1.18	2.00	6.06	-
2 (2 MAP)	3.61	0.90	2.00	6.07	-
3 (3 Air)	4.08	1.00	2.00	6.07	-
3 (frozen 3 Air)	3.86	-	-	6.31	-
3 (5hr MAP 3 Air)	4.26	1.00	2.30	6.04	-
3 (3 MAP)	3.72	1.65	2.00	5.95	-
4 (1 MAP 3 Air)	4.20	1.65	2.00	6	-
5 (2 MAP 3 Air)	3.98	1.00	3.36	5.96	3.42
6 (6 Air)	5.09	1.76	2.72	6.12	-
6 (frozen 6 Air)	4.91	-	-	6.25	-
6 (5hr MAP 6 Air)	5.67	1.52	2.60	6.12	1.42
6 (6 MAP)	3.08	0.00	2.40	5.85	2.32
6 (frozen 6 MAP)	3.53	1.63	2.51	5.97	2.44
6 (3 MAP 3 Air)	3.80	1.83	2.48	6	2.41
7 (1 MAP 6 Air)	4.90	1.58	2.83	6.12	1.12
8 (2 MAP 6 Air)	5.25	1.95	3.62	5.96	1.78
9 (3 MAP 6 Air)	5.28	4.21	4.78	6.08	1.73
9 (6 MAP 3 Air)	4.59	2.27	2.51	6.01	2.45
9 (frozen 6 MAP 3 Air)	3.59	1.58	2.00	6.11	2.03
10 (10 Air)	6.01	2.94	3.09	6.02	-
10 (frozen 10 Air)	7.25	-	-	6.39	-
10 (5hr MAP 10 Air)	5.67	2.20	3.53	6.02	1.75
10 (10 MAP)	5.68	2.78	5.08	5.97	1.84
11 (1 MAP 10 Air)	7.06	5.41	5.00	6.11	1.65
12 (2 MAP 10 Air)	6.30	2.30	5.62	5.98	2.75
12 (6 MAP 6 Air)	5.29	4.18	3.70	5.86	1.01
12 (frozen 6 MAP 6 Air)	4.02	3.20	2.90	6.12	2.6
13 (3 MAP 10 Air)	6.20	5.28	5.64	5.98	1.14
13 (10 MAP 3 Air)	6.11	5.66	5.35	6.21	2.21
15 (15 Air)	6.83	2.89	4.15	6.76	-
15 (frozen 15 Air)	8.53	-	-	6.7	-
15 (15 MAP)	5.74	1.18	3.06	5.79	1.57
16 (6 MAP 10 Air)	6.35	5.27	5.77	6.03	1.69
16 (frozen 6 MAP 10 Air)	6.22	5.40	5.24	6.2	1.92
16 (10 MAP 6 Air)	5.24	5.24	6.24	6.24	1.16
18 (18 Air)	7.42	5.30	5.39	6.82	-
18 (frozen 18 Air)	9.06	-	-	6.86	-
18 (15 MAP 3 Air)	5.43	1.48	5.05	5.91	1.13
21 (21 Air)	7.73	5.00	5.30	6.92	-
21 (frozen 21 Air)	8.94	-	-	7.32	-
21 (10 MAP 11 Air)	7.48	6.15	7.20	6.16	2.89
21 (15 MAP 6 Air)	7.16	3.80	6.08	6.08	2.04
25 (25 Air)	7.98	5.06	6.39	7.25	-
25 (frozen 25 Air)	6.68	-	-	7.79	-
25 (15 MAP 10 Air)	6.74	4.83	6.69	5.99	2.11

The major difference between this trial and the previous trial was that the scallops were packed at the processing site in Bundaberg and returned to the laboratory in the bulk packs. This reduced the delay in packaging to only several hours after shucking. A sample of scallops frozen on the capture vessel was also evaluated, as this method is how

the majority of the industry stores its catch. A control batch of scallops kept in bulk in air was also included in this trial. The number of sampling times and the length of the storage time were increased to obtain a better understanding of the changes that occur in MAP. As before the duplicate trays were tested for pH, total microbial count and hydrogen disulphide producers. This time the scallops were also appraised visually, for raw and cooked odour, cooked flavour and texture using the demerit point system.

Microbiological attributes

Table 58 shows the microbial counts for the total numbers present, those that are H₂S producers and the anaerobes. There was an overall appraisal of the microbiological conditions for all of the trials following this section so the discussion here will not be detailed. The total count increased consistently during storage. Unlike the first trial the count did increase when stored in MAP after day 10. Once removed from the MAP the count increased in a similar manner to the previous trial. The H₂S producers displayed more fluctuation in count during MAP storage but behaved in a similar manner to total count after exposure to air. As before the H₂S producers initially were only a fraction of the total count. The anaerobic count while starting with lower numbers to the H₂S producers did show similar trends to that of the total count. The identification of individual microbes present is present in Table 59.

Table 59. Bacterial flora of scallops during trial 3 storage at 4°C.

Time in air (days)		1	10	0	0	0	0	6	10	10	6
Time in MAP Days)		0	0	1	6	10	15	3	3	6	15
Total log count (cfu/g)		3.77	6.0	3.72	3.08	5.67	5.74	3.72	3.79	6.34	6.70
<i>Gram -ve</i>	Others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Pseudomonas</i>	8.3	0.	0.0	10.0	0.0	0.0	8.3	8.3	25.0	0.0
	<i>Acinetobacter</i>	33.3	0.0	9.1	0.0	0.0	0.0	0.0	0.0	0.0	16.7
	<i>Alcaligenes</i>	0.0	8.3	0.0	0.0	0.0	0.0	8.3	0.0	0.0	0.0
	<i>Flavobacterium</i>	16.7	25.0	0.0	10.0	40.0	0.0	8.3	25.0	0.0	16.7
	<i>Shewanella</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Combined	58.3	33.3	9.1	20.0	40.0	0.0	25.0	33.3	25.0	33.3
	Yeast	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Gram +ve</i>	Others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3
	<i>Brochothrix</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	8.3	0.0
	<i>Bacillus</i>	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Kurthia</i>	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Cornyformes</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Lactobacillus</i>	8.3	0.0	36.4	0.0	20.0	0.0	25.0	58.3	58.3	0.0
	<i>Streptococcus</i>	0.0	0.0	9.1	0.0	0.0	91.7	25.0	0.0	0.0	8.3
	<i>Staphylococcus</i>	16.7	0.0	18.2	20.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Micrococcus</i>	16.7	66.7	27.3	20.0	40.0	8.3	25.0	0.0	8.3	50.0
	Combined	41.7	66.7	90.9	80.0	60.0	100.0	75.0	66.7	75.0	66.7

pH

Table 58 shows the pH of scallops during storage. The pH of the scallops at the start of this trial was similar to those from the previous trial (pH 6.0-6.2) and they developed a slight decrease of 0.2 by the end of MAP storage (15 days). Air stored scallops initially also showed a small decrease in pH until day 10 then rapidly increased to 7.3 by day 25. This level was much higher than the pH of scallops from any of the other treatments. The scallops, after removal from the modified atmosphere, did not exhibit any large increases in pH for this trial.

Demerit point appraisal

The visual and sensory aspects of MAP seafood are an important part of this type of product. The very name of the project is extending the high quality life of seafood so that the end of shelf life for a particular product should not be based on microbiological aspects alone. A wide range of visual, olfactory and taste associated parameters were appraised. An example of the score sheet developed for scallops is present as Figure 1 in Appendix 3. There was no scoring on the first two days. The descriptions of the various parameters for scallops were formed as a basis for a much larger evaluation of the sensory attributes using a fully trained taste panel.

Unopened packs

Duplicate MAP packs of scallops were removed from storage and appraised for a number of parameters.

Colour overall

The scallops were evaluated visually while still contained in the retail pack. The colour ranging from bright white to grey was the first aspect appraised. The scores for this attribute can be seen as Table 60.

Table 60. Demerit scores of scallops during trial 3 storage at 4°C, part one.

Storage days and (conditions)	Colour overall	Mixture of grey to white	Parasites	Type of parasite	Flesh appearance	Drip score, qualitative
2 (2 Air)	-	0.5	-	-	0.5	-
2 (frozen 2 Air)	-	1	-	0	1	-
2 (2 MAP)	-	0	3	0	1	1
3 (3 Air)	1.5	1	0.25	0	1	-
3 (frozen 3 Air)	2	4	0	1	0.5	-
3 (5hr MAP 3 Air)	0	0.5	0.75	0.25	1.5	1.5
3 (3 MAP)	1	0.25	0.75	0.25	1	1
4 (1 MAP 3 Air)	1	0.25	0.63	0.5	1.25	1
5 (2 MAP 3 Air)	1	0.25	0.75	0.5	1.13	0.5
6 (6 Air)	1	0	0.5	0	0.25	0.5
6 (frozen 6 Air)	2	1	0.5	1	0.25	0.5
6 (5hr MAP 6 Air)	1.5	1	0.63	0	1	0.5
6 (3 MAP 3 Air)	1	0	0.25	1	1.2	0.75
6 (6 MAP)	0.5	0.5	0.5	0.5	1.5	1
6 (frozen 6 MAP)	2.25	2.5	0.25	0	0.75	1
7 (1 MAP 6 Air)	1	0.25	0.38	0	1	1.75
8 (2 MAP 6 Air)	1	0	0.25	0	1	0.75
9 (3 MAP 6 Air)	1.5	0.25	1	0.5	1.25	1.13
9 (6 MAP 3 Air)	0.5	0	0.5	0	1.75	1
9 (frozen 6 MAP 3 Air)	2.5	2	0	2	2	1.25
10 (10 Air)	3	4	2	0	1	1
10 (frozen 10 Air)	2.5	4	0.5	0	1	1
10 (5hr MAP 10 Air)	2	4	0.5	0	1	1.25
10 (10 MAP)	0.8	0.25	0.5	0	1.5	1
11 (1 MAP 10 Air)	2.5	2.5	0	0	1	1.25
12 (2 MAP 10 Air)	2.5	1.25	1	0.5	1.13	1
12 (6 MAP 6 Air)	1.3	0	0.25	0	1.5	1.15
12 (frozen 6 MAP 6 Air)	2.3	2.5	1	0.5	1.5	1.25
13 (3 MAP 10 Air)	1.3	0.25	1	0	1	1.25
13 (10 MAP 3 Air)	2	1.5	1	0.5	1	1
15 (15 Air)	3	0	0	0	1.25	-
15 (frozen 15 Air)	3	-	-	0	-	-
15 (15 MAP)	1	-	-	-	-	1
16 (6 MAP 10 Air)	2.3	3	0.5	-	2	1.5
16 (frozen 6 MAP 10 Air)	2.5	4	0	0	2.5	1.5
16 (10 MAP 6 Air)	2.3	3.5	0	-	1.5	1
18 (15 MAP 3 Air)	1	0	0	1	2	1
21 (10 MAP 11 Air)	2.5	1.75	1	-	2	1
21 (15 MAP 6 Air)	1.5	0.5	1	1	2.5	1.5
25 (15 MAP 10 Air)	1	0	1	1	2	2

Because of the different ages present within the samples there was varying results for this parameter. Frozen scallops can be easily discerned from fresh scallops because of their grey, slightly transparent appearance. Because of the mixture of ages in the batch the scallops started with ratings of white. As storage progressed the colour became grey. The scallops exposed to air only scored highest.

Mixture of grey to white

The proportion of grey scallops at the start of storage did differ between packs considerably as seen in Table 60. As storage progressed more scallops slowly became grey in appearance until the last four days where it was quite rapid for some treatments.

Parasites

The presence of parasites was the next most obvious parameter determined when the scallops were visually appraised. Table 60 shows that the incidence of parasites in most packs was none to slight. The scallops stored in air only exhibited more than any other treatment.

Type of parasite

There were two types of pigmented bodies present in the flesh of the scallops, one was white and the other orange. The orange parasite was not easy to discern at the start of storage but deepened in colour with storage. Many of them could have been identified as being white at the start of storage. The variability of the presence of these parasites can be seen in Table 60.

Flesh appearance

During storage enzymes still active in the flesh of scallops can cause damage to the texture and integrity of the scallop. The development of splits during removal of the meat from the shell can become larger during storage because of atmospheric pressure being exerted on the vacuum skin packs. Table 60 shows that the scallops during this trial varied greatly in the amount of cracks present in the flesh and that no trend during storage was discernible.

Drip, qualitative

The amount of moisture that leaked from the flesh of the scallops was measured in two ways. Before opening the packs a visual appraisal of the level of drip loss was made. The ratings were from none through slight to excessive. As Table 60 shows most of the packs had slight levels of drip loss with only a few becoming excessive. The vacuum skin packing would exert some pressure onto the surface of the scallop encouraging the loss of moisture so the levels observed indicate that this is a suitable form of packaging for scallops. The variability present within the batch of scallops did not lead to any obvious trends.

Drip, quantitative

To give some quantitative measurement to this visual appraisal the weight of the tray before and after the scallops were removed was recorded. These measurements were then used to convert the weight of the moisture remaining in the trays into a percentage of the weight of scallops present. The quantitative data displayed in Table 58 confirms the variation present within the original sample. The most moisture lost by any pack was 3.4%. This is quite low considering the moisture content of raw scallops.

Table 61. Demerit scores of scallops during trial 3 storage at 4°C, part two.

Storage days and (conditions)	Raw odour	Cooked drip loss	Cooked odour	Flavour	Texture	Total demerits
2 (2 Air)	-	-	-	-	-	-
2 (frozen 2 Air)	0	-	-	0	0	-
2 (2 MAP)	0	-	-	0	0	-
3 (3 Air)	1	-	-	1	0	5.75
3 (frozen 3 Air)	1	-	1	1	0	9.5
3 (5hr MAP 3 Air)	1	-	0	1.25	0	5
3 (3 MAP)	0.75	-	0.5	0.5	0	5.75
4 (1 MAP 3 Air)	0.25	0.3	0.5	1	0	6.18
5 (2 MAP 3 Air)	0.5	-	0.5	1.25	0	5.87
6 (6 Air)	2	1.25	0.5	2	1	9
6 (frozen 6 Air)	1.5	1	0.5	1.3	0	8.55
6 (5hr MAP 6 Air)	1.5	0.5	0.5	1.5	0	8.63
6 (3 MAP 3 Air)	0.5	1	1	1.75	0.25	7.7
6 (6 MAP)	0.5	0.75	0.5	1.3	0.25	7.3
6 (frozen 6 MAP)	0.5	0.5	0.25	1.3	0	9.3
7 (1 MAP 6 Air)	1.75	0.88	1.25	2	1	11.26
8 (2 MAP 6 Air)	2	0.75	0.75	2.2	1	9.7
9 (3 MAP 6 Air)	1	1.5	0.5	1.75	0.25	10.13
9 (6 MAP 3 Air)	1.25	1.4	1	1.8	0.5	9.7
9 (frozen 6 MAP 3 Air)	1.5	1.25	0.5	1.25	0	12.25
10 (10 Air)	3	1.5	2.5	2.3	0	20.3
10 (frozen 10 Air)	3	1	3	4	0	20
10 (5hr MAP 10 Air)	2	1.5	1.5	3.5	1.5	18.75
10 (10 MAP)	1.5	1.5	1.25	2.5	1	11.8
11 (1 MAP 10 Air)	2.75	1	3	4	1.5	19.5
12 (2 MAP 10 Air)	2.75	1	2	2.75	1	16.38
12 (6 MAP 6 Air)	1	1	1	1.75	0.5	9.45
12 (frozen 6 MAP 6 Air)	1.75	1.25	0.75	1.5	0.13	13.93
13 (3 MAP 10 Air)	1.25	1.25	1	2.5	1.2	12
13 (10 MAP 3 Air)	2.5	1.5	1.5	2.5	1	15.5
15 (15 Air)	-	-	-	-	-	-
15 (frozen 15 Air)	-	-	-	-	-	-
15 (15 MAP)	0.5	1	0.5	1	0	6.25
16 (6 MAP 10 Air)	2.5	1.5	1.75	1.75	0.5	17.3
16 (frozen 6 MAP 10 Air)	2	1.25	1.75	1.5	1	18
16 (10 MAP 6 Air)	2.5	1.25	2.6	3.75	1	19.4
18 (15 MAP 3 Air)	0.5	1	0.5	1.5	1	8.5
21 (10 MAP 11 Air)	3	2	3	4	1	22.25
21 (15 MAP 6 Air)	2	1	1	1.75	1	13.75
25 (15 MAP 10 Air)	2.5	1.5	2.4	2.3	1	15.7

Raw odour

The smell of the scallops was appraised as soon as the layer of permeable membrane was removed. The fact that the end point consumer may be preparing the scallops for consumption suggests that a package of this type have few off odours when opened. The scores for this trait are present in Table 61. Scallops stored in air lose freshness rapidly and quickly develop off odours. Scallops kept in MAP, while the fresh aroma of scallops did diminish, exhibited delayed development of off odours and these did not become excessive until the packs had been exposed to air for several days. If a rejection level for odour was placed at slight then most packs would have been acceptable for up to 6 days in air. This aspect will be investigated further when taste panels with any participants are conducted.

Cooked parameters

Two scallops were randomly selected from a pack and cooked in a microwave oven for one minute at the high power setting. The scallops were appraised for the amount of water expelled by cooking, odour, flavour and texture.

Cooked drip loss

This attribute is one industry uses to determine whether soaking in freshwater has occurred to increase the weight of product. Uptake of water by scallops readily occurs due to osmotic differences between the muscle structure and water. When the scallop is cooked hardening and shrinkage of the muscle occurs and this expels the excess water. The size can contract significantly and spattering will occur due to the water being expelled. Normal muscle tissue that has not been soaked in fresh water can also exhibit an increasing cook drip loss with storage time due to changes within the meat.

The scallops from all the treatments had similar ratings for cooked drip loss at the slight level with the exception of only one pack which had excessive drip loss (Table 61). The mixture of capture ages of the scallops as indicated by the ratings for some of the other parameters has diminished any opportunity for storage trends for this trait to be elucidated.

Cooked odour

The odour of scallops when cooked can be more intensive than when raw due to the steam being released from the flesh. The scores present in Table 61 show that the scallops did not develop off odours until they had been exposed to air for several days. Under modified atmosphere or just after removal from the bulk pack the odour ranged from normal scallop to neutral. After 6 days exposure to air off odours had developed in cooked scallops but only some of the packs presented excessive off odours by the end of 10 days storage in air.

Flavour

As shown in Table 61 scallops quickly lose their characteristic sweet flavour becoming neutral and start to develop spoilt flavours after 6 days storage in air. This loss of flavour even occurs during storage under a modified atmosphere.

Texture

The texture of scallops was quite stable during storage even after 25 days. The texture scores in Table 61 indicate that there was little proteolytic enzyme activity originally present in the muscle and there was insufficient produced by bacteria to have an impact on the texture.

Total demerit points

When the demerit points for all of the parameters are combined the overall effect of MAP of scallops becomes apparent (Table 61). There is little change to the most of the parameters of scallops while present in the bulk packs. The score at day 10, which is higher than day 6 and 15, is due to only one of the packs sampled. This pack attained scores for a number of parameters while the other in the set was consistent with the rest of the data. This sample also had higher total, H₂S producer and anaerobic counts than its partner in the set. While resulting in higher scores than expected this result is a good indication of the inherent difficulties in processing a catch with a mixture of storage ages.

Frozen scallops

The scallop trawl industry has a predominance of freezer boats over those with refrigerated seawater storage tanks (wet boats). This led to the processor requesting some evaluation of frozen scallops stored under MAP. The limited number of wet boats bringing in raw material could lead to sporadic processing resulting in supplies of MAP scallops to retailers becoming intermittent. As the addition of a second treatment being added to this trial would have led to an impossible work load samples for just one MAP storage time were taken. These were tested for the same parameters and at the same time as the scallops stored in refrigerated seawater. The data for all other parameters tested were analysed for significant difference for air storage and a MAP storage of 6 days.

pH

There was no significant difference between the types of scallop during air storage but there was a difference ($P < 0.05$) after MAP storage of 6 days. While the pH of RSW stored scallops was slightly lower than the frozen scallops, a difference of a pH of 0.1 or 0.2 does not constitute important changes to the quality of the scallop. The pH data is present in Table 58.

Microbial attributes

There were no significant differences for storage in air and after 6 days MAP between scallops originally stored in RSW and frozen for the aerobic and H_2S producer microbial counts. The anaerobic count was evaluated for 6 days MAP storage and no significant differences were identified. The microbiological counts can be seen in Table 58.

Demerit Point Appraisal

Colour overall

There was no difference in the colour of scallops between the two types of vessel storage. The scores for this attribute can be seen in Table 60.

Mixture of grey to white

There was no difference in the mixture of the colour of scallops between the two types of vessel storage. The scores for this attribute can be seen in Table 60.

Parasites

There was no significant difference in the presence of parasites on scallops between the two types of vessel storage. The scores for this attribute can be in Table 60.

Type of parasite

The variability of the presence of these parasites can be seen in Table 60. There was no significant difference between the two boat storage types for air storage. There were few parasites present in the samples stored in MAP so no analysis was possible.

Flesh appearance

There was no significant difference between vessel storage conditions for scallop appearance. Table 60 shows scores for the scallops during this trial.

Drip, qualitative

There was no significant difference between vessel storage conditions for scallop drip loss in the tray and Table 61 shows scores for the scallops during this trial.

Drip, quantitative

The drip loss quantitative data for scallops from the two original storage methods were not significantly different and it is present in Table 58.

Raw odour

The smell of the scallops for both storage types was similar. The scores for this trait are present in Table 61.

Cooked drip loss

There was no significant difference between the types of scallop after MAP storage of 6 days but during air storage there was a significant difference ($P < 0.05$). The frozen scallops exhibited a higher moisture loss during cooking as shown in Table 61.

Cooked odour, flavour and texture

There was no significant difference between vessel storage conditions for scallop cooked odour, flavour or texture. Table 61 shows the scores for scallops during this trial of these parameters.

Total demerit points

When the demerit points for all of the parameters are combined the overall effect of vessel storage conditions for scallops is that there was no significant difference (Table 61).

Conclusion

This limited comparison suggests that scallops frozen on board the capture vessel could be substituted from product that was brought to port in RSW.

Overall Microbiological Assessment of Three Trials

Raw materials

The total bacterial count of the fresh scallops ranged from 3,800 to 23,000 colony forming unit (cfu)/g. The fresh samples contained non-detectable levels of Gram negative H₂S producers (<10 cfu/g) and anaerobic bacteria (<100 cfu/g).

Storage in air

When stored aerobically, the total bacterial count of the fresh scallops increased by 3.4 to 11 folds in three days or 21 to 145 folds in six days. By the tenth day the bacterial count reached excessively high levels (3.2 to 9.1 x 10⁶ cfu/g). Thawed scallop samples when stored in air at 4°C, showed more lag phase at the early stages (up to day 6) than that of fresh scallops and from day 10 onward the growth rate exceeded that of fresh scallops. The spoilage bacterial composition of the two samples appeared to be different, with the pre-frozen sample contained more Gram negative H₂S producers. It is not clear if this difference was influenced by the natural differences in bacterial flora or by the freezing treatment or both.

Generic composition

Results from the first two trials indicated that the initial bacterial flora of the raw scallops were predominantly Gram positive bacteria (mainly from the genera *Micrococcus* and *Staphylococcus*) with some Gram negatives (mainly *Flavobacterium*). The ratio of Gram negatives bacteria in the flora increased during aerobic storage for up to day 6. On further storage, the bacterial composition showed varied trends.

The anaerobic bacterial count, which was undetectable in the fresh samples, showed negligible growth during the aerobic storage up to days 6 and 10 (mean of 200 and 6,500 cfu/g respectively).

Storage in MAP

The scallops packed in vacuum skin retail pack (VSP), stored in a CO₂-flushed master bag and held for 3 and 6 days showed bacterial growths of <1 to 1.07 and <1 to 1.8 folds of their respective initial counts. Products held under MAP for ten days showed bacterial growths of 3.2 to 84 folds (12,000 to 480,000 cfu/g). These growth rates are lower than those of the corresponding aerobically stored samples.

Generic composition

Results from one trial indicated that the Gram negative bacterial ratio of the bacterial flora increased from 17 to 27% up to day 6. It further increased to 82% and 73% at day 10 and 13 respectively. During the anaerobic storage, the dominant Gram negative flora changed from *Flavobacterium* to *Shewanella* with time. The Gram positive flora

composed of mainly *Micrococcus* with some *Staphylococcus* present in the initial product. The anaerobic bacterial counts remained low (<100 to 250 cfu/g) up to day 6. At day 10, the count ranged from 4,400 to 120,000 cfu/g.

Aerobic storage following MAP treatment

The bacterial counts of samples held aerobically for 3 days following 3 days of MAP treatment ranged from 1.2 to 4.9 folds (6,300 to 20,000 cfu/g) of their initial counts. Similar samples held aerobically for 6 days showed increases of 6.8 to 36.3 folds (28,000 to 190,000 cfu/g) of their initial counts. Samples with 6 days of MAP treatment developed counts ranging from <1 to 32 folds (6,000 to 39,000 cfu/g) of their initial counts at day 3 aerobic storage, and developed 7.9 to 157 folds increases in counts (54,000 to 190,000 cfu/g) at day 6 of aerobic storage. The majority of samples when held aerobically for 10 days following MAP treatment had total bacterial counts in excess of 1 million cfu/g and high anaerobic counts.

Discussion

Results obtained indicated that when fresh samples were held aerobically at 4°C for ten days, the bacterial load could reach in excess of 1,000,000 cfu/g (range 1,000,000 to 8,700,000 cfu/g). At this stage the colour, odour and flavour of the products have noticeably declined. The anaerobic count of these samples reached a level of 3,400 to 9,700 cfu/g.

After ten days MAP total bacterial counts ranged from 12,000 to 480,000 cfu/g. The sensory properties of these samples remained acceptable. However, these samples could develop excessively high (>1,000,000/g) total bacterial count within 3 to 6 days on exposure to air. Further more, the sample from day 10 could contain high level of anaerobic bacteria (120,000 cfu/g).

Samples held under MAP for up to six days contained total bacterial count of 1,200 to 6,800 cfu/g, when these samples were exposed to air for up to six days, the total bacterial count reached a range from 54,000 to 190,000 cfu/g. The sensory properties of these samples remained acceptable. The anaerobic bacterial counts of samples at the end of six days ranged from <100 to 5,000 cfu/g. The aerobic growth rates of MAP treated samples appeared to mimic, to a lesser extent, the corresponding growth rates of the fresh samples.

These results indicate that when products were held at 4°C, fresh scallop samples with total bacterial count of between 3,800 to 5,700 cfu/g packed in VSP and held under MAP condition for 1 to 6 days, will have a potential aerobic shelf-lives of a further 6 days.

Trials 4 and 5

Trials 4 and 5 incorporated all of the tests proposed for evaluation: microbiological, analytical and sensory.

Microbial attributes

Raw materials

In Trails 4 and 5, the total bacterial count of the fresh scallops ranged from 7,600 to 11,200 cfu/g. The statistical analysis of the microbiological data for both trials is summarised in Table 62.

Table 62. Mean log counts of spoilage bacteria in scallops stored at 4°C for trials 4 and 5.

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Storage days and (conditions)	Total count	H2S producers	gram + ve rods and cocci	gram + ve rods
0 fresh	3.96 ^{bc}	1.48 ^{ed}	2.00 ^e	2.00 ^e
3 (3 MAP)	3.98 ^{bc}	1.38 ^{de}	2.44 ^{de}	1.95 ^e
3 (3 Air)	4.36 ^b	1.20 ^d	2.88 ^{bcd}	2.48 ^{cde}
6 (6 MAP)	3.97 ^{bc}	1.34 ^d	2.81 ^{cde}	2.38 ^{de}
6 (6 Air)	4.97 ^a	2.31 ^{bc}	3.66 ^{ab}	3.35 ^{ab}
6 (3 MAP 3 Air)	3.87 ^{bc}	1.50 ^{cd}	2.72 ^{cde}	2.33 ^{cde}
7 (7 MAP)	3.89 ^{bc}	1.33 ^d	2.80 ^{cde}	2.00 ^e
10 (6 MAP 4 Air)	4.26 ^{bc}	2.02 ^{bcd}	2.89 ^{bcd}	2.69 ^{cd}
10 (3 MAP 7 Air)	5.42 ^a	2.78 ^b	3.93 ^a	3.89 ^a
10 (7 MAP 3 Air)	3.77 ^c	1.71 ^{cd}	2.37 ^{de}	2.30 ^{de}
11 (11 MAP)	4.13 ^{bc}	1.33 ^d	3.07 ^{abcd}	2.96 ^{bc}
12 (6 MAP 6 Air)	5.19 ^a	2.68 ^b	3.89 ^a	3.89 ^a
14 (7 MAP 7 Air)	5.03 ^a	4.08 ^a	3.56 ^{abc}	3.61 ^{ab}

* ^{abcde} Different letters signify significant differences between treatments (P < 0.05)

This data is also displayed as Figures 2 to 4 in Appendix 8. The identifications of individual microbes present during each trial were carried out and are present in Tables 63 and 64.

Table 63. Bacterial flora of scallops during storage trial 4 at 4°C.

Time in air (days)		1	3	6	0	3	7	0	6
Time in MAP Days		0	0	0	3	3	3	6	6
Total log count (cfu/g)		3.88	4.08	5.79	3.88	3.85	5.38	3.83	4.83
Gram -ve	Others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Pseudomonas</i>	25.0	16.7	0.0	25.0	16.7	0.0	33.3	16.7
	<i>Acinetobacter</i>	0.0	0.0	0.0	0.0	0.0	9.1	0.0	0.0
	<i>Alcaligenes</i>	8.3	0.0	0.0	8.3	0.0	0.0	0.0	0.0
	<i>Flavobacterium</i>	0.0	25.0	0.0	8.3	16.7	9.1	16.7	0.0
	<i>Shewanella</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Combined	33.3	41.7	0.0	41.7	33.3	18.2	50.0	16.7
	Yeast	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gram +ve	Others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Brochothrix</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Bacillus</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Kurthia</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Cornyformes</i>	8.3	0.0	0.0	25.0	16.7	0.0	0.0	16.7
	<i>Lactobacillus</i>	0.0	0.0	16.7	0.0	25.0	72.7	8.3	66.7
	<i>Streptococcus</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Staphylococcus</i>	41.7	8.3	0.0	0.0	0.0	9.1	8.3	0.0
	<i>Micrococcus</i>	16.7	50.0	33.3	33.3	25.0	0.0	33.3	0.0
	Combined	66.7	58.3	100.0	58.3	66.7	81.8	50.0	83.3

Table 64. Bacterial flora of scallops during storage trial 5 at 4°C.

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Time in air (days)		1	3	6	0	3	7	0	4	7	0
Time in MAP Days)		0	0	0	3	3	3	6	6	6	11
Total log count (cfu/g)		4.04	4.15	4.18	4.11	4.04	5.53	4.04	4.08	5.48	4.04
Gram -ve	Others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Pseudomonas</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	0.0	0.0
	<i>Acinetobacter</i>	0.0	0.0	0.0	16.7	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Alcaligenes</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Flavobacterium</i>	16.7	0.0	0.0	0.0	0.0	0.0	8.3	8.3	0.0	0.0
	<i>Shewanella</i>	0.0	0.0	0.0	0.0	0.0	8.3	0.0	8.3	8.3	0.0
	Combined	16.7	0.0	0.0	16.7	0.0	8.3	8.3	25.0	8.3	0.0

Yeast		0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0
Gram +ve	Others	0.0	0.0	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Brochothrix</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Bacillus</i>	0.0	9.1	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0
	<i>Kurthia</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Cornyformes	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Lactobacillus</i>	0.0	0.0	25.0	0.0	0.0	83.3	0.0	25.0	0.0	8.3
	<i>Streptococcus</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	<i>Staphylococcus</i>	41.7	27.3	16.7	16.7	45.5	0.0	8.3	8.3	0.0	25.0
	<i>Micrococcus</i>	41.7	63.6	41.7	50.0	54.5	0.0	75.0	41.7	91.7	66.7
	Combined	83.3	100.0	100.0	83.3	100.0	91.7	91.7	75.0	91.7	100.0

All of the fresh samples contained low or non-detectable levels of Gram negative H₂S producers (<10 cfu/g) and anaerobic bacteria (<100 cfu/g). The predominating bacteria in Trial 4 were a mixture of (66.7%) Gram-positive bacteria (*Staphylococci* and *Micrococci*) and (33.33%) Gram-negative bacteria (*Pseudomonads*). In Trial 5 the Gram-positive flora (*Staphylococci* and *Micrococci*) predominated (83.3%) with some (16.7%) Gram-negative bacteria present (*Flavobacterium*).

Growth during aerobic storage

When stored aerobically up to six days, the total bacterial count of the fresh scallops increased to 610,000 and 15,000 cfu/g respectively for Trials 4 and 5.

In Trial 4, the predominating bacteria following six days of aerobic storage were (100%) Gram-positive bacteria (*Lactobacilli*). This was a change from the initial mixture of Gram-positive population of *Staphylococci* and *Micrococci*. In Trial 5, the predominating flora were also (100%) Gram-positive bacteria consisted of *Micrococci*, *Lactobacilli* and *Staphylococci*.

Growth during MAP storage

Minimal growths were detected during MAP storage of up to six days, the total bacterial counts were 8,700 and 11,000 cfu/g for Trail 4 and Trial 5 respectively. There were only low levels of Gram-negative H₂S producers (<10 and 30 cfu/g respectively) and anaerobic bacterial counts (<100 and 4,500 cfu/g respectively).

In Trial 4 the predominating flora, following six days of MAP storage, were a mixture of (50%) Gram-positive bacteria (*Micrococci*, *Staphylococci* and *Lactobacilli*) and (50%) Gram-negative bacteria (*Pseudomonads* and *Flavobacterium*). In Trial 5, the predominating flora were mainly (92%) Gram-positive bacteria (*Micrococci* and *Staphylococci*) and some (8%) Gram-negatives (*Flavobacterium*).

Aerobic storage following MAP storage

The total bacterial counts of 6 days MAP treated samples which were subsequently stored aerobically (for six days) showed counts of 67,000 and 390,000 cfu/g for Trials 4 and 5 respectively (see Figure 2 in Appendix 8). The Gram-negative H₂S producers were 120 and 4,500 cfu/g respectively and the anaerobic bacterial counts were 8,500 and 8,600 cfu/g respectively. (For the 3 days MAP treated samples their corresponding counts were 240,000 and 290,000 cfu/g for Trials 4 and 5 respectively). In Trial 4 the predominating flora were (83.3%) gram-positive bacteria (*Lactobacilli* and coryneforms) with some

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(16.7%) Gram-negative bacteria (*Pseudomonads*). In Trial 5 the dominating flora (91.7%) were *Lactobacilli* with some (8.3%) Gram-negatives (*Shewanella*) present.

Chemical and physical analysis

Quality aspects of MAP stored scallops were also appraised in Trials 4 and 5. These were pH, K value, drip loss and visual assessment using the demerit system applied in earlier trials. There were significant differences between treatments present for some of the chemical and physical parameters. Most of the components previously appraised by demerit were covered by the taste panel evaluations so that only drip loss present in the sealed packs and the raw odour on opening were scored. The former was also supported with weight measurements of full packs and those after scallops have been removed. The moisture content of the scallops at the start of the trials was 82.8% for Trial 4 and 85% for Trial 5. The use of all the scallops for sensory, microbiological and chemical assessment prevented the use of conventional methods of measuring drip loss. Table 65 shows the statistical analysis for pH, K value, drip loss score and raw odour score.

Table 65. Mean pH, K value, drip loss score and raw odour score.

Storage days and (conditions)	pH*	K value	Drip loss score*	Raw odour score*
0 (fresh)	6.25 ^a	86.9	0.05 ^e	0.00 ^e
3 (3 MAP)	6.09 ^{ab}	85.4	0.75 ^{cd}	0.38 ^{de}
3 (3 Air)	6.17 ^a	89.5	0.50 ^d	0.75 ^{cd}
6 (6 MAP)	6.00 ^{bc}	87.0	1.25 ^{ab}	1.00 ^{bcd}
6 (6 Air)	6.23 ^a	88.0	0.05 ^d	1.00 ^{bcd}
6 (3 MAP 3 Air)	6.10 ^{ab}	88.8	1.00 ^{bc}	1.00 ^{bcd}
7 (7 MAP)	5.98 ^{bc}	88.0	1.00 ^{bc}	1.13 ^{bc}
10 (6 MAP 4 Air)	6.05 ^b	87.5	1.25 ^{ab}	1.13 ^{bc}
10 (3 MAP 7 Air)	6.09 ^b	85.8	1.50 ^a	1.38 ^{bc}
10 (7 MAP 3 Air)	6.00 ^{bc}	82.9	1.00 ^{bc}	1.00 ^{bcd}
11 (11 MAP)	5.86 ^c	87.7	1.15 ^{ab}	1.48 ^{ab}
12 (6 MAP 6 Air)	6.01 ^{bc}	88.6	1.38 ^a	1.63 ^{ab}
14 (7 MAP 7 Air)	5.93 ^{bc}	86.6	1.45 ^a	2.20 ^a

* abcde Different letters signify significant differences between treatments (P < 0.05)

pH

Scallops stored in air for 6 days exhibit a stable pH. The pH of the scallops drops while exposed to MAP storage. When the pack is removed and stored in air the pH then stabilises before a slight drop.

K value

The K value was already high for the scallops at the start of storage so there is little information that can be obtained on changes in quality using this parameter.

Demerit Point Appraisal

Drip loss score

A number of parameters were appraised when the scallops were unpacked from MAP and air storage. One of the most important parameters to processors was the loss in yield due to drip. Table 65 shows the significant differences between the score for drip loss. The amount of apparent drip in the packs was greater when scallops were stored in MAP. The drip loss scores show an increase with storage time but the actual weight of drip measured as a percentage of the packed weight (see Figure 5 in Appendix 8) was never higher than 1.2% during Trial 5.

Raw odour score

The taste panel could not appraise the odour of scallops after storage in MAP and/or air so a score was recorded when samples were taken for evaluation of microbiological and chemical quality. The odour did deteriorate during storage in MAP and in air becoming neutral after 6 days in MAP and/ or air but never became worse than slight even after 12 days storage (Table 65). There was no difference between the scallops stored in different atmospheres after the same storage time.

Sensory analysis

Mean sensory scores for Trials 4 and 5 are presented in Tables 66 and 67.

Table 66. Mean sensory scores for odour and appearance.

Storage days and (conditions)	Typical odour*	Other odour	Free moisture*	Greyness
0 (fresh)	64.82 ^{abc}	14.94	43.82 ^{ab}	10.26
3 (3 MAP)	68.58 ^a	14.06	48.99 ^a	10.04
3 (3 Air)	62.96 ^{abc}	11.74	33.67 ^{bc}	8.44
6 (6 MAP)	63.41 ^{abcd}	10.38	56.09 ^a	17.15
6 (6 Air)	55.91 ^d	17.87	32.64 ^a	10.89
6 (3 MAP 3 Air)	60.32 ^{cd}	12.68	44.58 ^{ab}	10.56
7 (7 MAP)	68.24 ^{ab}	11.84	53.00 ^a	7.63
10 (6 MAP 4 Air)	54.26 ^d	13.01	45.99 ^{ab}	12.86
10 (3 MAP 7 Air)	60.71 ^{bed}	12.93	44.77 ^{ab}	12.36
10 (7 MAP 3 Air)	55.70 ^d	12.72	50.12 ^a	11.10
12 (6 MAP 6 Air)	61.73 ^{abcd}	15.85	45.48 ^{ab}	11.36

* ^{abcd} Different letters signify significant differences between treatments ($P < 0.05$)

Scales: *odour*: None (0) to Very strong (100), *free moisture*: None (0) to A lot (100)
Greyness: Not at all grey (0) to Very grey (100)

Table 67. Mean sensory scores for texture, flavour and overall acceptability.

Storage days and (conditions)	Firmness	Moistness	Typical flavour	Other flavour	Overall acceptability*
0 (fresh)	35.42	67.44	68.08	14.25	75.49 ^a
3 (3 MAP)	66.86	65.03	67.80	18.77	70.92 ^{ab}
3 (3 Air)	60.38	70.96	66.66	15.94	70.94 ^{ab}
6 (6 MAP)	66.75	59.47	72.47	12.67	69.24 ^{abc}
6 (6 Air)	60.80	68.92	56.76	14.82	61.41 ^{cd}
6 (3 MAP 3 Air)	61.99	65.93	60.61	15.55	62.33 ^{bcd}
7 (7 MAP)	67.98	64.09	67.86	15.97	68.96 ^{abc}
10 (6 MAP 4 Air)	63.42	62.00	59.88	13.34	57.21 ^d
10 (3 MAP 7 Air)	60.85	66.56	63.47	13.50	64.33 ^{bcd}
10 (7 MAP 3 Air)	64.39	60.52	64.12	16.13	63.15 ^{bcd}
12 (6 MAP 6 Air)	65.78	66.62	61.78	19.56	60.00 ^{cd}

* ^{bcd} Different letters signify significant differences between treatments ($P < 0.05$)

Scales: *Firmness*- None (0) to Very firm (100), *Moistness*: None (0) to Very moist (100) ^a
Flavour: None (0) to Very strong (100), *Overall acceptability*: Dislike extremely (0) to Neither like nor dislike (50) to Like extremely (100).

Only typical odour, free moisture and overall acceptability showed any significant ($P < 0.05$) differences between treatments. There was more free moisture in the MAP

treatments than with the air-stored samples. Typical odour and overall acceptability decreased over the storage time.

Trial 4 and Trial 5 Descriptors

The descriptors used by panellists for trials 4 and 5 are present as Figures 6 to 13 in Appendix 8. To combine the treatments from Trial 4 and 5 a few assumptions have been made. The days 0 result from the first trial is assumed to be equivalent to the 'fresh' sample (actually Days 1) from Trial 5 and for these treatments the replication is four. Also 6 days MAP and 6 days Air from Trial 4 is classed as the same treatment as 6 days MAP and 7 days Air and 7 days MAP and 6 days Air from Trial 5. There were doubts about the validity of days 6 MAP result from Trial 4, so for the purpose of analysis it was classed as missing.

Discussion

Although the microbiological flora found in Trials 4 and 5 were somewhat different to those found in Trial 2, the overall microbiological growth showed a consistent pattern as in previous trials. Good quality fresh scallops, when stored aerobically at 4°C for 6 days, still retained acceptable microbial load (< 1,000,000 cfu/g).

- > Good quality fresh scallops when stored under MAP system at 4°C for 6 days showed minimal bacterial growth. When MAP treated scallops were subsequently stored aerobically at 4°C, they appeared to show the same growth rate as that of good quality fresh scallop.
- > Good quality fresh scallops MAP treated for 1 to 6 days will have a potential aerobic shelf life of a further 6 days.

These results indicate that shelf life can be extended under MAP but typical odour decreases, free moisture increases and overall acceptability decreases. There was no statistical difference between the air-stored scallops at 6 days and those tasted after combinations of MAP and air (3/3, 3/7, 6/4, 7/3, 6/4, 6/6). What it means is that the MAP maintains the quality while the product is in MAP for up to 6 or 7 days.

It was much more difficult to determine when the high quality life was lost from MAP stored scallops. This product received high overall quality scores all through the storage trials regardless of storage conditions. The overall quality never scored below 60%. Individual treatments became significantly different from the score for fresh scallops after 6 days storage in air and the MAP/air combinations of 3/3, 3/7, 6/4, 6/6, and 7/3. The only other parameter to exhibit changes was typical odour. Although the score did not go lower than 55% there were significant differences from the score for fresh scallops after 6 days storage in air and the MAP/air combinations of 3/3, 6/4, and 7/3.

Many of the other parameters used for describing bad quality were scored low and they did not change significantly during storage. The sensory scores for some parameters changed to those of lower quality after three days in air for both air and MAP storage. The physical parameters also did not provide a convenient timing for the loss of the HQL. Changes did occur after three days air only storage and three and six days MAP storage but these were not sufficiently different to designate the loss of HQL.

The microbiological data, while not directly influencing the normal desirable characteristics of scallops, may give some insight into the changes occurring. The total counts of scallops were significantly different from the starting level after 6 days in air and the MAP/air combinations of 3/7, 6/6 and 7/7. The increase in numbers of bacteria after these times should lead to off odours, flavours or texture. When the sensory and

microbiological data are used in combination then there could be a basis for suggesting that the HQL has been lost after 6 days storage under any conditions.

Conclusions for MAP scallops

Results from Trials 1 to 5 (Figure 14 Appendix 8) indicated that when fresh samples were held aerobically at 4°C for six days, the bacterial load would reach an average level of 470,000 cfu/g (range 15,000 to 710,000 cfu/g).

Trials 2 to 5 showed (Figure 15 Appendix 8) that when samples were held under MAP condition for six days, only minimal bacterial growth was observed. The average total bacterial count reached to a level of 6,800 cfu/g, ranged from 1,200 to 10,500 cfu/g.

When the samples were held under MAP for three days (Figure 16 Appendix 8) then followed by aerobic storage for six days, the average bacterial count reached 190,000 cfu/g (ranged from 28,000 to 290,000 cfu/g).

When the six days MAP treated samples (Figure 17 Appendix 8) were stored aerobically for a further six days, the average bacterial count was 180,000 cfu/g (ranged from 54,000 to 390,000 cfu/g).

The limited comparison carried out suggests that scallops frozen on board the capture vessel could be substituted from product that was brought to port in RSW.

Trials 4 and 5 confirmed that good quality fresh scallop (total count between 3,800 to 10,000 cfu/g) packed in VSP and held under MAP conditions for 1 to 6 at 4°C, will have a potential aerobic shelf-life of a further 6 days in air.

Finally, scallops can be stored in MAP with some initial loss of quality but will be stable until the microbial count reaches unacceptable levels.

Swordfish Trials

Bulk Packaging Experiments

Trial 1

This commodity is to be sold in bulk so a number of treatments were investigated using a limited quantity of cutlets in a storage trial. This trial was initiated even though the original samples contained high bacterial counts to find answers for some of the many questions relating to bulk packs of MAP seafood. Two different gases were compared, one containing a mixture of 55% carbon dioxide, 35% nitrogen and 5% oxygen and the other composed of 100% carbon dioxide. A limited number of bulk trays were obtained from New Zealand and these were filled with 3kg or 5kg of cutlets prior to vacuum skin packing using permeable film and then placed in a gas flushed barrier bag.

The smaller sized packs containing two layers of cutlets were stored in MAP for three days at 4°C and the larger packs containing three layers were stored in MAP for six days. After these times the packs were removed for sampling and stored in air for a further three days. The oxygen content of each pack was tested before opening. The packs with 55% carbon dioxide contained 7.1% and 7.2% oxygen while those flushed with 100% carbon dioxide contained 5.2% and 5.5% oxygen. Table 68 shows the data collected from this trial.

Table 68. Significant differences between different treatments for pH and microbial counts of swordfish stored in MAP and/or air at 4°C.

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Time in MAP days	Time in air days	Gas mixture	Layer	pH	Total log count	H ₂ S producers log count	Anaerobe log count
0	0	air	1	5.98 ^{bcdef}	5.060 ^{hij}	1.301 ⁱ	3.512 ^{ghi}
0	3	air	1	6.05 ^a	6.605 ^{cd}	3.136 ^e	3.541 ^{fghi}
3	0	55% CO ₂	1	5.95 ^{fg}	4.824	1.573 ^{hi}	3.602 ^{fghi}
3	0	55% CO ₂	2	6.02 ^{abcd}	5.366 ^{ghij}	1.350 ^{hi}	3.208 ^{ijk}
3	0	100% CO ₂	1	5.86 ^h	5.146 ^{hij}	1.651 ^{hi}	3.621 ^{fgh}
3	0	100% CO ₂	2	5.95 ^{efg}	5.073 ^{hij}	1.602 ^{hi}	3.322 ^{hijk}
6	0	55% CO ₂	1	5.95 ^{efg}	5.457 ^{hi}	2.863 ^e	3.224 ^{hijk}
6	0	55% CO ₂	2	5.94 ^{fg}	5.027 ^{hij}	2.062 ^{fgh}	3.021 ^{jk}
6	0	55% CO ₂	3	5.92 ^{gh}	5.040 ^{ij}	2.807 ^{ef}	3.343 ^{hijk}
6	0	100% CO ₂	1	5.87 ^h	4.792 ^j	1.778 ^{ghi}	3.816 ^{efg}
6	0	100% CO ₂	2	5.95 ^{efg}	4.975 ^j	2.497 ^{efg}	4.241 ^d
6	0	100% CO ₂	3	6.03 ^{ab}	5.937 ^{efg}	3.895 ^d	3.410 ^{hij}
3	3	55% CO ₂	1	5.94 ^{fg}	6.857 ^b	3.927 ^d	4.112 ^{de}
3	3	55% CO ₂	2	6.02 ^{abc}	5.575 ^{gh}	2.773 ^{ef}	3.943 ^{def}
3	3	100% CO ₂	1	5.98 ^{bcdef}	6.273 ^{cde}	3.106 ^e	5.432 ^{ab}
3	3	100% CO ₂	2	5.97 ^{cdefg}	6.045 ^{def}	3.012 ^e	4.806 ^c
6	4	55% CO ₂	1	5.99 ^{abcdef}	7.587 ^a	6.360 ^a	5.079 ^{bc}
6	4	55% CO ₂	2	5.97 ^{cdefg}	5.772 ^{efg}	4.560 ^{cde}	5.213 ^b
6	4	55% CO ₂	3	5.96 ^{defg}	5.860 ^{fg}	4.687 ^{bc}	5.337 ^b
6	4	100% CO ₂	1	5.97 ^{cdefg}	6.736 ^{bc}	5.108 ^{ab}	5.798 ^a
6	4	100% CO ₂	2	6.01 ^{abcde}	6.115 ^{ef}	5.774 ^b	3 ^k
6	4	100% CO ₂	3	6.05 ^a	6.257 ^{cde}	5.606 ^b	-

* abcdefghijk Different letters signify significant differences between treatments (P < 0.05)

The data indicates that there were significant differences between all of the different storage conditions for pH and log microbial counts. There were no spore formers present in the anaerobic flora. To identify the effect by the different treatments on pH, batches with the same number of layers were analysed independently. To do this a general ANOVA was applied to data for the 6 day MAP storage for all three layers and data for 3 and 6 day MAP storage for only the top two layers. The analysis of pH is present in Table 69.

Table 69. Significant differences between the different treatments for pH of swordfish after 3 and 6 days MAP storage at 4°C, for Trial 1.

Treatment	Conditions	6 days MAP	3 & 6 days MAP
Layer	1	5.945 ^a	5.939 ^a
	2	5.968 ^{ab}	5.975 ^b
	3	5.990 ^b	-
Gas content	55% CO ₂	5.955 ^a	5.974
	100% CO ₂	5.981 ^b	5.953
Storage procedures	Map only	5.943 ^a	5.950
	air after MAP	5.993 ^b	5.976

* ^{ab}Different letters signify significant differences between treatments (P < 0.05)

The pH increased the position which became further away from the permeable membrane. The bottom layer of cutlets has a higher pH possibly due to lack of penetration by the

modified atmosphere. This aspect requires further investigation and will be tested in the next trial. The storage of swordfish cutlets in a modified atmosphere with the higher CO₂ concentration did not lead to a significantly lower pH. Storage in air after MAP did lead to a significant increase in pH. While the pH exhibited significant differences for all of these treatments the difference between the highest pH measurement and that of the lowest was only 0.24 of a pH unit. This amount of change in pH would have little direct impact on quality. The analysis of the data identified significant treatment effects on the total count. Table 70 shows the means for the analysis.

Table 70. Significant differences between the different treatments for log total count of swordfish after MAP storage only and MAP followed by 3 days air, at 4°C for Trial 1.

Treatment	Conditions	6 days MAP	3 & 6 days MAP
Layer	1	6.143 ^a	5.959 ^a
	2	5.774 ^b	5.494 ^b
	3	5.472 ^c	
Gas content	55% CO ₂	5.790	5.808
	100% CO ₂	5.802	5.645
Storage procedures	Map only	5.205 ^a	5.083 ^a
	air after MAP	6.388 ^h	6.370 ^b

* abc Different letters signify significant differences between treatments (P < 0.05)

The log count for bacteria was significantly different between the different layers and the storage atmospheres for both MAP storage times and 6 days MAP only. The further away from the top layer the lower the log count. Storage in air after MAP results in significantly higher counts. There was no change to the log total count present due the CO₂ concentration in the modified atmosphere. The analysis of the effect of these treatments on the log count of the H₂S producers found similar trends. Table 71 below shows the data obtained from ANOVA.

Table 71. Significant differences between the different treatments for log count H₂S producers from swordfish after MAP storage only and MAP followed by 3 days air, at 4°C for Trial 1.

Treatment	Conditions	6 days MAP	3 & 6 days MAP
Layer	1	4.027 ^{ab}	5.959 ^a
	2	3.723 ^a	5.494 ^b
	3	4.249 ^b	
Gas content	55% CO ₂	3.890	3.183
	100% CO ₂	4.110	3.066
Storage procedures	Map only	2.650 ^a	1.922 ^a
	air after MAP	5.349 ^h	4.328 ^b

* abc Different letters signify significant differences between treatments (P < 0.05)

The analysis of the effect of these treatments on the log count of the anaerobic bacteria found similar trends to the other counts. Table 72 shows the data obtained from ANOVA.

Table 72. Significant differences between the different treatments for log count of anaerobes from swordfish after MAP storage only and MAP followed by 3 days air, at 4°C for Trial 1.

Treatment	Conditions	6 days MAP	3 & 6 days MAP
Layer	1	4.322 ^{ab}	4.094 ^a
	2	4.202 ^a	3.864 ^b
	3	4.479 ^b	-
Gas content	55% CO ₂	4.247 ^a	3.986
	100% CO ₂	4.421 ^b	3.972
Storage procedures	Map only	3.391 ^a	3.396 ^a
	air after MAP	5.277 ^b	4.562 ^b

* ^{abc} Different letters signify significant differences between treatments ($P < 0.05$)

The layers have significantly different anaerobic counts. The middle layer has a count lower than the one below on the bottom. Storage of the packs in air for three days leads to a rapid increase in anaerobic bacteria. When the air storage data is removed from the analysis no differences are present between layers and gas composition.

Another parameter evaluated was the drip present in the packs at the end of storage. The proportion of drip loss to the packed weight was 3% for the packs with more permeable membrane and 3.14% those with the normal permeable membrane. The sensory attributes were also rated using a demerit system similar to that applied to the MAP scallops. The scores for each layer of a tray were entered on appraisal sheets. Copies of these appraisal sheets are present as Figure 2 in Appendix 3. The data is limited because there was only one tray per treatment. The analysis of these scores is present in Table 73.

Table 73. Presence of significant differences for sensory scores of swordfish cutlets using the scores from layers one and two after 3 and 6 days MAP storage only and MAP followed by 3 days air, at 4°C for Trial 1.

Attribute	Significantly different treatments ($P < 0.05$)
colour of white muscle	layer, gas mixture, storage conditions
colour of red muscle	storage conditions
colour of red muscle after 30 min	storage conditions
parasites	layer
flesh appearance	none
raw odour	none
cooked drip loss	none
cooked odour	layer, gas mixture, storage conditions

A number of sensory parameters were effected by the treatments. The effect of different storage conditions was common to all parameters with significant differences except for presence of parasites. A layer effect was present for half of these parameters. The gas mixture caused significant changes for two parameters. The presence of parasites, while being scored as a visual defect, would not be influenced by the treatments directly.

The colour of the white muscle contained significant differences when the data for 6 days MAP storage was analysed. The analyses for these attributes after 3 and/or 6 days MAP storage and air storage following MAP are present in Table 74 and 75.

Table 74. Significant differences between different treatments for white muscle colour of swordfish from for MAP storage only and MAP followed by 3 days air, at 4°C for Trial 1.

Treatment	Conditions	6 days MAP	3 & 6 days MAP
Layer	1	1.863 ^a	1.344 ^a
	2	1.113 ^b	1.181 ^b
	3	1.088 ^b	
Gas content	55% CO ₂	3.890	1.219 ^a
	100% CO ₂	4.110	1.306 ^b
Storage procedures	Map only	1.000 ^a	1.922 ^a
	air after MAP	1.508 ^b	4.328 ^b

* ^{abc} Different letters signify significant differences between treatments ($P < 0.05$)

Table 75. Significant differences between different treatments for red muscle colour of swordfish from for MAP storage only and MAP followed by 3 days air, at 4°C for Trial 1.

Treatment	Conditions	3 & 6 days MAP
Storage procedures	Map only	19 ^a
	air after MAP	5 ^b

* ^{abc} Different letters signify significant differences between treatments ($P < 0.05$)

Significant differences were present for the colour of the red muscle after 30 minutes standing time unpacked. The analysis for this attribute after 3 and/or 6 days MAP storage and 3 days air storage following the MAP is present in Table 76.

Table 76. Significant differences between different treatments for red muscle colour of swordfish standing 30 minutes in air unpacked, after MAP storage only and MAP followed by 3 days in air, at 4°C for Trial 1.

Treatment	Conditions	3 & 6 days MAP
Storage procedures	Map only	1.438 ^a
	air after MAP	2.319 ^b

* ^{abc} Different letters signify significant differences between treatments ($P < 0.05$)

The analysis for presence of parasites in swordfish after 3 and/or 6 days MAP storage and 3 days air storage following the MAP is present in Table 77.

Table 77. Significant differences between different treatments for parasites in swordfish from for MAP storage only and MAP followed by 3 days air, at 4°C for Trial 1.

Treatment	Conditions	3 & 6 days MAP
Layer	1	0.069 ^a
	2	0.000 ^b

* ^{abc} Different letters signify significant differences between treatments ($P < 0.05$)

The cooked odour data exhibited a number significant treatment differences. These are presented in Table 78.

Table 78. Significant differences between different treatments for cooked odour of swordfish from for MAP storage only and MAP followed by 3 days air, at 4°C for Trial 1.

Treatment	Conditions	3 & 6 days MAP
Layer	1	0.994 ^a
	2	1.206 ^b
Gas content	55% CO ₂	1.169 ^a
	100% CO ₂	1.031 ^b
Storage procedures	Map only	0.607 ^a
	air after MAP	1.431 ^b

* ^{abc} Different letters signify significant differences between treatments (P<0.05)

The presence of different layers of cutlets in a MAP tray does lead to different pH and microbial counts which are not related to distance from the permeable membrane. There were also some low scoring sensory parameters in the lower layers and some in the upper layers. Some further experimentation is required to determine whether this type of pack is safe to produce.

Trial 2

The next visit to the factory found that some of the procedures required were not followed. As happens all too often the skipper of the capture vessel decided to delete the one change required to be preformed on board. The washing of the belly cavity with a chlorine solution, which would have taken only a number of seconds after the gut was removed, was decided to take too much time and was dispensed with. This left the contaminated area open to microbial growth for up to 8 days while the catch was present in the hold.

The washing of the belly cavity with chlorine was carried out on the loading table after this area and the skin had been scrubbed down with hard brushes. The cutting tables, knives and gloves of workers were scrubbed down with chlorine and dried. Fresh reinforced paper towel was placed under each fish to absorb blood and juices falling onto the table where the loins were removed. The loins were placed on fresh paper towel and cut into 2 cm wide cutlets. These were transferred onto another cleaned table with paper before being packed into the plastic trays in three layers. The total weight of each tray was 5kg.

The effect of layering was again a key aspect to be investigated. Packs with different rates of gas permeability were also compared. Shrink wrap film with a higher level of permeability was only available in New Zealand at the time of this trial so an alternative was developed. A modification of the vacuum skin membrane was made by inserting a window of higher permeability material to produce a pack with an increased gas exchange rate. The samples were packed in the trays at the factory but were sealed in skin packs and placed in gas flushed barrier bags in the laboratory. The data obtained from the swabs and meat samples taken at the factory is present in Table 79.

Table 79. Microbial counts from the processing site and progressive samples taken during processing.

Sample No.	Type	Source of sample	pH	Total log count cfu/g or cm ²	H ₂ S log count cfu/g or cm ²	Anaerobe log count cfu/g or cm ²	Pasteurised anaerobe log count cfu/g or cm ²	Coliform presence
1	Swab	Fish 1 on loading bay right side belly	ND	4.11	1.56	0	0	1/3
2	Swab	Fish 1 on loading bay left side belly	ND	4.28	1.63	0	0	0/3
3	Swab	Fish 2 on loading bay right side belly	ND	2.95	<1	2.0	0	0/3
4	Swab	Fish 2 on loading bay left side belly	ND	3.95	0.90	0	0	0/3
5	Swab	Fish 1 after Cl ₂ wash right side belly	ND	3.15	0.60	0	0	1/3
6	Swab	Fish 1 after Cl ₂ wash left side belly	ND	3.34	0.85	0	0	3/3
7	Swab	Fish 2 after Cl ₂ wash right side belly	ND	3.60	<1	0	0	3/3
8	Swab	Fish 2 after Cl ₂ wash left side belly	ND	3.18	<1	0	0	0/3
9	Swab	Surface of fish 1 left side	ND	3.0	0.60	0	0	2/3
10	Meat	Under belly lining fish 1 right side (skin removed)	ND	2.0	<10	0	0	0/3
11	Meat	Under wound right side Fish 1 (skin removed)	6.52	3.76	1.76	1.70	0	0/3
12	Meat	Under undamaged skin right Fish 1 (skin removed)	6.54	2.48	<1	0	0	0/3
13	Meat	Ex loin (off end cutting table) belly of Fish 2	5.85	2.0	<1	2.0	0	1/3
14	Meat	Head of fish 2	5.92	1.70	<1	1.70	0	0/3
15	Swab	Surface of cutlet before packing Fish 2	ND	<1	0	0	0	0/3
16	Meat	Packed cutlets Fish 3 (Box 1)	5.89	3.08	<1	0	0	3/3
17	Meat	Packed cutlets Fish 3 (Box 2)	5.92	3.20	0.30	0	0	2/3

The counts for the belly cavity show that this was a major source of contamination. There was a 1:5 to 1:10 reduction in bacterial count after washing this area with the chlorine solution. There was a minor increase in the skin surface count from the previous trial. The flesh immediately inside the tissue lining the belly cavity had low microbial counts as did the flesh under the skin. The meat in close proximity to a wound inflicted by a small shark did contain higher counts and could be a source of contamination for the cutlets if not trimmed sufficiently. The cleaning of the cutting tables with chlorine and placement of paper under each fish led to surface counts on the cutlets of <10cfu/cm². This resulted in very low counts within the cutlets packed in MAP.

The cutlets from fish number three were packed in MAP for six days and stored for a further three days in air at 4°C. The cutlets from each layer were evaluated for pH, microbial and sensory attributes. Table 80 shows the pH and microbial data obtained from this second storage trial.

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Table 80. pH and microbial counts of swordfish cutlets stored for 6 days in MAP and then air at 4°C, Trial 2.

Days in MAP	Days in air	Membrane permeability rate	Layer	pH	Total log count (cfu/g)	H ₂ S producer log count (cfu/g)	Anaerobe log count (cfu/g)	Pasteurised anaerobe log count (cfu/g)
0	0	air	1	5.92 ^a	3.14 ^{cde}	1.54 ^{abcd}	0 ^c	< 10
6	0	normal	1	5.29 ^{bc}	2.92 ^{cde}	0.5 ^{de}	0 ^c	< 10
6	0	normal	2	5.35 ^b	2.45 ^{de}	1.31 ^{bcde}	0 ^c	< 10
6	0	normal	3	5.35 ^b	2.81 ^{cde}	0.74 ^{cde}	0 ^c	< 10
6	0	fast	1	5.20 ^c	2.35 ^e	0 ^e	0 ^c	< 10
6	0	fast	2	5.32 ^{bc}	2.6 ^{de}	0 ^e	1 ^{bc}	< 10
6	0	fast	3	5.31 ^{bc}	2.7 ^{cde}	0.65 ^{de}	0 ^c	< 10
6	3	normal	1	5.89 ^a	3.45 ^{bc}	2.33 ^{ab}	1.09 ^{abc}	< 10
6	3	normal	2	5.93 ^a	4.13 ^{ab}	2.33 ^{ab}	2.76 ^{ab}	< 10
6	3	normal	3	5.94 ^a	4.54 ^a	2.85 ^a	2.92 ^a	< 10
6	3	fast	1	5.90 ^a	3.02 ^{cde}	0.65 ^{de}	1.5 ^{abc}	< 10
6	3	fast	2	5.88 ^a	2.89 ^{cde}	1.6 ^{abcd}	2.35 ^{ab}	< 10
6	3	fast	3	5.94 ^a	3.28 ^{cd}	2.02 ^{abc}	2.59 ^{ab}	< 10

* ^{abcdefg} Different letters signify significant differences between treatments (P < 0.05)

The pH of swordfish cutlets was significantly higher during Trial 1. The pH data exhibited significant differences between the layers and the two storage times. Table 81 shows the analysis of pH for layer and storage time.

Table 81. Significant differences between the pH of swordfish from different treatments for MAP storage only and MAP followed by 3 days air, at 4°C for Trial 2.

Treatment	Conditions	Mean pH
Layer	1	5.58 ^b
	2	5.62 ^a
	3	5.63 ^a
Storage time	6	5.32 ^a
	9	5.9 ^b

* ^{abc} Different letters signify significant differences between treatments (P < 0.05)

The top layer was significantly lower than the next two. These pH differences suggest that it is difficult for the gas to penetrate through the fish to the lower layers. This has occurred because the whole upper surface of these cutlets was exposed to the modified atmosphere while those below were in contact with each other and/or the base of the pack. Only areas where there was no overlay and the sides of the cutlets in the lower layers were exposed and able to absorb the modified atmosphere. Analysis with the bottom layer removed resulted in significant differences in pH between the layers again but no differences between the packs with different permeability rates. The analysis of the microbiological data identified significant differences between the two films and the storage times. Table 82 shows the analysis of log total count for film permeability and storage time.

Table 82. Significant differences between the log total counts of swordfish from different treatments for MAP storage only and MAP followed by 3 days air, at 4°C for Trial 2.

Treatment	Conditions	Means
Film permeability	normal	3.38 ^a
	fast	2.81 ^b
Storage time	6	2.64 ^a
	9	3.55 ^h

* ^{ab} Different letters signify significant differences between treatments ($P < 0.05$)

The film with higher permeability did result in lower log bacterial counts. These increased significantly after exposure to air. Tables 83 and 84 show the significant differences for log count for H₂S producers and log count of anaerobic bacteria for the analysis of variance.

Table 83. Significant differences between the log count for H₂S producers from swordfish from different treatments for MAP storage only and MAP followed by 3 days air, at 4°C for Trial 2.

Treatment	Conditions	Means
Film permeability	normal	1.67 ^a
	fast	0.81 ^b
Storage time	6	0.53 ^a
	9	1.96 ^b

* ^{ab} Different letters signify significant differences between treatments ($P < 0.05$)

Table 84. Significant differences between the log count for anaerobic bacteria from swordfish from different treatments for MAP storage only and MAP followed by 3 days air, at 4°C for Trial 2.

Treatment	Conditions	Means
Storage time	6	0.17 ^a
	9	2.2 ^h

* ^{abc} Different letters signify significant differences between treatments ($P < 0.05$)

The log count of hydrogen producers held similar differences to that identified for log total count. The log count of anaerobes held significant differences only for storage conditions and increased during storage in air. The treatments had no significant effect on the microbial counts during MAP storage only.

The physical attributes were again scored using the appraisal sheets present in Appendix 3. The analysis of these scores is present in Table 85. Another parameter evaluated was the drip present in the packs at the end of storage. The proportion of drip loss to the packed weight was 3% for the packs with more permeable membrane and 3.14% those with the normal permeable membrane.

Table 85. Analysis of demerit scores for swordfish cutlets from different treatments for MAP storage only and MAP followed by 3 days air, at 4°C for Trial 2.

Attribute	Any significant treatments	Mean scores
colour of white muscle	storage 6 days MAP	1.00 ^a
	storage 6 days MAP then 3 days air	1.63 ^b
colour of red muscle	none	2.03
colour of red after 30 min	none	2.15
parasites	none	0.08
flesh appearance	none	0
raw odour	storage 6 days MAP	0.72 ^a
	storage 6 days MAP then 3 days air	1.64 ^b
cooked drip loss	none	0.95
cooked odour	storage 6 days MAP	0.78 ^a
	storage 6 days MAP then 3 days air	1.73 ^b
flavour	storage 6 days MAP	1.18 ^a
	storage 6 days MAP then 3 days air	3.15 ^b
texture	storage 6 days MAP	0.57 ^a
	storage 6 days MAP then 3 days air	1.29 ^b

* ^{abc} Different letters signify significant differences between treatments ($P < 0.05$)

Air storage after MAP was the only treatment which had an effect on the sensory quality of the swordfish cutlets. This led to significant increases in scores. When the data was analysed for 6 days MAP storage only there was no treatment effect. While all of these analyses confirm that there were only some significant differences between the layers in the packs it does not identify how safe it would be to produce these types of packs. To assist with this particular aspect the identifications of the individual bacteria present in each layer were determined.

Trial 3

As the data compiled on bulk packaging of swordfish was extensive and the effect of layers still not conclusive a full storage trial with taste panel assessment was initiated. Approximately 70kg of swordfish cutlets were obtained from two individual fish for the storage trial. The majority of cutlets were placed in three layers in bulk packs containing absorbent pads on the bottom. These were heat sealed using a permeable membrane. The packs were then placed individually into barrier bags and sealed after a 100% CO₂ flush. Three kilograms of cutlets was also placed on stainless steel trays and kept in air as a control.

The microbial count was low at the start of the storage trial. Unfortunately other quality indicators developed quickly. The batch of swordfish used in this trial had been held over the weekend and there were signs that poor handling had been carried out. The first fish after cutting into cutlets was rejected due to proteolytic damage. The cutlets fell apart when picked up due to softening of the connective tissue. The next fish appeared to be better but was out of rigour and the muscle tissue was quite opaque. This was packed and called fish "one". A third fish (new two) appeared poorly bled but has more translucent flesh and was also packed. The packs contained approximately 4.5kg of cutlets and at least two contained mixtures of both fish. The packs were tested for microbial content, pH, visual parameters and sensory characteristics. Table 86 contains the total count of swordfish stored both in MAP and/or air.

Table 86. Total microbial log counts from two swordfish stored in MAP and air at 4°C for trial 3.

Layer	Fish	Treatment	Storage time in air at 4°C (days)				
			0	1	2	3	4
	one	AIR	3.32	3.48	4.01	4.90	5.89
	two	AIR	3.34	3.54	3.94	4.93	6.30
top	one	3d MAP	3.65	2.78	-	-	5.20
middle	one	3d MAP	3.42	3.45	-	-	5.40
bottom	one	3d MAP	3.53	3.58	-	-	5.48
top	two	3d MAP	4.12	4.12	-	-	6.36
middle	two	3d MAP	3.49	3.68	-	-	7.65
bottom	two	3d MAP	3.98	4.33	-	-	7.31
top	one	7d MAP	3.54	3.95			
middle	one	7d MAP	3.15	5.30			
bottom	one	7d MAP	2.98	5.92			
top	two	7d MAP	6.64	5.80			
middle	two	7d MAP	3.76	6.80			
bottom	two	7d MAP	5.98	6.87			
top	one	14d MAP	5.64				
middle	one	14d MAP	6.87				
bottom	one	14d MAP	7.06				
top	two	14d MAP	7.07				
middle	two	14d MAP	7.66				
bottom	two	14d MAP	7.34				

The swordfish cutlets, when stored only in air, developed counts, which made the product rejectable by the fourth day. The fish stored in MAP retained acceptable counts for most of the treatments with the exception of top and bottom layer of the pack filled with cutlets from the two fish stored seven days in MAP. The packs stored for 3 days in modified atmosphere developed high counts after a further four days in air and the cutlets from the two fish were rejectable. After one day in air following the seven days MAP the bottom layer of the pack filled with cutlets from the one fish and all the layers filled with the two fish contained unacceptable microbial counts. No cutlets were acceptable after 14 days MAP storage. The log counts for hydrogen disulphide producers are presented in Table 87.

Table 87. H₂S producer log counts from two swordfish stored in MAP and air at 4°C for trial 3.

Layer	Fish	Treatment	Storage time in air at 4°C (days)				
			0	1	2	3	4
	one	AIR	0.5	0.5	3	2.83	3.55
	two	AIR	0.5	0	0	1.65	2.02
top	one	3d MAP	2.02	0	-	-	1.00
middle	one	3d MAP	1.65	1.48	-	-	0.50
bottom	one	3d MAP	0.50	1.35	-	-	0.50
top	two	3d MAP	2.44	3.11	-	-	6.15
middle	two	3d MAP	2.89	3.15	-	-	6.60
bottom	two	3d MAP	3.03	3.77	-	-	6.60
top	one	7d MAP	1.24	3.86			
middle	one	7d MAP	2.15	5.14			
bottom	one	7d MAP	1.15	5.70			
top	two	7d MAP	5.94	5.47			
middle	two	7d MAP	3.05	6.67			
bottom	two	7d MAP	5.78	6.86			
top	one	14d MAP	5.00				
middle	one	14d MAP	6.81				
bottom	one	14d MAP	7.06				
top	two	14d MAP	6.86				
middle	two	14d MAP	7.53				
bottom	two	14d MAP	7.13				

The counts for hydrogen disulphide producers were only a minor component of the total counts most of the storage times. After three days in MAP and four days in air total counts had become rejectable for the two fish and the hydrogen disulphide producers were

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a minor proportion of the total counts. The former increased to more than half of the total count of the cutlets after 7 days in MAP. Table 88 shows the log count for gram positive anaerobes during storage.

Table 88. Log count of gram +ve anaerobes in swordfish cutlets stored in MAP and air at 4°C for trial 3.

Layer	Fish	Treatment	Storage time in air at 4°C (days)				
			0	1	2	3	4
	one	AIR	0	0	0	2.55	2.85
	two	AIR	0	0	0	2.30	2.30
top	one	3d MAP	2.30	0	-	-	0
middle	one	3d MAP	0	0	-	-	0
bottom	one	3d MAP	0	0	-	-	0
top	two	3d MAP	0	0	-	-	0
middle	two	3d MAP	2.30	0	-	-	3.18
bottom	two	3d MAP	2.48	0	-	-	0
top	one	7d MAP	0	0			
middle	one	7d MAP	0	0			
bottom	one	7d MAP	0	1.70			
top	two	7d MAP	3.23	2.18			
middle	two	7d MAP	0	0			
bottom	two	7d MAP	1.70	1.70			
top	one	14d MAP	4.08				
middle	one	14d MAP	5.18				
bottom	one	14d MAP	5.65				
top	two	14d MAP	3.88				
middle	two	14d MAP	5.09				
bottom	two	14d MAP	5.09				

The log counts of gram positive anaerobes in swordfish cutlets for this trial were low during all types of storage until day 14. Before this time, the counts did not rise much above a log count of 3. The proportion of these bacteria in comparison to the total bacterial count did not increase with storage time in MAP. This calculation was greater than 5% only for one sample, the top layer of the pack containing cutlets from fish number one stored in MAP for three days. There were coliforms present in one of the swordfish from the start of storage. Table 89 shows the log counts for these bacteria.

Table 89. Log count of coliforms in cutlets from two swordfish stored in MAP and then air at 4°C for trial 3.

Layer	Fish	Treatment	Storage time in air at 4°C (days)				
			0	1	2	3	4
	one	AIR	2.10	1.00	0.95	1.30	1.70
	two	AIR	0	0	0	0.70	1.26
top	one	3d MAP	1.00	0	-	-	2.54
middle	one	3d MAP	0	1.00	-	-	2.77
bottom	one	3d MAP	0.70	1.00	-	-	2.65
top	two	3d MAP	0.70	1.02	-	-	2.48
middle	two	3d MAP	0	1.18	-	-	4.15
bottom	two	3d MAP	0	1.36	-	-	4.08
top	one	7d MAP	0	2.69			
middle	one	7d MAP	1.30	2.03			
bottom	one	7d MAP	1.56	4.23			
top	two	7d MAP	4.65	4.51			
middle	two	7d MAP	2.38	4.16			
bottom	two	7d MAP	4.21	4.58			
top	one	14d MAP	4.28				
middle	one	14d MAP	5.36				
bottom	one	14d MAP	6.28				
top	two	14d MAP	4.18				
middle	two	14d MAP	5.41				
bottom	two	14d MAP	6.40				

Initially, fish one contained low numbers of coliforms while there were no detectable counts present in cutlets from fish two. As storage times progressed fish two developed higher counts than fish one. During storage there were more coliform bacteria present than anaerobes but they were still a small percentage of the total count. There were no *Escherichia coli* present in any sample.

Statistical analysis of the microbial counts for MAP storage only identified significant differences between storage times ($P < 0.01$), fish ($P < 0.01$) and layers ($P < 0.05$). Table 90 displays the mean log counts for significantly different groups.

Table 90. Mean log microbial count of significantly different groups stored in MAP only.

Treatment	Parameter	Total log count	H2S log count	Coliforms log count	Gram +ve anaerobes log count
Storage time	3 days	3.70 ^b	2.09 ^b	0.31 ^b	1.18 ^b
	7 days	4.34 ^b	3.22 ^b	2.35 ^b	0.69 ^b
	14 days	6.94 ^a	6.73 ^a	5.32 ^a	4.82 ^a
Fish number	1	4.43 ^b	3.06 ^b	2.23 ^b	1.91
	2	5.56 ^a	4.96 ^a	3.08 ^a	2.55
Layer	1	5.11 ^b	3.92	2.38 ^b	2.23
	2	4.73 ^a	4.01	2.41 ^b	2.10
	3	5.15 ^b	4.11	3.19 ^a	2.36
Interactions					
Fish one	Day 3	3.54 ^b	1.39 ^d	0.45 ^c	0.77 ^{bc}
Fish one	Day 7	3.22 ^b	1.51 ^d	0.94 ^c	0 ^c
Fish one	Day 14	6.52 ^b	6.29 ^b	5.31 ^a	4.97 ^a
Fish two	Day 3	3.86 ^b	2.79 ^d	0.17 ^c	1.58 ^b
Fish two	Day 7	5.46 ^b	4.92 ^c	3.75 ^b	1.39 ^b
Fish two	Day 14	7.36 ^a	7.17 ^a	5.33 ^a	4.68 ^a
Day 3	Layer 1	3.88 ^{cd}	2.23 ^b	0.58 ^{ef}	1.15 ^{bc}
Day 3	Layer 2	3.46 ^d	2.27 ^b	0 ^f	1.15 ^{bc}
Day 3	Layer 3	3.76 ^d	1.76 ^b	0.35 ^{ef}	1.23 ^{bc}
Day 7	Layer 1	5.09 ^{bc}	3.59 ^b	2.33 ^d	1.58 ^b
Day 7	Layer 2	3.46 ^d	2.60 ^b	1.84 ^{de}	0 ^c
Day 7	Layer 3	4.48 ^{cd}	3.46 ^b	2.87 ^{cd}	0.50 ^{bc}
Day 14	Layer 1	6.35 ^{ab}	5.93 ^a	4.23 ^{bc}	3.97 ^a
Day 14	Layer 2	7.27 ^a	7.17 ^a	5.39 ^{ab}	5.14 ^a
Day 14	Layer 3	7.20 ^a	7.09 ^a	6.34 ^a	5.37 ^a

* abcdef Means followed by different letters are significantly different ($P < 0.05$)

There were no significant differences present for the interaction of fish and layer for any of the bacterial counts. The interaction of storage time and layer contained significantly higher counts as storage progressed and the highest after 14 days of MAP storage. The interaction of fish and storage identified total count and hydrogen disulphide producer count of fish number two was significantly different. After 14 days they were higher than fish one for any storage time while the coliform and gram +ve anaerobic counts of both fish at this time were significantly higher at this time. Table 91 contains the pH measurements of swordfish during storage.

Table 91. pH of cutlets from two swordfish stored in MAP and then air at 4°C for trial 3.

Layer	Fish	Treatment	Storage time in air at 4°C (days)				
			0	1	2	3	4
	one	AIR	6.26	6.27	6.32	6.56	6.37
	two	AIR	5.84	5.85	5.90	5.99	6.07
top	one	3d MAP	6.34	5.89	-	-	5.87
middle	one	3d MAP	6.34	-	-	-	5.93
bottom	one	3d MAP	5.89	5.80	-	-	5.91
top	two	3d MAP	6.09	6.29	-	-	6.48
middle	two	3d MAP	6.29	-	-	-	6.57
bottom	two	3d MAP	6.26	6.51	-	-	6.57
top	one	7d MAP	5.84	6.17			
middle	one	7d MAP	5.86	6.37			
bottom	one	7d MAP	5.85	6.54			
top	two	7d MAP	6.35	6.85			
middle	two	7d MAP	6.93	7.08			
bottom	two	7d MAP	6.96	7.15			
top	one	14d MAP	6.19				
middle	one	14d MAP	6.43				
bottom	one	14d MAP	6.55				
top	two	14d MAP	6.22				
middle	two	14d MAP	6.29				
bottom	two	14d MAP	6.32				

There was a consistent increase in pH during aerobic storage of swordfish cutlets. This normally happens during storage of fish. Because of the different layers, drip score has been restricted to the whole pack rather than layers. The air only stored cutlets were scored for the amount of free fluid present in the tray. Table 92 shows the drip scores for both treatments.

Table 92. Drip score of packs of swordfish stored in MAP and then air at 4°C for trial 3

Fish	Treatment	Storage time in air at 4°C (days)				
		0	1	2	3	4
one	AIR	0	0	0	0.25	-
two	AIR	0	0	0.35	0.33	1.5
one	3d MAP	-	0.5	-	-	0.5
two	3d MAP	1.0	1.25	-	-	1.0
one	7d MAP	1.6	1.0			
two	7d MAP	1.0	-			

The other parameters scored by demerit system showed similar trends to those exhibited by the microbiological data. Tables 93 to 95 show the demerit scores for each parameter while Table 96 shows the total demerit score. Because of the handling of the different layers only the whole pack it was impossible to determine raw odour scores for the middle layer of packs without the influence of the others present.

Table 93. Raw odour, white muscle colour and red muscle colour scores of cutlets from two swordfish stored in MAP and then air at 4°C for trial 3.

Layer	Fish No.	Treatment	Demerit parameter														
			Raw odour score					Colour score for white muscle					Colour score for red muscle				
			Storage time (days)					Storage time (days)					Storage time (days)				
			0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
	one	AIR	0	0.75	0.70	1.25	1.30	1.00	1.00	1.00	0.75	2.00	1.50	1.50	2.00	2.25	2.50
	two	AIR	0	0.50	1.50	2.25	2.25	0.50	1.25	2.00	2.25	3.00	1.50	2.25	2.50	2.25	2.70
top	one	3d MAP	1.00	0.90	-	-	2.75	1.00	1.75	-	-	2.50	1.25	1.75	-	-	2.50
bottom	one	3d MAP	0.75	1.10	-	-	2.40	2.00	2.00	-	-	2.60	2.00	2.00	-	-	2.60
top	two	3d MAP	1.00	1.50	-	-	1.80	1.50	1.50	-	-	1.75	2.00	1.50	-	-	1.75
bottom	two	3d MAP	0.75	1.25	-	-	2.00	2.00	1.50	-	-	1.80	2.25	1.50	-	-	1.80
top	one	7d MAP	1.25	2.00				1.75	1.25				1.75	2.00			
bottom	one	7d MAP	2.25	2.60				2.30	2.00				2.30	2.00			
top	two	7d MAP	2.20	2.00				1.25	1.00				1.25	1.00			
bottom	two	7d MAP	2.50	2.50				2.00	2.00				2.00	2.00			
top	one	14d MAP	2.50					2.00					-				
bottom	one	14d MAP	2.70					2.40					2.40				
top	two	14d MAP	2.80					2.00					2.00				
bottom	two	14d MAP	2.00					2.00					2.00				

Table 94. Colour score 30 minutes after unpacking for red muscle, parasite presence score and flesh appearance score of swordfish stored in MAP and then air at 4°C for trial 3.

Layer	Fish No.	Treatment	Demerit parameter														
			Colour score for red muscle after 30 min					Parasite presence score					Flesh appearance score				
			Storage time (days)					Storage time (days)					Storage time (days)				
			0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
	one	AIR	1.50	1.50	2.00	2.25	2.50	0	0	0.5	0	0	1	0	0	0	0
	two	AIR	1.50	2.25	2.50	2.75	2.70	0	0	0	0	0	0	0	0	0	0
top	one	3d MAP	2.00	2.50	-	-	3.00	0	0	-	-	0	0	0	-	-	0
bottom	one	3d MAP	2.25	2.75	-	-	2.60	0	0	-	-	0	0	0	-	-	0
top	two	3d MAP	1.25	2.25	-	-	2.00	0	0	-	-	0	0	0	-	-	0
bottom	two	3d MAP	1.75	2.25	-	-	2.00	0	1	-	-	0	0	1	-	-	0
top	one	7d MAP	2.75	2.50				0	0				0	0			
bottom	one	7d MAP	2.75	2.50				0	0				0	0			
top	two	7d MAP	2.00	1.50				0	0				0	0			
bottom	two	7d MAP	1.75	2.50				1	0				0	0			
top	one	14d MAP	2.25					0					0				
bottom	one	14d MAP	2.50					0					0				
top	two	14d MAP	2.75					0					0				
bottom	two	14d MAP	2.25					0					0				

Table 95. Total demerit score for swordfish stored in MAP and then air at 4°C for trial 3.

Layer	Fish	Treatment	Storage time in air at 4°C (days)				
			0	1	2	3	4
	one	AIR	5	4.75	6.2	6.5	8.3
	two	AIR	3.5	6.25	8.5	10	10.65
top	one	3d MAP	5.25	7.65	-	-	11.25
bottom	one	3d MAP	7	8.6	-	-	10.2
top	two	3d MAP	5.75	7.5	-	-	7.55
bottom	two	3d MAP	6.75	9.25	-	-	7.8
top	one	7d MAP	8.5	9.00			
bottom	one	7d MAP	10.05	9.6			
top	two	7d MAP	7.45	6			
bottom	two	7d MAP	9	9.5			
top	one	14d MAP	9				
bottom	one	14d MAP	10.1				
top	two	14d MAP	10.3				
bottom	two	14d MAP	8.5				

The quality of the raw material prior to packing prevented the sensory evaluation of bulk packs. Further research is needed to confirm the safety of this product.

Retail Packaging Experiments

Trial 1

The quality of swordfish supplied was suitable for MAP and so a quantity of cutlets was arranged for a packaging trial. The sample arrived but was of limited quality. The fish used was one which buyers in the US describe as jellied. The flesh is less firm and exhibits similar characteristics to the condition known as Pale Soft Exudative (PSE) which is commonly found in pork. The presence of a myxozoan parasite, *Kudoa* sp., has been identified as responsible for soft texture in swordfish and is the subject of a recent project application to FRDC. One of the fish in the previous bulk trial also exhibited this condition and was the reason for poor sensory scores. The temperature of the swordfish cutlets was monitored during transport to the laboratory. As the bacterial count was expected to be low the storage trial was initiated using 60% CO₂ in the atmosphere. Table 96 shows the data obtained.

Table 96. Data collated from taste panel trial one of swordfish cutlets stored at 4°C.

Physical or Microbial Parameter	Storage time in air (days)				Storage time in MAP (days)				
	0	2	3	6	3	6	8	10	13
pH	6.08	0.00	3.01	6.11	5.92	5.90	5.90	6.00	6.09
Total log count**	4.80 ^b	4.78 ^b	5.05 ^b	7.57 ^a	4.53 ^b	4.88 ^b	4.74 ^b	4.82 ^b	5.11 ^b
Psychrotropic log count**	4.13 ^c	4.23 ^{bc}	5 ^b	7.4 ^a	3.33 ^d	4.09 ^{cd}	4.21 ^c	4.14 ^c	5 ^b
Hydrogen disulphide producers log count	0	0	0	0	0	0	0	0	0
Coliform log count*	0 ^c	0.69 ^{bc}	2 ^a	0.7 ^{bc}	1.15 ^{ab}	0 ^c	0.85 ^{bc}	1 ^{abc}	0.85 ^{bc}
Anaerobic log count	2.10	0	0	1.70	0.00	1.70	0.40	3.12	2.10
Drip in tray as % of product	-	-	-	-	2.76	-	2.21	2.54	1.70
Raw drip score	1.5	0.1	0.2	-	-	-	-	-	-
Colour of white muscle score**	1 ^e	2 ^b	2 ^b	3 ^a	1.25 ^{de}	1.5 ^{cd}	1.75 ^{bc}	2.13 ^b	2 ^b
Colour of red muscle score**	1.25 ^e	1.5 ^{de}	1.75 ^{cd}	2.75 ^a	1.5 ^{de}	1.75 ^{cd}	2 ^{bc}	2.23 ^b	1.75 ^{cd}
Colour of red muscle score after 30 mins**	1.25 ^c	1.5 ^{bc}	1.75 ^{bc}	2.75 ^a	1.5 ^{bc}	1.5 ^{bc}	1.75 ^{bc}	1.93 ^b	1.63 ^{bc}
Parasite score	0	0	0	0	0	0	0.50	0.50	0
Flesh appearance score	0	0	0	0	0	0.25	0	0	0
Raw odour score**	0 ^f	0.75 ^e	1.75 ^{bc}	2 ^{ab}	1.35 ^{cd}	1.25 ^d	2 ^{ab}	2.23 ^a	2 ^{ab}
Total demerit scores**	3.5 ^f	5.75 ^e	7.25 ^{cd}	10.5 ^a	5.6 ^e	6.25 ^{de}	8 ^{bc}	9 ^b	7.38 ^{cd}
Taste panel score parameter									
Typical swordfish odour	60.81	62.96	52.74	-	58.19	52.03	50.42	42.84	-
Other odour	17.93	20.01	29.75	-	18.20	29.68	29.12	33.98	-
Free moisture	45.79	40.53	59.03	-	58.53	53.81	44.87	47.08	-
Firmness	42.94	36.54	43.44	-	55.02	46.84	42.80	50.23	-
Moistness	56.75	60.07	55.45	-	55.28	47.26	49.34	49.75	-
Flakiness	27.64	22.21	31.30	-	38.84	28.55	29.23	34.76	-
Fibrousness	29.22	20.20	29.77	-	26.00	36.44	34.90	36.96	-
Typical flavour	61.12	56.88	53.28	-	55.28	50.50	48.91	45.20	-
Other flavour	13.13	15.04	26.74	-	15.99	30.05	22.29	23.66	-
Overall quality	63.48	56.46	55.51	-	64.39	64.38	55.07	48.00	-

^{abc} Different letters signify significant differences between treatments (** = P < 0.01, * = P < 0.05)

The identification of individual microbes present during trial 1 was carried out and is present in Table 97.

Table 97. Bacterial flora of swordfish during storage at 4°C for trial 1.

Time in air (days)		0	3	0	0
Time in MAP Days)		0	0	3	10
Total log count (cfu/g)		4.81	5.04	4.54	4.82
Gram -ve	Others	0.0	0.0	0.0	0.0
	<i>Pseudomonas</i>	91.7	18.2	16.7	25.0
	<i>Acinetobacter</i>	8.3	0.0	8.3	16.7
	<i>Alcaligenes</i>	0.0	9.1	16.7	25.0
	<i>Flavobacterium</i>	0.0	36.4	25.0	33.3
	<i>Shewanella</i>	0.0	0.0	0.0	0.0
	Combined	100.0	63.6	66.7	100.0
-----		-----		-----	
	Yeast	0.0	0.0	0.0	0.0
Gram +ve	Others	0.0	9.1	8.3	0.0
	<i>Brochothrix</i>	0.0	8.3	0.0	0.0
	<i>Bacillus</i>	0.0	0.0	0.0	0.0
	<i>Kurthia</i>	0.0	0.0	0.0	0.0
	<i>Cornyformes</i>	0.0	18.2	0.0	0.0
	<i>Lactobacillus</i>	0.0	0.0	0.0	0.0
	<i>Streptococcus</i>	0.0	0.0	0.0	0.0
	<i>Staphylococcus</i>	0.0	9.1	0.0	0.0
	<i>Micrococcus</i>	0.0	18.2	16.7	0.0
	Combined	0.0	36.4	33.3	0.0

The temperature of the swordfish cutlets during transport was quite high, reaching 10°C at one point. This probably led to a high bacterial count at the start of storage. The storage period in MAP was shortened due to low sensory scores by the taste panel.

The initial bacterial count of the sample was high (64,000 cfu/g) with lower level of psychrotroph count (15,000 cfu/g). The bacterial flora was a mixture of Gram negative bacteria that consisted of *Flavobacterium* (33%), *Pseudomonas* (25%), *Alcaligenes* (25%) and *Acinetobacter* (17%).

On aerobic storage for three days at 4°C the count reached 110,000 cfu/g, the flora was predominantly (100%) Gram negative bacteria and a high level of psychrotrophs (100,000 cfu/g). *Pseudomonads* were found to be the dominant (92%) flora with *Acinetobacter* the remainder. Product stored aerobically for 6 days reached a bacterial count in excess of 1 million cfu/g (39,000,000 cfu/g) and would be considered unsafe to eat.

Products stored for three days under MAP at 4°C showed little change in the bacterial count (35,000 cfu/g) from that of the initial level. The flora composed of 64% Gram negative bacteria (*Flavobacterium*, *Pseudomonas* and *Alcaligenes*) and 36% Gram positive bacteria (coryneforms and *Staphylococcus*).

Ten days MAP stored products also showed minimal change from the initial level of bacterial count (66,000 cfu/g). The flora composed of 67% mixed Gram negative (*Flavobacterium*, *Pseudomonas*, *Alcaligenes* and *Acinetobacter*) and 33% Gram positive bacteria (*Micrococcus* and *Brochothrix*).

The anaerobic count remained low in most samples (<100 cfu/g) and did not rise above 1,500 cfu/g throughout the trial. Coliform bacteria were detected during the storage period; however no *Escherichia coli* was detected.

The sensory panels comments for trial 1 are present in Appendix 4 while the scoring of descriptors used by panellists are present as Figures 1 to 4 in Appendix 9. There were no significant ($P > 0.05$) changes with time for any of the sensory characteristics of swordfish. Overall quality showed a general downward trend. The swordfish became unacceptable after 10 days in MAP but was still acceptable at 8 days. Although not significant, a general trend existed for typical odour to decrease and 'other' odour to increase over the storage time.

The profile of the cooked fish odours changed for both storage treatments with time. Initially the odour was mainly sweet, fresh and meaty. The fresh odour decreased markedly after the first two days in either treatment. Sweet odours were not detected in air stored samples after 3 days, but were detected up to 8 days in MAP stored fish. The meaty odour was noted more frequently with increasing time in air stored samples. The frequency of detection was lower in the 8 and 10 day MAP samples. This may be due to a masking by odour described as 'off', ammonia, sulphur and sweaty. The ammonia note was detected with increasing frequency over time in the air stored samples, particularly in trial one. It was not detected until day 8 in MAP samples. A sour/acid note was detected at varying levels throughout the trial in both treatments. Specific off odours were not described in any comments for the air stored samples. After 6 days some tasters noted 'old', 'stale' odours in the MAP samples, and after 10 days comments were made about 'off', 'rotten potato', 'milky', 'boiled milk', 'stale' and 'baked' odours.

In trial one the flesh was dark and tasters often described it as grey and translucent, but it was not undercooked. There were no consistent differences in appearance between the air and MAP stored samples. Coagulated protein on the surface of the cooked flesh was more obvious in the MAP packaged fish.

There were no significant ($P > 0.05$) changes for any of the texture or flavour characteristics of the swordfish. The nature of the changes in firmness and moistness may reflect changes in the pH and hence water holding capacity of the muscle, but further trials would be needed to confirm this. There were no consistent trends for the textural characteristics of firmness, moistness, flakiness and fibrousness. The analysis showed significant ($P < 0.05$) differences between treatments with the typical swordfish flavour initially being higher than at day 3 in air and all the tested storage times of MAP treated fish. Ten days in MAP produced a lower typical swordfish flavour than samples in MAP for 3 days or in air for less than 2 days. The typical swordfish flavour showed a general trend to decline over the storage time.

Samples stored in MAP were more frequently described as firm and chewy, and those stored in air as soft. Textural changes did not appear to vary consistently with time. Flavour changes followed a similar pattern to odour. Sweetness and freshness decreased with length of storage in air. A fresh flavour was detected by at least 30% of panellists until day 16, when the sweetness of the flesh also disappeared. Stale and bitter flavours were detected increasingly with storage time in the air stored samples, and irregularly in the MAP stored samples.

Trial 2

By this time the project was almost three quarters completed so another storage trial was quickly arranged. The transport refrigeration had been overhauled so that the next shipment was held at appropriately low temperature until delivery. Table 98 shows the chemical, physical, microbiological and sensory data obtained from air and MAP storage of swordfish in retail packs for trial 2.

The identity of individual species of bacteria obtained from swordfish during this trial has been listed in Table 99.

Extending the high quality life of seafood

Table 98. Data collated from second taste panel appraisal of swordfish cutlets stored at 4°C

Physical or Microbial Parameter	Storage time in air (days)					Storage time in MAP (days)					
	0	2	3	4	7	3	8	10	14	16	18
pH**	6.27 ^{cde}	6.65 ^a	6.47 ^b	6.39 ^{bc}	-	6.30 ^{cde}	6.16 ^e	6.23 ^{de}	6.20 ^{de}	6.32 ^{bcd}	-
Log total plate count**	1.59 ^f	3.79 ^{de}	5.51 ^{bc}	6.34 ^b	8.97 ^a	2.98 ^{ef}	3.03 ^{ef}	3.75 ^{de}	4.57 ^{cde}	2.98 ^{ef}	4.66 ^{cd}
Psychrotropic log count	0 ^f	3.91 ^{cd}	5.64 ^{bc}	6.25 ^b	9.13 ^a	0 ^f	1.24 ^{ef}	3.57 ^d	4.71 ^{bcd}	2.94 ^{de}	4.76 ^{bcd}
Hydrogen disulphide producers log count	0 ^d	1.60 ^{ab}	2 ^{ab}	2.2 ^{ab}	2.12 ^{ab}	1.09 ^{bcd}	0.35 ^{cd}	1.37 ^{bc}	2.19 ^{ab}	1.35 ^{bc}	2.55 ^a
Coliform log count	0	0	0	0	0	0	0	0	0	0	0
Anaerobic log count	0	0	0	0	1	0	0	0	3.94	0	0
K value	45.3	55.4	56.9	77.6	-	-	89.1	86	-	92.2	-
Drip in tray as % of product	-	-	-	-	-	0.37 ^c	0.8 ^{bc}	1.05 ^{ab}	1.25 ^a	1.38 ^a	-
Colour of white muscle score**	1 ^c	1.5 ^b	0.25 ^d	2.2 ^a	-	1.1 ^c	1.63 ^b	1.43 ^b	2 ^a	2.23 ^a	-
Colour of red muscle score**	1.5 ^e	2 ^{cd}	1.9 ^d	2 ^{cd}	-	2 ^{cd}	2.15 ^{cd}	2.23 ^{bc}	2.5 ^{ab}	2.55 ^a	-
Colour of red muscle score after 30 mins**	1.5	2 ^b	1.9 ^b	2 ^b	-	2 ^b	2.1 ^b	2.5 ^a	2.45 ^a	2.55 ^a	-
Parasite score	0	0	0	0	-	0	0	0	0.25	0.25	-
Flesh appearance score	0	0	0	0	-	0	0	0	0	0	-
Raw odour score**	0 ^f	0.75 ^{de}	0.75 ^{de}	1.5 ^b	-	0.38 ^{ef}	1.25 ^{bc}	0.9 ^{cd}	1.38 ^b	2.2 ^a	-
Raw odour score after 30 mins**	0 ^f	0.75 ^{de}	0.75 ^{de}	1.5 ^{bc}	-	0.38 ^{ef}	1.15 ^{cd}	1.2 ^c	1.63 ^b	2.3 ^a	-
Total common demerit scores	4 ^f	7 ^{de}	5.55 ^{ef}	9.2 ^{bc}	-	5.85 ^e	8.28 ^{cd}	8.25 ^{cd}	10.2 ^b	12.08 ^a	-
Taste panel score parameter											
Typical swordfish odour	61.63	54.03	52.59	55.61		55.42	53.00	53.88	56.52	49.75	
Other odour	17.64	24.09	19.09	21.43		14.28	12.84	15.09	17.21	23.16	
Free moisture	48.01	35.66	54.18	32.88		43.07	45.16	51.20	41.59	28.48	
Firmness	40.36	43.10	38.58	41.21		36.61	37.56	46.43	51.84	46.88	
Moistness	58.13	64.21	53.24	51.50		54.96	54.48	58.01	58.15	55.41	
Flakiness	22.34	27.96	26.60	29.32		34.32	37.60	36.34	40.61	35.95	
Fibrousness	25.49	29.60	30.60	20.87		32.94	23.23	32.90	30.13	23.01	
Typical flavour	62.34	55.28	46.00	51.54		51.07	54.36	44.54	51.67	43.34	
Other flavour	12.89	19.41	18.36	20.14		11.31	15.15	16.66	13.38	21.56	
Overall quality	71.18	60.53	54.23	57.38		58.26	64.72	61.26	60.56	55.66	

** abc Different letters signify significant differences between treatments (P < 0.01)

Table 99. Bacterial flora of swordfish during storage at 4°C for trial 2.

Time in air (days)	0	4	0	0
Time in MAP Days	0	0	3	15
Total log count (cfu/g)	1.78	6.36	3.48	4.58
Gram -ve	Others	0	0	0
	<i>Pseudomonas</i>	0	50	0
	<i>Acinetobacter</i>	0	0	0
	<i>Alcaligenes</i>	40	41.7	0
	<i>Flavobacterium</i>	0	8.3	8.3
	<i>Shewanella</i>	0	0	0
	Combined	40	100	8.3
	Yeast	0	0	0
Gram +ve	Others	20	0	0
	<i>Brochothrix</i>	0	0	0
	<i>Bacillus</i>	0	0	0
	<i>Kurthia</i>	0	0	0
	<i>Cornyformes</i>	0	0	0
	<i>Lactobacillus</i>	0	0	0
	<i>Streptococcus</i>	0	0	0
	<i>Staphylococcus</i>	20	0	8.3
	<i>Micrococcus</i>	20	0	83
	Combined	60	0	91.7

The product used in this trial had a low initial bacterial count of 80 cfu/g and no psychrotroph was detected (<10 cfu/g). The flora composed of a mixture of 40% Gram negative (*Alcaligenes*) and 60% Gram positive bacteria (*Micrococcus* and *Staphylococcus*).

Aerobically stored products increased their bacterial counts to 320,000 cfu/g at 3 days and 2,300,000 cfu/g at 4 days. The psychrotroph counts increased to the levels as the corresponding total bacterial counts. The bacterial composition of the four days air-stored products were all Gram negative bacteria, which consisted of mainly (92%) *Pseudomonas* and *Alcaligenes*, and a smaller proportion (8%) of *Flavobacterium*.

MAP stored product reached a count of 3,000 cfu/g after 3 days with no detectable psychrotroph count (<10 cfu/g). The flora consisted of *Micrococcus* (84%), *Staphylococcus* (8%) and *Flavobacterium* (8%).

Fourteen days MAP stored products reached a count of 38,000 cfu/g. The psychrotroph count increased to 51,000 cfu/g. The bacteria consisted of a mixture of 64% Gram positives (*Micrococcus* and *Staphylococcus*) and 36% Gram negative bacteria (*Alcaligenes*, *Pseudomonas* and *Acinetobacter*). The anaerobic count remained low throughout the trial. Coliform bacteria and *Escherichia coli* were not detected.

The sensory panels comments for trial 2 are present in Appendix 4 while the scoring of descriptors used by panellists are present as Figures 5 to 8 in Appendix 9. In trial two the initial overall quality score was higher than in trial one (72 compared to 63). This reflects the natural variations in the quality of the fish available and probably caused the shorter shelf life results obtained in trial one. There were no significant ($P > 0.05$) changes with time for any of the characteristics of the swordfish. In trial two the overall quality of the swordfish was still acceptable after 16 days in MAP.

The profile of the cooked fish odours changed for both storage treatments with time. Initially the odour was mainly sweet, fresh and meaty. Again the fresh odour decreased markedly after the first two days in either treatment. Sweet odours were not detected in air stored samples after 3 days, but were detected up to 16 days in MAP stored fish. A meaty odour was noted more frequently with increasing time in air stored samples and was consistently high in the MAP samples after 10 days in trial two. Again this may be due to a masking by odour described as 'off', ammonia, sulphur and sweaty. The ammonia note

was detected with increasing frequency over time in the air stored samples, particularly in trial one. It was not detected until day 8 in MAP samples and appeared to peak after 10 days in trial two. A sour/acid note was detected at varying levels throughout in both treatments with a large increase after 4 days in air, but this variation may be due to individual fish variation, particularly with stress levels after catching. Specific off odours were not described in any comments for the air stored samples. After 6 days some tasters noted 'old', 'stale' odours in the MAP samples, and after 10 days comments were made about 'off', 'rotten potato', 'milky', 'boiled milk', 'stale' and 'baked' odours.

There was a noticeable difference in colour between the fish in the two trials. In trial one the flesh was darker and tasters often described it as grey and translucent, but it was not undercooked. There were no consistent differences in appearance between the air and MAP stored samples. Coagulated protein on the surface of the cooked flesh was more obvious again in the MAP packaged fish.

Summary of swordfish retail trials 1 and 2

Figures 9 to 17 in Appendix 9 show data from both trials for all microbiological, chemical and sensory parameters.

- > Initial sample of trial one had a high initial count (64,000 cfu/g). Consisted of a 100% mixture of Gram negative bacteria. Some detectable psychrotrophs.
- > Initial sample of trial two had a low count (80 cfu/g). Consisted a mixture of Gram positive (60%) and Gram negative (40%) bacteria. Psychrotrophs not detectable.
- > Stored aerobically for 4 days during trial 1; total bacterial count reached > 1,000,000 cfu/g. Consisted of 100% Gram negative bacteria predominantly *Pseudomonas* and *Alcaligenes*. High level of psychrotrophs (compared to total count).
- > Stored aerobically for 3 days during trial 2; total bacterial count reached < 1,000,000 cfu/g. Consisted of 100% Gram negative bacteria predominantly *Pseudomonas*. High level of psychrotrophs (compared to total count).
- > MAP stored for 3 days; showed minimal increase in total and psychrotroph counts compared to those of the initial sample. Mixture of Gram positive (*Micrococcus* and coryneforms) and Gram negative (*Flavobacterium* and *Pseudomonas*) bacteria.
- > MAP stored for 10 days; showed minimal increase in total count and psychrotroph counts compared to initial or day 2 aerobic samples. Mixture of Gram positive (*Micrococcus*) and Gram negative (*Flavobacterium*, *Pseudomonas* and *Alcaligenes*).
- > MAP stored for 14 days; showed noticeable increase in total and psychrotroph counts compared to those of the initial sample. Mixture of Gram positive (*Micrococcus*) and Gram negative (*Alcaligenes*) bacteria.
- > Coliforms were not detected in samples which had the low initial count. Coliforms were detected in most the samples which had the high initial count.
- > The initial overall quality score was lower in trial one than trial 2. This reflects the natural variations in the quality of the fish available and is supported by the bacterial counts.
- > Overall quality showed a general downward trend in both trials but was slower in trial two. The decrease in overall quality scores with time appear to be mainly due to a reduction in fresh and sweet odours and flavours with a concurrent increase in 'other' odours described as 'off, sweaty, ammonia and sulphur.
- > Trial one product had a shorter shelf life than two. In trial one the overall quality scores indicated that the fish was still acceptable after 8 days in MAP but became unacceptable after 10 days in MAP, whereas in trial two the overall quality scores remained acceptable for the entire period it was stored (16 days MAP).
- > Fish stored in air lost its overall quality more rapidly than that stored in MAP.
- > The combined analysis (using storage times/ packaging combinations common to both trials) showed fish stored for ten days in MAP having a significantly ($P < 0.05$) lower typical swordfish flavour than those stored in MAP for 3 days or in air for less than 2 days.

Salmon Trials

The MAP of salmon has been studied by a number of overseas researchers. The data produced could be utilised by this investigation. The conditions applied and the shelf life extensions obtained during these studies were compiled. Table 100 contains a list of research papers describing the application of MAP to salmonoids.

Table 100. Experiments from the literature of experiments applying MAP to salmonids.

Authors	Product	Atmosphere	Ratio gas:fish	Temp °C	Air shelf life	MAP shelf life	Extension %
Farber	trout	100% CO ₂	-	4	-	-	-
Barnett 1987	trout deboned	80/20 CO ₂ /N ₂	xs	1.7	12	20	60
Cann	trout	60/40 CO ₂ /N ₂	3:1	0	-	8	-
Cann	trout	40/30/30 CO ₂ /N ₂ /O ₂	3:1	5	-	8	-
Cann	salmon steaks	60/40 CO ₂ /N ₂	3:1	10	-	3.8	-
Cann	salmon steaks	60/40 CO ₂ /N ₂	3:1	0	-	12.9	-
Cann	salmon steaks	60/40 CO ₂ /N ₂	3:1	5	-	7.1	-
Cann	salmon steaks	60/40 CO ₂ /N ₂	3:1	10	-	3.4	-
Pastoriza	salmon slices	100% CO ₂	2:3	2	9	18	100
Paarup	trout (gravad)	60/15/25 CO ₂ /N ₂ /O ₂	-	2	-	39	-
Stier	salmon skin-on fillets	60/15/25 CO ₂ /N ₂ /O ₂	xs (3L)	4	-	12	100
Stier	king salmon fillets	100% CO ₂	xs (3L)	4.4	-	12	100
Stier	king salmon	100% CO ₂	xs (3L)	22	-	<2	<100
Barnett 1982	chum & coho h&g	90/10 CO ₂ /O ₂	Xs	0	12	>21	-
Haard & Lee	salmon steaks	100% CO ₂ + 2.02 kPa	Xs	3	-	>20	>100(x4)
Ashie	trout	80/20 CO ₂ /O ₂	-	1.7	12	20	60
Reddy (Garcia)	salmon fillet	100% CO ₂	-	-	-	48	>100
Reddy (Garcia)	salmon fillet	70/30 CO ₂ /air	-	-	-	24	>100
??	salmon h & g	60/20/20 CO ₂ /N ₂ /O ₂ 1%	xs	1 (&6)	-	28	-
Brown	silver salmon steaks	20/80 CO ₂ /air	xs	4.5	??	14?	-
Brown	silver salmon steaks	40/80 CO ₂ /air	xs	4.5	??	14?	-

There has been a wide range gas mixtures applied to several species of salmon with mixed levels of shelf life extension.

Trial 1

After the initial quality appraisal, the remaining salmon pieces were packed in a 60% CO₂/ 40% N₂ modified atmosphere in the tray system sealed with an impermeable film and stored at 4°C for up to 11 days. It was anticipated that treatment with a chlorine solution would lead to lower surface microbial counts and the data obtained supports this. The microbial quality of fillets cut after this new procedure, as seen in Table 101 for day 0 of the MAP storage, was much better than the two previous samples.

Table 101. Data collated from appraisal of third sample of salmon pieces stored in MAP at 4°C.

Parameter	Storage time (days)			
	0	3	6	10
pH**	6.21 ^a	6.16 ^{ab}	6.21 ^a	6.12 ^b
Total log count cfu/g *	2.84 ^a	0.95 ^b	0 ^b	3.02 ^a
Psychrotropic log count cfu/g	0	0	0	2.54
Hydrogen disulphide producers log count cfu/g	0	0	0	0.4
Coliform log count cfu/g	0	0	0	0
Anaerobic log count cfu/g	0	0	0	0
Pasteurised anaerobic log count cfu/g	0	0	0	0
% Drip*	0 ^b	0.2 ^b	0.84 ^a	0.78 ^a
Raw drip score	0.25	0.25	0.63	0.63
Colour score**	1 ^b	1.1 ^b	1.45 ^a	1.5 ^a
Flesh appearance score	0	0	0	0
Raw odour score**	0.5 ^b	0.8 ^b	1.25 ^{ab}	2 ^a
Cooked drip score	0 ^b	1 ^a	1 ^a	1.25 ^a
Cooked odour score	2.17	2	3	3.5
Flavour score	2.67	3	3.13	4
Texture score	0.42	0	1.13	1.38
Moisture score	2	1.45	0.88	1.25
Total demerit scores	9.08	9.60	12.45	15.5

^{abc} Different letters signify significant differences between treatments (** = P < 0.01, * = P < 0.05)

There were significant differences between storage times for pH but there was no conclusive trend. While there were significant differences between the total microbial counts at different storage times there was also no trend. The total plate log counts were low at the start and during storage. The counts were undetectable for almost all of the other microbial tests. After 10 days storage in MAP at 4°C the high quality life had expired and some off odours and off flavours became detectable. These counts were exceptional and the product was ready to go to the next stage of taste panel assessment.

Trial 2

The next shipment of salmon pieces were packed in a 60% CO₂/ 40% N₂ atmosphere in the tray system that was sealed with an impermeable film which resisted the fogging condition that develops when moisture condenses on films after removal from the chiller. Some pieces were also stored in air and both treatments kept at 4°C. The data obtained for physical testing, demerit assessment and microbiological appraisal is present in Tables 102.

Table 102. Data collated from appraisal of salmon pieces stored in MAP and air at 4°C during storage trial two.

Physical or Microbial Parameter	Storage time in air (days)					Storage time in MAP (days)			
	0	1	2	3	6	3	6	7	8
pH**	6.21 ^{cd}	6.38 ^{ab}	6.32 ^{bcd}	6.23 ^{cd}	6.34 ^{abc}	6.20 ^d	6.24 ^{cd}	6.46 ^a	NA
Total plate log count**	4.27 ^d	5.01 ^d	5.50 ^{cd}	7.28 ^b	8.93 ^a	5.17 ^{cd}	6.91 ^b	6.45 ^{bc}	7.10 ^b
Psychrotropic log count**	4.15 ^e	4.99 ^{de}	5.49 ^{cde}	7.27 ^{ab}	8.79 ^a	6.01 ^{bcd}	6.89 ^{bc}	6.30 ^{bcd}	7.11 ^b
Hydrogen disulphide producers log count**	0.40 ^f	2.45 ^e	3.28 ^{cde}	4.32 ^{bcd}	6.00 ^a	3.59 ^{de}	4.82 ^{abc}	5.54 ^{ab}	5.83 ^{ab}
Coliform log count**	1 ^f	2.49 ^{ef}	2.71 ^{de}	4 ^{bcd}	5.82 ^a	2.91 ^{cde}	4.53 ^{abc}	5.20 ^{ab}	5.60 ^{ab}
Anaerobic log count	0	2.98	1.40	2	2.10	2.88	3.53	0	0
Raw drip score	0	0	0.20	0.50	0.25	NA	NA	NA	NA
% Drip	NA	NA	NA	NA	NA	1.21	1.21	2.50	NA
Colour score	1.28	1.20	1.25	1.80	2.25	1.23	2	1.38	NA
Flesh appearance score	0	0	0.50	1	0.75	1.10	0.42	0.15	NA
Raw odour score**	0.75 ^d	1 ^c	0.75 ^d	1 ^c	2.25 ^a	1 ^c	1 ^c	1.23 ^b	NA
Total common demerits**	2.03 ^d	2.20 ^d	2.50 ^{cd}	3.80 ^b	5.25 ^a	3.33 ^{bc}	3.42 ^{bc}	2.75 ^{bcd}	NA
Taste panel score parameter									
Overall quality score**	70.3 ^a	57.3 ^{bc}	62.6 ^b	57.6 ^{bc}	NA	58.4 ^{bc}	56.3 ^{bc}	53.5 ^c	NA
Typical salmon odour	49.8	54.4	53.1	50.2	NA	43.7	50.7	42.2	NA
Other odour**	10.7 ^d	12.7 ^c	17.8 ^b	22.5 ^{ab}	NA	17.0 ^b	20.3 ^{abc}	27.5 ^a	NA
Free moisture in cooking container	29.8	33.8	38.7	27.7	NA	33.1	33.5	35.7	NA
Moistness	47.8	42.4	48.0	49.6	NA	46.8	47.8	45.3	NA
Firmness	62	64.4	56	63.1	NA	58.6	59.7	57.1	NA
Flakiness	46.8	43.5	41.5	39.8	NA	39.0	41.4	41.8	NA
Fibrousness	24.9	35.8	29.5	27.4	NA	30.2	25.4	31.8	NA
Flavour intensity	55.0	46.3	44.4	53.2	NA	42.5	44.5	46.2	NA
Other flavour intensity	14.4	14.0	15.2	18.2	NA	15.5	15.8	19.0	NA

** abc Different letters signify significant differences between treatments ($P < 0.01$), NA-not appraised because of excessive bacterial counts or rated by other method

The identification of individual microbes present during trial 1 was carried out and is present in Table 103.

Table 103. Bacterial flora of salmon during trial two storage at 4°C.

Time in air (days)		0	3	0	0
Time in MAP Days		0	0	3	8
Total log count (cfu/g)		4.26	7.28	5.18	7.08
Gram -ve	Others	8.3	0.0	0.0	0.0
	<i>Pseudomonas</i>	66.7	100.0	91.7	8.3
	<i>Acinetobacter</i>	8.3	0.0	0.0	0.0
	<i>Alcaligenes</i>	0.0	0.0	0.0	0.0
	<i>Flavobacterium</i>	8.3	0.0	0.0	0.0
	<i>Shewanella</i>	0.0	0.0	0.0	0.0
	Combined	91.7	100.0	91.7	8.3
	Yeast	0.0	0.0	0.0	0.0
Gram +ve	Others	0.0	0.0	0.0	0.0
	<i>Brochothrix</i>	0.0	0.0	0.0	0.0
	<i>Bacillus</i>	0.0	0.0	0.0	0.0
	<i>Kurthia</i>	0.0	0.0	0.0	0.0
	<i>Cornyformes</i>	0.0	0.0	0.0	0.0
	<i>Lactobacillus</i>	0.0	0.0	0.0	66.7
	<i>Streptococcus</i>	0.0	0.0	0.0	8.3
	<i>Staphylococcus</i>	0.0	0.0	0.0	16.7
	<i>Micrococcus</i>	8.3	0.0	8.3	0.0
	Combined	8.3	0.0	8.3	91.7

The initial counts of 18,600 cfu/g for total count and 14,000 cfu/g for psychrotrophs were much higher than the previous samples sent. Unlike the previous trial which were prepared by the quality manager, these samples were processed on the normal filleting line by regular staff indicating that improvements were required in the line. While samples at the end of storage were appraised for microbial and some pack attributes, they were not evaluated by taste panel because of very poor odour when unpacked and the anticipated microbial count. The significant differences detected between the pH of air and MAP stored salmon pieces at different storage times do not indicate there was any major effect by MAP on pH. The total microbial count started at much higher levels than the previous trial. The presence of coliform bacteria at the start of storage and high levels during the trial indicates contamination of the raw material.

The bacterial flora was composed of 92% Gram negative and 8% Gram positive bacteria. The Gram negative bacteria were predominantly *Pseudomonas* (73%) with *Flavobacterium* and *Acinetobacter* present in smaller numbers. The Gram positive bacteria detected were *Micrococcus*. The microbial counts increased significantly with storage time for both treatments but they developed much more slowly under MAP conditions. Aerobic storage at 4°C for 3 days increased the bacterial count to 19,000,000 cfu/g with high number of psychrotrophs (18,500,000 cfu/g). The bacterial flora was predominated by *Pseudomonas* (100%)

Products stored under MAP for 3 days showed an increase in bacterial count to 150,000 cfu/g. It also contained high level of psychrotrophs (1,000,000 cfu/g). The bacterial flora consisted mainly of Gram -ve *Pseudomonas* (92%) with a smaller proportion of Gram +ve *Micrococcus* (8%). After 3 days storage in air and 7 in MAP the counts of the salmon became too high to be safe for the taste panel and were not presented. The salmon pieces stored in MAP had significantly lower total numbers than air stored product after three and six days but only on day six for the other types of count. The majority of bacteria present in both treatments were psychrotrophs. The coliforms present at the start of storage increased to high levels by the end of storage. The hydrogen disulphide producers also increased in a similar manner.

Products stored under MAP for 8 days finished with a total bacterial count (all psychrotrophs) of 13,000,000 cfu/g. The bacterial flora consisted of mainly the Gram -ve bacteria *Lactobacillus* (67%), *Staphylococcus* (17%) and *Streptococcus* (8%) and the

Gram +ve bacteria *Pseudomonas* (8%). Anaerobic counts did not exhibit any significant differences during storage. The anaerobic counts were relatively low with one sample at 3,400 cfu/g and the rest of the samples <1000 cfu/g.

There were some significant differences detected between the air and MAP stored salmon pieces for other parameters. Because the taste panel also evaluated the samples only four demerit parameters were scored. The drip released from the salmon pieces during storage scored low during air storage and only reached 2.5% of the pack weight under MAP. The colour score consistently increased during air storage but varied during MAP storage. The raw odour was scored significantly higher at the end of storage. There was no effect on the flesh appearance score. The total demerits, common to both treatments, had increased significantly by the end of air storage but were stable during MAP storage.

Figures 1 to 4 in Appendix 10 contain graphs of the frequency of selection of standard descriptors for odour, appearance, texture and flavour by the taste panel. The percentage of selection of descriptors generally decreased across the board for day 3 samples. This is not due to changes in characteristics of the fish but rather that on that tasting day two panellists were not present who normally utilise descriptors to further describe the samples. 'Other' odour in the product increased significantly in intensity with time, regardless of storage method. After 8 days in MAP, 17% of tasters detected an 'off' odour. The appearance of the cooked samples did not alter dramatically over the storage time nor were there any clear trends for the texture. The flavour of the day 0 sample was more frequently described as fishy and the tendency to describe it as meaty increased over the storage time.

The salmon remained acceptable at all sensory testing dates in either air or MAP, but was significantly ($P < 0.01$) lower in overall quality compared to day 0. Quality of fish stored 6 days in MAP was scored at a similar level to that stored for 3 days in either air or MAP. The only differences in characteristics of the salmon noted by the panel were in odour of the cooked product. The odour was mostly described as meaty, baked, fishy. There was a significant trend for the "other odour" to increase with storage time. In air a sweet and stale odour was noted after 2 days. After 8 days in MAP the odour was mainly described as 'stale', 'oily' and 'off'. There was a trend for the flesh to soften slightly over time in both types of storage. The flavour of the MAP stored samples was less frequently described as 'fresh' or 'sweet' than of those stored in air. For all parameters there were significant panellist differences indicating that individuals were using different parts of the scales. The overall quality scores deteriorated from the first sample but there was little significant difference between the two treatments. The MAP salmon at 6 and 7 days had overall quality scores similar to those stored in air after 3 days. Other odour, these are usually off odours, developed during either storage.

Summary

Extension of shelf life through the use of MAP was limited by the poor quality of the starting material. While the shelf life was more than doubled it was only extended for seven days, a time that good quality fresh salmon can normally be kept. It was apparent that some improvement in handling and processing practices before another taste panel trial needed to be conducted.

Trial 3

The application of chlorine dioxide sprays to deslimed salmon reduced the bacterial count considerably. The integration of this procedure to the processing line led to bacterial levels suitable for the next storage trial. Fish were deslimed before and after ice slurry storage and sprayed with chlorine dioxide after desliming and prior to filleting. Table 104 and 105 show the microbiological, physical and demerit data obtained during air and MAP storage.

Table 104. Data collated from appraisal of salmon pieces stored in MAP and air at 4°C during storage trial three.

Physical or Microbial Parameter	Storage time in air (days)				Storage time in MAP (days)				
	1	2	3	6	3	6	8	10	13
Total log count**	2.94 ^d	3.14 ^d	4.27 ^{cd}	7.44 ^a	3.26 ^d	3.32 ^d	4.45 ^{cd}	5.55 ^{bc}	6.27 ^{ab}
Psychrotroph log count**	2.65 ^e	2.81 ^e	2.99 ^e	3.16 ^{de}	3.99 ^{de}	4.48 ^{cd}	5.46 ^{bc}	6.36 ^{ab}	7.33 ^a
H ₂ S producer log count**	0.35 ^{de}	1.05 ^{cd}	1.72 ^{bc}	2.36 ^{ab}	0.00 ^e	0.00 ^e	2.43 ^{ab}	2.82 ^a	0 ^e
Coliform log count**	0.5 ^{cd}	0 ^d	1.74 ^{abc}	3 ^a	0.70 ^{bcd}	2 ^{ab}	2 ^{ab}	2 ^{ab}	2 ^{ab}
Anaerobic log count**	0 ^e	0 ^e	2.45 ^{cde}	4.50 ^{ab}	1 ^{de}	2 ^{cde}	4.10 ^{abc}	5.17 ^a	3.22 ^{bcd}
Pasteurised anaerobe log count	0	0	0	0	0	0	0	0	0
pH**	6.35 ^{ab}	6.43 ^a	6.25 ^{bc}	6.29 ^{bc}	6.35 ^{ab}	6.15 ^c	6.24 ^{bc}	6.24 ^{bc}	6.31 ^{ab}
pack drip as % of product weight	-	-	-	-	0.77	0.64	1.14	1.53	1.23
Drip score	0.2	0.1	0.1	0.25	0.25	0	1	0.5	0.25
Colour of flesh score	0.8	1.2	1.5	2.2	1.75	1.5	2.25	2.6	2.5
Flesh appearance score	0.25	0.75	0.9	0.5	0.5	1.2	1	1.8	1.5
Raw odour score	0.5	1	0.75	0.8	1.2	0.75	1.25	2.5	2.5
Total common demerits	1.75	3.05	3.25	3.75	3.7	3.45	5.5	7.4	6.75
Taste panel score parameter									
Overall quality score**	69.9 ^a	66.5 ^{ab}	49.6 ^d	55.9 ^{bcd}	64.4 ^{abc}	53.0 ^{cd}	56.0 ^{bcd}	57.2 ^{abcd}	50.2 ^d
Typical salmon odour	55.9	53.6	40.9	40.7	50.0	38.8	44.3	49.7	45.6
Other odour**	10.6 ^{cd}	14.9 ^{bcd}	28.7 ^a	25.8 ^{ab}	5.9 ^d	18.9 ^{abcd}	19.6 ^{abc}	14.4 ^{bcd}	22.9 ^{abc}
Free moisture in cooking container	37.2	34.6	34.4	26.9	31.7	34.1	30.7	22.4	37.5
Moistness	50.4	51.8	50.0	52.5	47.9	56.3	54.0	50.9	53.8
Firmness	61.3	61.4	53.1	55.3	60.7	57.8	58.3	62.9	56.0
Flakiness	62.3	56.2	54.9	64.4	54.7	50.9	62.2	47.7	51.5
Fibrousness**	30.7 ^{ab}	27.2 ^{abc}	29.7 ^{ab}	33.7 ^{ab}	18.1 ^c	32.7 ^{ab}	23.8 ^b	25.4 ^{abc}	36.3 ^a
Flavour intensity**	54.7 ^a	51.9 ^{ab}	42.3 ^{bcd}	52.9 ^{ab}	49.1 ^{abc}	40.0 ^{cd}	37.1 ^d	45.5 ^{abcd}	42.9 ^{bcd}
Other flavour intensity	11.1	13.4	15.6	17.8	9.3	19.3	18.4	14.3	23.7

** abc Different letters signify significant differences between treatments P < 0.01

Scales : Overall quality Very poor (0) to Very good (100)

Odour None (0) to Very strong (100)

Free moisture None (0) to A lot (100)

Flavour - Very weak (0) to Very strong (100)

Moistness - Very dry (0) to Very dry (100)

Firmness - Very soft (0) to Very firm (100)

Flakiness - None (0) to Very flaky (100)

Table 105. Bacterial flora of salmon during trial three storage at 4°C

Time in air (days)		1	3	6	0	0
Time in MAP Days)		0	0	0	6	13
Total log count (cfu/g)		2.94	4.27	7.44	3.32	6.27
Gram -ve	Others	0	0	0	0	0
	<i>Pseudomonas</i>	17	75	33	9	0
	<i>Acinetobacter</i>	0	0	0	18	0
	<i>Alcaligenes</i>	17	8	0	0	0
	<i>Flavobacterium</i>	25	17	67	27	0
	Combined	58	100	100	55	0
Gram +ve	Others	17	0	0	9	0
	<i>Brochothrix</i>	8	0	0	0	0
	<i>Lactobacillus</i>	0	0	0	36	100
	<i>Streptococcus</i>	0	0	0	0	0
	<i>Staphylococcus</i>	0	0	0	0	0
	<i>Micrococcus</i>	17	0	0	0	0
	Combined	41.7	0.0	0.0	45.5	100.0

Aerobic storage

The initial salmon sample in this trial contained 900 cfu/g total bacteria and 450 cfu/g psychrotrophs. After three days of aerobic storage, these counts increased to 61,000 and 31,000 cfu/g respectively. In six-day aerobically stored sample these counts increased further to 29,000,000 cfu/g and 23,000,000 cfu/g respectively

The bacteria in the initial sample were a mixture of 58% Gram negative and 42% Gram positive bacteria. The Gram negative bacteria consisted of mainly *Flavobacterium*, *Pseudomonas* and *Alcaligenes*. The Gram positive bacteria were *Micrococcus*, and *Brochothrix*

Only Gram negative bacteria were isolated from the sample which had been aerobically stored for three-day. The bacteria consisted of *Pseudomonas* (75%), *Flavobacterium* (17%) and *Alcaligenes* (8%). The bacterial flora after six days storage was Gram negative. They consisted of *Flavobacterium* (67%) and *Pseudomonas* (33%).

There were no significant differences for the pH of salmon flesh during air storage. The only demerit score to show an increase with time was the colour of the flesh. By day six the colour had become dull with some brownness apparent. The low numbers of H₂S producing bacteria supports the low odour score recorded at the end of storage.

MAP storage

The six-day MAP stored sample had a total bacterial count of 2,100 cfu/g and a psychrotrophic count of 2,100 cfu/g. These counts reached 2,200,000 cfu/g and 2,900,000 cfu/g respectively in the thirteen-day MAP stored sample.

In the six-day MAP stored sample the bacterial flora consisted of a mixture of 55% Gram negative and 45% Gram positive bacteria. The Gram negatives bacteria isolated were *Flavobacterium*, *Acinetobacter* and *Pseudomonas* and the Gram positive bacteria were *Lactobacillus*. The bacteria isolated in the thirteen-day MAP sample were all *Lactobacillus*.

There were only minor differences for the pH of salmon flesh during MAP storage. The percentage of drip within packs was low even after thirteen days storage and was easily

taken up by the absorbent pads, thus the low drip scores. Most of the demerit scores showed increases with time. By day eight the colour had become dull with some brownness apparent and became worse with further MAP storage. Some gaping of the flesh also developed but the condition could only be scored lower than a moderate rating. A low level of off odour was present by day eight and this increased with time.

Coliforms and anaerobic counts

Coliform bacteria were not detectable in the initial sample, however were detected in the stored samples (aerobic and MAP). The levels of these bacteria were low when compared to the total bacterial population present in the respective samples.

The anaerobic count remained low throughout the storage period.

Of the sensory parameters only other odour, fibrous texture, flavour intensity and overall acceptability showed significant differences ($P < 0.05$). There was a significant differences ($P < 0.05$) between panellists suggesting that further training was necessary.

Figures 5 to 8 in Appendix 10 contain graphs of the frequency of selection of standard descriptors for odour, appearance, texture and flavour by the taste panel.

Summary

The initial sample had a satisfactory level of bacteria, consisting of a mixture of Gram negative and Gram positive bacteria. On aerobic storage (day 3) the sample became dominated with Gram negative bacteria. Excessive bacterial counts had developed by day six. The Gram negative bacteria *Flavobacterium* and *Pseudomonas* dominated the bacterial flora.

The MAP sample, which had been stored for six days, contained an acceptable level of bacteria consisting of a mixture of Gram negative and Gram positive bacteria. The MAP samples stored for thirteen days developed very high total bacterial counts consisting totally of the Gram positive bacteria *Lactobacillus*.

The salmon stored in air for up to 3 days or in MAP for up to 8 days remained acceptable to consumers. A significant ($P < 0.01$) loss of overall quality was noted after only 1 day's storage in air.

There was a significant ($P < 0.01$) trend for 'other' odour to increase over the storage time. Descriptor selection indicated this odour as more meaty and at 8 days MAP, 17% of the of tasters detected an off odour.

The panel identified no significant differences ($P > 0.05$) for texture or flavour characteristics.

The shelf life for Atlantic salmon was more than doubled during this trial by using MAP technology. A maximum of 13 days was achieved.

Conclusion

The work conducted on improving the production line was successful in reducing initial bacteria to levels suitable to achieve long shelf life. These trials reinforce the importance of having integrated quality assurance systems before any MAP products are attempted.

Trout Trials

The factory inspection and bacterial counts of samples indicated that this facility showed good potential for the production of a MAP product. Further samples were shipped to the laboratory for appraisal and the data obtained is present in Table 106 below.

Table 106. Data collated from appraisal of rainbow trout shipped to the laboratory

Physical or Microbial Parameter	Raw fillets	Smoked whole
pH	6.28	-
Total plate log count	2.73	1.7
Hydrogen disulphide producers log count	0	0
Coliform log count	0	0
<i>E. coli</i> log count	0	0
Anaerobic log count	0	0
Pasteurised anaerobic log count	0	0

The low counts obtained indicated that a storage trial could be started directly. There was an opportunity to compare both MAP methods applied previously before going to the taste panel trials. Because the trays from the saucer scallops trials incorporating a vacuum skin pack (VSP) covered with a permeable membrane were used they contained only one trout fillet. This was placed in a barrier bag with another pack, evacuated and filled with a 100% CO₂ atmosphere. Two fillets were placed in the lidded retail pack which was then evacuated and filled with a 60% CO₂/ 40% N₂ atmosphere. Both type packs and sample kept open to the air were stored at 4°C for up to 14 days.

Trial 1

Table 107 shows the microbiological, physical and demerit data obtained from this storage trial.

Aerobic storage

The initial (day 0) trout sample contained 2,500 cfu/g total bacteria and 2,200 cfu/g psychrotrophs. These counts increased to 34,700 cfu/g and 26,900 cfu/g respectively after three days of aerobic storage (day 3). These counts eventually reached 141,254,000 cfu/g and 120,226,000 cfu/g after six days of aerobic storage. The total count became excessive after four days.

During this storage period there was a noticeable increase in the counts of H₂S producing bacteria. Over this period of storage, the counts increased from an initial of 70 to 1,500 and then 2,240,000 cfu/g respectively.

The pH did not exhibit any real change during aerobic storage. The demerit scores showed major increases between days three and six. The raw odour at the end of storage did not reach levels as high as many other species of seafood. The colour of the fillets was the only parameter which did deteriorate quickly.

MAP retail pack during storage

The sample which was stored for nine days under MAP condition, had a total bacterial count of 117,500 cfu/g and a psychrotrophic count of 85,100 cfu/g. The 14 days MAP stored sample had counts of 72,444,000 cfu/g and 55,000,000 cfu/g respectively.

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Table 107. Data collated from trial one of trout fillets stored at 4°C

Physical or Microbial Parameter	Storage time in air (days)				Storage time in lidded trays with MAP containing 60% CO ₂ (days)					Storage time in VSP trays with MAP containing 100% CO ₂ (days)				Storage time in VSP with MAP then air storage (days)				
	0	2	3	6	2	3	6	9	14	2	3	6	9	2/4	3/3	3/6	6/3	9/5
pH	6.25	m	6.27	6.43	6.17	6.12	6.3	6.25	6.24	6.13	6.05	6.11	6.08	6.40	6.26	6.30	6.33	6.29
Total log count	3.41 ^c	3.75 ^{de}	4.54 ^{cd}	8.15 ^a	3.35 ^c	3.17 ^c	4.93 ^c	5.08 ^c	7.86 ^a	3.12 ^c	3.39 ^c	3.75 ^{de}	3.52 ^{de}	3.87 ^{de}	3.50 ^e	4.97 ^c	3.75 ^{de}	6.29 ^b
Psychrotroph log count	3.34 ^{de}	3.78 ^{de}	4.43 ^{cd}	8.08 ^a	3.27 ^{de}	2.85 ^c	4.93 ^c	4.93 ^c	7.74 ^a	3.06 ^c	2.86 ^c	2.94 ^e	3.47 ^{de}	3.79 ^{cde}	3.50 ^{de}	4.91 ^c	3.79 ^{cde}	6.19 ^b
Hydrogen disulphide producers log count	1.82 ^g	2.86 ^{ef}	3.17 ^{ef}	6.35 ^b	1.97 ^g	2.00 ^g	4.49 ^d	5.01 ^{cd}	7.30 ^a	1.72 ^g	1.80 ^g	2.46 ^{fg}	2.94 ^{ef}	3.52 ^c	2.88 ^{ef}	4.82 ^{cd}	3.32 ^c	5.27 ^c
Coliform log count	4 ^a	3.99 ^a	3 ^{ab}	3 ^{ab}	2.98 ^{abc}	2.45 ^{abcd}	2 ^{bcd}	2 ^{bcd}	2 ^{bcd}	1.99 ^{bcd}	1.98 ^{bcd}	1.92 ^{bcd}	1.82 ^{bcd}	1.63 ^{bcd}	1.33 ^{cdef}	0.8 ^{def}	0.59 ^{ef}	0 ^f
Anaerobic log count	0 ^d	0 ^d	0 ^d	1.15 ^{cd}	0 ^d	0 ^d	0 ^d	2.68 ^{bc}	5.39 ^a	0 ^d	0 ^d	1 ^{cd}	0 ^d	0 ^d	0 ^d	1.62 ^{cd}	0 ^d	4.49 ^{ab}
Pasteurised anaerobic log count	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drip in tray as % of product	-	-	-	-	0.23 ^g	0.42 ^{fg}	0.82 ^{defg}	0.83 ^{defg}	3.95 ^a	0.24 ^g	0.66 ^{efg}	1.15 ^{cdef}	1.49 ^{bcd}	2.23 ^b	1.04 ^{defg}	1.92 ^{bc}	1.53 ^{bcd}	3.32 ^a
Raw drip score	0 ^b	0 ^b	0 ^b	0 ^b	0.1 ^b	0 ^b	0.75 ^a	0.75 ^a	0.25 ^{ab}	0 ^b	0 ^b	0 ^b	0.125 ^b	0 ^b	0 ^b	0.25 ^{ab}	0.25 ^{ab}	0.25 ^{ab}
Colour score	1 ^{ef}	0.5 ^f	0.5 ^f	1.75 ^{abcd}	1 ^{ef}	1.38 ^{cde}	1.63 ^{abcd}	1.75 ^{abcd}	2.13 ^a	1 ^{ef}	1.25 ^{de}	1.5 ^{bcd}	2.13 ^a	1.63 ^{abcd}	2.13 ^a	1.88 ^{abc}	2 ^{ab}	2.1 ^a
Colour score after 30 min	1 ^{ef}	0.5 ^f	0.5 ^f	1.75 ^{abcd}	1 ^{ef}	1.38 ^{cde}	1.63 ^{abcd}	1.75 ^{abcd}	2.13 ^a	1 ^{ef}	1.25 ^{de}	1.5 ^{bcd}	2.13 ^a	1.63 ^{abcd}	2.13 ^a	1.88 ^{abc}	2 ^{ab}	2.1 ^a
Flesh appearance score	0 ^d	0 ^d	0.5 ^{bc}	1 ^a	0.25 ^{cd}	0 ^d	0.5 ^{bc}	0 ^d	0.38 ^c	0 ^d	0 ^d	0.25 ^{cd}	0 ^d	0 ^d	0.5 ^{bc}	0 ^d	0 ^d	0.75 ^{ab}
Raw odour score	1 ^{cd}	0.5 ^f	0.7 ^{ef}	1.25 ^c	1 ^{cd}	1 ^{cd}	1 ^{cd}	1 ^{cd}	2.75 ^a	1 ^{cd}	1 ^{cd}	1 ^{cd}	1.25 ^c	1 ^{cd}	0.9 ^{cde}	1 ^{cd}	1.1 ^{cd}	1.75 ^b
Raw odour score after 30 min	1 ^{cd}	0.5 ^f	0.7 ^{ef}	1.25 ^c	1 ^{cd}	1 ^{cd}	1 ^{cd}	1 ^{cd}	2.75 ^a	1 ^{cd}	1 ^{cd}	1 ^{cd}	1.25 ^c	1 ^{cd}	0.9 ^{cde}	1 ^{cd}	1.1 ^{cd}	1.75 ^b
Cooked drip score	0 ^g	0.2 ^{fg}	0.2 ^{fg}	0 ^g	0.75 ^{cde}	0.5 ^{ef}	1.1 ^{abcd}	1.25 ^{ab}	1.4 ^a	0.5 ^{ef}	1.25 ^{ab}	0.5 ^{ef}	1.38 ^a	0.65 ^{def}	1 ^{abcd}	1.13 ^{abc}	0.88 ^{bcd}	0.88 ^{bcd}
Cooked odour score	1 ⁱ	3 ^{ef}	1.75 ^h	5 ^a	2.25 ^{gh}	2 ^{gh}	2.5 ^{fg}	3.5 ^{cde}	4.5 ^{ab}	2.5 ^{fg}	2.25 ^{gh}	2 ^{gh}	3.75 ^{cd}	4 ^{bc}	3 ^{ef}	4 ^{bc}	3.25 ^{de}	5 ^a
Cooked flavour score	1.5 ^g	3 ^{cde}	3 ^{cde}	3.88 ^{abcd}	2.75 ^{efg}	2.5 ^{efg}	3.25 ^{cde}	3.25 ^{cde}	5 ^{ab}	2.63 ^{efg}	2.25 ^{fg}	2.5 ^{efg}	3 ^{cde}	3.75 ^{bcd}	4.25 ^{abc}	3.63 ^{bcd}	3.75 ^{bcd}	5.25 ^a
Texture score	1 ^{bcd}	0.5 ^{def}	0.75 ^{cdef}	1 ^{bcd}	0.25 ^f	0.63 ^{cdef}	1.25 ^{bcd}	0.75 ^{cdef}	2.38 ^a	0.38 ^{ef}	0.75 ^{cdef}	0.75 ^{cdef}	1.13 ^{bcd}	1 ^{bcd}	0.5 ^{def}	1.25 ^{bcd}	1.35 ^{bc}	1.75 ^{ab}
Moisture score	0 ^d	0.2 ^d	0.75 ^{abcd}	0.75 ^{abcd}	0.4 ^{cd}	0.6 ^{bed}	0.85 ^{abcd}	1.48 ^{ab}	1.75 ^a	0.25 ^d	0.63 ^{bcd}	0.5 ^{bcd}	0.88 ^{abcd}	1 ^{abcd}	0.88 ^{abcd}	1.75 ^a	1.75 ^a	1.38 ^{abc}
Total demerit scores	7.5 ^d	8.9 ^{cd}	9.35 ^{cd}	17.63 ^b	10.75 ^c	10.98 ^c	15.45 ^b	16.48 ^b	25.33 ^a	10.25 ^c	11.63 ^c	11.5 ^c	17 ^b	15.65 ^b	16.18 ^b	17.75 ^b	17.43 ^b	22.95 ^a

^{abc} Different letters signify significant differences between treatments (**=P<0.01, *=P<0.05)

The H₂S producing bacteria also showed a noticeable presence in these samples (102,000 and 20,000,000 cfu/g at 9 and 14 days storage respectively).

VSP tray in MAP during storage

The higher concentration of carbon dioxide inhibited the growth of all types of bacteria more effectively than the MAP mixture but it did lead to a higher percentage drip loss at day nine.

Once the VSP tray was open to the air growth rates increased but not always faster than that present under a mixed modified atmosphere. This type of packaging resulted in product with similar demerit scores to the MAP. It appears that trout will have similar shelf life packed by either method. The only difference between the two types of pack is that the lidded pack with internal modified atmosphere has a better visual presentation and the further trials will be conducted using this method.

Coliforms and anaerobic counts

Coliform bacteria were detected in the samples throughout the trial. The levels of these bacteria were low compared to the total bacterial population of the respective samples.

Low levels of anaerobic counts were detected in some of the stored samples. These reached high levels only after 14 days MAP storage.

Summary

The initial sample (day 1) contained moderate levels of bacteria, consisted of a high proportion of coliforms. The bacterial count reached extremely high counts after six days of aerobic storage and was dominated by H₂S producing bacteria.

The MAP retail packs stored for nine days showed a moderate increase in bacterial count. The bacterial flora of these packs was also dominated by H₂S producing bacteria. The MAP retail packs stored for 14 days developed a high level bacterial count which included large numbers of anaerobes. The product by this time would certainly have become a health risk for consumers. The VSP system resulted in conditions very similar to the MAP retail packs.

Trial 2

The extensive amount of work involved in evaluating all of the parameters for two pack types presented above restricted the evaluation of rainbow trout stored in MAP by taste panel to only one pack type. For these trials it was decided that the MAP retail packs had the best customer appeal and were appraised because of better appearance.

Aerobic storage

The initial (day 0) trout sample contained 1230 cfu/g total bacteria and 8 cfu/g psychrotrophs. These counts increased to 14,450 cfu/g and 11,220 cfu/g respectively after three days of aerobic storage. The counts reached 33,884,000 cfu/g and 36,308,000 cfu/g after six days of aerobic storage.

During this storage period there was a noticeable increase in the counts of H₂S producing bacteria which increased from an initial of 25 to 630 and then 912,000 cfu/g respectively. The latter occurrence is due to a high proportion *Pseudomonas* in the microbial flora during aerobic storage.

The initial composition of the bacterial flora consisted of 67% Gram negative bacteria (*Flavobacterium*, *Pseudomonas*, *Shewanella*, *Alcaligenes* and *Acinetobacter*) and 33% Gram positive bacteria (*Brochothrix*, *Micrococcus* and others). After three days of aerobic storage, the bacterial flora in the sample was 100% Gram negative bacteria. These consisted of *Pseudomonas* (67%), *Flavobacterium* (25%) and *Alcaligenes* (8%).

The six days aerobically stored sample contained 100% Gram negative bacteria. The flora consisted of *Peudomonas* (92%) and *Alcaligenes* (8%).

Table 108. Data collated from trial two of trout fillets stored at 4°C

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Physical or Microbial Parameter	Storage time in air (days)					Storage time in MAP (days)				
	0	1	2	3	6	2	3	6	9	14
pH	6.27	6.25	6.39	6.36	6.37	6.27	6.03	6.11	6.20	6.20
Total log count*	3.09 ^c	3.39 ^{de}	3.58 ^{de}	4.16 ^{cd}	7.53 ^a	3.01 ^c	2.98 ^c	3.51 ^{de}	4.88 ^c	6.57 ^b
Psychrotroph log count*	0.92 ^c	3.04 ^{cde}	3.55 ^{bcd}	4.05 ^{bc}	7.56 ^a	2.65 ^{cde}	1.24 ^{de}	2.50 ^{cde}	4.72 ^{bc}	5.88 ^{ab}
H ₂ S producers log count*	1.41 ^{cd}	0.94 ^d	2.69 ^{bc}	2.80 ^{bc}	5.96 ^a	1.63 ^{cd}	1.85 ^{cd}	1.89 ^{cd}	4.03 ^b	5.60 ^a
Coliform log count*	1.39 ^{abc}	0.92 ^{bc}	1.94 ^{ab}	2.13 ^{ab}	3.00 ^a	1.60 ^{abc}	0.00 ^c	0.70 ^{bc}	0.00 ^c	0.00 ^c
Anaerobic log count	0	0	0	0	0	0	0	0	4.97	4.15
Pasteurised anaerobic log count	0	0	0	0	0	0	0	0	0	0
Drip in tray as % of product	-	-	-	-	-	1.38	2.13	3.04	2.85	3.68
Raw drip score	1	0.5	0.5	1	0.5	1	1	1	1.25	0.8
Colour score	1	1	2	1.5	1.5	1.5	1.5	1.5	2	2
Colour score after 30 min	1	1	2	1.5	1.5	1.5	1.5	1.5	2	2
Flesh appearance score	0	0	0.2	0.4	0.2	0.25	0	0	0.2	0.25
Raw odour score	0	0	0.5	0.5	0.5	0.5	1.2	0.75	1.5	3
Raw odour score after 30 min	0	0	0.5	0.5	0.5	0.5	1.2	0.75	1.5	3
Total demerit scores	3	2.5	5.7	5.4	4.7	5.25	6.4	5.5	8.45	11.05
Taste panel score parameter										
Fishy odour	43.2	36.6	36.6	37.3	38.3	35.4	43.8	35.3	38.9	-
Meaty odour	32.7	26.5	27.5	34.2	32.6	30.5	31.7	28.0	25.6	-
Muddy odour	12.0	18.7	14.1	8.6	12.2	15.1	11.6	10.5	14.8	-
Other odour	4.8	1.7	3.2	2.9	11.0	4.2	9.6	5.8	8.2	-
Free moisture	34.4	28.2	28.8	36.9	36.8	32.7	33.6	36.4	24.1	-
Intensity of Colour	36.8	38.3	31.6	26.0	31.2	38.5	44.7	40.1	28.1	-
Moistness	49.5	55.6	56.5	54.3	53.4	51.8	54.7	49.9	56.3	-
Firmness	53.5	54.1	51.6	51.2	51.4	56.8	54.5	49.9	49.6	-
Flakiness	30.9	32.7	25.6	32.6	32.9	32.7	39.4	33.7	36.3	-
Fibrous	44.3	33.9	28.7	31.7	25.7	36.0	33.4	31.8	33.2	-
Flavour intensity	47.6	41.4	42.6	45.1	45.8	39.5	46.7	42.3	39.5	-
Meaty flavour	33.4	36.8	27.6	37.6	30.8	31.8	34.2	31.6	32.3	-
Sweet flavour*	38.6 ^a	26.6 ^{bc}	23.1 ^{cd}	23.1 ^{cd}	20.5 ^{cd}	22.0 ^{cd}	23.5 ^{cd}	25.9 ^{bc}	16.9 ^d	-
Muddy flavour	23.4	27.5	19.7	19.3	16.3	21.6	13.6	14.1	22.8	-
Other flavour*	7 ^a	5.5 ^a	5.8 ^a	4.1 ^a	15.4 ^b	8.5 ^a	4.5 ^a	3.4 ^a	8.3 ^a	-
Overall quality*	64.3 ^a	61 ^a	59.7 ^a	54.3 ^{abc}	46.9 ^b	59.1 ^a	59.5 ^a	55.6 ^{ab}	44.1 ^c	-

* abc Different letters signify significant differences between treatments (P < 0.01)

Table 109. Bacterial flora of trout during trial 2 storage at 4°C.

Time in air (days)		0	3	6	0	0
Time in MAP Days		0	0	0	9	14
Total log count (cfu/g)		3.09	4.16	7.53	4.88	6.57
Gram -ve	Others	0	0	0	0	0
	<i>Pseudomonas</i>	25	67	92	0	0
	<i>Acinetobacter</i>	8	0	0	0	8
	<i>Alcaligenes</i>	8	8	8	0	0
	<i>Flavobacterium</i>	18	25	0	0	0
	<i>Shewanella</i>	8	0	0	17	0
	Combined	67	100	100	17	8
Gram +ve	Others	17	0	0	8	8
	<i>Brochothrix</i>	8	0	0	0	0
	<i>Cornyformes</i>	0	0	0	0	0
	<i>Lactobacillus</i>	0	0	0	75	8
	<i>Streptococcus</i>	0	0	0	0	76
	<i>Staphylococcus</i>	0	0	0	0	0
	<i>Micrococcus</i>	8	0	0	0	0
	Combined	33	0	0	83	92

MAP storage

The sample stored for nine days under MAP, had a total bacterial count of 76,000 cfu/g and a psychrotrophic count of 52,500 cfu/g. The MAP sample stored 14 days had counts of 3,715,000 cfu/g and 578,600 cfu/g respectively. The H₂S producing bacteria also showed a noticeable presence in these samples (10,700 and 398,100 cfu/g at nine and 14 days storage respectively).

The nine days MAP stored sample flora consisted of a mixture of 83% Gram positive and 17% Gram negative bacteria. The flora mainly consisted of *Lactobacillus* (75%) and others, while the Gram negative flora were *Shewanella* (17%). After 14 days MAP storage the bacteria was a mixture of 92% Gram positive bacteria composed of 76% *Streptococcus*, 8% *Lactobacillus* and 8% of other species while the Gram negative bacteria were all *Acinetobacter*.

Coliforms and anaerobic counts

Coliform bacteria were detected in samples throughout the trial. The levels of these bacteria were low compared to the total bacterial population of the respective samples and mainly present under aerobic conditions.

Low levels of anaerobic counts were detected during the later stages of MAP storage.

Summary

The initial sample (day 0) contained relatively low levels of bacteria, they consisted of a moderate proportion (67%) of Gram negative bacteria. The bacterial count reached to moderate levels after three days of aerobic storage, and the flora were 100% by Gram negative bacteria. The bacterial count reached extremely high counts after six days of aerobic storage, and was composed of 100% Gram negative bacteria. The dominant Gram negative bacteria during this storage were *Pseudomonas* and *Alcaligenes*.

During the aerobic storage period there was a noticeable increase in the counts of H₂S producing bacteria. The MAP sample stored for nine days showed a moderate increase in bacteria with a large proportion (75%) *Lactobacillus*. After fourteen days there was a high bacterial count. The flora was dominated by Gram positive bacteria (*Streptococcus* and *Lactobacillus*) with some Gram positive (*Acinetobacter*) also present to a lesser extent.

The trout developed a moderate amount of drip by the end of MAP storage. This was reflected in a higher demerit score for this parameter than air storage. The colour and appearance of the trout in MAP was similar to product air stored for much less time. The odour scores were similar for both treatments after six days storage but the MAP packs exhibited excessive off odours by day 14.

The taste panel identified differences for sweet flavour, other flavour and overall quality during the storage trial. The sweet flavour dropped off almost as soon as the fish were stored while there was some other flavour present in fish stored in air for six days. The overall quality deteriorated with time and became unacceptable after six days in air and nine days in MAP.

Trial 3

The next trial involved the implementation of improvements in processing techniques and the packaging of fish in MAP within the factory. It was anticipated that the experiments described earlier in the section for salmon would be as effective for rainbow trout. The data presented here shows that this experiment was not as successful. The trial was compounded by the local weather conditions. There had been low water levels in the

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river supplying the farm for some time and just prior to the trial enough rain had fallen to increase flow but not discolour the water. After a prolonged dry spell the sudden influx of water can stir up the sediments in the riverbed and this combined with run off from farm paddocks can lead to major increases in water born bacteria.

Table 110. Data collated from trial three of trout fillets stored at 4°C

Physical or Microbial Parameter	Storage time in air (days)				Storage time in MAP (days)				
	1	2	3	4	1	2	4	7	10
pH*	m	6.23 ^b	6.33 ^{ab}	6.07 ^c	6.43 ^a	6.34 ^{ab}	6.29 ^b	6.22 ^b	6.26 ^b
Total log count*	4.67 ^{cd}	5.09 ^c	5.91 ^b	6.87 ^a	4.50 ^c	4.54 ^{de}	4.61 ^{de}	4.96 ^{cd}	6.57 ^a
Psychrotroph log count*	4.64 ^d	5.03 ^c	5.85 ^b	6.81 ^a	4.48 ^d	4.54 ^d	4.56 ^d	5.06 ^c	6.57 ^a
Hydrogen disulphide producers log count*	2.85 ^f	3.91 ^{cd}	4.88 ^b	6.22 ^a	2.70 ^f	2.96 ^{ef}	3.59 ^{de}	4.33 ^{bc}	6.01 ^a
Coliform log count*	2 ^c	2 ^c	4 ^a	4 ^a	2 ^c	1.98 ^c	2 ^c	3 ^b	4 ^a
Anaerobic log count	1.27	m	0	2.62	2	m	1.24	1.41	4.15
Pasteurised anaerobic log count	0	m	0	0	0	m	0	0	0
Raw drip score	m	0	0	0.25	0	0	0.25	0.25	0.2
Colour score	m	1	1.25	1.5	1	1	1.75	2	2
Colour score after 30 min	m	1	1.25	1.5	1	1	1.75	2	2
Flesh appearance score	m	0	0	0.25	0	0	0.25	0.5	0.5
Raw odour score	m	0	0.5	1.1	0	0	2	2	1.9
Raw odour score after 30 min	m	0	0.5	1.1	0	0	1.75	1.5	1.5
Total demerit scores	m	2	3.5	5.7	2	2	7.75	8.25	8.1
Taste panel score parameter									
Fishy odour	45.1	39.7	36.3	-	35.3	41.9	35.5	37.9	39.2
Meaty odour*	26.0 ^c	23.7 ^c	27.9 ^{bc}	-	27.6 ^{bc}	31.9 ^{abc}	25.1 ^c	32.0 ^{abc}	35.8 ^{ab}
Muddy odour	29.0	24.9	11.3	-	17.9	19.7	20.5	24.9	14.1
Other odour	14.7	24.3	10.6	-	7.5	9.5	16.8	17.1	15.2
Free moisture*	45.7 ^b	24.0 ^c	34.7 ^{bc}	-	29.4 ^{bc}	28.3 ^c	29.4 ^{bc}	26.0 ^c	45.4 ^{ab}
Intensity of Colour	33.0	26.3	24.9	-	28.5	33.0	35.6	31.7	36.9
Moistness	58.8	60.1	54.0	-	63.8	59.4	57.2	53.3	53.9
Firmness	51.0	48.5	46.8	-	51.1	54.2	57.5	48.7	49.2
Flakiness	37.9	30.6	34.3	-	23.6	24.0	25.0	33.6	29.5
Fibrous*	30.0 ^{abc}	23.9 ^{bc}	16.9 ^c	-	35.2 ^{ab}	23.3 ^c	29.4 ^{abc}	35.9 ^a	37.3 ^a
Flavour intensity	42.6	41.1	43.28	-	41.3	46.9	38.0	42.5	43.5
Meaty flavour	31.6	31.6	30.5	-	39.1	32.5	34.5	39.6	33.4
Sweet flavour	29.1	23.1	22.0	-	22.0	30.7	21.7	21.9	22.6
Muddy flavour	37.5	36.5	25.9	-	28.6	28.0	34.9	23.4	17.1
Other flavour	24.0	26.3	17.9	-	15.9	16.0	13.8	19.8	15.0
Overall quality	56.7	49.4	45.6	-	48.8	52.6	51.6	47.8	53.2

* abc Different letters signify significant differences between treatments (P < 0.01)

m=some data was lost

Table 111. Bacterial flora of trout during trial 3 storage at 4°C.

Time in air (days)	1	3	4	0	0
Time in MAP Days	0	0	0	7	10
Total log count (cfu/g)	4.67	5.91	6.87	4.96	6.57
Gram -ve					
Others	0	0	0	16.5	8
<i>Pseudomonas</i>	17	75	42	16.5	0
<i>Acinetobacter</i>	8	0	0	0	0
<i>Alcaligenes</i>	0	0	0	0	0
<i>Flavobacterium</i>	50	8	16	0	8
<i>Shewanella</i>	8	17	42	67	67
Combined	83	100	100	100	83
Gram +ve					
Others	0	0	0	0	0
<i>Brochothrix</i>	0	0	0	0	0
<i>Cornyformes</i>	0	0	0	0	0
<i>Lactobacillus</i>	0	0	0	0	0
<i>Streptococcus</i>	0	0	0	0	17
<i>Staphylococcus</i>	0	0	0	0	0
<i>Micrococcus</i>	17	0	0	0	0
Combined	17	0	0	0	17

Aerobic storage

The initial (day 1) trout sample contained 47,000 cfu/g total bacteria and 44,000 cfu/g psychrotrophs. These counts increased to 890,000 cfu/g and 740,000 cfu/g respectively after three days of aerobic storage. These counts reached 7,600,000 cfu/g and 6,500,000 cfu/g after four days of aerobic storage.

During this storage period there was a noticeable increase in the counts of H₂S producing bacteria. Over this period of storage, the counts increased from an initial of 710 to 76,000 and 1,700,000 cfu/g respectively. The latter occurrence is reflected in the following results which show the increasing flora proportion of *Shewanella* (an H₂S producing bacteria) during aerobic storage.

The initial composition of the bacterial flora consisted of 83% Gram negative bacteria (*Flavobacterium*, *Pseudomonas*, *Shewanella*, and *Acinetobacter*) and 17% Gram positive bacteria (*Micrococcus*).

After three days of aerobic storage, the bacterial flora in the sample was 100% Gram negative bacteria. These consisted of *Pseudomonas* (75%), *Shewanella* (17%) and *Flavobacterium* (8%).

The four days aerobically stored sample contained 100% Gram negative bacteria. The flora consisted of *Pseudomonas* (42%), *Shewanella* (42%) and *Flavobacterium* (16%). There was a significant drop in pH of the trout at this time. The colour had deteriorated but no gaping was evident. The fish quickly lost its freshness when unpacked and by the time the taste panel had overwhelmingly rejected the product it had developed some off odours. This aspect was confirmed by significant increases in numbers of H₂S producers at each sampling time.

MAP storage

The sample stored for seven days under MAP, had a total bacterial count of 92,000 cfu/g and a psychrotrophic count of 120,000 cfu/g. The MAP sample stored ten days had counts of 3,800,000 cfu/g and 3,700,000 cfu/g respectively.

The H₂S producing bacteria also showed a noticeable presence in these samples (26,000 and 1,200,000 cfu/g at 7 and 10 days storage respectively). This was reflected with the high proportion of *Shewanella* in the bacterial flora shown in Table 112 and the raw odour scores in Table 111. The higher demerit scores from MAP is due to the odour becoming trapped in the headspace and building up over time.

The seven days MAP stored sample contained 100% Gram negative bacteria. The flora consisted of *Shewanella* (67%), *Pseudomonas* (16.5%) and bacteria from the family *Enterobacteriaceae* (16.5%).

The bacterial flora in the ten days MAP stored sample consisted of a mixture of 83% Gram negative and 17% Gram positive bacteria. The Gram negative bacteria composed of 67% *Shewanella*, 8% *Flavobacterium* and 8% bacteria from the *Enterobacteriaceae* family. All of the Gram positive bacteria were *Streptococcus*.

There was no change in pH and drip loss and gaping was not apparent during MAP storage. The flesh colour did fade over time. The total demerit points increased during storage but not rapidly.

There were only three taste panel parameters which exhibited significant differences during the trial. The MAP samples were rated higher meaty odours than air stored trout.

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There were no consistent trends for free moisture or fibrous texture over time for either treatment.

Coliforms and anaerobic counts

Coliform bacteria were detected in samples throughout the trial. The levels of these bacteria were low compared to the total bacterial population of the respective samples but were higher than the previous trial.

Low levels of anaerobic counts were detected in some of the stored samples.

Summary

This trial started with relatively high levels of bacteria, much higher than the previous trial despite improved processing procedures and chemical treatment. These consisted of a high proportion (83%) of Gram negative bacteria. The bacterial count reached to high levels after three days of aerobic storage, and the flora were 100% by Gram negative bacteria. The bacterial count reached extremely high counts after four days of aerobic storage, and was composed of 100% Gram negative bacteria. The dominant Gram negative bacteria during this storage were *Pseudomonas*, *Shewanella* and *Flavobacterium*.

During the aerobic storage period there was a noticeable increase in the counts of H₂S producing bacteria.

The MAP sample stored for seven days, showed a moderate increase in bacterial count. The bacterial flora of the sample was 100% Gram negative bacteria, with a large proportion (66%) *Shewanella*.

The MAP sample stored for ten days, developed a high level bacterial count. The flora was dominated by Gram negative bacteria *Shewanella* and with some Gram positive *Streptococcus* also present to a lesser extent.

Very little drip loss was present in this product. The odour at unpacking and visual acceptability did deteriorate during storage.

The overall quality of the fish was low while there was a difference between the two treatments at the start of the trial. There were significant changes in the meaty odour, free moisture and fibrous texture during storage.

This trial should have shown improvements in many of the parameters tested but the rain had a major impact on the quality by increasing initial counts and imparting higher muddy flavours in the product than the previous one.

Conclusion

The prospects for producing a MAP trout product are good even though there were large differences between the two taste panel appraised trials (see Figures 1 and 2 in Appendix 11). If the unusual weather conditions encountered during the third trial do not become a regular occurrence this factory can easily produce good quality trout with twice the shelf life using MAP technology.

Benefits

Both wild capture and aquaculture industries have benefited from this research. The project assisted industry with improving the microbiological quality of the seafood products being produced. The processing line evaluations and chemical treatments resulted in a doubling of shelf life under normal conditions as well as extending that while in MAP. These improvements should directly result in better quality for the end consumer.

The samples appraised by the supermarket, catering and hospitality representatives were well received and were perceived as having better quality than the normal supply at a similar post harvest age. There was a reluctance to pay a premium for this product but this attitude may change when the cost due to wastage is properly considered and the MAP product becomes readily available.

This project has led to Nortas conducting MAP production trials in house to determine the shelf life attainable under their new processing conditions. These trials will also assist with determining which MAP equipment should be purchased.

This MAP salmon product will be sold through supermarkets so that the consumer will directly benefit from this project by the presence in the marketplace of better quality seafood.

Satellite Seafoods have also initiated moves towards producing a MAP swordfish product by pricing packaging machines. It is also likely that Goulburn Valley trout farm will eventually go into MAP production.

Since running the workshop FishMac have also indicated that they were going to investigate the suitability of scallops supplied by freezer vessels for MAP.

An industry brochure describing how to package seafood in MAP has been prepared and is present in Appendix 12.

Further Development

The need to produce a bulk pack was identified by the Marketing component of this investigation and it recommended that funds for a second project investigating bulk packs be sort. The packing equipment available to the researchers restricted the volume of a mono layer bulk pack to approximately 1.5kg of seafood. There was some limited work carried out within this project on multilayer bulk packs. The success of this project is dependent on the production of MAP seafood products by a participating company and is more achievable by developing retail packs with a number of companies.

The recommendation made by the marketing report was followed and an application to FRDC for funding a project in 1998-1999 was prepared and submitted. The application was unsuccessful so the design of bulk packaged MAP seafood has to be resolved by industry.

Conclusion

All of the objectives identified in the project contract have been met.

1. The market research and industry discussions identified a range of species and markets where opportunities existed. These discussions involved seafood processors, supermarket seafood buyers, seafood chefs and caterers and packaging and equipment suppliers. The project findings have been regularly disseminated to industry through newsletters and a workshop that was run at the conclusion of the project.
2. Two types of packages were evaluated and are suitable for a wide variety of species. The first package was an impermeable tray sealed with a vacuum pack using a permeable membrane that was placed in a barrier bag and then evacuated and flushed with a 100% CO₂ atmosphere. The other pack was composed of an impermeable tray, which allowed for a head space equal to that of product which was evacuated, flushed with a 60/40 mix of CO₂ and N₂, and sealed with an impermeable non-fogging transparent membrane.
3. The choice of the type of package to be used will be determined by the method of distribution, conditions of retail presentation and anticipated shelf life. The pack size can differ depending on the amount of a particular species a customer may want at any one time. Bulk packs can be produced using a permeable membrane pack in a barrier bag but the seafood should be restricted to only one layer deep.
4. The microbiological soundness of MAP seafood has been proven with the extension of shelf life of four different seafood commodities. Some species identified during the marketing study were found to be unsuitable for MAP processing because of initial high bacterial counts, even after improvements were recommended to the processors.
5. There were a number of industry partners who participated in the development of products within the project with four different products being produced. A number of these are now continuing with this product into the commercial arena.
6. The safety and shelf life of four MAP seafood products have been documented in this report. The newsletters and workshop disseminated the major findings for these products. The improvements to processing lines of a number of companies initiated by this project has led to better quality seafood to the consumer. The industry standards present in the non-technical summary section of this report have also been presented in an article about the project in the latest edition of Seafood Australia.

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Appendix 1: Intellectual Property

No intellectual property was identified in the course of operating this project.

Appendix 2: Project Staff

Name	Position
Steve Slattery	Seafood Chemist
Wee Sang Kwee	Senior Microbiologist
Reginald Reeves	Laboratory Technician
Browyn Warfield	Marketing Officer

Appendix 3 Score Sheets For Demerit Assessment

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SCALLOPS STORED AT 4°C IN MAP

SAMPLE A

TIME IN CO2 PACK	TIME IN AIR	DATE SAMPLED

COLOUR MeatOverall	V.Bright white/White/ Dull white / Grey	
	0 1 2 3	
Mixture of white to grey	<20% 40 60 80 >80%	
	0 1 2 3 4	
COLOUR Roe Overall	V.Bright red/Red/ Dull Red / Grey or Yellow	
	0 1 2 3	

PARASITES	None / Slight / Excessive	
	0 1 2	
Type	Translucent/Orange	
	0 1	

FLESH APPEARANCE	Entire/Slight cracks/Moderate/Almost split	
	0 1 2 3	

DRIP	None / Slight / Excessive	
	0 1 2	

TASTE Raw Odour	No off odours/Neutral/Slight/Excess Off odour	
	0 1 2 3	
Description	.....
Cooked drip	None / Slight / Excessive	
	0 1 2	
Cooked Odour	No off odours./Neutral / Slight/Excess Off odour	
	0 1 2 3	
Description	.....
Flavour	V. sweet/Sweet/Neutral/Slightly spoilt/Spoilt	
	0 1 2 3 4	
Texture	Chewy / Firm / Weak / Gummy / Soft	
	0 1 2 3 4	

SAMPLE B

COLOUR MeatOverall	V.Bright white/White/ Dull white / Grey	
	0 1 2 3	
Mixture of white to grey	<20% 40 60 80 >80%	
	0 1 2 3 4	
COLOUR Roe Overall	V.Bright red/Red/ Dull Red / Grey or Yellow	
	0 1 2 3	

PARASITES	None / Slight / Excessive	
	0 1 2	
Type	Translucent/Orange	
	0 1	

FLESH APPEARANCE	Entire/Slight cracks/Moderate/Almost split	
	0 1 2 3	

DRIP	None / Slight / Excessive	
	0 1 2	

TASTE Raw Odour	No off odours/Neutral/Slight/Excess Off odour	
	0 1 2 3	
Description	.....
Cooked drip	None / Slight / Excessive	
	0 1 2	
Cooked Odour	No off odours./Neutral/Slight/Excess Off odour	
	0 1 2 3	
Description	.....
Flavour	V. sweet/Sweet/Neutral/Slightly spoilt/Spoilt	
	0 1 2 3 4	
Texture	Chewy / Firm / Weak / Gummy / Soft	
	0 1 2 3 4	

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SWORDFISH STORED AT 4°C IN MAP

SURFACE SAMPLE STILL IN PACK GAS MIXTURE 100%CO₂ 56%CO₂
 TIME IN PACK TIME IN AIR DATE SAMPLED TASTER

DRIP None / Slight / Excessive
 0 1 2

COLOUR WHITE MUSCLE White/Cream/ Dull cream / Grey
 0 1 2 3
 IN PACK RED MUSCLE V.Bright Red/Red/ Dull Red / Brown
 0 1 2 3
 DEPACK RED MUSCLE (30 MIN AIR) V.Bright Red/Red/ Dull Red / Brown
 0 1 2 3

PARASITES None / Slight / Excessive
 0 1 2
 Type Transluscent/White
 0 1

FLESH APPEARANCE Entire/Slight Gaping/Moderate/Badly gaping
 0 1 2 3

TASTE Raw Odour No off odours/Neutral/Slight/Excess Off odour
 0 1 2 3
 Raw Odour (30 MIN AIR) No off odours/Neutral/Slight/Excess Off odour
 0 1 2 3
 Description
 Cooked drip None / Slight / Excessive
 0 1 2
 Cooked Odour No off odours./Neutral / Slight/Excess Off odour
 0 1 2 3
 Description
 Flavour V. sweet/Sweet/Neutral/Slightly spoilt/Spoilt
 0 1 2 3 4
 Texture Chewy / Firm / Weak / Gummy / Soft
 0 1 2 3 4

BOTTOM LAYER

COLOUR WHITE MUSCLE White/Cream/ Dull cream / Grey
 0 1 2 3
 IN PACK RED MUSCLE V.Bright RED/RED/ Dull RED / BROWN
 0 1 2 3
 DEPACK RED MUSCLE (30 MIN AIR) V.Bright RED/RED/ Dull RED / BROWN
 0 1 2 3

PARASITES None / Slight / Excessive
 0 1 2
 Type Transluscent/WHITE
 0 1

FLESH APPEARANCE Entire/Slight Gaping/Moderate/Badly gaping
 0 1 2 3

TASTE Raw Odour No off odours/Neutral/Slight/Excess Off odour
 0 1 2 3
 Raw Odour (30 MIN AIR) No off odours/Neutral/Slight/Excess Off odour
 0 1 2 3
 Description
 Cooked drip None / Slight / Excessive
 0 1 2
 Cooked Odour No off odours/Neutral/Slight/Excess Off odour
 0 1 2 3
 Description
 Flavour V. sweet/Sweet/Neutral/Slightly spoilt/Spoilt
 0 1 2 3 4
 Texture Chewy / Firm / Weak / Gummy / Soft
 0 1 2 3 4

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SALMON STORED AT 4°C IN MAP

SURFACE SAMPLE STILL IN PACK GAS MIXTURE		100%CO ₂	56%CO ₂	
TIME IN PACK	TIME IN AIR	DATE SAMPLED	TASTER	
DRIP		None / Slight / Excessive 0 1 2		
COLOUR	IN PACK MUSCLE	V. Bright orange/orange/ Dull orange/ BROWN 0 1 2 3		
	DEPACK MUSCLE (30 MIN AIR)	V. Bright orange/orange/ Dull orange/ BROWN 0 1 2 3		
FLESH APPEARANCE		Entire/Slight Gaping/Moderate/Badly gaping 0 1 2 3		
TASTE	Raw Odour	No off odours/Neutral/Slight/Excess Off odour 0 1 2 3		
	Description	.....	
	Cooked drip	None / Slight / Excessive 0 1 2		
	Cooked Odour	baked, meaty,oily/earthy,musty/musty,sour/sour,stale fruit/rancid,sweaty 1 3 5 7 9		
Flavour	Description	.....	
	strong meaty,sweet,oily/loss of sweet,meaty,sl	musty/sour,musty/sour,bitter/putrid,nauseating 1 3 5 7 9		
	Texture	Chewy / Firm / Weak / Gummy / Soft 0 1 2 3 4		
MOISTURE		Moist / Slight Moist/ Slight dry/ Dry 0 1 2 3		

Sample 2

DRIP		None / Slight / Excessive 0 1 2		
COLOUR	IN PACK MUSCLE	V. Bright orange/orange/ Dull orange/ BROWN 0 1 2 3		
	DEPACK MUSCLE (30 MIN AIR)	V. Bright orange/orange/ Dull orange/ BROWN 0 1 2 3		
FLESH APPEARANCE		Entire/Slight Gaping/Moderate/Badly gaping 0 1 2 3		
TASTE	Raw Odour	No off odours/Neutral/Slight/Excess Off odour 0 1 2 3		
	Description	.....	
	Cooked drip	None / Slight / Excessive 0 1 2		
	Cooked Odour	baked, meaty,oily/earthy,musty/musty,sour/sour,stale fruit/rancid,sweaty 1 3 5 7 9		
Flavour	Description	.....	
	strong meaty,sweet,oily/loss of sweet,meaty,sl	musty/sour,musty/sour,bitter/putrid,nauseating 1 3 5 7 9		
	Texture	Chewy / Firm / Weak / Gummy / Soft 0 1 2 3 4		
MOISTURE		Moist / Slight Moist/ Slight dry/ Dry 0 1 2 3		

TROUT STORED AT 4°C IN MAP

Extending the high quality life of seafood

SURFACE SAMPLE STILL IN PACK GAS MIXTURE 100%CO₂ 56%CO₂
 TIME IN PACK TIME IN AIR DATE SAMPLED TASTER

DRIP		None / Slight / Excessive			
		0	1	2	3
COLOUR	IN PACK MUSCLE	V.Bright orange/orange/ Dull orange/ Brown			
		0	1	2	3
	DEPACK MUSCLE (30 MIN AIR)	V.Bright orange/orange/ Dull orange/ Brown			
		0	1	2	3
FLESH APPEARANCE		Entire/Slight Gaping/Moderate/Badly gaping			
		0	1	2	3
TASTE Raw Odour		No off odours/Neutral/Slight/Excess Off odour			
		0	1	2	3
	DEPACK ODOUR	No off odours/Neutral/Slight/Excess Off odour			
		0	1	2	3
	Description	.....		
	Cooked drip	None / Slight / Excessive			
		0	1	2	3
	Cooked Odour	baked, meaty,oily/earthy,musty/musty,sour/sour,stale fruit/rancid,sweaty			
		1	3	5	7
	Description	.....		
	Flavour	strong meaty,sweet,oily/loss of sweet,meaty,sl musty/sour,musty/sour,bitter/putrid,nauseating			
		1	3	5	7
	Texture	Chewy / Firm / Weak / Gummy / Soft			
		0	1	2	3
MOISTURE		Moist / Slight Moist/ Slight dry/ Dry			
		0	1	2	3

Sample 2

DRIP		None / Slight / Excessive			
		0	1	2	3
COLOUR	IN PACK MUSCLE	V.Bright orange/orange/ Dull orange/ Brown			
		0	1	2	3
	DEPACK MUSCLE (30 MIN AIR)	V.Bright orange/orange/ Dull orange/ Brown			
		0	1	2	3
FLESH APPEARANCE		Entire/Slight Gaping/Moderate/Badly gaping			
		0	1	2	3
TASTE Raw Odour		No off odours/Neutral/Slight/Excess Off odour			
		0	1	2	3
	DEPACK ODOUR	No off odours/Neutral/Slight/Excess Off odour			
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	Description			
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		1	3	5	7
	Texture	Chewy / Firm / Weak / Gummy / Soft			
		0	1	2	3
MOISTURE		Moist / Slight Moist/ Slight dry/ Dry			
		0	1	2	3

Appendix 4 Sensory Comments

Scallop Trial Four Comments

<p>Odour and appearance</p> <p>day 0 air musty weedy slight yellowing on outer surface grilled and weedy smell but not overpowering slight yellowness on edge smooth surface minor cracks at edges burnt odour very minimal/small cracks in meat, white in appearance musty smell odour slight grill smell and cracks smooth minor cracks clean solid white in colour, odour like that of a clean smelling scallop</p> <p>day 3 air cardboardy smoky smell baked type odour milky cabbagey fresh/clean smell, scallopy like crab like odour burnt smell grilled smell creamy pinky tinge very fine amount of OFF WHITE/greying, SMALL some yellowing on outer edges shine on the surface</p> <p>day 3 MAP only very slight ammonia type smell - not offensive stale odour brussel sprout, cabbage type odour pink colour clean scallopy like odour and a few fine cracks in the flesh, not gaping though... hint of aromatic 'garlic' clean and strong odour..... shiny grilled crab like odour slight weedy</p> <p>day 3 MAP and day 3 air perfect lacks the nice fresh odour I would expect. there is quite a strong odour but I can't identify it. Sort of savoury v sl cabbage type smell salty a bit of a cabbage smell ammonia & cabbage cardboardy, oily chip smell</p>	<p>heavy grilled smell slight musty / stale odour faint garlic cream parts on the surface very small yellow patches, on edge and tiny? cracking confined to only one END of scallop, not across whole animal pale pink-cream colour - off-white shiny product grilled small over shadows sweet slight yellowing</p> <p>day 6 air slight boiled milk type odour burnt cabbage fishy odour good appearance little cracking/splitting nil yellowing sweaty smell and but fresh odour overall sweetness departs after minute or so good over all slight absence of normal seafood odour smooth shiny</p> <p>day 6 MAP baked odour slight cabbage/brussel sprout type odour pinky off- white not very scallop like in the flavour department cabbagey weedy other smells : mix of ammonia & cabbage good colour a lot of free moisture slight yellowing on outer edges strong grilled smell followed by sweet not much smell of sea slight stale odour - musty faint garlic</p> <p>day 7 MAP only a hint of grey slight cabbage smell appearance fine no problems smells like an old fish, before it goes rotten very light on the grey scale, definitely more white than anything fishy grilled smell not unattractive very low on the sulphur, big on the meaty scallopy nose... stale</p> <p>day 6 MAP and day 6 air slightly cardboardy odour - oily potato chips mainly grilled smell difficulty to detect other cabbage type odour</p>
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very slight in the sulphur, nose..
 lacks fresh sea smell
 smells like crab a bit
 slight pinky creamy tinge
 cracks filled with 'collagen?'
 no off odours detected or discolouring
 small orangey sludge build up in the cooking
 vessel, not present in previous

Texture and flavour

day 0

both beautiful
 little chewy but good
 full typical scallop flavour
 slight weedy taste, texture slightly softer the
 previous
 musty
 perfect texture and dam nice flavour
 very good sample little bit of grilled taste but
 not detract from scallop
 good

clean and pleasant

day 3 air

slight sticky texture, bitter cabbage/brussel
 sprout type flavour
 more salty
 smooth texture
 mushy and soft to start, but you got left with
 a chewy bit.....
 a slight weedy taste, not strong..
 texture perfect, very slightly salty
 very salty
 grilled

day 3 MAP

sticky texture, cabbage/brussel sprout type
 flavour (strong)
 grilled

strong fresh flavour, texture firm/ good.
 meaty little scallop this one....

texture perfect, slightly salty
 slight acid/astringent aftertaste

day 3 MAP and day 3 air

slight sticky, very slight cabbage type
 flavour
 metally kind of flavour on the side of the
 tongue?? only slight?
 prawn like
 slight cabbage
 slight tingle on tongue
 slight stale after taste
 faint garlic

day 6 air

perfect
 slight 'chemical' taste and not real fresh

very slight sticky texture, cabbage flavour
 no body, soft and gooey, scallop slop
 flavour weak and non-nondescript, not
 yucky just blah

great texture a little weedy in flavour
 strong salt aftertaste

salty, tree tremendous texture

day 6 MAP

OK but lacks the really fresh taste
 slight cabbage/brussel sprout type flavour
 one of them has a slight hint of yellow
 through it??

that metally taste down the side of my
 tongue????

texture not too bad

small amount of froth like substance on the
 surface ??

one sample slightly dry the other fine
 slight stale aftertaste

losing the meaty intensity

day 7 MAP

variable degree of bitterness between
 samples

slight sticky texture, slight cabbage type
 flavour

great flavour slight tingle on the tongue
 sensation but not detractive

stronger than previous metally taste on the
 side of my tongue.

the acid/sour note dominates although there
 is no identifiable off flavour

cabbagey

day 3 MAP and day 7 air

a lot more meaty then fishy

not very scallopy

cabbage

very slight sticky, cabbage type flavour
 good sample no problems what so ever

day 7 MAP and day 3 air

lacks texture

FRESH/STALE?? gives the impression of
 FRESH but after time I get that metally kind
 of sense on the side of tongue(maybe a stale
 sort of thing)??

cabbagey

better than other samples

tasted more acrid than most, possibly not as
 fresh??

slightly tough but not over tough
 cabbage type flavour and very salty

day 6 MAP and day 4 air

slight sticky texture. cabbage type flavour
 and some fishy flavours

cabbagey

very moist...not a great deal of body!!

a savoury sort of taste. lacks the really

<p>fresh taste very slight old flavour I could be wrong day 6 MAP and day 6 air fairly sticky texture which tends to bind teeth together. Cabbage type flavour slight old flavour like soured milk affect really strong in the metally taste down the side of the tongue, also a chlorine (slight) taste up near the roof and as an after taste???? slight cabbage cabbagey full scallop flavour bitter flavour underlying the more favourable attributes oystery!!! day 3 MAP very sweet very nice scallop... very similar to each other a slightly sour aftertaste but not at all objectionable a little chewy that's all</p>	<p>day 3 MAP and day 3 air the 2 samples had slightly different texture not fantastic but a scallop very good product no complaints slight very slight acid</p> <p>General comments</p> <p>days 0 slight weedy taste but not poor by any standard good damned scallops clean and pleasant taste and texture, just not incredibly strong in either department good sample a bit small</p> <p>days 3 - air slight stringy texture very good product it's a scallop, just not a really strong tasting one.....</p>
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Scallop Trial Five Comments

<p>Odour and appearance</p> <p>day 0 air appear cracked slight yellow odour & appearance good burnt odour overall I'd call it clean soft/weak odour, appearance- not all that flash, looks a bit tired? potato smell baked smell, creamy colour creamy colour day 3 air slight cabbage type odour not as fresh and clean seafood smell some absence of typical sea smell, minor SO₂ odour grilled odour but good spots in scallop ? not sure what it is maybe parasites? slight pink slight pink hue slightly darker centre area on one, not a yellowing day 3 MAP cabbage/brussel sprout type smell very soft nose good fresh odour vegetable very soft off white towards an very light</p>	<p>orangery hint in the centre of the animal slight pinkish more discoloured than most - yellow throughout good appearance beware of the roe day 3 MAP and day 3 air slight burnt odour very soft odours.... don't smell all that scallopy? grilled odour slight pink hue sunken/squashed?? look? roe attached signs of colour of roe day 6 air baked odour rubbery smell not so much an OFF ODOUR as more a slight hint of, stale water ?? grilled smell black spots good overall appearance stringy bits attached (orange) day 6 MAP slight burnt potato smell very slight on the sulphury grilled odour not vivid white good firm looking scallop roe attached</p>
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Days 7 - MAP

slight sulphur odour
 cabbage/brussel sprout type odour
 slight yellowing
 grilled smell
 baked very soft hint of a mouldy/dank kind
 of odour??
 slight potato smell
 background sulphur smell
 good appearance roe attached colour
 present

overall a good solid white and minimal
 cracks/splits. appear to be firm, not sunken
 sample, slight yellowing though on outer
 look moist?

day 3 MAP and day 7 air

grilled smell
 smells strong and clean, no other odour
 that potato smell again!
 little odour at all
 very good appearance
 solid firm looking scallop
 cracks but not open cracks
 some discolouration on one side of one
 plump

day 6 MAP and day 4 air

grilled smell
 not a really crisp odour
 a baked odour
 milky fish
 it is another seafood odour - maybe cooked
 lobster??
 very light tinges of yellow near edges
 basically white..

slight H₂S

day 7 MAP and day 3 air

over whelming grilled smell which masks
 every thing else
 very low on the sulphur tinge
 a baked odour
 certainly not the typical scallop odour! Not
 fresh, but not stale. It was an acceptable
 seafood odour, but not typical. A bit like
 pan fried whiting??

slight fishy and potato-type smell
 roe attached colour
 has a slight mushy/spongy sort of
 appearance

slight pinky creamy tinge

day 7 MAP and day 6 air

kind of fresh smell but sweaty slightly
 brown patches
 sunken look?

day 6 MAP and day 7 air

a real seafood odour
 lacks a typical sea smell

cabbage type flavour
 little typical odour
 very soft ammonia smell, if any?? very
 meaty odour
 faint garlic
 steamy weedy
 plump, better overall appearance. than
 other

Texture and flavour**days 0 air**

chewy roe?? slight tangy taste
 cooked flavour ie grilled taste but great
 texture as new
 very good texture and flavour
 cabbage type flavour
 slight cabbage flavour
 nothing flash, flavour not all that
 impressive, bit towards the stale side
 very soft flavour, texture not to fantastic,
 falls apart very quick

cabbage

rubbery texture, milky/creamy taste
 blancmange or junket texture

day 3 air

slight cabbage type of taste
 texture - turns to mush very quick.
 FLAVOUR- not to strong, goes very
 quick.. soft sulphur like flavour left??
 only fair flavour
 possibly a bit acid and a bit bitter
 great scallops taste & texture

day 3 MAP

slight sticky type texture, cabbage/brussel
 sprout type flavour
 not actually sour/stale taste more hints of
 that sort of flavour, sulphur like after taste
 left behind not strong though
 still sweet and fresh, but with an aftertaste
 of stale and bitter/acid
 slight after taste but a scallop ie type taste
 not negative (mature??) rubbery & slightly
 dry could be the roe ligament)?

day 7 MAP

relatively bland flavour
 cabbage type flavour
 good slight chewy texture (roe attached)
 fine sample
 tender with slight cabbage taint!
 had all the scallop tastes + an acidic
 (maybe bitter?) kind of sensation on the
 front region of the tongue, but it still
 tasted sweet???

this sample was of a different texture. a
 little crunchy, firm but not tough

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<p>also a slight 'other' taste - slightly scented, I think</p> <p>day 3 MAP and day 7 air slight tanginess again more meaty than fishy/sea, lightest hint of that meaty taste I mentioned, good body, doesn't fall apart as quick as others.... just a touch bitter little bit watery</p> <p>day 6 MAP and day 4 air slight old or flavour detected, becoming more pronounced plus tanginess on tongue? that metally taste there softly, around the outside of the tongue strong scallop still slight sweaty flavour very firm around the edges possibly slight acid/bitter. Texture with the grain was soft, across the grain was crunchy</p> <p>day 7 MAP and day 3 air detect a tangy flavour when very hot but disappears after 10 seconds exposure flavour - slight hint of a metally kind of taste (like if you chew alfoil??) texture - a little soft again, not typical. lobster/fishy, but not real fresh (although not actually stale) good texture and flavour, better of the three samples</p> <p>day 7 MAP and day 6 air very light on in the stale dept' it's more similar to that metally taste I've mentioned, down the side of the tongue similar to licking alfoil?? still had those taste similar to a scallop.....?</p> <p>day 6 MAP and days 7 air good firm initial bite, soft springy texture tasted fresh and very meaty/strong cabbagey</p> <p>General comments</p> <p>day 0 air good product slight chewy & slight tangy but OK texture put me off kind of like a really frozen scallop? scallop but low grade on the overall very nice</p>	<p>day 3 Air average to low not as good as some - a bit of an aftertaste?? - fatty seafood taste?? besides spots & signs of the roe</p> <p>day 3 MAP well, they were scallops but I ain't paying more then \$10/kilo.. not very flash..... bit tough and not so nice to taste due to the loss of moisture the product tasted a bit rubbery/drier but not any better or worse than Days 3 Air</p> <p>day 6 MAP strange sweet?? after taste??</p> <p>day 7 MAP very good sample strong acidic tingle taste</p> <p>day 3 MAP and day 7 air good sample with sweet flavour slight oldness or development in the last scallop, similar to vanish smell condensing on tongue I might have completely miss read the odd flavour but that metallic taste?, it is like licking alfoil and down the sides of my tongue?????</p> <p>pretty average and ordinary</p> <p>day 6 MAP and day 4 air this one tastes a bit old and slight acid / sour not fantastic but still a scallop, metallic taste stays with me awhile, maybe I taste the tin they are prepped in???</p> <p>day 7 MAP and day 3 air good scallops just that tanginess when very hot is that normal for scallops?? OK, maybe not the freshes tasting scallop??</p> <p>day 7 MAP and day 6 air not all that fantastic</p> <p>day 6 MAP and day 7 air <i>No comments</i></p> <p>day 3 MAP and day 3 air <i>No comments</i></p> <p>day 6 air good appearance, poor flavour and texture not real flash, bland!! very plain and ordinary - no flavour fine product just a weedy mature taste</p>
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Broadbill Swordfish Retail Pack Trial One Comments	
<p>Odour Comments</p> <p>day 0 fresh fish odour cooked and lactic acid smell sweaty and sulphury odours are present but weak muddy odour salty meat odour</p> <p>2 days air dark yellow in colour unpleasant bitter aftertaste, general overall flavour - poor gamey oily/buttery very meaty cat food cooked fish and sour</p> <p>3 days air fishy cooked odour with sour note but acceptable nose of old/very matured meaty, not so much off stale odour</p> <p>3 days MAP fresh fish cooked smell plus sweet smell very light in the sweaty, very meaty nose, somewhat cleaner than the 3 day air sample</p> <p>6 days MAP not very fishy smelling, more meaty old odour a bit of sweaty smell</p> <p>8 days MAP stale odour doesn't smell too good this smells a combination of fresh and old - which actually smells OK, it reminds of certain canned fish products vegetable-like rubbery off odour</p> <p>10 days MAP I normally don't eat things that smell like this! there was a very slight hint of an off-type odour (kind of sweaty/stinky) oldish odour with cooked fish smell not entirely unacceptable but definitely not high quality odour! very poor - hopefully the last?!!! strange old rotten fruity potato smell</p> <p>Appearance Comments</p> <p>day 0 off white and slight grey and slightly shiny clean/fresh cooked meaty fish nose for the rest... very good flavour some fat and connective tissue evident but not detrimental to appearance very dark for fish</p>	<p>2 days air free moisture in dish poor texture free moisture in dish dark yellow in colour unpleasant bitter aftertaste general overall flavour - poor slight tinnie nose looks rather unattractive greyish slight dry</p> <p>3 days air looks quite good highly visible connective/ fat striations?? yellowish tinge to some edge and yellow hue to free moisture in the dish poor appearance, free liquid yellow colour - not very nice grey connective tissue slightly dark but OK</p> <p>3 days MAP appearance is good little coagulated protein, looks more eatable. grey spot in sample jellied connective tissue present</p> <p>6 days MAP little bedraggled slightly greyish looks OK</p> <p>8 days MAP slightly milky aroma OK the liquid in the dish is brown free moisture is brownish colour</p> <p>10 days MAP little old looking but other wise quite good very poor - hopefully the last?!!!</p> <p>Texture and Flavour Comments</p> <p>day 0 very good flavour light on in the specs and coagulated protein good firm initial bite very good flavour metallic taste sea flavour powdery a little bit dry in texture</p> <p>2 days air metallic flavour free moisture in dish dark yellow in colour unpleasant bitter aftertaste general overall flavour - poor does have a slight old-fish kind of smell a very soft fish. Tastes better than it looks typical fish flavour very slightly sour and ??? another ??</p>

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<p>3 days air texture a bit sticky, mushy flavour, except for acid taste old meat?? slight soury tainty, not real fishy, no real texture at all, mush..... very poor metallic flavour chalky after chewing tender and oily</p> <p>3 days MAP texture, dry & unchewy taste, ok but bland with some acid slight sweet, slight sweaty/salty?? Actually has a texture ie some sort of body to it, soft and falls apart, fishy like flavour but not that strong... good metallic flavour two different textures in one sample-soft and firm oily smooth</p> <p>6 days MAP slightly sour tasting and not very fishy buttery flavour good flavour dry texture (not good) taste (acid sour flavour little bitterness too) oily / buttery flavour very slight acid and tender</p> <p>8 days MAP slight acid or bitter aftertaste very soft fish, tastes better than it smells metallic flavour little poorish look tasted like roast meat</p> <p>10 days MAP cotton wool texture. seems very dry stale taste very poor - hopefully the last?!!! none of the strange off-putting aroma came through in the flavour metallic flavour</p>	<p>General Comments</p> <p>day 0 much to dry light tinnie taste slightly chewy on final palate very good flavour quite soft flavour ok, but texture too soft</p> <p>2 days air free moisture in dish dark yellow in colour unpleasant bitter aftertaste. general overall flavour - poor not an off smell though drier texture than I like sample ok not as sourish as day one</p> <p>3 days air texture to sticky & mushy & flavour leaves acid/sour taste in mouth - OK for further processing but not fresh nor high quality presentation</p> <p>3 days MAP not as much acid in this one but a little dry and tough if you combine the flavour of this with double the texture of previous sample it would be acceptable better than days 3 air but not all that flash, similar to a very frozen fish meat, bit soft in the flavour and weak in the texture..... tender pleasant texture</p> <p>6 days air texture a little firm sorry chaps but this sample fails the high quality grade(1) to dry texture (2) flavour just acceptable (3) slight bitter after taste I liked it!</p> <p>8 days MAP little dry and bedraggled but OK, acceptable</p> <p>10 days MAP texture a bit to dry for high quality product and chewy. Flavour has some aged fish flavour plus a off flavour which cannot identify possibly weedy? acid/bitter after taste very poor - hopefully the last?!!!</p>
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Broadbill Swordfish Retail Pack Trial Two Comments**Odour Comments****1 day air**

buttery

the cooked odour is ok, but the sourish smell detracts from general odour

strong meaty going to slightly off

2 days air

slight old odour not necessarily off yet but on the verge of being

slight acidic odour

3 days air

loss of sweetness

boiled fish

buttery odour

good odour with slight acid/sourness but very acceptable

4 days air

cooked fish / oily smell, not fresh or sweet but not off, just cooked fish

boiled fish

8 days MAP

weedy with slight musty smell

light on in the sulphur and oily statements.....

very meaty though and a slight hint of sweet

10 days MAP

strong boiled milk type odour

soft sulphury nose, strong meaty fish pong.....

milky odour, sweet cooked fish odour (like with coconut milk)

14 days MAP

distinctive meaty smell - maybe like liver

cooked fish odour, no fresh fish smell detected

boiled milk odour

light acidic, sulphury/tinnie nose, not all that

meaty compared to the others

slight stale odour

16 days MAP

cooked fish aroma slightly developed but without the decline into a critical mass which could be

termed an off odour

baked smell

ght tinnie nose..... smells kind of burnt??

Appearance Comments**1 day air**

colour ok, slight markings but not unattractive

looks pretty good

2 days air

can't fault the look of this sample, it is damned good

3 days air

no comments

3 days MAP

good appearance shiny, moist, firm and juicy

gelatinous blob through piece

4 days air

yellowish colour too

white flesh, looks like snack meat but not offensive

free moisture - yellow, stale/old appearance

8 days MAP

good looking piece

slight browning on one corner, not from blood spot, more like a burning, but there is a couple of blood spots present

grey blotches

blue grey connective tissue

open/gaping flesh, visible coagulated protein within.....

ok appearance, good colour but a little deflated

14 days MAP

good looking fish, coagulated protein, crisp edge, looks good

pretty white with what appears to be a consistent texture throughout?

slight greenish colour

days MAP

shiny fresh looking subject, with excellent appearance and visual disposition

brownish and a bit on the dry side to look at.....

Texture and Flavour Comments**1 day air**

extremely sticky, nearly binds teeth together

good fish flavour, a little bland but the taste is fine, the texture is unfortunately far too soft

very soft but with a nice flavour, seems a bit dry in texture

very tender, nearly mushy

a little bland, little washed out but acceptable sample

a hint of acidity in the flavour, texture a bit dry and cotton woolly

3 days air

not much flavour and too dry

slight acid/bitter after taste

metallic flavour

3 days MAP

maybe a hint of acid flavour

soft texture, bitter/acidic aftertaste

flavour fine but texture is far too soft and mushy.

Also no depth in fish flavour, like a fatty fish taste? Texture fails again

16 days MAP

slight bland flavour inclining to a bitter or off

flavour on the tip and sides of tongue, at very

least bland, at worst bitter

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<p>sweaty would be a choice and tastes 'burnt' with an off sort of taint old meaty sock, text - mushy with a slight pastiness.....</p> <p>General Comments</p> <p>1 day air flavour is fine but subject far too soft in texture odour starting to deteriorate a little but very tender and tastes quite good sample is ok little acid but quite acceptable, not a fresh piece of fish obviously but quite acceptable</p> <p>3 days air very soft texture, fair appearance and taste</p> <p>3 days MAP if the texture was firmer this product would probably be OK, there is some loss of favour but it probably would be OK if texture was good</p> <p>4 days air texture acceptable but flavour washed out</p>	<p>8 days MAP product fell apart when trying to fork, it also has a tangy off taste but the fish cooked flavour is still there! good</p> <p>10 days MAP light on in flavour flavour ok, aroma ok, texture too sticky and soft dry cotton wool text with a hint of clean acid flavour bland washed out flavour & dried texture major detractors but still acceptable with right sauces passable but not flash.....</p> <p>16 days MAP the bland has a to bitter-like flavour and is the only detraction from an otherwise good product, the off flavour is similar to the dark flesh of fish tasted old and stale too dry and not much flavour</p>
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Atlantic Salmon Trial Two Comments	
<p>Odour comments</p> <p>day 0 air cooked fish aroma but not as strong as yesterdays? no off odours available/detectable by the nose hardly any odour slight stale/weedy odour present smells other than fresh, not so much off, just not fresh.???? a tinnie/sulphury smell, then again, maybe it's just me??</p> <p>1 day air absence of typical salmon odour, slight stale odour cooked fish odour (salmon definitely) natural sea odour - good raw fish odour somewhat offish/old sort of odour</p> <p>2 days air slight boiled milk type odour cooked salmon odour with very slight sweet smell meaty salty odour</p> <p>3 days air baked musty football sock??..... smells 'matured' oily nose is kind of old?? mainly cooked baked salmon odour but another odour is detectable, not stale but like a gas flush, neutral in effect but still part of the aroma make up. pleasant</p> <p>3 days MAP acid smell quite noticeable definitely smells sweet, and a bit fishy salty sweet odour but also a little sweaty very teen weeny amount of sweetness</p> <p>6 days MAP acidic type of odour milky odour and sweet which reacts like a fresh smell slight salty odour stale stale/musty??? maybe just a matured nose??? fishy though</p> <p>8 days MAP acidic odour an unfresh nose.... baked sweat?? mixture of baked fish, milk and soap odour okay but becoming quite strong</p> <p>Appearance comments</p> <p>Day 0 a bit blotchy brown edge free fat/oil visible</p>	<p>good pink appearance with some coagulation okay no brown specks, just brown fishy bits on one side....</p> <p>1 day air a lot of coagulated protein and external fat - obscures true colour looks a bit sad, ie white appearance all over and falls apart on the touch.. pink flash and dark flesh present but still attractive slight fatty / protein layer on surface - non detractive visible fat</p> <p>2 days air appears dryish free fat present grey brown flesh on edge of sample lots of coagulated protein okay some grey through the pink but acceptable to the eye some orange patches, white blobs</p> <p>3 days air palish..... mainly pink but some dark flesh on edges dry appearance</p> <p>3 days MAP looks like salmon? Appears a bit dry? good good pink colour some coagulation lots of oil in drip</p> <p>6 days MAP brown flesh at one end has a slightly off brown colour, yellow/greenish?? free moisture is oily only a little protein on surface pink to grey colour slightly pale smooth pink colour coagulated to some degree some orange specks</p> <p>8 days MAP acceptable appearance & colour pink as would expect of salmon coagulated oily bits too, free moisture was more oil, brown fleshy bits are not that brown-whitey sort of colour</p> <p>Texture comments</p> <p>Day 0 it tasted dry too?? fibrous and chewy, chewy not for rubbery, though pleasant texture, though very dry texture, although flaky pasty kind of firm and soft moisture, sample very good dry texture detracts from flavour chewy texture as</p>

<p>well - tastes like frozen sample to me (frozen then defrost)etc quite dry really like frozen fish that has been defrosted & cooked ie freezer Burn affect? dryish texture firm texture slightly dry but okay a little dry and slightly fibrous but acceptable Day 1 air slightly dry texture dry texture dry....fibrous and plenty of body.... a little pasty dry texture - not oily texture - smooth and mushy, solidish and a bit oily, flakish but doesn't really fall apart more fibrous the flaky, sticky but not an oily texture Day 2 air <i>no texture comments</i> Day 3 air falls apart initially and is fibrouschewy dry texture highly present like frozen sample cooked straight away without defrosting slightly dry tough Day 3 MAP fibrous and flaky in a fishy kind of way, falls apart in mouth yet has a body to masticate?? dry a little dry and chewy but superior to day 3 air in acceptability, still a bit dry though Day 6 MAP good firm initial bite, good/slightly firm texture, just a little dry? Day 8 MAP very dry, chewy texture</p> <p>Flavour comments</p> <p>Day 0 a slight bitterness to it, tinnie/sulphury....kind of blood like taste?? fresh blood of course (serious) but that could be the tinniness??? not all that salmony like slight bitter/acid aftertaste metallic flavour a real bitter kind of taste in back of mouth/roof little bland but I am not sure if this is the fish or my taste buds half my fish was dry and the other half moist with a slight blandness bland tasting like soaked in water or frozen & defrosted a hundred times delicate fresh taste, not a strong flavour at all meaty but okay salmon flavour but no great intensity involved blandness present no off flavours just a tad bland or shy of salt,</p>	<p>flavour not that of this mornings catch but very acceptable slight tinnie taste, little oil and a slight baked.. Day 1 air quite bland flavour a bit musty on the flavour slight bitterness in there some, oily, fishy/meaty isn't all that strong stale Day 2 air <i>no flavour comments</i> Day 3 air tinnie and old burnt oily taste..not all that strong in the fish flavour okay but not as good as fresh salmon taste brown skin part - muddy acid taste Day 3 MAP heavy after salt??.was moister than it looked?? okay seems to lack salmon flavour, bland in taste or less salmon than I am used to eating only slightly oily brown part at edge - muddy flavour Day 6 MAP slight acidity noticed flavour becoming dull metallic flavour stalish the piece with the skin on it tasted quite muddy Day 8 MAP nice flavour rather bland, lack of typical salmon flavour dry brown flesh - muddy flavour brown flesh tasted quite muddy</p> <p>General comments</p> <p>Day 0 dryish and not all that salmony.... very dry flavourless sample, sample lacks normal oil content that gives smooth texture and typical flavour characteristics. strange bitter after taste lurking around the upper reaches of the palette flavour a little down on yesterday (preliminary sample) - but still a very good sample I have no problems with this one except slight blandness textural dryness really does deduct from the overall qualitative milieu of the sample!</p>
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<p>texture a bit dry and bland in flavour not as good as last weeks salmon, more salmon flavour in the dark flesh then pink flesh good texture a tad dry but firm to taste, flavour okay with some blandness present but overall acceptable reasonably good product a little dry and a little bland but still a very good sample, keep it going! Day 1 air very pleasant slightly affected by acid in flesh possibly resulting from harvest method or some other cause!</p>	<p>not classed as high class.....edible though oldish sort of taste ie, not fresh sort of flavour/after-taste?? a tad dry but fishy Day 2 air <i>no general comments</i> Day 3 air texture much too dry for a good quality product, with resultant fibrous down side better than the other Day 3 MAP bit baked..... bit dry in texture sample need more moisture and flavour for my taste Day 6 MAP dry texture, lack of typical salmon taste, slight aftertaste -sour/bitter Day 8 MAP <i>No general comments</i></p>
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Atlantic Salmon Trial Three Comments

<p>Odour comments</p> <p>1 day air sulphur sharp odour</p> <p>2 day air chemical smell distinct sulphur smell sharp arid odour smells a bit muddy maybe herbaceous as well but not a unpleasant smell more fresh freshwater fish smell</p> <p>3 day air low level odour slight fishy smell, not bad and muddy metallic smell slight weedy odour sweaty</p> <p>3 day MAP maybe a little muddy smell very slight smells a lot more interesting than the other sample</p> <p>6 day air sulphuric smell</p> <p>6 day MAP almost odourless cooked chicken smell slight gaping flesh</p> <p>8 day MAP a sharp odour not a lot of odour a hint of sour smell smelled fatty not very salmon but a little fishy rather bland or little smell on the whole sulphide smell</p> <p>10 day MAP a bit cabbagey sharp acrid odour slight metallic muddy odour</p> <p>13 day MAP doesn't smell off, just a bit bland meaty baked odour more meaty than fishy, but very strong across the board light sulphide smell well past its use by date</p> <p>Appearance comments</p> <p>1 day air minimal amount of coagulated protein pale colour compared with yesterday paler than normal very pale, allot of coagulated protein and free fat present</p>	<p>2 day air a little free fat and coagulated proteins on the surface of the sample very pale colour very pale pinky orange colour sitting in a puddle with white bits of coagulated protein and some dark brown flesh</p> <p>3 day air coagulated protein (and free fat in dish) grey pale colours</p> <p>3 day MAP a little coagulated protein some free fat in dish greater depth of colour than 517</p> <p>6 day air grey colour on exterior - coagulated protein pale pale colours in the pinker range rather than orange turning brown</p> <p>6 day MAP brown colour coagulated protein and free fat on surface of sample</p> <p>8 day MAP light brown colour very pale colours very pale in colour some brownish discolouration on flesh a little bit of coagulated proteins present</p> <p>10 day MAP colour quite rich in the orange and pink shades</p> <p>13 day MAP good colour quite a deep pink/orange two small gaps, moist appearance, anticipate the texture to be prominent?? very pale</p> <p>Texture comments</p> <p>1 day air beautiful quite firm</p> <p>2 day air large flakes almost like canned tuna style look to it pleasant texture, nice and meaty</p> <p>3 day air very big flakes that come apart easily but very dry as well only very slight stickyness very nice texture</p> <p>3 day MAP a bit more cotton woolly than 517 and less flakey</p>
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6 day air

very dry

8 day MAP

moist initially but then dries and gets a cotton wool effect in the mouth its fibrous but the fibers are soft

10 day MAP

doesn't form a wad in the mouth

13 day MAP

falls apart into several good size chunk, not very fibrous at all...

slightly forms a wad in the mouth

Flavour comments**1 day air**

Delicious

metallic flavour

the taste of the dark flesh on the outside of sample was a strong blood fish taste as in tailor that has not been bled Taste fishy rather than salmon

2 day air

metallic

not a LOT of flavour but very tasty none the less

very slight metallic flavour-can't taste the muddy flavour I could smell

3 day air

has an aftertaste but I can't really describe it, could be sweetness remains in mouth a long time after swallowing

pretty bland, low level flavour profile stale

tasteless - like eating cotton wool

3 day MAP

lots of flavour but texture is too dry

quite a lot of flavour

slight metallic flavour

slightly stale

6 day air

not a lot of flavour but what is there is nice enough

6 day MAP

astringent

hint of sour flavour

8 day MAP

almost no salmon flavour but a clean acid flavour present

little bit fishy and meaty but overall has a stale taste funny aftertaste to it almost on the back of the throat Dark muscle is the part that adds any flavour

slightly acidic taste

10 day MAP

metallic flavour

not very fishy but a clean acid flavour evident

13 day MAP

a bit bland with just a hint of bitterness metallic flavour

more meaty as opposed to fishy, still a bit salmon like in flavour, just very meaty.....

not much flavour at all quite dry and uninteresting

General comments**1 day air**

not bad, well at least it wasn't undercooked like yesterdays samples

over cooked

Tastes great despite pale colour and hint of acidic odour

2 day air

meat seemed better down bottom of the chunk where it had been sitting in the liquid. Less dry than the rest of the piece

3 day MAP

over cooked

6 day air

rubbery, comes apart in muscle groups smells awful but tastes OK

6 day MAP

deeper colour not a lot of taste and slight sourness

starting to pick up a sour taste (slightly bitter after taste), better of the two sample but just only. Sample 153 too dry

8 day MAP

lacks flavour but the texture is good

good product for fish curry

wouldn't pay for it if served at a restaurant

10 day MAP

good flavour

good for use in highly flavoured (added)

since it has little flavour of its own

nice texture

13 day MAP

not the freshest flavour

seems to have lost all flavour maybe

slightly fishy but none of the oily flavour associated with salmon

this sample seemed to be from a much larger fish - it was quite coarse and almost tough

Rainbow Trout Trial Two Comments

Odour comments

0 day air

crisp/fresh sort of odour

hint of metallic odour

metallic

1 day air

earthy

torn between sulphury and metal???

2 day air

more meaty than fish

mossy smell but very slight

not a lot of odour/s

2 day MAP

slightly earthy

very little odour at all but slight baked

smell

very slight ammoniac

3 day air

buttery

hardly any odour at all but what is there is

hard to name mostly musty or muddy

sulphury/metal nose, more meaty than fishy

3 day MAP

fishy like

oily odour

smelled metallic fishy smell only light

sweet

6 day air

metallic

6 day MAP

hardly any odour at all

mouldy/musty is maybe more an 'unfresh'

sort of smell??

oily odour

9 day MAP

a bit sort of spicy

maybe not OFF ODOUR, but a kind of milky/creamy sort of nose???? very faint??

odour is not really strong but is it more meaty or baked than fishy though there is a fishy smell. Typical trouty odour -very little muddy or metallic smell.

something unusual about the odour but not sure what!

Appearance comments

0 day air

lots of coagulated protein - like cooked egg

white over the fish, free liquid in the tray

about half way up side of fish piece

very slight coat of coagulated protein,

almost a smear.

1 day air

almost white , very pale pink

very slight in the gap dept'

1 day air

2 day air

bit more than slight but not quite moderate

coagulated protein, good looking sample

otherwise

liquid in dish has a green hue

2 day MAP

washed put

3 day air

A Soft 'look'??

liquid in the dish is GREEN/Yellow!!!!

very pale colour, more white than pink

3 day MAP

solid looking flesh....

6 day air

one or two brown specks looks like

undissolved instant coffee

solid looking

6 day MAP

green yellow colour of liquid in the baking dish

very slight gaping

9 day MAP

considerable darkening of the flesh in the

belly-flap region, colour is washed out...

free moisture is a yellow colour

very pale and the free moisture is opaque

Texture comments

0 day air

No comments

1 day air

A little mushy

2 day air

juicy

2 day MAP

wads in the mouth a bit

3 day air

soft, but not quite mushy

3 day MAP

excellent texture- very sticky

fish like

6 day air

texture looks like it is in flakes until touched then looks like it's in lengths of fibres

very smooth texture

9 day MAP

soft to compress but chewy after

soft??? ALMOST mushy like??? goes a bit cotton-woolly like late in the chew?

Flavour comments

0 day air

dies off rather quick?

<p>compared to yesterday there is no musty mouldy flavour at all no really distinct sort of flavour. meaty/muddy sorta fishy with a dash of oil?</p> <p>2 day air musty flavour stronger than the odour oiler than the others</p> <p>2 day MAP tastes very trouty but too dry washed put/blandish?</p> <p>3 day air earthy taste not a lot of flavour weedy/grassy sorta flav, I didn't pick fresh</p> <p>3 day MAP not a lot of flavour at all</p>	<p>6 day air almost a plastic sort of taste???? Buttery- but I don't see it as being similar to Oily though??</p> <p>6 day MAP really good flavour tastes sweet and meaty but it's a bit too dry and forms a bit of a mat in the mouth unfresh sort of taste, very meaty though</p> <p>9 day MAP bland first bite was extremely muddy - taken from near belly flap area I think second bite wasn't so bad but there was also a strong weed / metal flavour sour taste I put with the milky/creamy odour, even tastes a little like a dairy product??? along with the metal taste washed out sort of a fish flavour more of a meaty than a fishy.....</p>
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Rainbow Trout Trial Three Comments

<p>Odour comments</p> <p>0 day air a little muddy odour present. metal sort of nose.... and dirty .. oily odour</p> <p>0 day MAP only very slight sweaty odour smelled a bit like worn socks not a lot of fish odour quite sharp - cleared the sinuses tinnie? very muddy odour</p> <p>1 day air earthy smell. hard to know if musty odour is stronger than muddy fish oil muddy muddy metallic odour very sharp on the nose</p> <p>1 day MAP almost odourless muddy</p> <p>2 day air fish oily only a little weedy/muddy odour present strong muddy metallic odour doesn't smell fresh but doesn't smell off or old either. Fish smell is overpowered by muddiness very strange unfish like nose, kind of smells like the color green???</p> <p>2 day MAP not a lot of odour at all rather muddy</p>	<p>very slight metallic muddy odour but mainly smells of cooked meat and fresh water fish</p> <p>3 day air quite a sharp smell not off or off putting but quite fishy as well</p> <p>3 day MAP oily odour sharp muddy odour not really strong strange non-typical odour. Don't know what it is!</p> <p>6 day MAP cluttered, ie not very anything, kind of a meaty muddy fishy thing... ;-)> muddy metallic odour but not overpowering. oily odour slightly raw fish odour stale/old/musty odour</p> <p>9 day MAP muddy slightly earthy metallic odour very meaty baked smell smells like old boots strong aromatic odour</p> <p>Appearance comments</p> <p>0 day air juice is very yellow moisture in dish was very yellow pale coloured flesh quite good colour and appearance</p>
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Extending the high quality life of seafood

<p>uneven colour across flesh, washed out?? 0 day MAP oily slight discolouration @ the flesh extremities some lack of typical pink colour very pale colour but very acceptable appearance 1 day air gross beige/pink/whitish colour looks like a fish bit very pale colour Very poor. No typical pink colour, a lot of coagulated protein and discolouring 1 day MAP good appearance - a little under cooked greenish liquid in the dish Very pale colour looks incipit looks slimy or glossy not sure if could be termed gaping but looks a bit loose very uneven color, severe browning on flesh extremities.... 2 day air fair good appearance. looked a bit speckled and sitting in a pale puddle of green juice looks raw in the middle 2 day MAP very minimal discolourization?) browning of flesh very slight) 3 day MAP looks like a little bit of gaping very pale colour and juice is transparent with just a tinge of yellow 6 day MAP quite incipit colour, not appetising to look at very poor very washed-out sorta look, uneven lack of colour 1 day MAP bit of everything good sweet flavour no muddiness but too dry rubbery flavour still a little weedy/muddy in taste. Only a slight bitter aftertaste. 2 day air I might say fresh, for it doesn't taste off, but it doesn't quite taste like a bit of trout, more a fake trout, very sweet and meaty??? not a lot of flavour. Doesn't taste very fresh but OK</p>	<p>only slightly muddy/weedy in flavour stale rubbery flavour very dirty weedy metallic flavour but could taste the fish oils in the mouth after swallowing which were good 2 day MAP beautiful flavour but slight metallic to it (I wonder if this builds up over time) nice and strong fishy flavours in the mouth leaves a wonderful aftertaste. earthy flavour mixed with other flavours muddy taste when I first tasted a fairly small Piece from near the top of the fish I got only V SL muddiness. Then I found I had a fair bit left at the end that was down near the ribs/gut that was much muddier, I gave my overall 3 day air dry taste strange taste as well bit musty or dirty but not exactly muddy maybe better described as stale flavour 3 day MAP peculiar flavour . Sort of acid and not typical theres a funny flavour as an aftertaste with this sample maybe slightly herbaceous or weedy only little bit muddy more earthy flavour than anything else 6 day MAP earthy flavour seems to dominate with no subtle fish flavour just not a clean, def' fish?? stale flav stale/old the fish taste is quite strong but very metallic flavour - leaves a nice aftertaste - a little sharp weedy/green/plant like flavour 9 day MAP not much flavour at all stale/old flavour taints present - unpleasant aftertaste tastes alright quite fresh and no to little muddiness but very meaty and baked</p> <p>Texture comments</p> <p>0 day air a little dry bouncy chewy texture really good chalky very little texture as it where? 0 day MAP goes to cotton wool texture</p>
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<p>slight gritty texture after chewing texture relatively good - a little soft/mushy</p> <p>1 day air goes to cotton wool only slightly sticky has a really good texture firm but falls apart in the mouth slightly firm texture VERY SMOOTH</p> <p>1 day MAP a little mushy much firmer than 704 but less flaky as well a bit drier than last sample texture is still okay but bit drier PASTY LIKE??</p> <p>2 day air goes to cotton wool in the mouth good texture? quite soft and less flaky than other samples</p> <p>2 day MAP dry to the tongue? initial bite is quite moist then sample mats in the mouth in a chewy stringy piece Very sticky</p> <p>3 day air slight proteolysis very firm almost crunches when chewed</p> <p>3 day MAP pretty flaky until chewed for a while then seems to mat in the mouth. Good texture overall sawdust after chewing-early proteolysis</p> <p>6 day MAP dry/fibrous fish like dryish yet kind of firm tough for fish very moist on the initial bite seems to spring back after chewing mats a little in the mouth but good texture overall</p> <p>9 day MAP chalky not bad not too dry but more fibrous than flakey. Slightly mats in the mouth</p> <p>Texture comments</p> <p>0 day air An unpleasant overwhelming mud-like quality combined with an over-powering cluttered sort of off-taste. I gave it a high rating because the flavour was really good and left a good aftertaste not bad though the sample is showing its age.</p> <p>0 day MAP Very Poor flavour/odour. Texture Ok. Base quality of the sample is very poor due</p>	<p>to flavour taints - can't taste anything relative to the treatment</p> <p>1 day air marked it down a bit because of the muddiness in the smell and flavour not much fish flavour very poor compared to sample 387 Why are the weather patterns on a global scale so irregular of late????</p> <p>1 day MAP best sample I have tasted in this current trial. marked down a bit because of the dryness but very good flavour leaves excellent after taste in the mouth pale and odourless with earthy flavour</p> <p>2 day air have to mark it down as the metallic muddy flavours were overpowering any fish flavour. Texture wise not the best either too soft and not flakey enough. sample is slightly stringy but very moist tasted a lot better than it smelt, yet still not quite a fish like nose or flav???.... probably say it was better than the first one, but I don't know exactly what this one tasted like??</p> <p>2 day MAP Great flavour etc but a pity about the lack of flakiness and the dry texture after the initial chewing. impression of the muddiness interesting???</p> <p>3 day air sitting in a green/yellow puddle</p> <p>3 day MAP free moisture in dish was yellow and oily looking not at all inviting</p> <p>6 day MAP good flavour overall smell a bit muddy aftertaste is sharp and sample seems to mat in the mouth when chewing but overall good sample it didn't taste half as bad as it smelt relativley nice fish, just confused odours and flavs?? very poor over all. texture too dry. muddy/weedy and stale flavour.</p> <p>9 day MAP good texture, poor taste quite strong flavoured overall quality not that bad but the texture could have been moister</p>
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Appendix 5 Workshop Programme

**Modified Atmosphere Packaging (M.A.P.) -
the future of seafood packaging**

Workshop Program

Registration

- 10.00am Steve Slattery, Department of Primary Industries
Overview of FRDC funded project and results*
- 10.30am Morning tea*
- 10.45am Steve Slattery, Department of Primary Industries
Shelf life results from M.A.P. seafood project*
- 11.15am Ellen Buckle, Department of Primary Industries
Sensory evaluation for M.A.P. seafood*
- 11.45am Bronwyn Warfield, Department of Primary Industries
Marketing study results for M.A.P. seafood project*
- 12.15pm David Tupper, Executive Chef, Pandanus
Trends in the use of seafood in the food service sector and what chefs are
looking for when buying seafood*
- 12.45pm Lunch*
- 1.45pm Robert Elliott, Franklins Limited
The role and future of seafood in Australian supermarkets*
- 2.30pm Lawrie Stewart, Cryovac
Trends in M.A.P. packaging and equipment*
- 3.15pm Andrew Lebreton, Harvest FreshCuts
Commercial use of M.A.P. - issues and problems*
- 4.00pm Reg Warren, Queensland Health Department
Labelling requirements for M.A.P. products*
- 4.15pm Workshop concludes*

Proudly hosted by:



Appendix 6 Contacts List

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 Extending the high quality life of seafood

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PYRMONT NSW 2009

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Queensland Health
Department
PO Box 48
BRISBANE QLD 4001

Appendix 7 Figures From Scallop Storage Trials

Extending the high quality life of seafood

Figure 1

Changes in volume of barrier bags during storage at 4°C

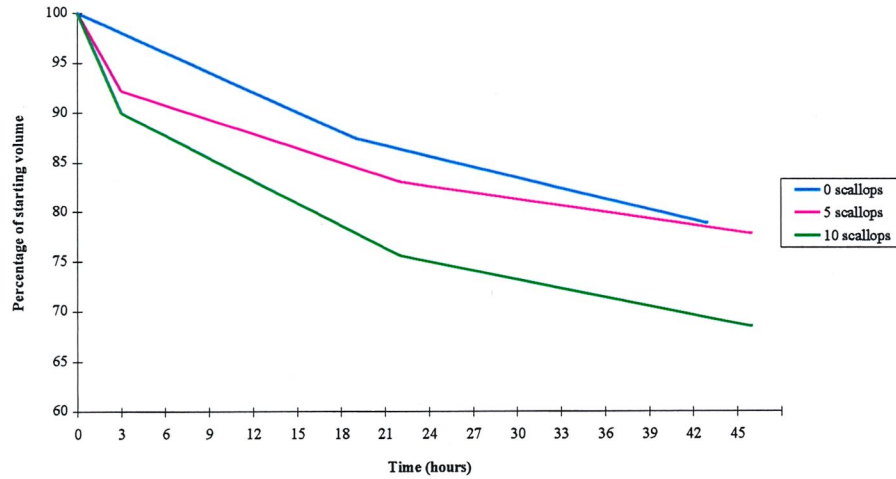


Figure 3

Total log count of H₂S producers from scallops stored in MAP and/or air at 4°C for Trials 4 and 5.

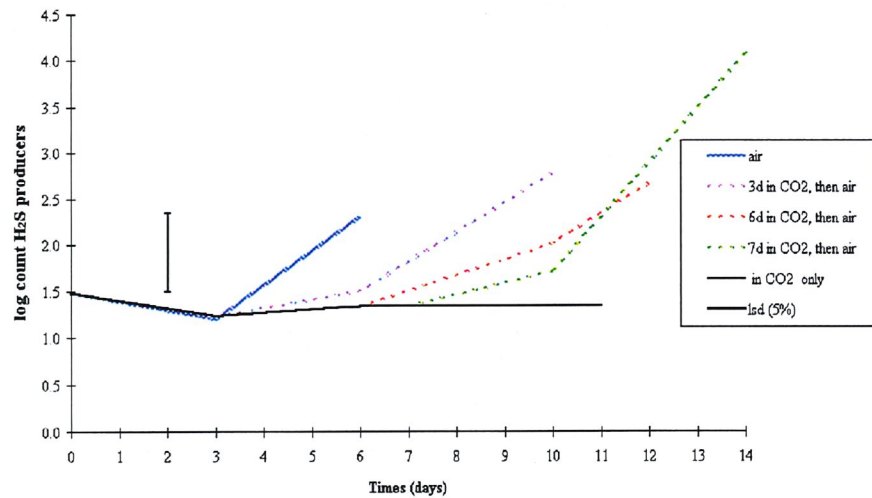


Figure 2

Total log count from scallops stored in MAP and/or air at 4°C.

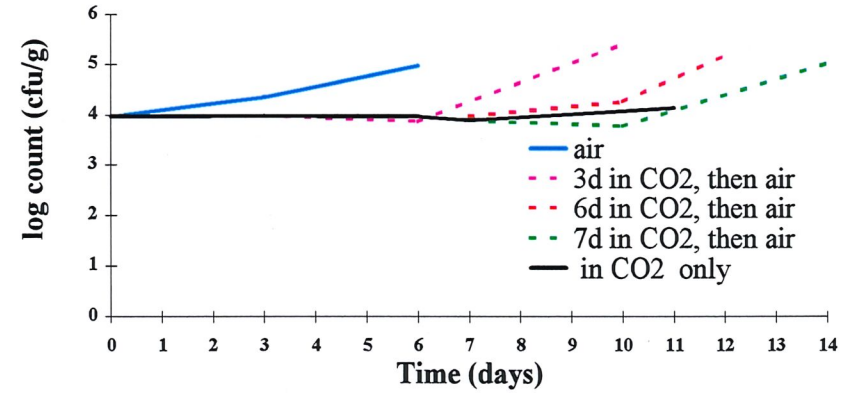
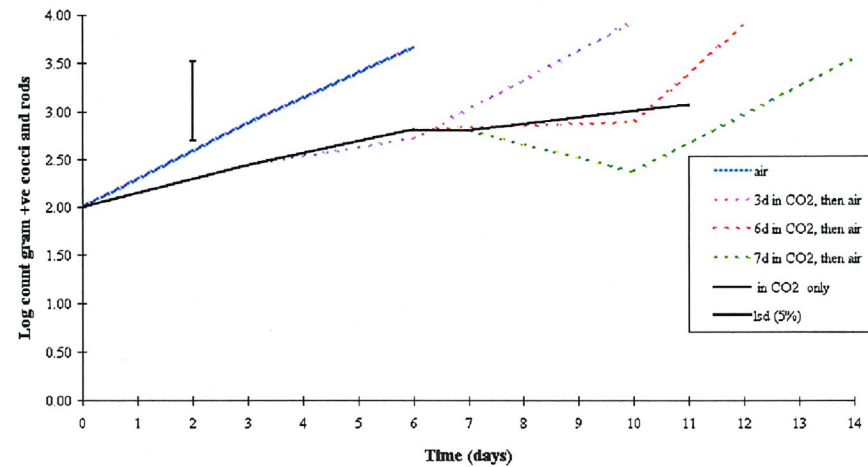


Figure 4

Total log count of gram +ve cocci and rods from scallops stored in MAP and/or air at 4°C for Trials 4 and 5.



Extending the high quality life of seafood

Figure 5

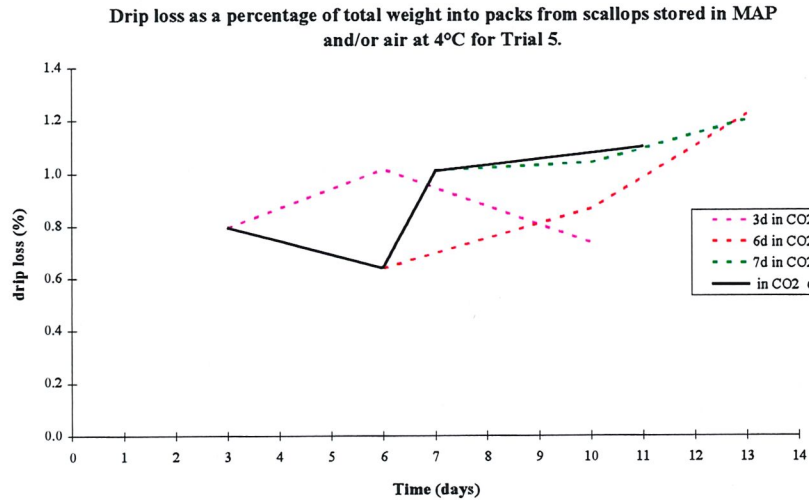


Figure 7

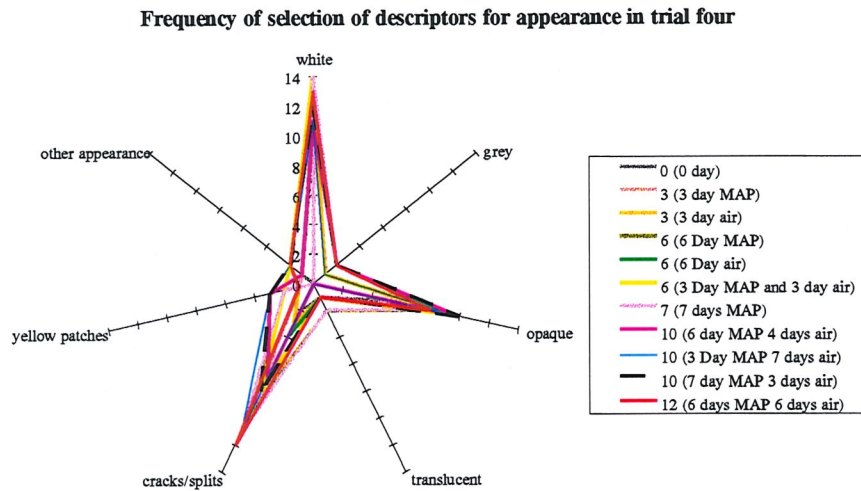


Figure 6

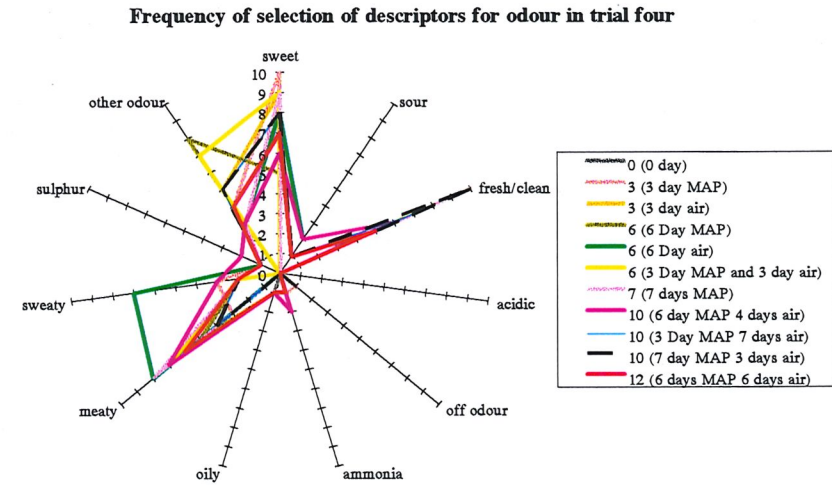
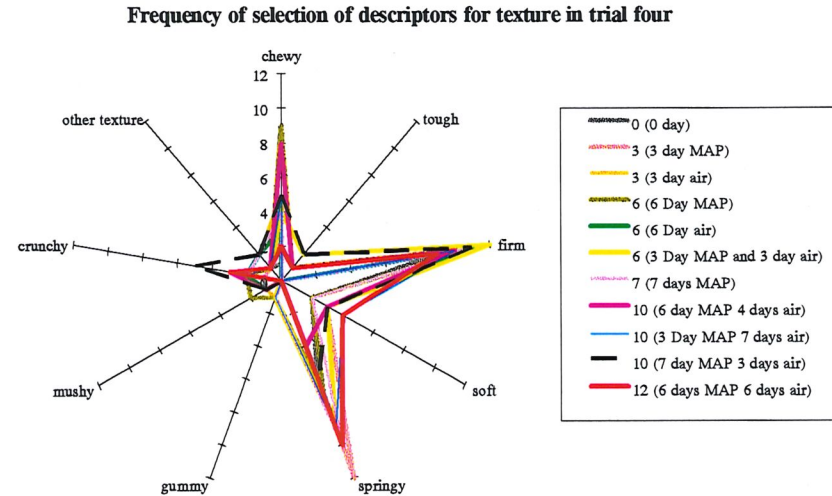


Figure 8



Extending the high quality life of seafood

Figure 9

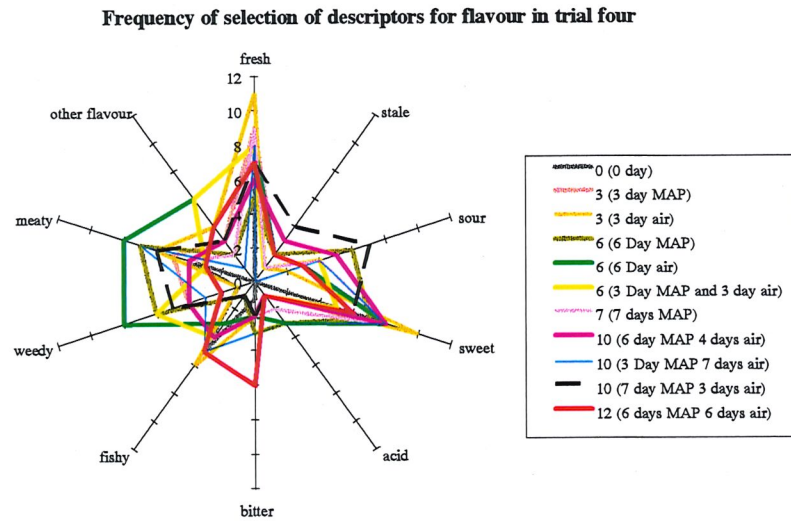


Figure 11

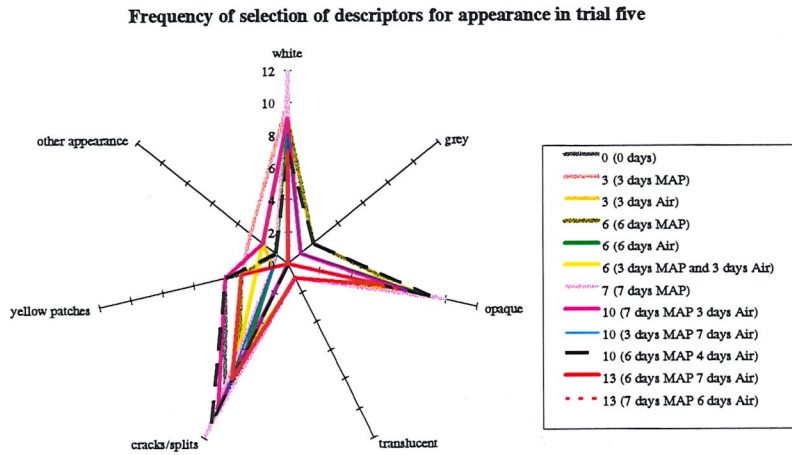


Figure 10

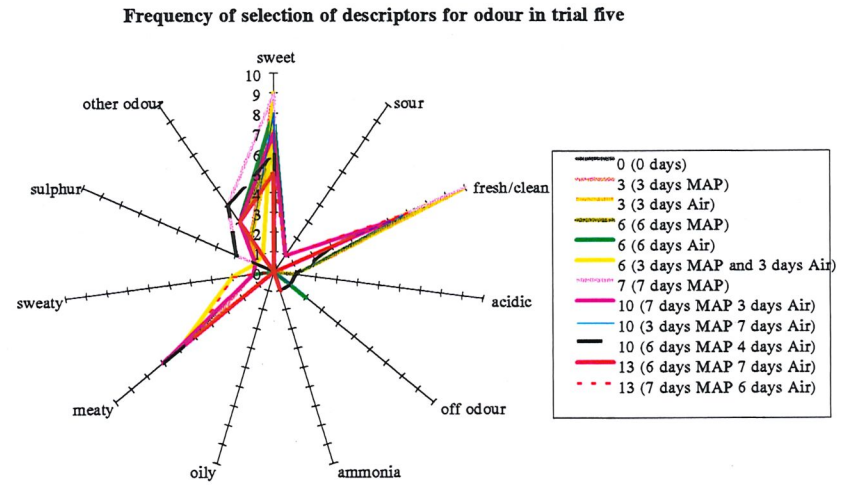
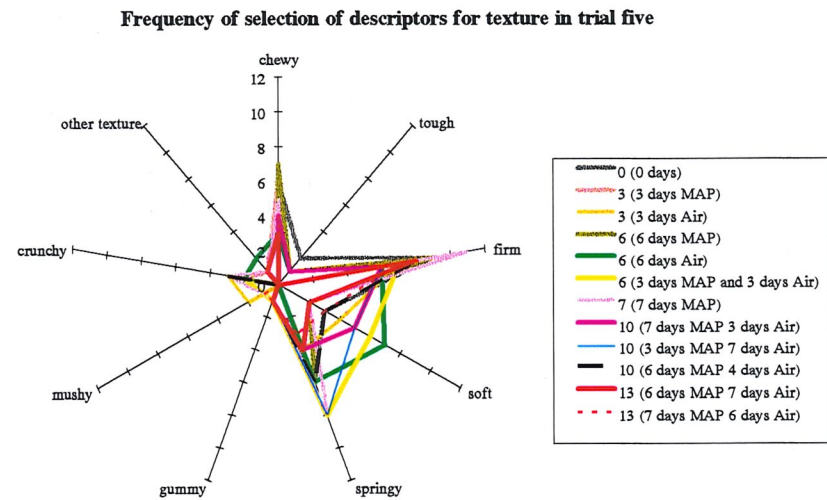


Figure 12



Extending the high quality life of seafood

Figure 13

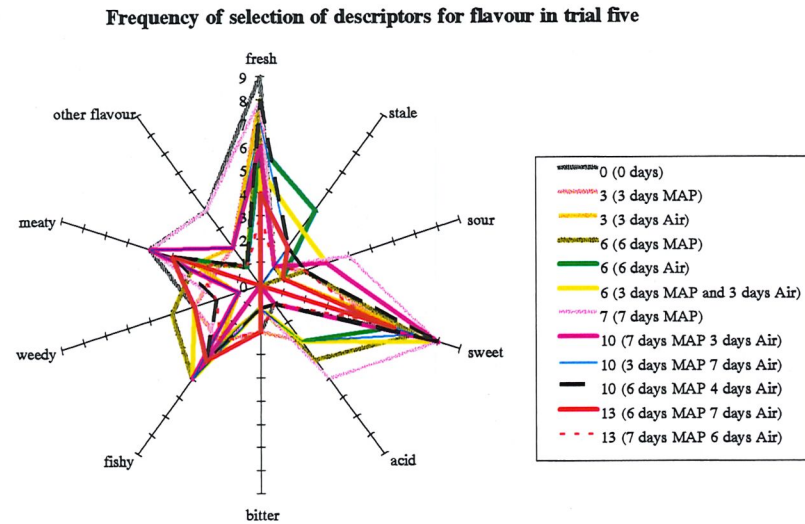


Figure 15

Bacterial growth in scallops stored in MAP at 4°C.

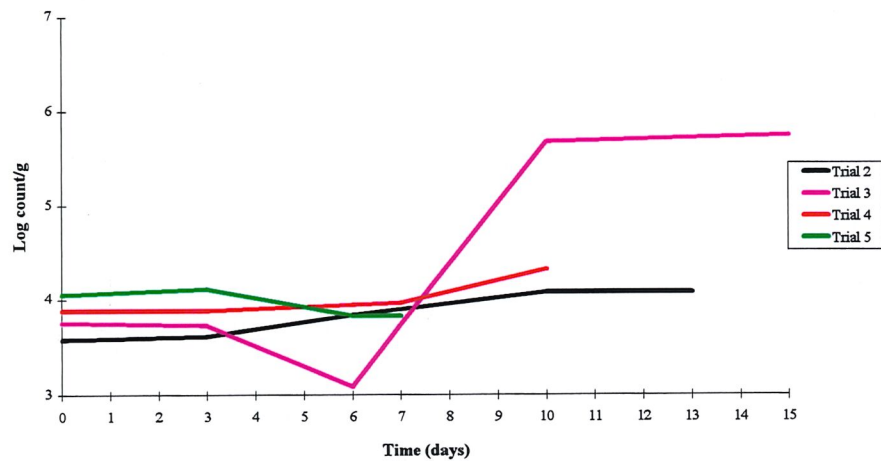


Figure 14

Bacterial growth in fresh scallops stored aerobically at 4°C.

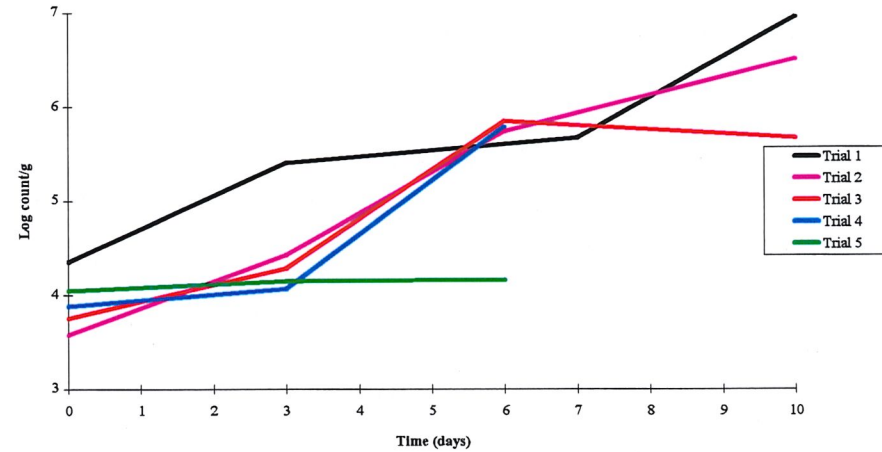
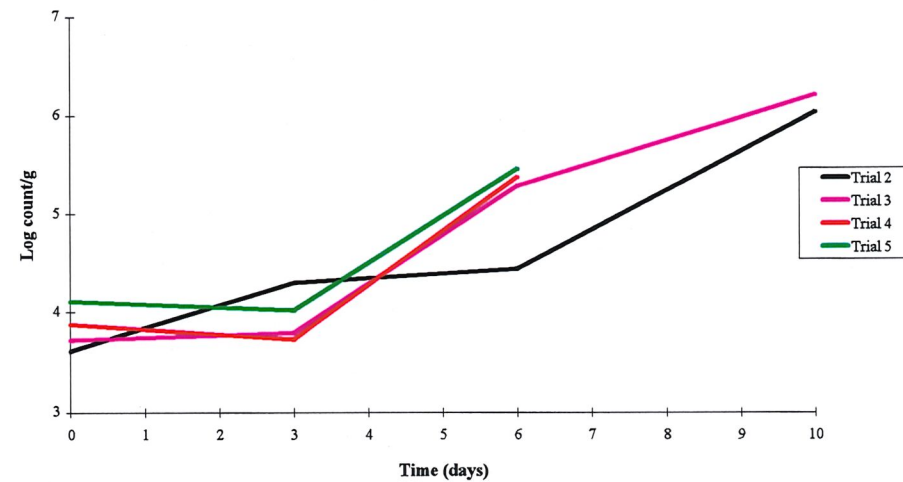


Figure 16

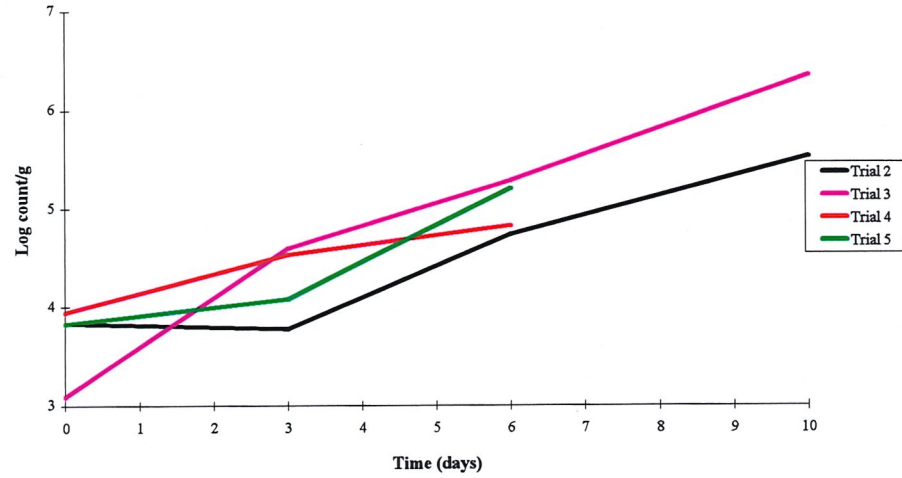
Bacterial growth in scallops stored in air after 3 days MAP storage at 4°C.



Extending the high quality life of seafood

Figure 17

Bacterial growth in scallops stored in air after 6 days MAP storage at 4°C.



Appendix 8 Figures From Swordfish Storage Trials

Extending the high quality life of seafood

Figure 1

Frequency of selection of descriptors for odour of swordfish in trial 1

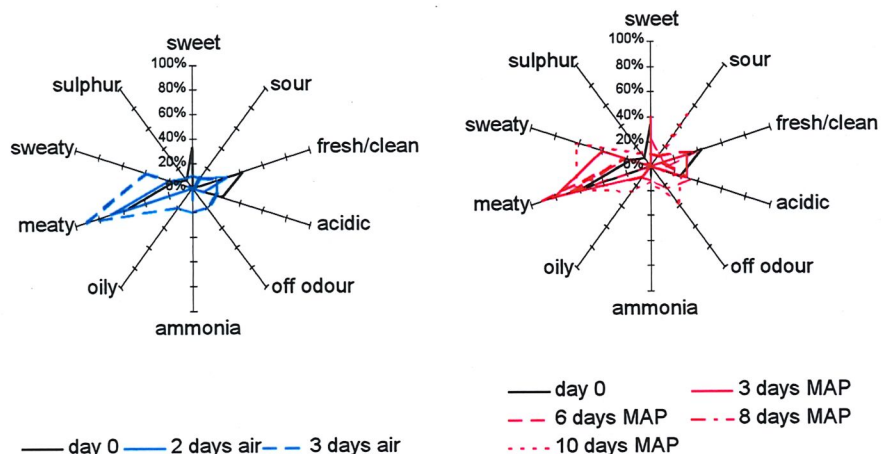


Figure 2

Frequency of selection of descriptors for appearance of swordfish in trial 1

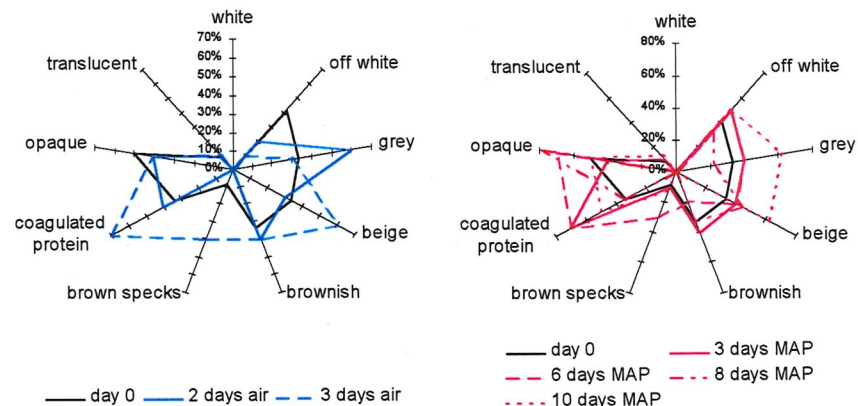


Figure 3

Frequency of selection of descriptors for texture of swordfish in trial 1

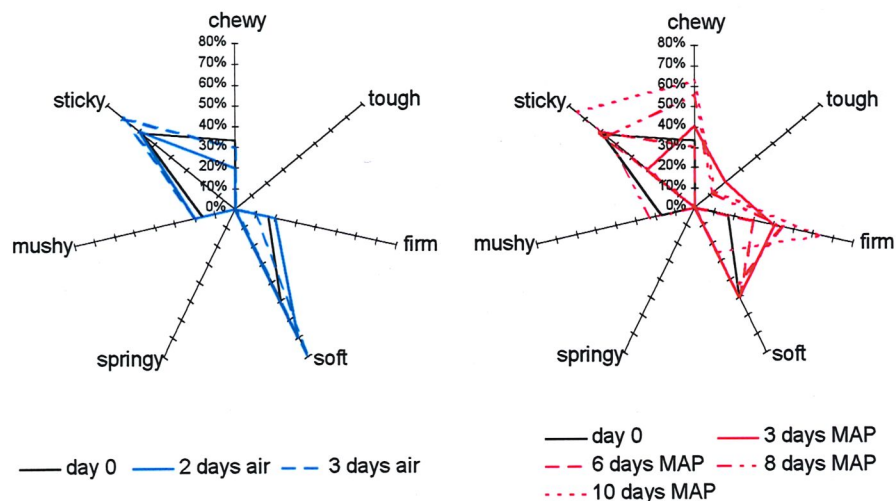
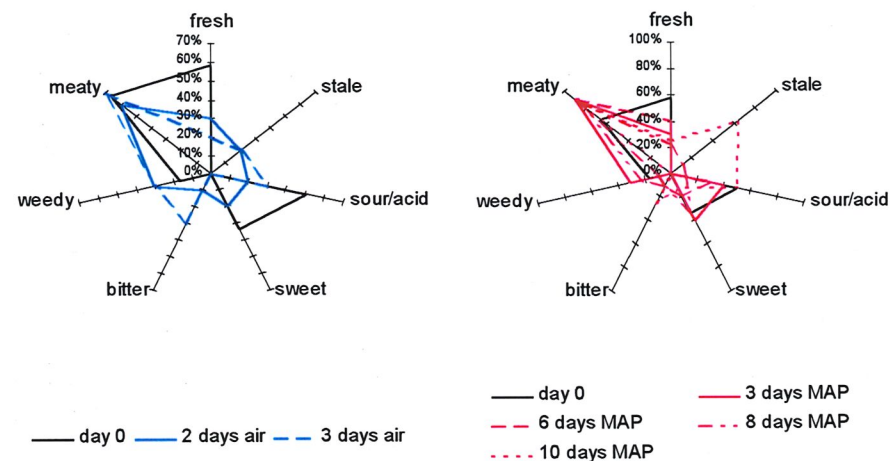


Figure 4

Frequency of selection of descriptors for flavour of swordfish in trial 1



Extending the high quality life of seafood

Figure 5

Frequency of selection of descriptors for odour of swordfish in trial 2

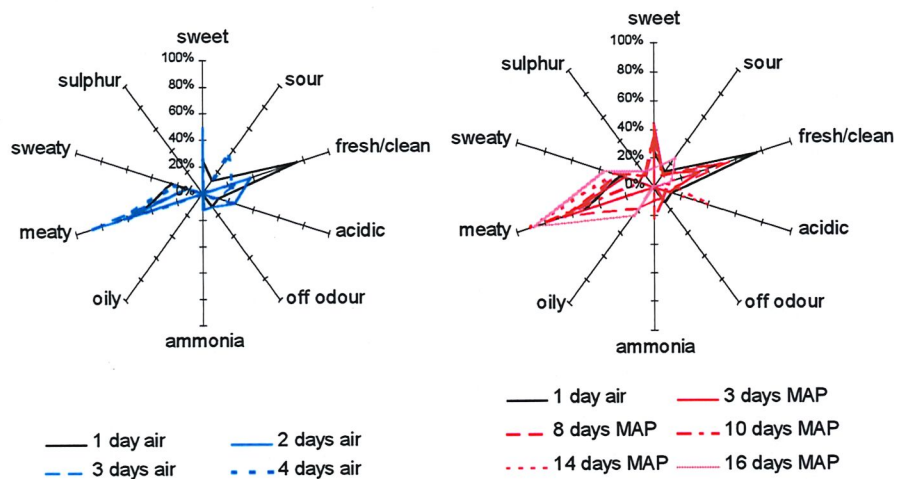


Figure 6

Frequency of selection of descriptors for appearance of swordfish in trial 2

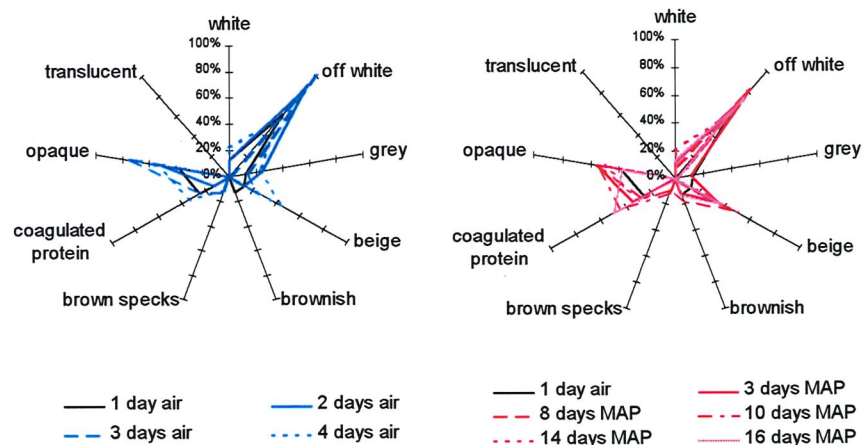


Figure 7

Frequency of selection of descriptors for texture of swordfish in trial 2

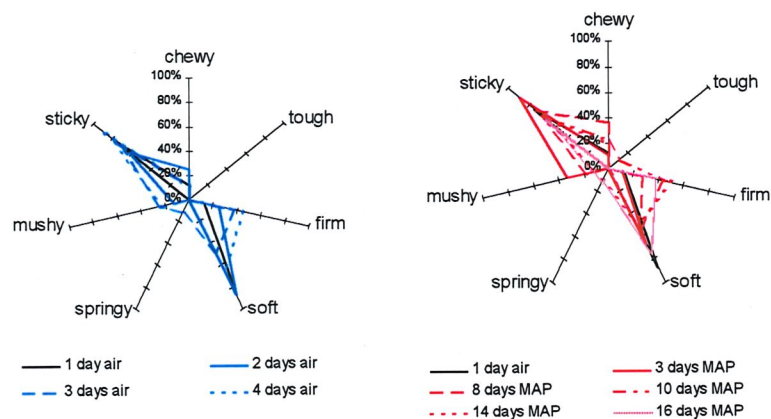
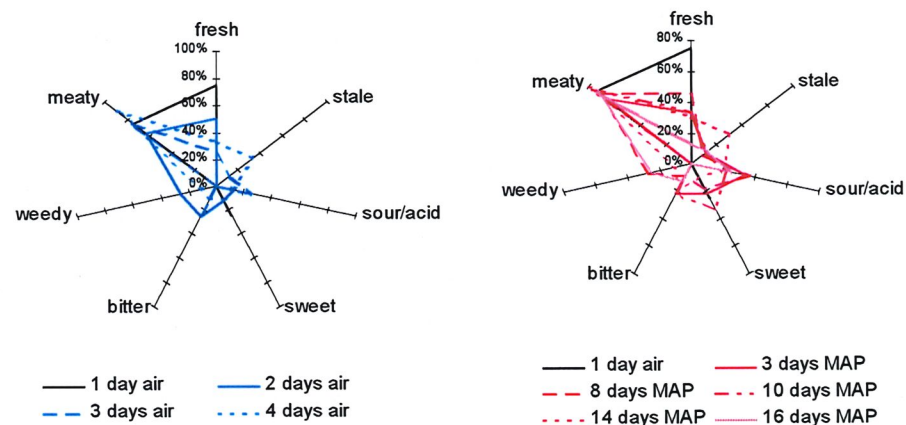


Figure 8

Frequency of selection of descriptors for flavour of swordfish in trial 2



Extending the high quality life of seafood

Figure 9

Total bacterial count of swordfish stored in retail packs in air or MAP at 4°C

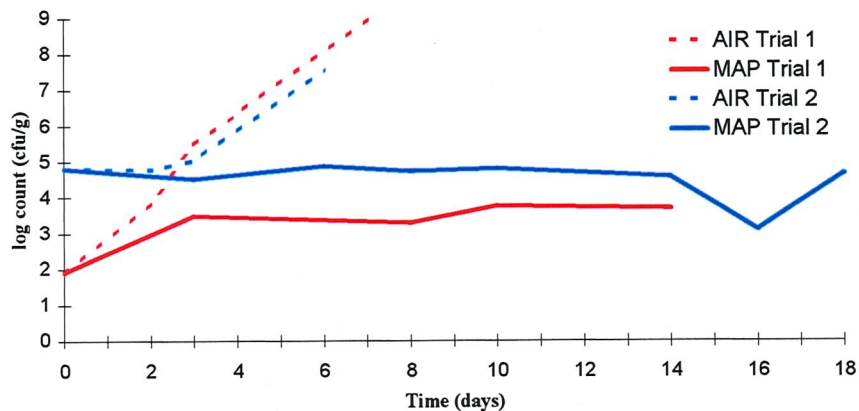


Figure 11

Log count of anaerobic bacteria of swordfish stored in retail packs at 4°C

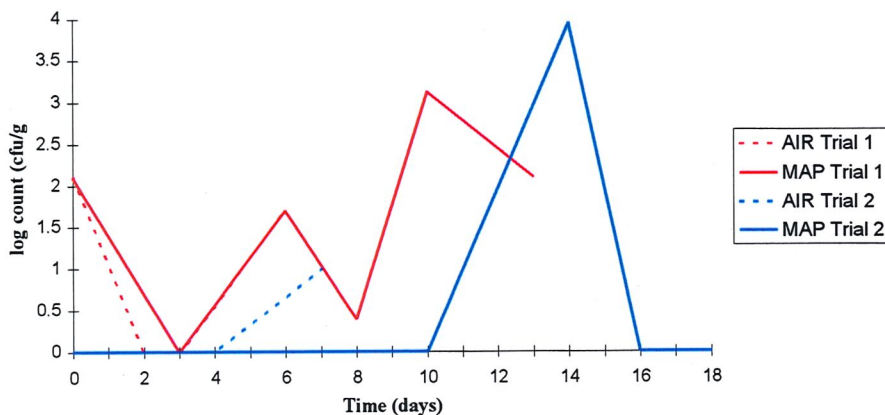


Figure 10

Log count of H₂S producing bacteria from swordfish stored in retail packs in air or MAP at 4°C

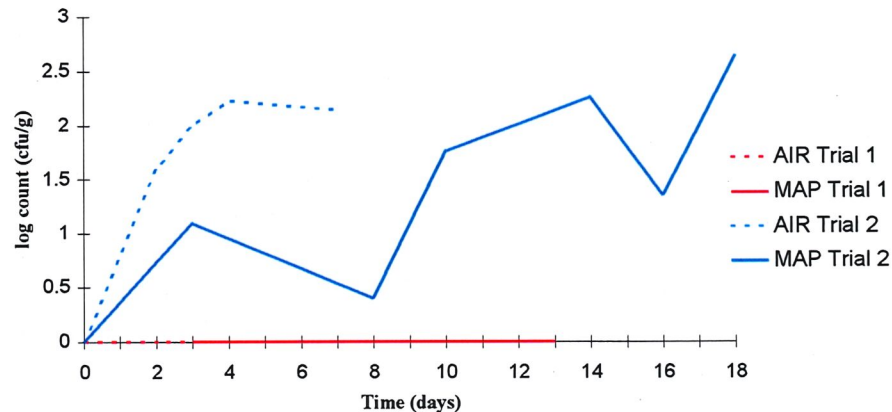
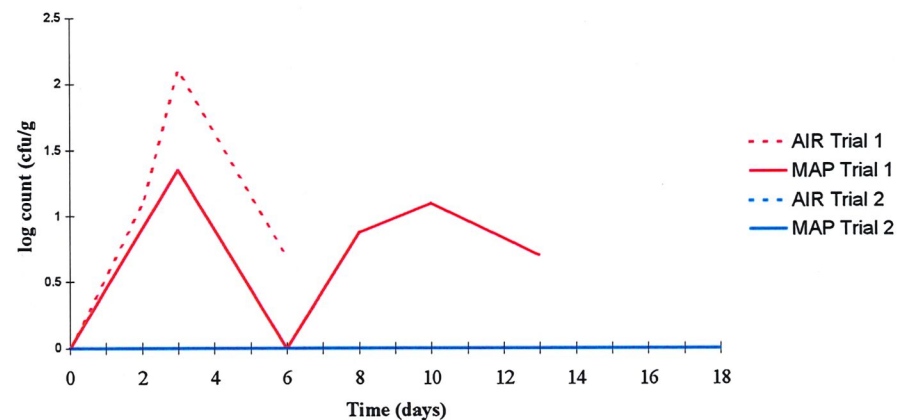


Figure 12

Log count of coliform bacteria of swordfish stored in retail packs at 4°C.



Extending the high quality life of seafood

Figure 13

pH of swordfish stored in retail packs at 4°C.

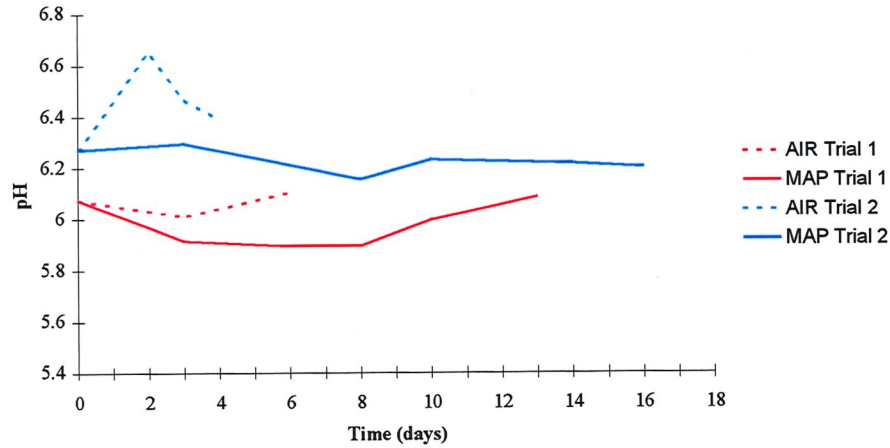


Figure 15

Demerit score for red muscle of swordfish stored in retail packs at 4°C.

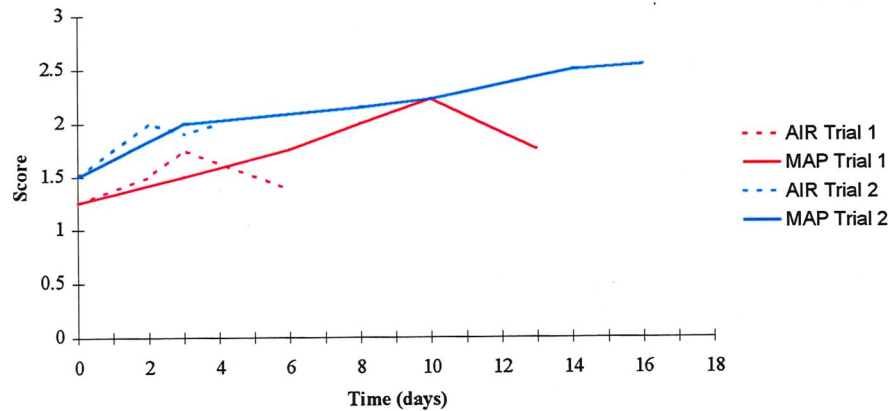


Figure 14

Demerit score for white muscle of swordfish stored in retail packs at 4°C.

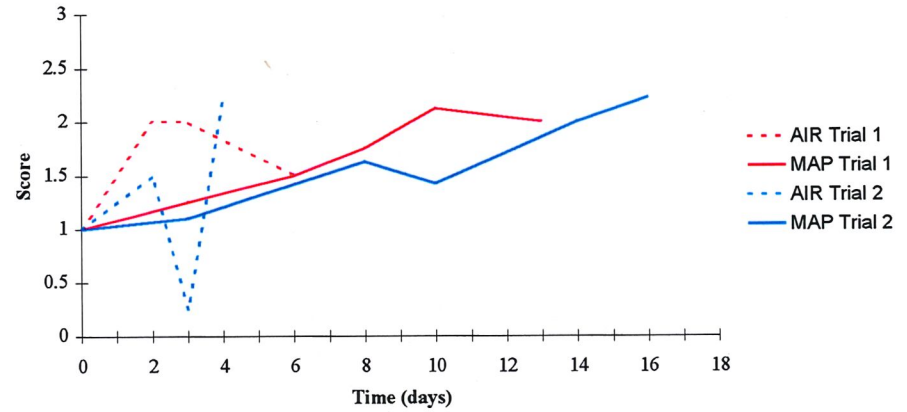
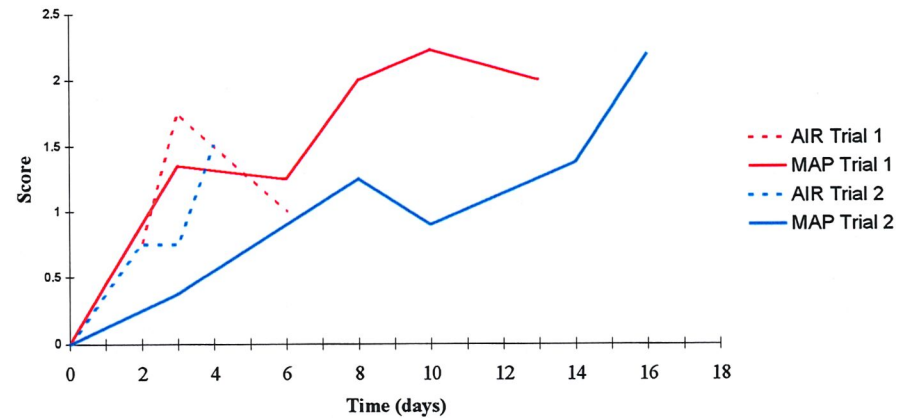


Figure 16

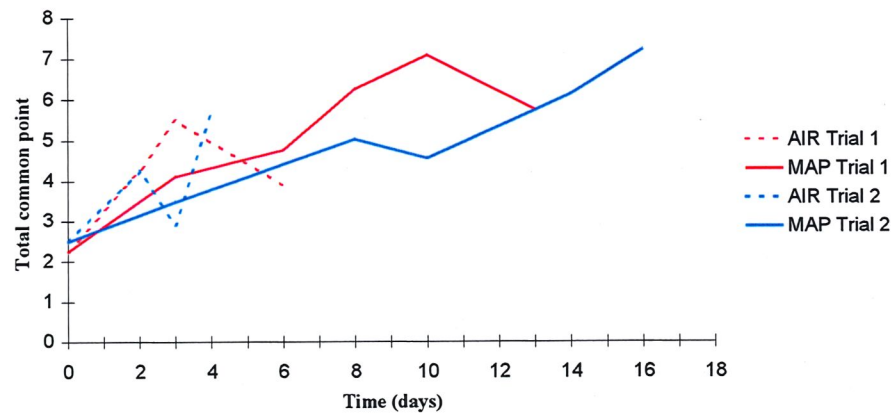
Demerit score for odour of swordfish stored in retail packs at 4°C.



Extending the high quality life of seafood

Figure 17

Total common demerit points for swordfish stored in retail packs at 4°C.



Appendix 9 Figures From Atlantic Salmon Storage Trials

Extending the high quality life of seafood

Figure 1

Frequency of selection of odour descriptors for salmon - trial two

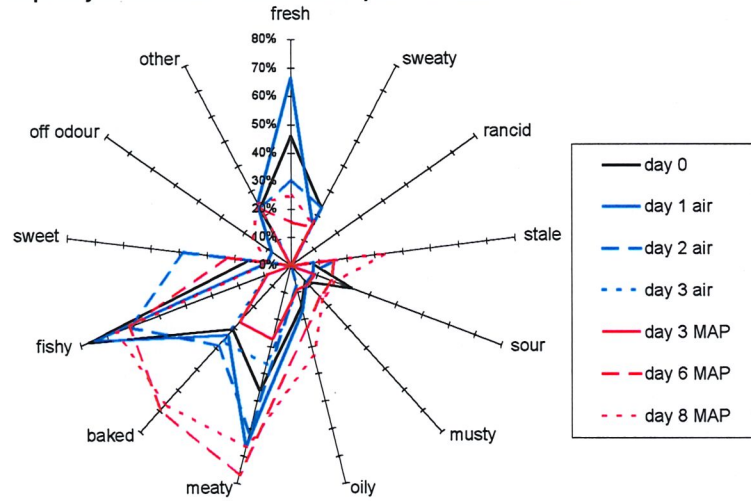


Figure 3

Frequency of selection of texture descriptors for salmon - trial two

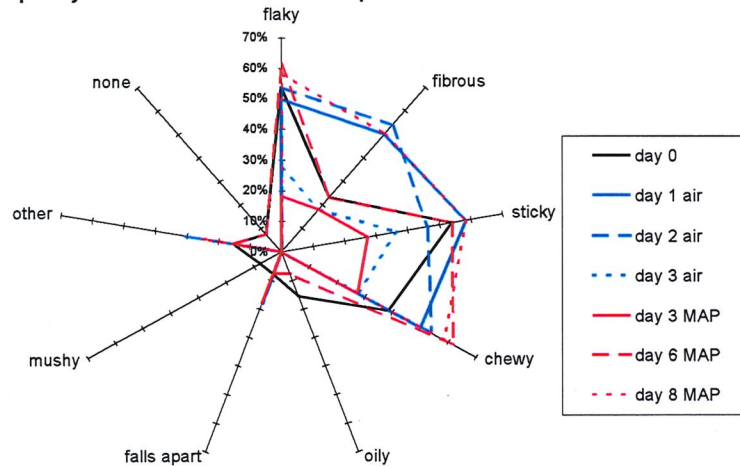


Figure 2

Frequency of selection of appearance descriptors for salmon - trial two

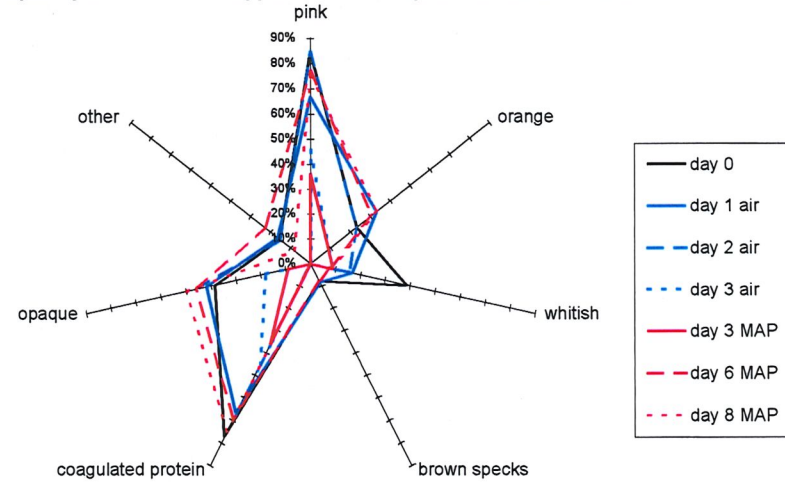
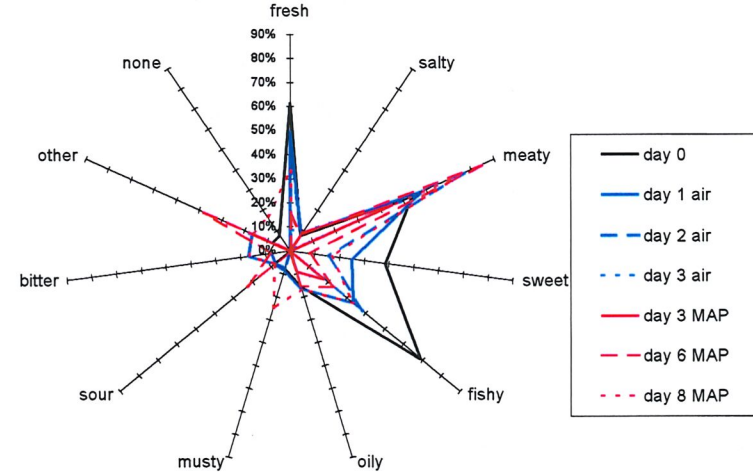


Figure 4

Frequency of selection of flavour descriptors for salmon - trial two



Extending the high quality life of seafood

Figure 5

Frequency of selection of odour descriptors for salmon - trial three

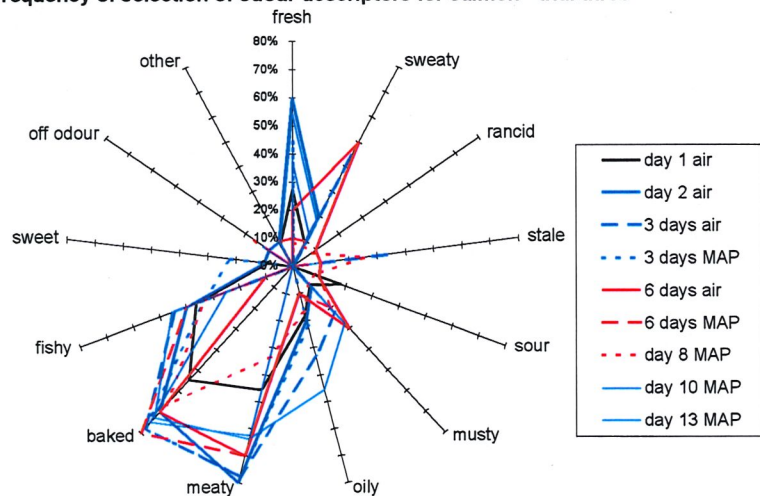


Figure 7

Frequency of selection of texture descriptors for salmon - trial three

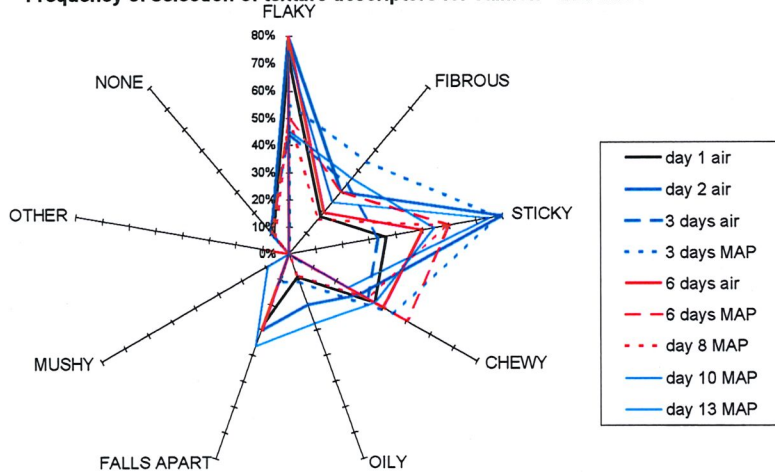


Figure 6

Frequency of selection of appearance descriptors for salmon - trial three

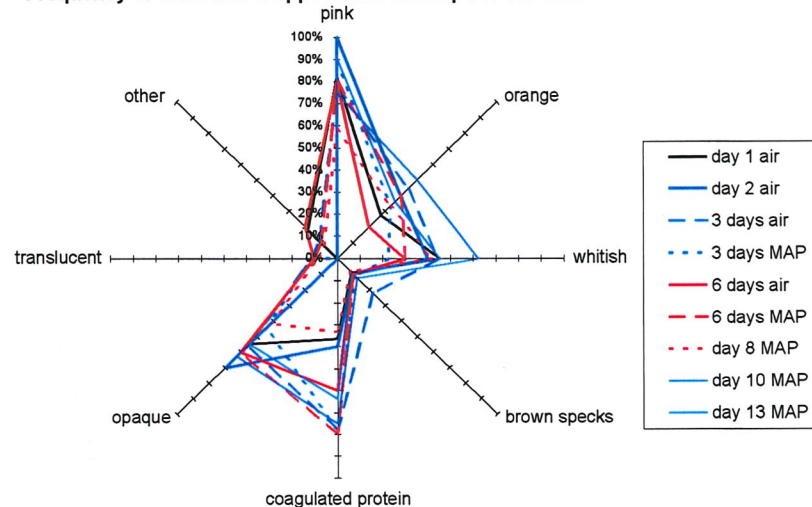
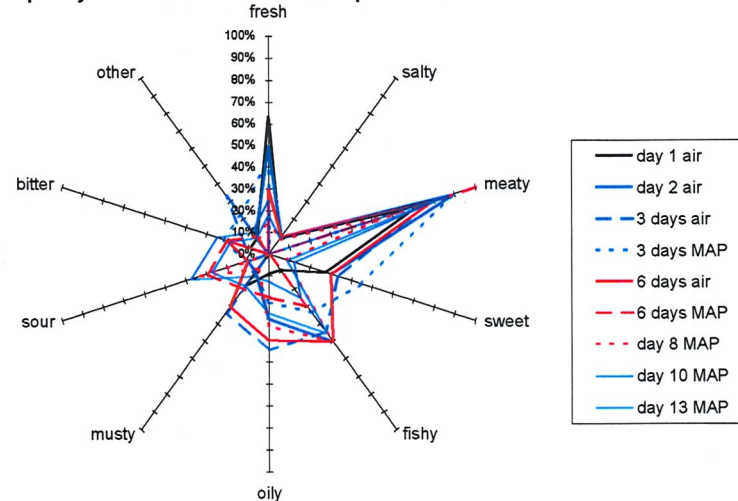


Figure 8

Frequency of selection of flavour descriptors for salmon - trial three



Appendix 10 Figures From Rainbow Trout Storage Trials

Extending the high quality life of seafood

Figure 1

Total microbiological log count of rainbow trout stored in air or MAP at 4°C from both trials

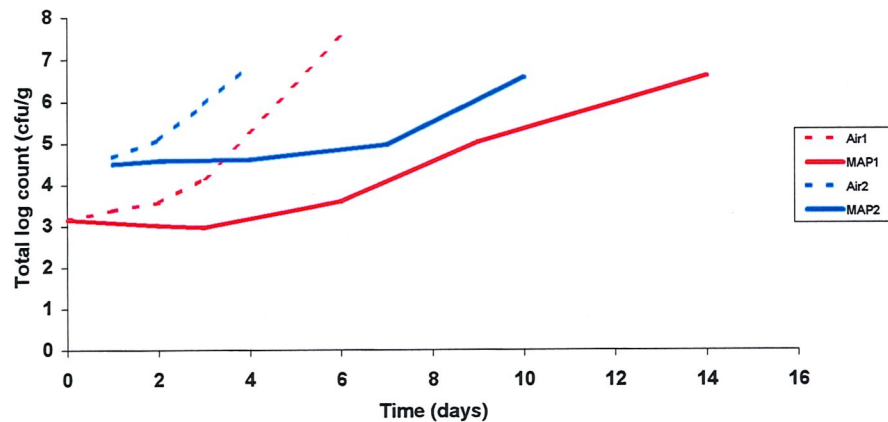
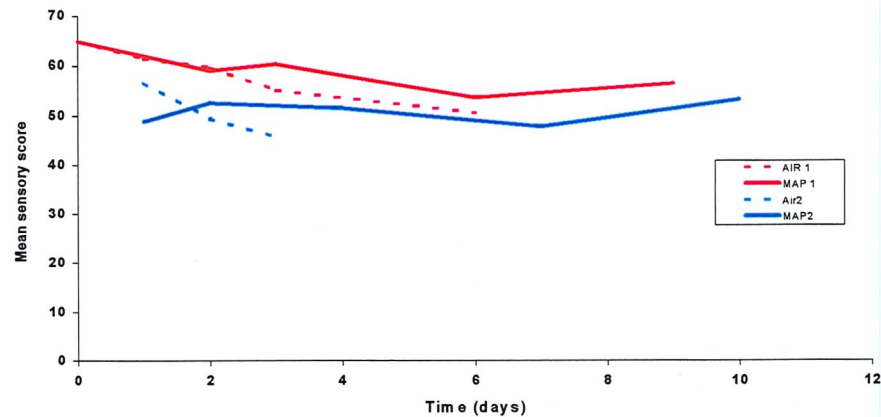


Figure 2

Overall quality score of rainbow trout stored in air or MAP at 4°C from both trials



Appendix 11 Industry Brochure

10 things to know about...

PACKAGING SEAFOOD IN MODIFIED ATMOSPHERE

- 1** Recent research, funded by the Fisheries Research & Development Corporation (FRDC) and undertaken by the Centre for Food Technology, shows that modified atmosphere packaging (MAP) can double the shelf life of fresh seafood. However, the initial quality of the seafood must be high and contain low microbial counts.
- 2** MAP involves the storage of food in an atmosphere of carbon dioxide (CO₂) or a combination of CO₂ and other gases. The CO₂ and a reduction or absence of oxygen retards the growth of oxygen-loving spoilage bacteria. These conditions can however encourage the growth of pathogens if present. To ensure proper penetration of gas, seafood can only be packed as one layer.
- 3** Two types of MAP are produced. One involves permeable film that is wrapped over a tray of seafood. This allows the transfer of gas but not moisture. Some films can form a vacuum skin pack. The covered trays are then placed in a barrier bag (made of an impermeable film) which is evacuated, flushed with the modified atmosphere then sealed. Protection only occurs while the barrier bag is sealed. These packs are used for bulk product or when product is unpacked on delivery.
- 4** The other type of MAP is a lidded pack that has an impermeable tray and uses an impermeable film for the lid. The tray is evacuated and flushed with the modified atmosphere that is then sealed in with the seafood.
- 5** The major factor determining shelf life is the initial bacterial count. Seafood should only be packed in MAP when the count is below 10,000 bacteria per gram and preferably below 1,000 per gram.
- 6** Other quality aspects of the seafood to be packed should also be high. MAP products exhibit more drip loss than normal so only the freshest material should be used. Absorbent pads can be placed on the bottom of trays under the seafood.
- 7** The combination of gases applied can vary with the type of package and fish used. Barrier bags containing packs with permeable film can be flushed with 100percent CO₂ as pack collapse is not important.
- 8** Seafood has a large capacity to absorb CO₂ and when this is the only gas present the pack collapses when the internal pack pressure drops below atmospheric pressure. An inert filler gas such as nitrogen should be included to keep lidded packs in good shape. As the CO₂ controls the growth of bacteria the concentration of this gas should not fall below 40percent.
- 9** Sometimes oxygen is included in the gas mixture. This mixture is used only for lean fish or when colour changes can occur in its absence such as with tuna. The proportion of gas to product is also important to inhibit bacteria and prevent pack collapse. A ratio by volume of 1:1 should be used.
- 10** For more information about packaging of seafood in modified atmosphere, contact
Steve Slattery, Seafood Group,
Centre for Food Technology.
07 3406 8555 Fax 07 3406 8665.
e-mail: cft@dpi.qld.gov.au
Internet: www.dpi.qld.gov.au/cft
The Centre is located at 19 Hercules Street, Hamilton, Brisbane, Q, 4007