IMPROVING QUALITY OF AUSTRALIAN SARDINES THROUGH UTILIZATION OF FLOW-ICE TECHNOLOGY

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AUSTRALIAN SEAFOOD COOPERATIVE RESEARCH CENTRE

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Table of Contents

Table of Figures

Table of Tables

2008/717 IMPROVING QUALITY OF AUSTRALIAN SARDINES THROUGH UTILIZATION OF FLOW-ICE TECHNOLOGY

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OBJECTIVE:

1. Assess the utility of flow-ice in preserving the freshness of Australian sardines from the point of harvest to processing, and wholesale and retail supply chains.

NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED

This project has demonstrated the cooling capacity of flow ice and its affect on the quality of sardines and in doing so has contributed to increased awareness and knowledge within industry as to the usefulness of flow ice in relation to current practices. Although further trials may be necessary, flow ice was shown to have potential for improving sardine shelf life, and the industry partner is now also very interested in using the ice to improve the shelf life of filleted sardines. The industry partner has recently entered into negotiations with a flow ice machine manufacturer for installation of equipment on the company vessel.

Trials were carried out on the *Gemma Marie (*White Fisheries) based at Port Lincoln, South Australia. Experiments involved comparisons between flow ice (FI), ice slurry (IS) and refrigerated seawater (RSW) at a fish:cooling medium ratio of 1:1. Core temperatures were recorded from fish stored in FI and IS for up to two days; with associated shelf-life trials running up to 6 days. Fish were also sent to markets (SAFCOL, Angelakis and Cappo Bros in Adelaide, and Sydney Fish Market) for appraisal and sale.

The data collected indicates the greater cooling effectiveness of flow ice and its effect on fish quality (lower QIM scores). Flow Ice cooled sardines to $2^{o}C$ three times faster than Ice Slurry (i.e 9min vs 30min). Fish sent to market were better than average, and, in one case, the best they had seen in a long time. However, there was no difference in price between sardines stored in flow ice and those in ice slurry.

The study was terminated due to persistent mechanical failures of the leased flow ice machine. Thus, further work is necessary to explore the potential of flow ice, particularly at higher fish:cooling medium ratios.

It may be that the market for fresh whole fish is not the best test of such a product and it is therefore suggested that other tests such as storage, filleting and cooking trials be carried out using the technology.

ACKNOWLEDGEMENTS

The authors would like to thank the Skipper and Crew of the *Gemma Marie* for enormous help and extreme patience during the project. Thanks also to Peter White of White Fisheries and Christian Pyke, Executive Officer of the South Australian Marine Scale Sardine Industry Association.

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1. BACKGROUND

The Fishery

South Australian waters support the most valuable Australian Sardine (*Sardinops sagax*) resource in Australia. The sardine fishery is Australia's greatest by weight for a marine scale-fish. The total annual catch increased from 3,836 tonnes in 1999/2000 to 39,185 tonnes in 2005. The Total Allowable Commercial Catch (TACC) for 2009 was set at 30,000 tonnes. It is fished by 14 licence holders who have an equal share of the TACC but can lease quota to each other so that catch volume can match market opportunity with a majority of licence holders being vertically integrated with tuna farming companies - the biggest market for this catch. Since 1998, the exploitation capacity of the fleet has increased in line with the increases in TACC. For example, most tuna-farming company aligned sardine license-holders operate state-of-the-art purse seine vessels capable of handling more than 100 tonnes/night.

The South Australian Sardine Fishery (SASF) was initiated to provide fresh and frozen fodder for the tuna mariculture industry and most of the catch (about 98%) is still used for this purpose. SASF production has also been supplemented / replaced by imported frozen baitfish feeds from the USA (California, Gulf of Mexico), Chile, Morocco and New Zealand. Many of these countries have lower costs of production than found in the SASF due to the relatively cheap labour and fuel and/or significantly greater volumes harvested. The price for South Australian sardines has had to remain depressed ($0.50 - $0.55/kg) in order to compete with imported product.

The South Australian Sardine Industry must diversify its market base and increase the proportion of the annual catch that is value-added to offset the factors described above, and the associated risks of sustained low returns. The industry believes that a target of 10% be set for value-adding (Strategic

Plan). This target reflects the quantity of sardines that the three non-tuna farming aligned sardine licence holders can catch and process on-land in two processing factories. The primary foci for such diversification are considered to be fresh chilled and IQF (individual quick frozen) products (whole fish and fillets) for human consumption markets in Sydney and Melbourne. There is also interest in producing more IQF bait for recreational and commercial fishers. In order to achieve the increase in the proportion of fish targeted to value-adding options, current post harvest handling practices must be further improved to reduce damage to the fish and to extend their short shelf-life.

A key factor in the successful exploitation of these market opportunities is the maintenance of fish quality for what is a notoriously delicate fish. Musgrove et al (2007b) found that deterioration in South Australian sardines (as measured using a Quality Index Method (QIM) approach) was directly correlated with post mortem heat production, probably attributable to autolysis of the gut and other organs. The evidence for this was that temperatures in the gut cavity of sardines were elevated by up to 8^{o}C for up to 15 hours post-capture (compared to muscle temperatures in the same fish) even though the fish were kept in onboard refrigerated seawater (RSW) tanks. That study also found that many catches of sardines were not fit for human consumption or other value-adding options upon landing at the jetty after just 15 hours storage in RSW. That study recommended improvements be made to the immediate cooling of sardines to be used for value-adding markets using flow ice rather than RSW. This recommendation is consistent with the conclusion of a study in WA where better quality and shelf life was obtained in anchovies chilled using an ice slurry with the addition of a sanitizer (Stevens and Hughes, 1996). Operational differences between the WA and SA sardine fisheries such as the larger nightly quantities of catch, and longer steaming time from fishing grounds to port mean that the SA industry needs to upgrade its processes and practices beyond what is effective in WA.

Flow ice

Flow-ice is a pumpable suspension of microscopic ice crystals and seawater at a ratio of between 22 : 78 and 40 : 60, respectively (Paul, 2002). The product (also called micro-ice, binary ice and slurry ice) is widely used in Northern Hemisphere fisheries and is recognised as a very effective means of maintaining quality and extending shelf-life for many species. Flow-ice crystals melt when heat is absorbed, with a phase change that is instantaneous and cannot be compared to normal ice melting. Flow-ice has greater values of heat transfer and faster reaction kinetics than single phase fluids such as cold water or brine. Furthermore, the high surface area:volume ratio of flow-ice allows the ice crystals to coat the immersed object. There are also more crystals per ml in flow ice suspension than in other types of ice slurry (plate, crushed, flake or tube) which means effective cooling of flow-ice is greater than alternatives at identical ice temperatures. The result is that flow-ice can cool the core temperature of fish 3-4 times faster than RSW or crushed ice slurry. Several studies have compared the efficacy of different cooling methods on product shelf life, for example, Losada et al (2004) reported a significantly greater shelf life for sardines (*Sardina pilchardus*) cooled with flow ice (12-15 days) than with flake ice (5 days). Paul (2002) reported that plaice (*Pleuronectes platessa*) cooled from 16^{o}C to 2^{o}C in 10 min immersed in flow ice, but 35 min in to reach the same temperature in flake ice. Similar results have been obtained with species such as albacore tuna (*Thunnus alalunga*), herring (*Clupea harengus*), cod (*Gadus morhua*) and shrimp (*Parapenaeus longirostris*) (Paul, 2002).

At the time this project was initiated there did not appear to be a user of flow-ice technology in any Australian seafood sector, apart from limited trials on one boat in the SESSF. Since that time flow ice equipment has been bought by a Tasmanian salmon aquaculture company (Tassal) and salmon and mussel processors in New Zealand. The same New Zealand manufacturer (Ice Solutions Ltd) has also supplied flow (Beluga™) ice machines to the Australian dairy, poultry, baking and fruit processing industries.

The Market for Value-Added Sardines

There are no up to date figures on the size of Australian markets for sardines, however in 2002 the domestic human consumption market was estimated at between 416 and 624 tonnes (fresh and frozen sardines), 4,115 tonnes (canned sardines), and the recreational and commercial bait market was estimated at 3,800 tonnes (Onley, in (Musgrove *et al.*, 2007b)).

In 2006 average wholesale prices for sardines at the Melbourne and Sydney Fish Markets (MFM/SFM) were $3.70 and $4.05/kg respectively (Econsearch, 2006). Econsearch (2006) estimated that if product were sent from South Australia, the back-calculated beach prices would be about $1.25/kg (MFM) and $1.40/kg (SFM), given a freight charge of $2.00/kg (MFM) to $2.50/kg (SFM) and market commissions of 7.5 per cent. These prices are significantly greater than the $0.50-0.55/kg the industry gets from the tuna fodder market. The potential growth in volume and price for higher quality product supplied to the human consumption market is unknown, but comments from some seafood wholesalers in 2002 indicated a capacity for 20 tonnes per week into each of the Melbourne and Sydney markets (= 1,000 tonnes pa each).

Other possible markets include the food service sector - hotels and restaurants. Selling fresh-chilled product directly to such markets (or through a wholesaler without going through the auctions) with guarantees of supply and quality would attract a premium price to producers and processors. The healthy and nutritious attributes of sardines, their amenability to various cooking styles and presentations, and their novelty value make them a desirable addition to menus, particularly those that specialise in seafood and/or Australian produce. Again, the size and price of this market for sales cannot be accurately estimated until the chefs/suppliers see the quality of the product and determine the reliability of supply. Finally there is potential in national and overseas markets for frozen high quality product.

Taking the Improved Products to Market

Two sardine licence holders/sardine processing enterprises are committed to value-adding of SA sardines. These are Peter White fishing with "*Gemma Marie*" with processing and selling through Samtass Bros Seafoods, and

Branko Sarunic fishing with the “*Andrew Wilson*”. Branko is part-owner of the processing company “Sardine Temptations”. These operators and potentially others are awaiting the results of this trial to decide upon their level of investment into flow-ice technology

Benefit-Cost Analysis for Flow-ice with Sardines

A benefit:cost analysis (BCA) on the use of flow ice machines in the SA sardine market was prepared by EconSearch in 2006. Two sizes of flow-ice machine were modelled, viz, the DWT1.3 (producing 6,606L flow ice / 24 hours and the DWT4.3 (26,422L / 24h). For the DWT1.3 it was found that the landed beach price equivalent (LBPE) at which the investment would yield a breakeven return ranged from $1.46/kg for 50 t sardines processed per annum down to $1.15/kg for 100t/an. For the DWT4.3 the breakeven price ranged from $1.26/kg for 200 t/an down to $1.06/kg for 400t/an (Econsearch, 2006). The volume of product that the industry was looking to direct toward value-adding (10% of TACC, ~3,000 t/an) would necessitate the use of a larger machine, raising the possibility of further economies of scale.

Comparing the estimated beach price (i.e. Melbourne Wholesale Fish Market $1.25, Sydney Fish Market $1.40) with the LBPE suggests that investing in flow-ice could achieve between $0.10/kg and $0.34/kg (small and large machine, respectively) above break-even. Thus, depending on investment and auction outlet targeted the fisher would be $0.37 - $0.61/kg better off. In summary, the cost benefit analysis demonstrated significant return on investment even with current prices and volumes for product. The full BCA is presented in the FRDC report (Musgrove *et al.*, 2007a). The ASCRC’s Program Leader for Commercialisation (at the time) reviewed the BCA and gave a favourable report.

Summary

This project was developed by SAMSSIA and SARDI to assist operators in the SASF increase the value of their catch by trialling technology that would improve the post-harvest quality of whole and processed sardines (fresh and frozen). It was suggested that such improvements would assist in the production of high quality fish for the valuable domestic and export human consumption markets.

2. NEED

This project contribute toward Seafood CRC Program 1B: Output 1.7 "Smart processing technologies and practices"

Milestone 1.7.2
Application of innovative technologies for controlling spoilage to enhance shelf-life and marketability

Milestone 1.7.6
Harvest, post-harvest and processing practices evaluated and enhanced to maximise and protect quality attributes

Milestone 1.7.8.
Technology and capability to support innovation of new seafood products developed

This project also fits into the CRC “Smart Processing” theme

Global economic factors and market forces warrant the need for a significant portion of the SASF harvest to diversify from the domestic tuna feed market into higher value markets. This need is in part driven by the strength of the Australian dollar. Over the last 24 months the volume of relatively cheap imported feed has forced a significant decrease in the beach price of locally caught sardines, necessary so local catch can maintain market share. The strength of the dollar is forecast to remain high.

The South Australian Sardine Industry needs to diversify its market base and increase the portion of the annual catch that is value-added to offset the issues described above, and the associated risks of sustained low returns.

The suitability of South Australian sardines for value-adding is negatively affected by high volume of the nightly catch and the limited capacity of most sardine vessels to adequately chill fish on board. There was a need to trial technology that would remove heat from fish immediately postharvest more efficiently than current practices. It was suggested that this would reduce spoilage and extend the shelf-life for value-added grade fish.

3. OBJECTIVE

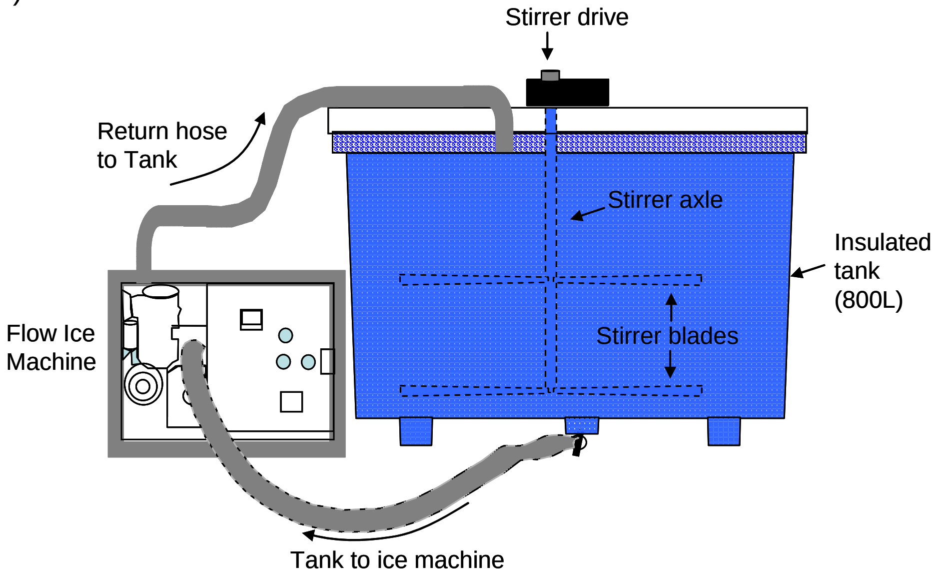
Assess the utility of flow-ice in preserving the freshness of Australian sardines from the point of harvest to processing, and wholesale and retail supply chains.

4. METHODS

4.1. Flow Ice Machine

The flow ice machine (MicroIce® 1.025, 1.5kW$_R$, Pam Refrigeration, South Africa) (FIM) was set up on the sardine fishing vessel the "*Gemma Marie*" (White Fisheries Pty Ltd) initially, then at the Lincoln Marine Science Centre, Port Lincoln. The FIM was connected to an 800L insulated tank (Big Chilli Coolers Ltd) (Fig 1) containing about 500L of fresh seawater (salinity ~ 36ppt). A double-bladed stirrer was fixed to the tank's lid and used to maintain the flow ice in suspension.

Fig 1. Flow ice machine schematic and photo of FIM in place on the *Gemma Marie*
The photo also shows some of the smaller ice boxes (100L) used for fish cooling trials and the submersible pump (in front of the FIM) used for moving seawater
a) Flow ice machine schematic



b) FIM and ice boxes in place on the *Gemma Marie*

c) Open 100L ice box showing sardines in flow ice

4.2. Cooling trials

Two trials were run to determine the cooling rate of sardines put into flow-ice (FI), ice slurry (IS) and refrigerated seawater (RSW), the latter being the industry standard. Both trials included a QIM shelf life component, with a storage treatment and market perception component added to the second trial.

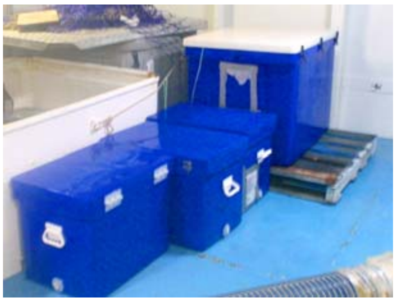
4.2.1. Initial cooling after submersion in Flow Ice (FI), Ice Slurry (IS) or Refrigerated Sea Water (RSW) and shelf life trials

Within half an hour of pumping on board twenty kg of freshly caught sardines were placed in each of six identical 100L plastic ice boxes (Fig 1) containing either FI, IS or RSW (2 boxes per treatment) at a ratio of approximately 1:1 weight of fish to cooling medium. Core temperatures were taken at intervals from individual fish from each treatment over the first 50 min of cooling. To achieve this fish were removed from the cooling medium and a 15cm (3mm diameter) temperature probe (TPS WP80 Temperature Conductivity meter) inserted into the gut through the mouth. Temperature readings stabilised within 20secs and were recorded then the fish was discarded.

4.2.2. Storage medium/shelf life trial/market trial

Fish were also subjected to a combination storage medium/shelf life/ market trial. Six ice boxes were used (Fig 2), three for each of the FI and IS fish. Fish were put into these ice boxes at a ratio of approximately 1:1 (30kg of fish: 30L of cooling medium) immediately upon arriving aboard from the net via the fish pump. The flow ice machine had been relocated to the Lincoln Marine Science prior to the experiment and flow ice produced there was brought aboard in a 400L ice box (Fig 2). Approximately the same quantity of meltwater was drained from each ice box 1 hour and 3 hours after loading with fish. On each occasion the ice boxes were topped up to the original level with either ice slurry or flowice, depending on treatment.

Fig 2 Ice boxes used to for cooling and storage of fish.
The larger ice box (400L) at the back of the photo was used for storing flow ice during the trial.



When the boat pulled up at the jetty ice boxes were removed to a 4^{o}C constant temperature (CT) room at the Lincoln Marine Science Centre. Five replicate samples of sardines from each treatment were then packed out in 14kg polystyrene eskies (10kg sardines/ box) as per commercial practice (ie the fish were inside a bag with flake ice on top of the liner). iButton temperature data loggers were placed in the centre of one esky from each treatment, on top of the fish (surface) and attached to the outside of each esky (outside); these were set to take temperature readings at 5min intervals. With the co-operation of Sydney Fish Market the boxes were labelled with "dummy" company names to disguise the treatments. The same names were used in labelling the eskies sent to Adelaide. The following day eskies were sent by refrigerated truck to Sydney Fish Market (2 day trip), and to SAFCOL, Angelakis and Cappo Bros in Adelaide (overnight) for evaluation, auction and sale (Fig 3).

Fig 3 Polystyrene eskies containing fish for market trials in Adelaide and Sydney

The remaining fish were used for storage and shelf life trials. The three ice boxes from each treatment stored in the 4°C Constant Temperature (CT) room at LMSC were sampled during the six day storage period with shelf-life trials set up on Day 0 of storage, the other on Day 2 (Table 1). There were thus two trials undertaken, the first set up on Day 0 and run until Day 4, with sampling on Days 0,1 and 4 (Table 1). The second trial was set up on Day 2 using stored fish from the CT room and sampled with the same frequency as the first trial.

Table 1 Experimental setup for ice storage/shelf-life trials

	Trial Day						
Shelf life Trial	**0**	**1**	**2**	**3**	**4**	**5**	**6**
1	0	1			4		
2			0	1			4

On Day 0 of each trial the QI (Quality Index, Table 2) was assessed for 10 fish from each replicate of each treatment (3 ice boxes per treatment, 2 treatments: 60 fish); for Trial 1 this was the day of arrival at the laboratory.

Table 2 Quality Index method (QIM) used to assess sardines during shelf life/storage trials.

Modified from Musgrove et al (2007a).

QIM Sardines	Quality Parameter	Description	Score
Body	Rigor	Pre	0
		In	1
		Post	2
	Slime	Absent	0
		Present	1
	Smell	Fresh oily / Oceany	0
		Fishy, stale / rancid oil	1
		Rotten	2
Skin (Average of both sides)	Appearance	More than 2/3 bright, shiny	0
		1/3 to 2/3 dull	1
		More than 2/3 dull	2
	Colour	Predominately blue/ green	0
		Predominately grey, yellow	1
	Scale loss	No loss	0
		<50%	1
		>50%	2
Eyes (Top eye)	Pupils	Clear / Shiny black	0
		Cloudy	1
	Shape	Flat	0
		Slightly sunken / Puffy	1
		Sunken / Burst	2
	Iris	No blood / Silver	0
		Gold	1
		Bloody tinge / Bloody	2
Gills	Colour	Bright red or brown if brined	0
		Slightly dark or slightly faded if brined	1
		Very dark or very faded if brined	2
Belly	Colouring	Consistent silver	0
		Yellow / slightly brown / pink patches	1
		Dark brown patches	2
	Condition	Firm	0
		Soft	1
		Very Soft	2
		Burst	3
Vent	Condition	Normal / Tight	0
		Open / Stained	1
Quality Index			0-23

On the same day, samples of fish were taken from each replicate of each treatment and placed on flake ice in a closed 20kg esky at 4°C (Fig 4). Six eskies were set up for each treatment, 3 opened on Day 1 and 3 on Day 4 of each trial, and quality assessed.

Fig 4 Sardines placed on ice within a 20kg esky for the shelf life trials

4.2.3. Salinity measurement

Measurements were taken of the salinity (WTW LF320 conductivity meter) of the water in the bottom of each ice box within each treatment on the Day 3, 4 and 5. Measurements were taken at this position because the sardines generally sank to the bottom of each ice box.

4.2.4. Data analysis

Data were analysed using GLM and Regression modules on SPSS v17. Significant differences were accepted at $P<0.05$. Ice hours/days were calculated where appropriate, following Bremner et al (1987) as follows:

Ice hours = rate of deterioration (r) x storage time (hours).

Where $r = (1 + 0.1t)^2$ and t = temperature in °C over a given storage period, in this case fractions of an hour, as temperature was taken at 5 minute intervals.

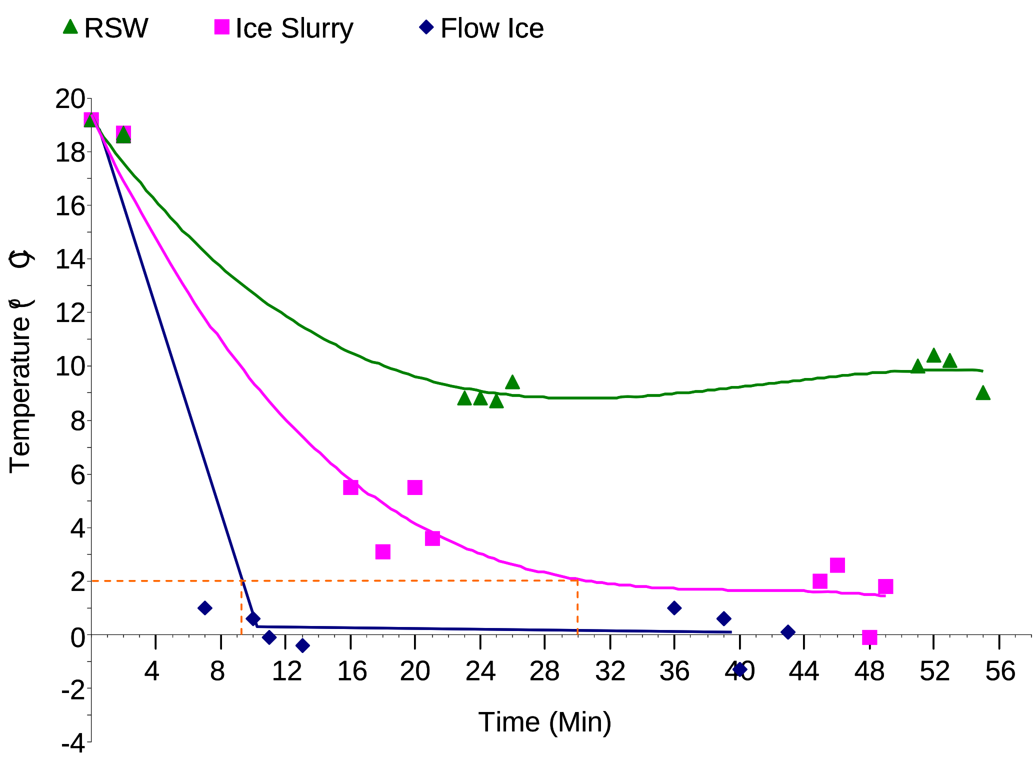
5. RESULTS AND DISCUSSION

5.1. Initial cooling after submersion in Flow Ice (FI), Ice Slurry (IS) or Refrigerated Sea Water (RSW)

Sardines in FI reached 2°C after approximately 9min and O°C within 11 min (Fig 5). Fish in ice slurry took 30min to reach 2°C and few cooled beyond this point. Core temperatures for RSW fish did not get below 7°C. Starting temperatures (i.e. before fish were loaded) for both the RSW ice box and RSW onboard tank were both 2°C, that for flow ice was -3 and Iced slurry was -2°C.

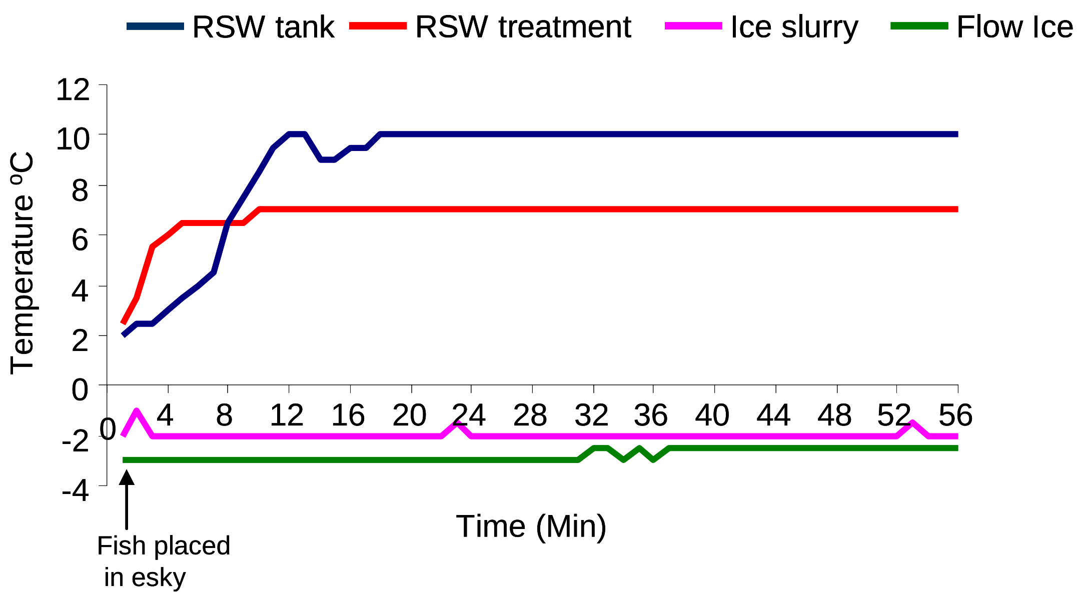
Fig 5 Sardine core temperatures: Initial (from the net) and when submerged in Flow Ice, Ice Slurry and Refrigerated Seawater

RSW and Ice Slurry regression lines are fitted by polynomial regression (R^2 >0.98, P<0.001), Flow Ice line fitted using group (time x temperature) means. Data was collected in January, 2009.



FI maintained a slightly lower temperature than IS (Fig 6) and RSW was much higher in the ice box and the onboard RSW tank. Given the difference in cooling rate between FI and IS, the relative cooling potential of FI is becoming apparent. More data are needed to clarify the cooling potential of each medium.

Fig 6 Temperature profiles of experimental ice boxes and RSW tank taken at the same time as sardine core temperatures (Fig 5)

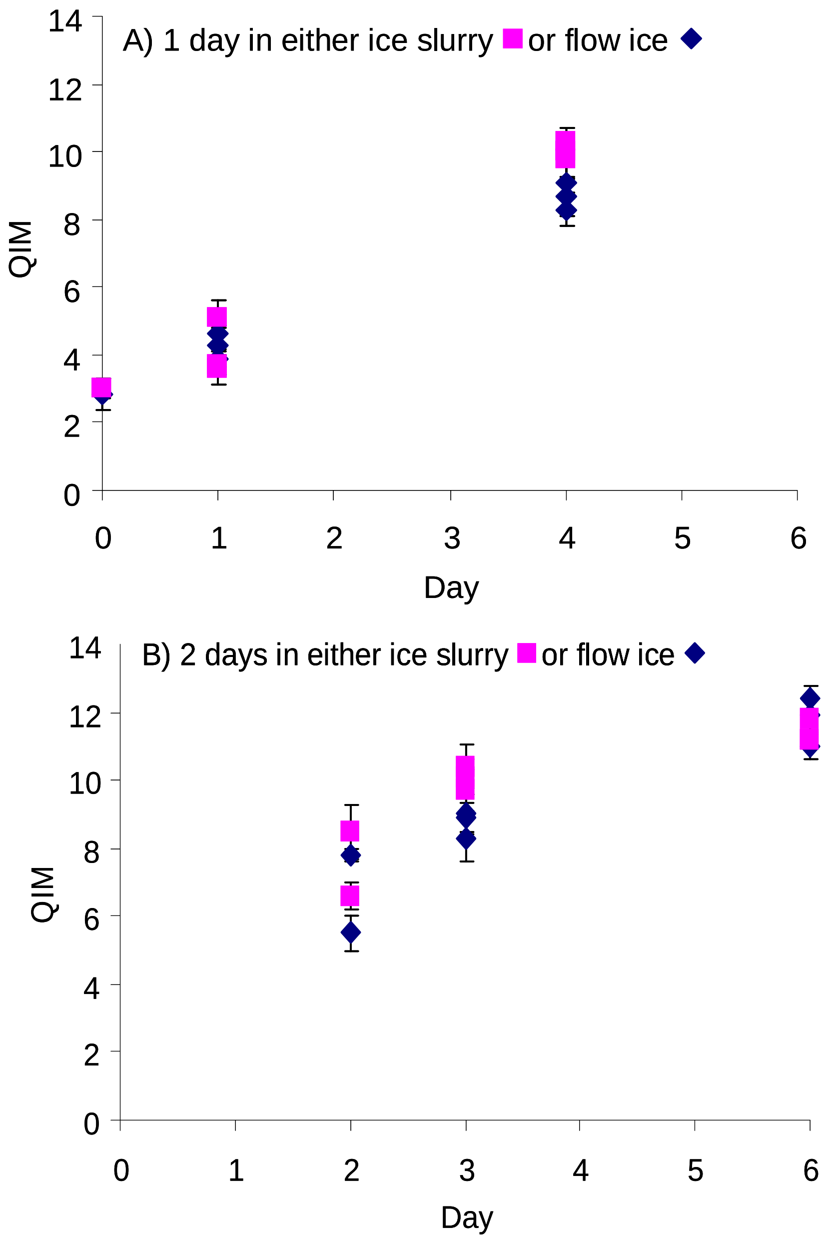


5.2. *Storage medium/shelf life trial/market trial*

5.2.1. QIM

Fish subjected to 4 day shelf-life trials after storage in FI for one or two days (Fig 7) showed significantly lower QI (i.e. were of better overall quality) than those stored in ice slurry. on Day 4 after 1 day storage (Fig 7a) and on the second day of the second trial (Day 3 overall, Fig 7b) (ANOVA, P≤ 0.006). After 6 days (i.e. the fourth day of the two day storage + four day shelf life) this difference had disappeared (Fig 7b).

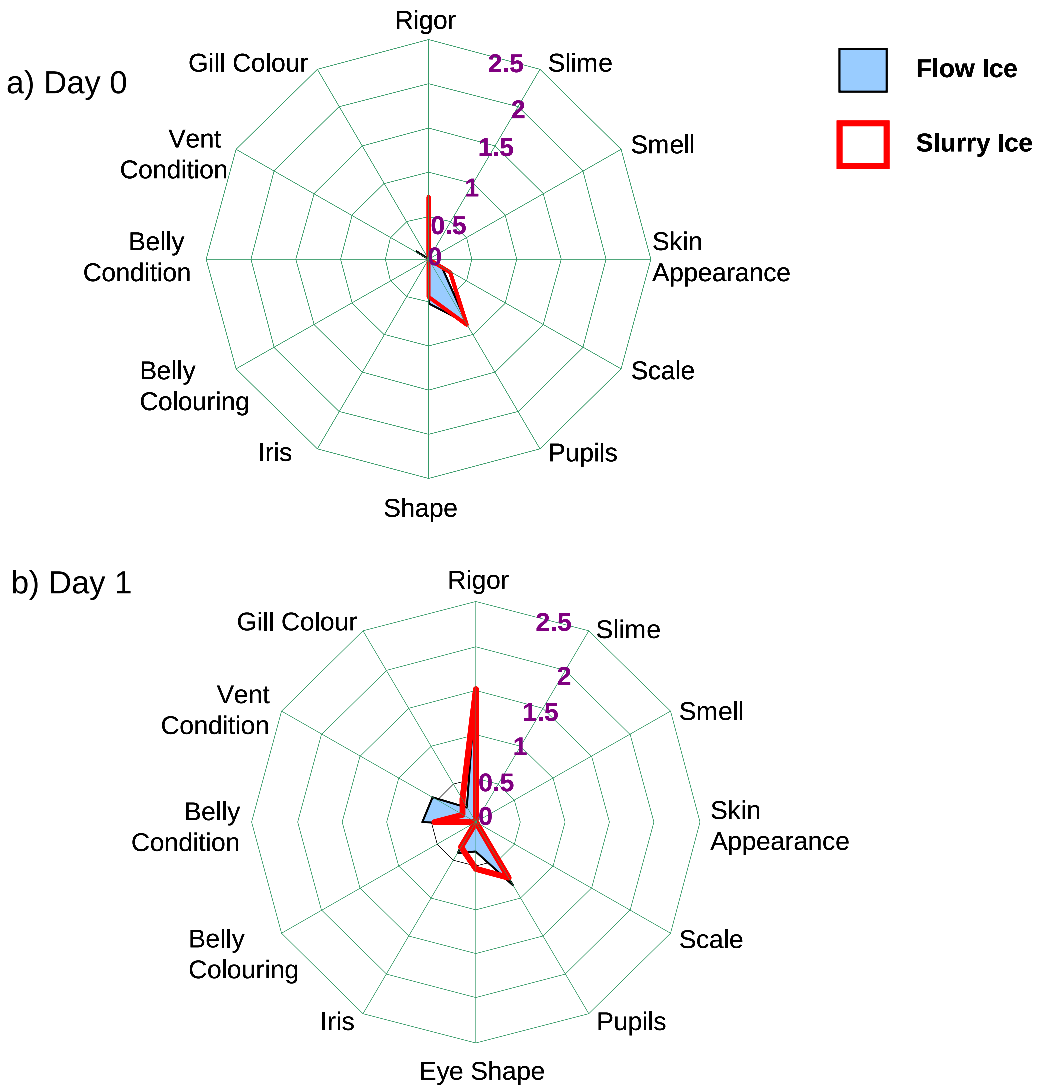
Fig 7 Sardine quality (QIM) after storage in either ice slurry or flow ice for 1 or 2 days then a 4 day shelf life trial



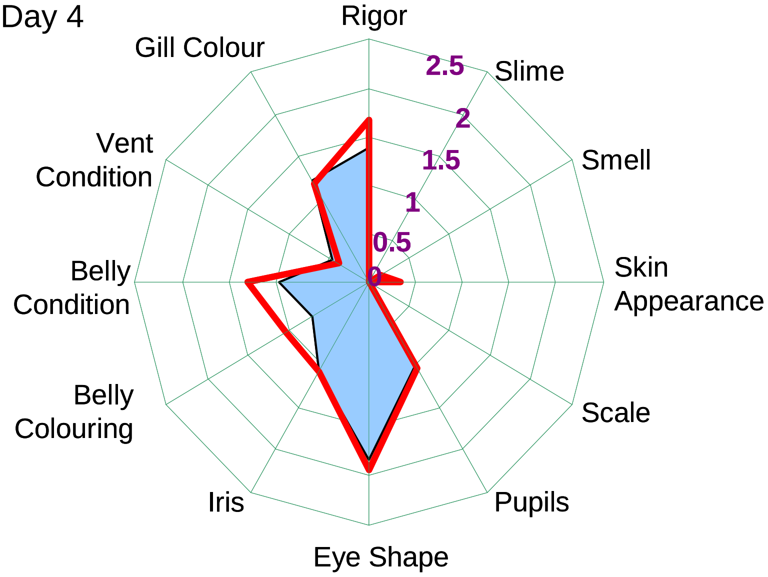
Examination of the QIM Quality Parameters (Fig 8) suggests vents were in poorer condition in FI sardines by Day 1 of the shelf life trial. By Day 4 (5 days post harvest) of the trial IS sardines had poorer belly condition and skin appearance and were more likely to be post rigor.

Fig 8 Average QIM Quality Parameters (ref Table 2)

(a) Day 0, (b) Day 1 and (c) Day 4 of the first four day shelf life trial (i.e. storage in ice slurry or flow ice for 1 day, ref Fig 7a)



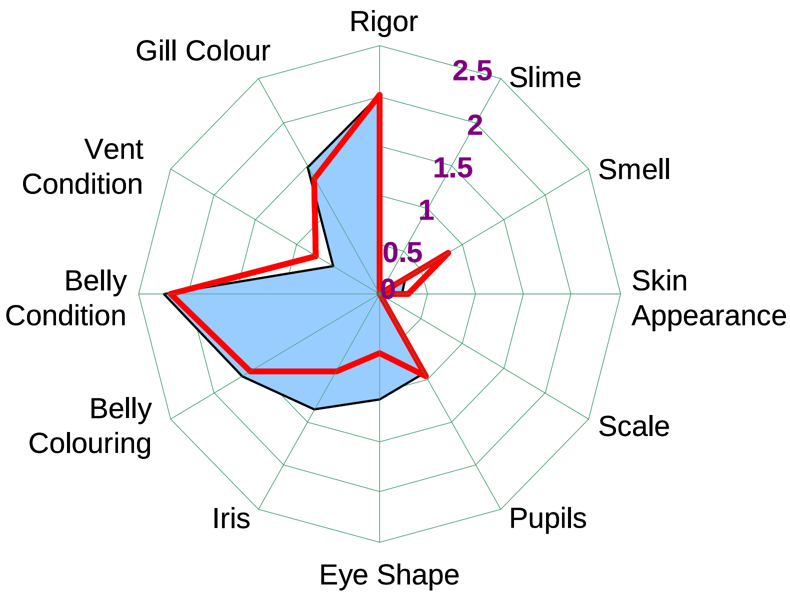
c) Day 4



Although there was no overall difference between treatments by Day 4 of the second shelf life trial (Day 6 post harvest), some of the quality parameters did appear to be different (Fig 9). Thus, the iris colour and the eye shape were in poorer condition in FI sardines, whereas those kept in IS smelled a little worse (maximum value for smell is 2, ref Table 2).

Fig 9 Average QIM Quality Parameters (ref Table 2) at Day 4 of the second four day shelf life trial

(i.e. storage in ice slurry or flow ice for 2 days, ref Fig 7b)

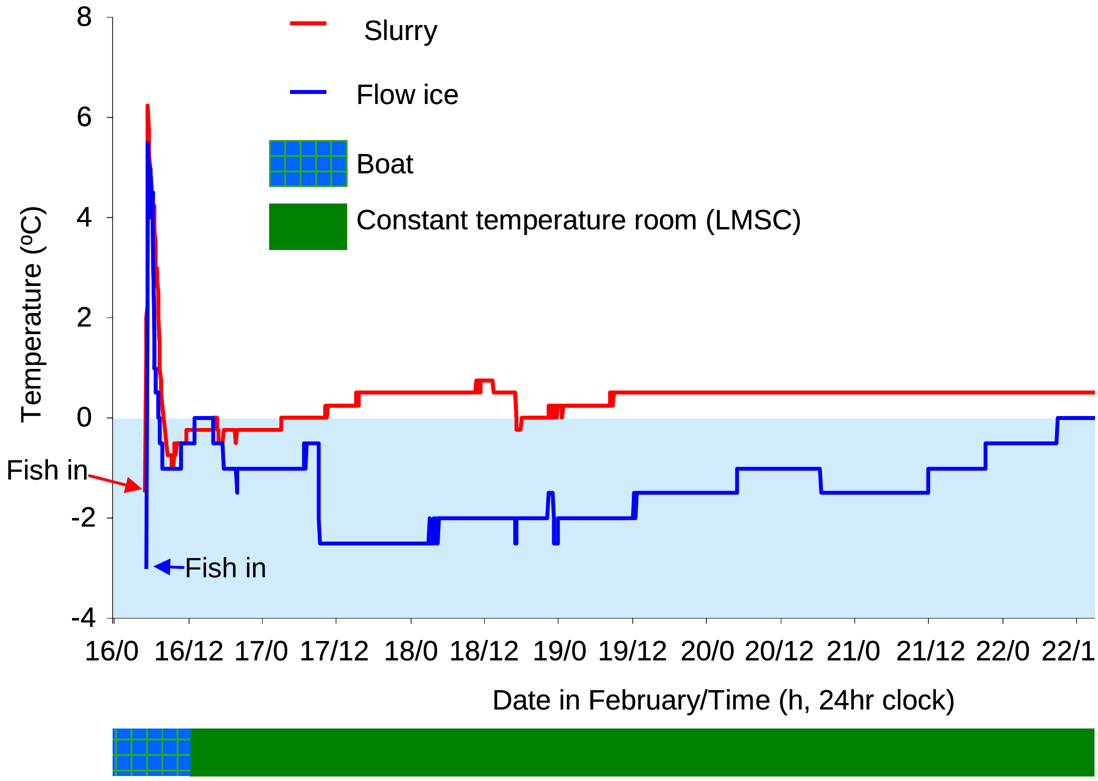


5.2.2. Temperature profiles

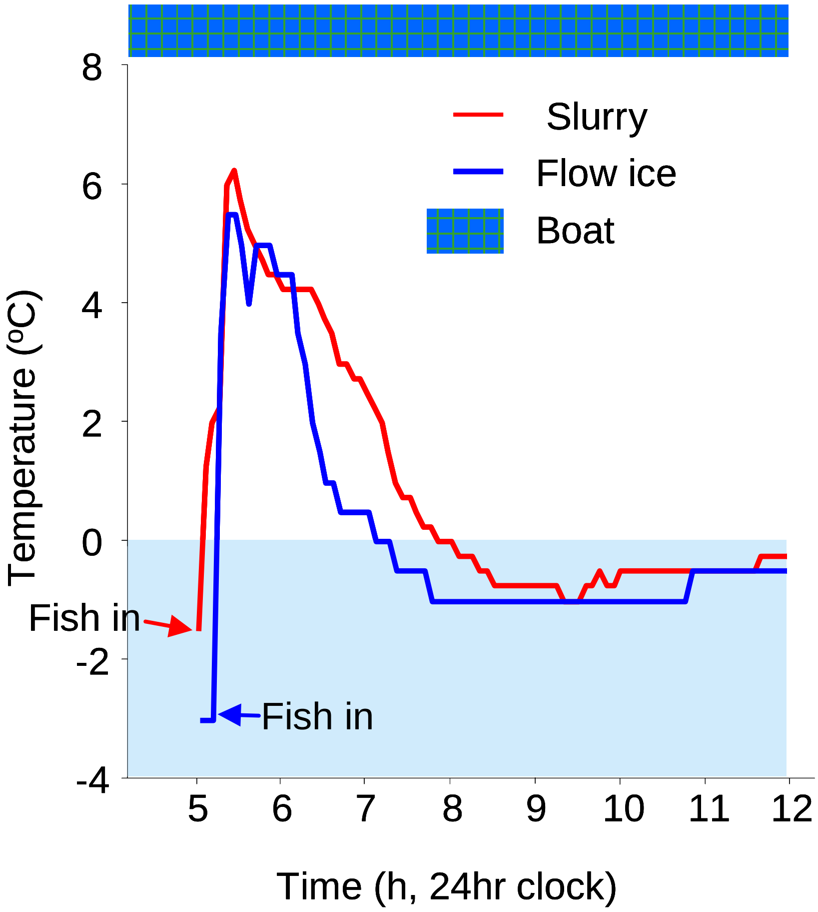
Temperature profiles recorded for ice slurry and flow ice (Fig 10a) show an initial spike as fish were put into both treatments on the boat. A lower FI temperature was then maintained during the holding period at the LMSC. Fig 10a expands the temperature log taken on the boat. The more rapid drop in temperature in the FI is probably related to the more efficient cooling rate observed for this medium in the first trial (Fig 5).

Fig 10 Temperatures logged during boat and on-land storage trials February 16th to 24th, 2009.

A) Logged temperatures from ice boxes containing flow ice or ice slurry on board the Gemma Marie and during storage in an LMSC constant temperature room at 4oC. IButtonTM data loggers used.

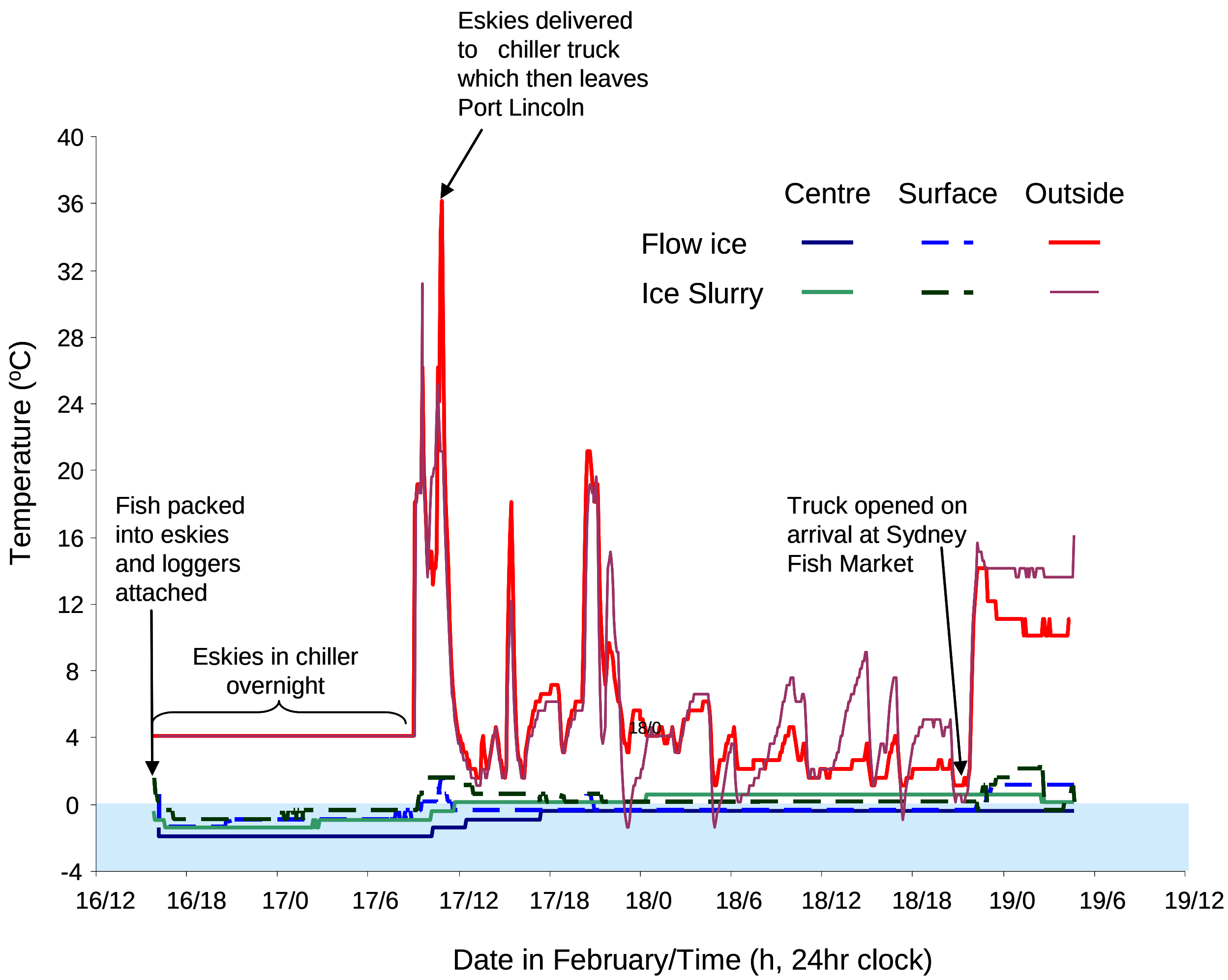


B) Logged temperatures from ice boxes containing flow ice or ice slurry on board the *Gemma Marie*, February 16th 2009



Sardine core and surface temperatures remained low and relatively stable during transport of eskies to Sydney Fish Market (SFM) (Fig 11). Temperatures for IS sardines ranged from -1.5 to 0.5°C and those for FI sardines from -2 to -0.5°C, after a slight peak at packing on the morning of 17/02. The outside temperature was 36°C on the packing day and further smaller peaks presumably represent loading of other produce into the chiller truck en route to SFM, and unloading at the market.

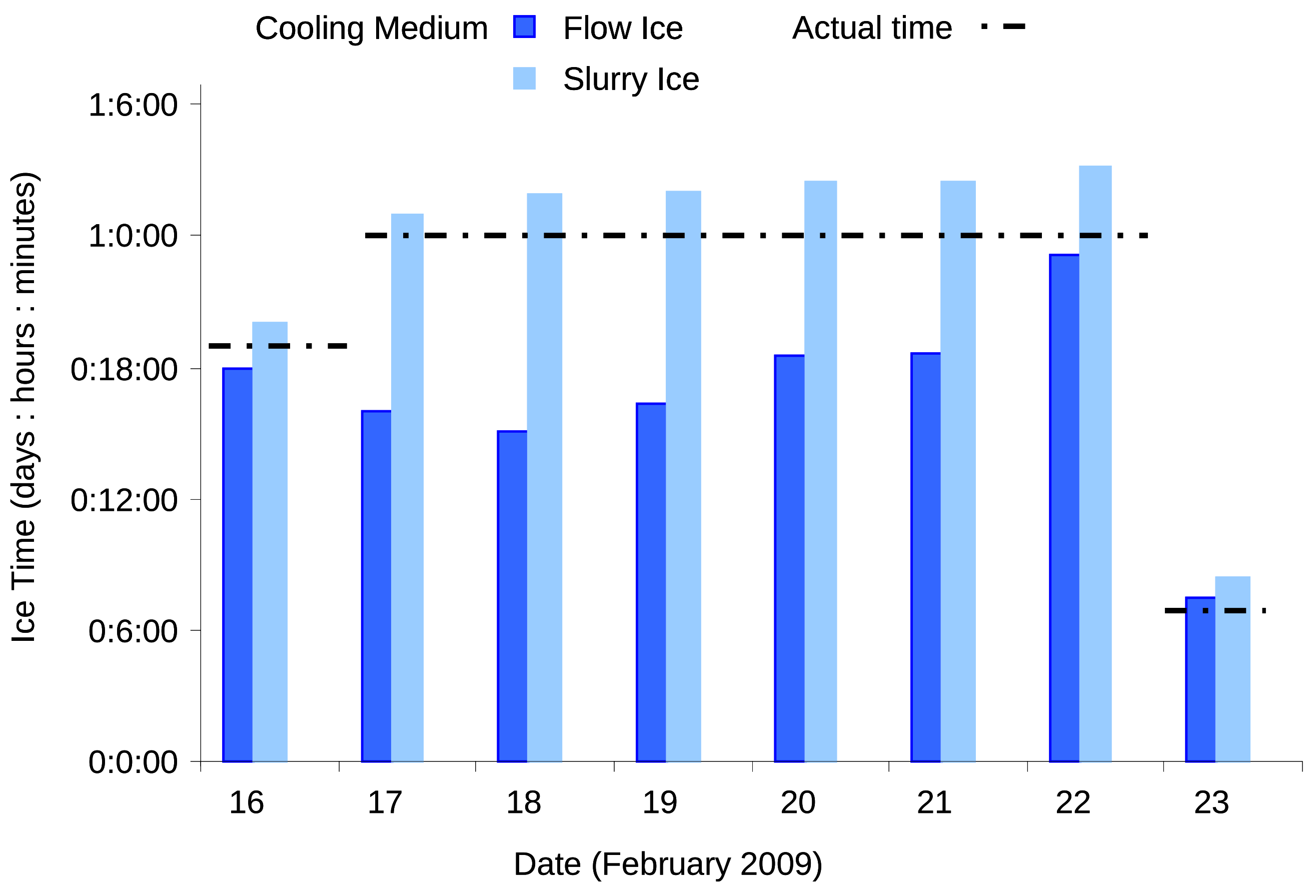
Fig 11 Logged temperatures in eskies during transport of sardines to Sydney Fish Market.



Ice days

Data from the loggers placed in ice boxes kept in the CT room were converted into ice days to facilitate comparisons between treatments (Fig 12). The flow ice treatment (total = 5:13:44) was well below slurry ice (total = 7:17:26). The increase in ice hours for the flow ice treatment, particularly in the latter stages of the experiment, was due to a reduced flow ice production and thus availability for the experiment (Fig 12).

Fig 12 Ice Time (Ice days:hours:minutes) for sardines in flow and slurry ice from capture (16/02/09) until trial's end (23/02/09).



Ice days appeared to vary between treatments during the trip to the SFM (Table 3) but this difference was probably due to the difference in outside temperatures experienced by the logged eskies (>10 ice hours). When treatment ice days are expressed as a percentage of outside ice days this difference largely disappears (Table 3) although slurry ice fish were still slightly warmer than flow ice fish.

Table 3. Ice days calculated for ice slurry and flow ice-treated sardines sent to the SFM on the 16-19th February 2009

(refer Fig 3). Ambient ice days refers to the temperature data taken from the logger attached to the outside of each esky and converted to ice days for comparison.

Treatment	Logger placement in esky	Ice days (D:h:m)	Treatment Ice days as Percentage of ambient Ice days
Slurry Ice	Core	2:11:10	35.32
	Surface	2:13:29	36.70
	Outside	6:23:32	
Flow Ice	Core	2:1:17	31.42
	Surface	2:7:06	35.13
	Outside	6:12:52	
	Difference in outside temps experienced by treatments	0:10:40	

It was shown that FI has a greater initial cooling capacity than SI, and FI ice days were lower overall than those for IS during the above trials. QIM data also suggested that FI sardines were of better quality than those stored in IS. However this increased cooling effect, and subsequent quality difference, was not reflected in price or perceived quality of the fish at any of the markets (Table 4). Both treatments were reported as being of the same high quality, and none of the buyers at any of the markets tested distinguished between the two treatments.

It may be that the market for fresh whole fish is not the best test of such a product and it is therefore suggested that other tests such as storage, filleting and cooking trials be carried out using the technology. The usefulness of flowice is supported by work on other fish species comparing flow ice with flake ice or refrigerated seawater (eg sardines, *Sardina pilchardus* (Losada *et* *al.*, 2007) and (Campos *et al.*, 2005) and hake, (*Psetta maxima*), turbot (*Merluccius merluccius*) and horse mackerel (*Trachurus trachur*us) (Pineiro *et al.*, 2004), (Carrera *et al.*, 2008)).

For example, Losada (2007) reported that flow ice significantly increased shelf life of sardines when compared to flake ice, as measured by both sensory and biochemical methods. Pineiro et al., 2004 found that flow ice had a faster chilling rate than RSW or flake ice for both turbot and horse mackerel. Bacterial counts were also lower and biochemical breakdown slower on flow ice than other media. Flow ice increased turbot shelf life to 22 days compared to 14 for flake ice and horse mackerel increased from 5 to 12 days. Note that these trials were carried out with flake ice not ice slurry (flake ice plus water).

Table 4 Prices achieved on 17/02/09 at two markets (auction) and two processors.

SAFCOL - South Australian Fishermen´s Cooperative Ltd.

Market	**Price ($)**	**Comments**
SAFCOL	4.50	Buyers all impressed with both batches (treatments); no differences between batches. Best fish seen in a long time. Large size, very firm, little scale loss. No burst bellies. Will retail for $8-$9/kg.
Sydney Fish Market	7.30 (average) (range: 6.98 - 7.82)	No discernable difference noticed by either QA or Buyers, both batches looked the same standard good but not the best. Fish quality was similar to/slightly better than other suppliers from SA.
Cappo Bros	4.50	
Angelakis	4.50	

5.2.3. Salinity

Salinity was significantly higher in ice boxes containing flow ice (32.02$\pm$0.5 ppt) than those with slurry ice (21.78$\pm$ 0.57 ppt) (one way ANOVA, $P<0.001$). There were no differences in salinity between days within treatments ($P\geq0.05$).

5.3. Technical issues

Further work was significantly hampered by technical difficulties with the small demonstration flow-ice machine. These warranted pump replacements on three occasions, a replacement ice generator motor, and significant repairs to the ice generator due to faulty assembly (by the manufacturer), as well as sundry other incidents requiring servicing and adjustments. On the 25th of May the ice generator seized completely and the flow ice machine was sent back to the supplier without completing scheduled experiments. Other delays were caused by timing of fishing activity in relation to vessel renovation, and suitable weather.

6. Benefits and Adoption

The key industry partner (White Fisheries) has benefitted directly from the efforts of the Principal and Co-Investigators in discussions of results during the project. In addition the Principal Investigator organised a number of flow ice machinery quotes for White Fisheries from a range of companies around the world, and one of these, Ice Solutions (NZ), was asked to quote on fitting out the *Gemma Marie* boat for a Beluga™ Flow Ice machine. To facilitate this process the PI also organised for the Director of Ice Solutions (NZ) to visit Port Lincoln to meet with Peter White and discuss the potential installation. At the time of writing White Fisheries are in negotiation with Ice Solutions with a view to fitting a Beluga machine into the Gemma Marie.

7. Further Development

Further work may be needed in this area, particularly in relation to storage to increase the time available for onshore processing. Work was planned comparing FI and IS cooled fish, with sardines going through White Fisheries' filleting machine upon arrival at the jetty. Storage time in the two media and filleting machine reject rates were to be assessed and compared. The ratio of fish:ice also remains to be tested. The current work used the recommended

1:1 recommended by the supplier; other ratios could be tested, and the fish put through storage and filleting trials.

To that end, Ice Solutions (NZ) Ltd has offered the use of a small flow ice machine free of charge for 2 to 3 months. This may allow further trials to be carried out with sardines, including the fish to ice ratio work.

8. Planned outcomes

This project has demonstrated the cooling capacity of flow ice and its affect on the quality of sardines. Although the quantity of data gathered was limited by technical issues the data that were gathered were significant in showing beneficial effects of FI; results supported by published work carried out on other fish species. The project and related other activities of the PI and CI's (i.e. discussion of results and the organisation of quotes), contributed to the decision of the Industry partner to seriously consider installation of flow ice equipment on his boat. This installation will contribute to an increase in the quality and quantity of fresh sardines on State and national markets, fulfilling the public outcome stated in the proposal:

"The increase in quality and quantity of an Australian seafood product will provide the Australian customers with premium, safe, high-quality, tasty and healthy product…"

The project has also contributed to increased awareness and knowledge within industry as to the usefulness of flow ice in relation to current practices, contributing to the fulfilment of the proposed private outcome, *vis*:

"development of their skills and knowledge relating to new product development and the production of safe, high quality, value-added seafood products. Improved revenue for sardine fishers, processors and others in the supply chain."

9. Conclusion

Trials have been carried out on the *Gemma Marie* (White Fisheries). Experiments involved comparisons between flow ice (FI), ice slurry (IS) and refrigerated seawater (RSW) at fish:cooling medium ratio of 1:1. Core temperatures were recorded and fish stored in FI and IS for up to two days; with associated shelf-life trials running up to 6 days. Fish were also sent to markets (SAFCOL, Angelakis and Cappo Bros in Adelaide, and Sydney Fish Market) for appraisal and sale.

The data collected indicates the greater cooling effectiveness of flow ice and its effect on fish quality (lower QIM scores). Flow Ice cooled sardines to 2^{o}C three times faster than Ice Slurry (i.e 9min vs 30min). Fish sent to market were better than average, and, in one case, the best they had seen in a long time. However, there was no difference in price between sardines stored in flow ice and those in ice slurry.

Further work may be necessary to explore the potential of flow ice, particularly at higher fish:cooling medium ratios, as the research team was unable to repeat the above trials or do further work due to persistent mechanical failures of the small demonstration flow ice machine leased for this trial.

It may be that the market for fresh whole fish is not the best test of such a product and it is therefore suggested that other tests such as storage, filleting and cooking trials be carried out using the technology.

10. References

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11. Appendix 1: Intellectual property

There are no intellectual property issues arising from this work.

12. Appendix 2: Staff

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