Report to Seafood Services Australia

Development of Value Added Prawn Products through Assessing and Refining the Cold Chain and Freezing Techniques of Brine Immersion Freezers.

Project No. 97/405

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Final Report

CENTRE FOR **FOOD TECHNOLOGY**

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NON TECHNICAL SUMMARY

Research results have demonstrated that the final frozen temperature of prawns from IQF treatments was within the range where ice crystals are formed, hence product damage could occur if the temperature was not adequately reduced before storage.

Treatment with cryogens such as CO_2 after glazing reduce product temperature sufficiently to maintain product quality. The method is cost effective, as the cryogen is only required to remove specific heat from the product, latent heat being removed by the brine immersion freezer. The temperature reduction before packaging removes the requirement for double handling by processing establishments and, hence improves efficiency. On average the product temperature was lowered to -25°C with a 3min application of the cryogen. Further improvements to the efficiency have been gained from glazing product with fine sprays as opposed to the industry standard dip glazes.

Post glazing temperature of prawns was approx. 6°C lower when 1/3rd of the IQF brine solution was replaced with ethanol (CH_2COOH_5), without an increase in freezing time. This concentration resulted in noticeable effects to the prawns flavour, odour and texture by taste panellists. Slight improvements were noted with levels as low as 10% replacement, but the added compliance costs for the required licenses to transport and store ethanol, workplace health and safety issues &c. may negate the benefits for processing efficiency.

Amounts of ethanol above 10% (w/w) of the freezing solution resulted in a noticeable effect on product flavour and aftertaste which was identified by sensory panellists. A significant alcohol odour was also present in the product. Assessment of the products over 12mths indicated the odour and flavour taints reduced with storage time, but further research is recommended to confirm this and investigate methods to increase the dissipation rate of ethanol through packaging options such as permeable liners or boxes. It is not recommended that ethanol be used in processing prawns until this further research is undertaken.

Both cooked and green tiger prawns appear to have longer thawed and frozen shelf life when treated with CO_2 cryogen after glazing. The sensory scores for the appearance of CO_2 treated prawns were consistently higher than that for prawns frozen by brine or ethanol treatments over the storage period. CO_2 treatment has been demonstrated to retard microbial growth after thawing on both cooked and green product, indicating a likely increase to thawed shelf life.

Packaging weights between 5 and 10Kg were determined as the most likely to be acceptable to larger retailers and wholesalers. It is likely that the foodservice industry would require packaging between 2½ and 5Kg. Waxed boxes are required for robustness during frozen storage and transport. Solid blocks of CO_2 were shown to provide adequate cooling to keep product frozen for 24hrs during transport. This method is particularly applicable for the local domestic market and is a clean and cheap method of cooling.

BACKGROUND

Freezing can substantially slow or halt the action of bacterial and endogenous enzymic systems in seafood. Seafood products need to be frozen as soon as possible after harvest/capture and a rapid freezing rate is desirable. Rapid freezing and maintenance of low temperatures prolongs the shelf life and enhances the product quality (Anon 1996).

Fresh prawns have a relatively short shelf life but this can be significantly extended when frozen as long as good freezing techniques are combined with rapid handling, packing and storage. Under poor freezing conditions the product can experience cell damage from large ice crystals growth which can result in greater drip loss and drier, tougher prawns (Anon 1996). Dehydration, oxidation and damage from enzymes can occur if the storage temperature is not low enough. Prawns should be rapidly frozen (minimum freezing rate of around 5°C/min/cm^3) and stored at stable frozen temperatures to prevent these problems.

Immersion freezing is particularly suitable for prawns. The prawns are placed into a eutectic brine solution (the salt concentration where the freezing point of the brine is lowest, generally around 26% salt which freezes at -21°C), which is chilled and circulated in a refrigerated tank. The freezing rate is rapid due to the direct contact between the product and brine solution. Unfortunately, immersion freezing is limited in its capacity to achieve suitable frozen temperatures as the freezing point of the brine is around -21°C (the freezer cannot operate at a lower temperature than the brine solution) and glazing results in a substantially increased product temperature.

This project investigated several options to reduce the temperature of IQF prawns before storage and assessed the sensory and storage characteristics of prawns frozen using the developed techniques.

NEED

This project addresses the industry's need for efficient and effective processing methods by developing freezing techniques to maximize storage life and quality. To overcome the problems associated with IQF prawns, producers have resorted to double handling products, stacking them for 24hrs to refreeze and then re-stacking for storage. This creates inefficiencies in the processing system and added costs to the producers.

This research will provide alternative ways to reduce product temperature and hence enhance the efficiency of brine immersion systems used in prawn processing establishments.

OBJECTIVES

1. Determine a more efficient and effective freezing medium and handling procedure for use with brine immersion freezers.

2. To facilitate the development of a convenient and high quality frozen prawn product suitable for the catering and foodservice trade.

3. Develop a suitable packaging system that is compatible with enhanced freezing techniques and provides greater flexibility in wholesale and retail marketing and facilitates more efficient processing, handling and storage and assured quality.

4. Develop a quality assured handling procedure for the product that ensures a high level of consumer confidence in product quality and safety.

All project objectives were successfully achieved.

The following body of the report is separated into sections based on the work conducted for each project objective.

Section 1. Freezing solutions and Handling methods

Freezer solutions and alternate handling procedures were assessed through data logging product during freezing and subsequent packaging and storage.

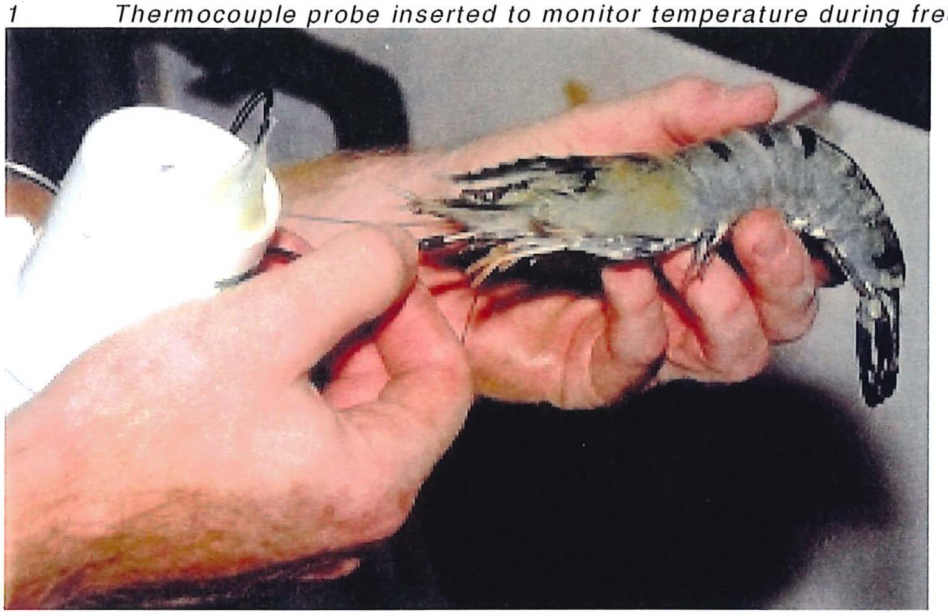
Methods

Equipment and Temperature Recording

A common immersion freezer, consisting of saturated salt solution circulated through a refrigerated tank, was utilised for processing trials. Temperature monitoring of the product was done with "T" type thermocouple probes inserted into the prawn meat and attached to either Hobo XTI's or Datataker DT 500 dataloggers (Plate 1). The probes were fixed in place with elastic bands to prevent separation of product and probe during freezing.

Data logged from all trials was downloaded from the dataloggers and transferred to a spreadsheet program (Microsoft Excel 7.0). Standard format graphs were produced from the sets of data.

PLATE 1 *Thermocouple probe inserted to monitor temperature during freezing*



Freezing trials

99.9% pure food grade ethanol was added to a reduced salt (20%) brine solution. After freezing prawns were glazed by dipping in fresh water (ambient water with ice added until temperature is approx. 0°C), packaged and stored for 24 hrs before sensory trials. Prawns were also arranged in a single layer on wire trays after being removed from an immersion freezer and sprayed with carbon dioxide snow at -80°C. Temperature was monitored and snow application times recorded.

Glazing

Following standard commercial practises, prawns were glazed after freezing. Standard glazing practises were compared with chilled water (0°C) sprays. Glazes were applied to the prawns by dipping prawns, still in freezer baskets, into iced water and/or spraying chilled

water through a "U" shaped plastic pipe in a fine mist over both the top and bottom of the product. Prawns were arranged into a single layer prior to sprayed glaze application. Temperature monitoring was maintained during glazing.

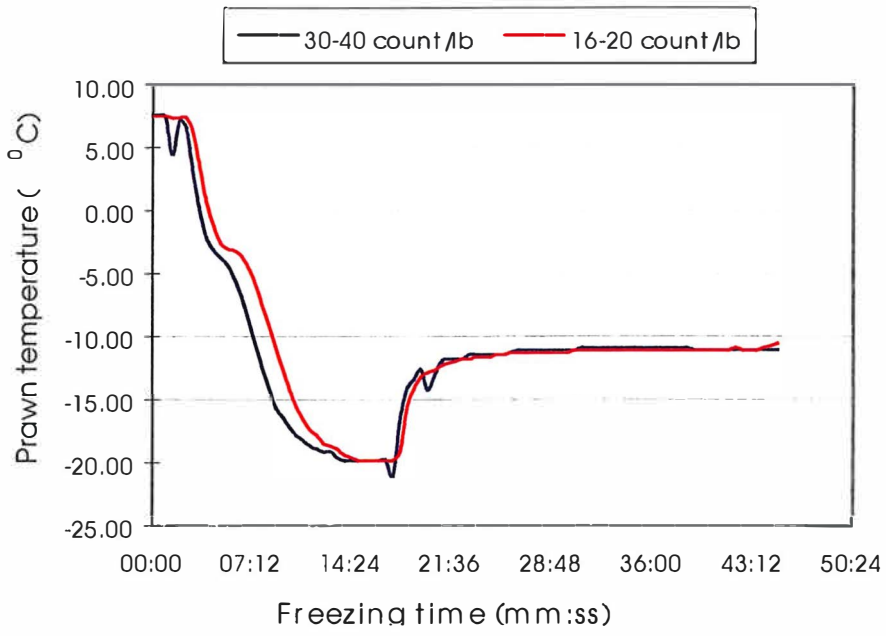
Sensory Trials

Frozen prawn samples were defrosted in ambient fresh water and gently agitated for 10 mins. Prawns were presented to panellists with head and shell intact. Three samples, two of which were identical, were presented simultaneously on coded dishes to the judges. Judges were required to taste the samples in a predetermined order. All tasters were randomly assigned samples in different order. Tasters were asked to choose the sample that was different using standard triangle test procedures (AS 2542.2.2 – 1983). All tasters were required to make a choice. Results were analysed by comparing the number of correct judgments with statistical probability tables (source: Fisher & Yates; Statistical Tables for Biological, Agricultural and Medical Research) at the 1% level.

Results and discussion

The brine immersion freezer is a rapid method for freezing prawns and commercial freezing times typically range from 11 to 14mins (Figure 1) depending on the size grade of the prawn. Generally, 2 baskets holding approx. 15-18Kg of prawns are frozen at the same time. After freezing, the product is dipped into chilled fresh water which rinses the excess brine and provides a protective glaze to maintain product quality during frozen storage. Temperature equilibration periods were significant after packaging and could result in inefficient handling practices and a loss of product quality. A significant temperature increase was noted during glazing and packaging operations.

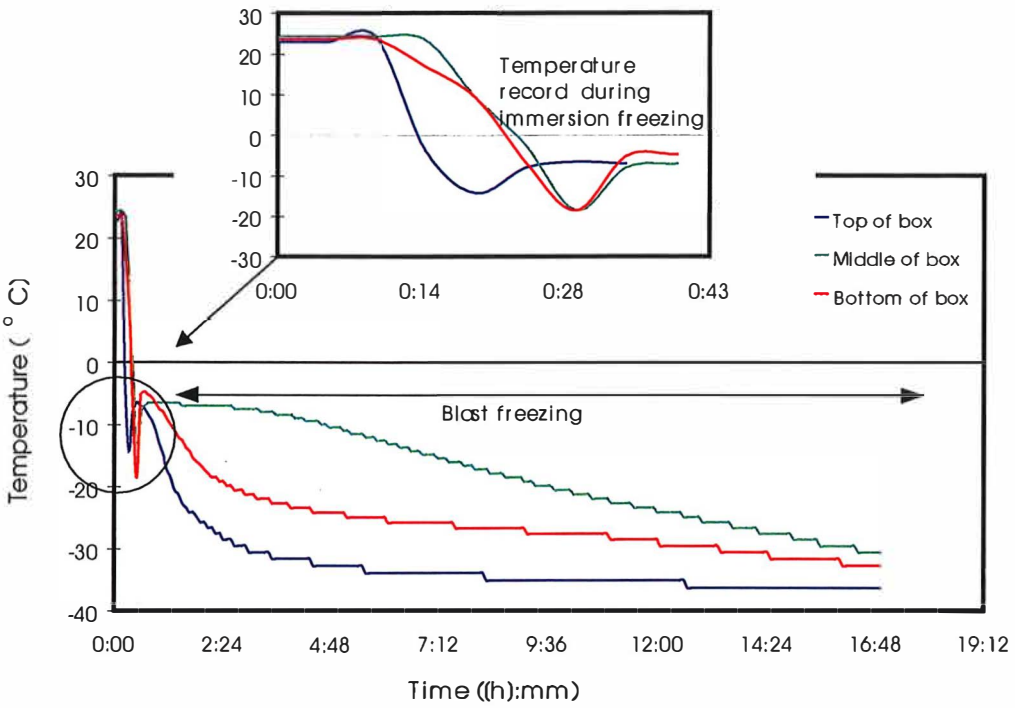
FIGURE 1 Temperature record of commercial IQF freezing of black tiger prawns.



Blast freezing after packing showed temperatures in the middle of the boxes remained above –25°C for approx. 11½ hrs (Figure 2).

This could subject the product to enzymatic and physical damage that would become apparent after thawing (Londahl 1997). In a commercial setting the re-freezing time could be significantly increased due to the increased heat loads on the freezer from greater volumes of product.

FIGURE 2 Temperature record of brine immersion freezing (insert) and blast freezing

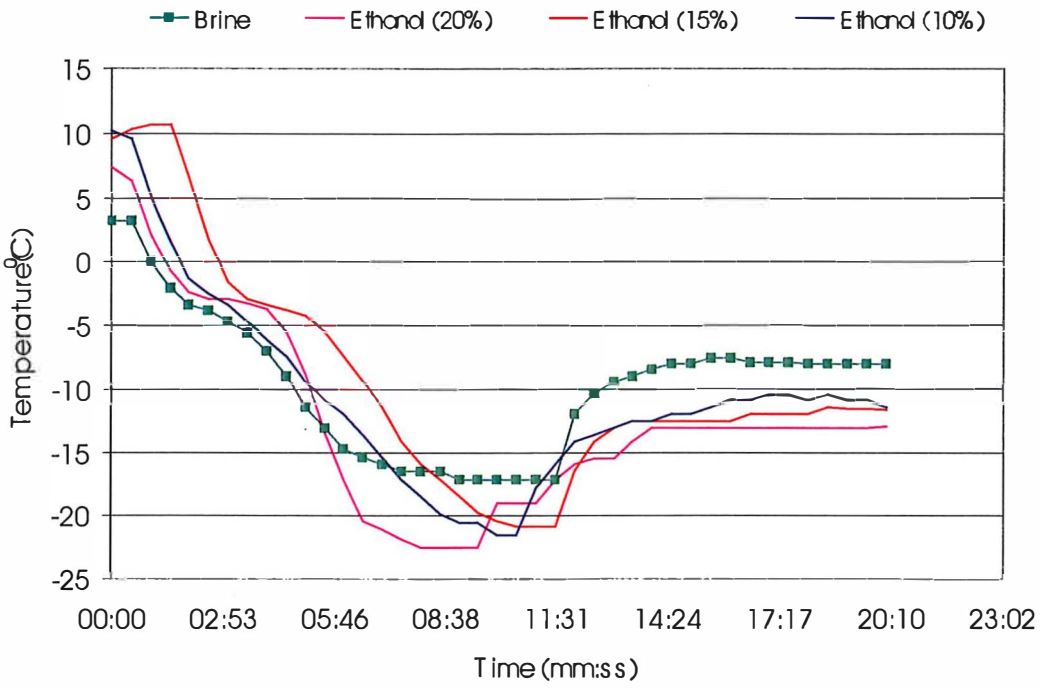


Changes to the freezing solution used in immersion freezers need to be neutral to the flavour and appearance of the prawns. Direct contact freezing with ethanol solutions has been previously investigated in the United State and has been used successfully with vegetable products (Masahiro 1977; Elias 1978; Orre 1988). Unlike pure ethanol, other freezing point depressants such as calcium chloride, glycerol and sorbitol would require high concentrations to reduce the freezing point of the solution sufficiently and would therefore require pre-packing of the prawns. The benefit of the water glaze would be lost in this circumstance.

Under standard triangle taste test conditions no statistical difference between freezing treatments was determined when ethanol was added to the brine solution for all concentration levels up to 65%(w/w) ethanol in the freezing solution. However, an aftertaste or dry feeling left in the mouth was noted by tasters. This was generally detected after the triangle test had been completed by the panellists.

At very low concentrations, the ethanol (10 - 20% (w/w)) freezing treatments were not significantly different in sensory characteristics to the brine frozen control samples but the temperature increase during glazing and packing, although not as high as brine frozen prawns (Figure 3, may be insufficient to prevent quality loss and improve commercial efficiency of the freezing process.

FIGURE 3 *Temperature of black tiger prawns frozen with low concentrations of ethanol added to the freezing solution*



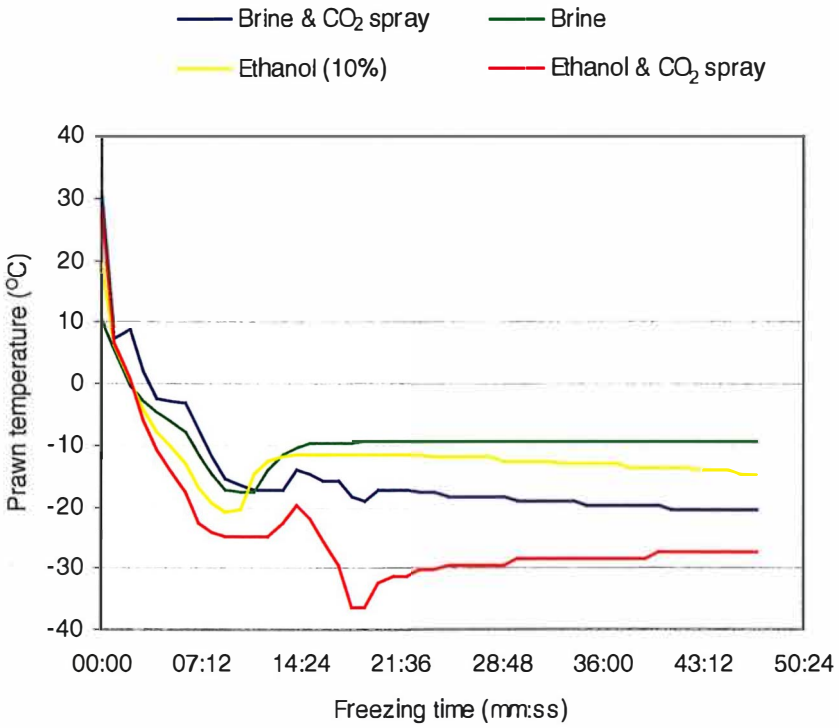
The most significant barrier to ethanol use in immersion freezing solutions is the residual odour noted in the frozen products, particularly when the packaging is first opened. As frozen product assessment was carried out through the project, there was some indication that the intensity of the odour decreases during storage. Further research would need to be undertaken to confirm this. Further likely barriers to ethanol freezing under commercial conditions are likely to be the added compliance factors required for licenses and workplace health and safety issues associated with the purchasing and storage of ethanol products.

Carbon dioxide (CO_2) solidifies at -80°C and as it is cheaply produced it is ideal to finish off the brine immersion freezing process. If the product temperature is approximately -10°C, the rate at which the temperature can be lowered using CO_2 snow is significantly increased. The spray of water to glaze the product results in a significantly lower temperature increase than dip glazing. Spacing the sprays of CO_2 snow onto the product allows residual snow to sublimate and reduce the product temperature, thus reducing the total amount of snow required and overall cost.

As shown in Figure 4 the product temperature after CO_2 application is significantly lower than both standard brine and ethanol freezing. The initial freezing in brine sufficiently reduces the product temperature to ensure the CO_2 application remains cheap and efficient.

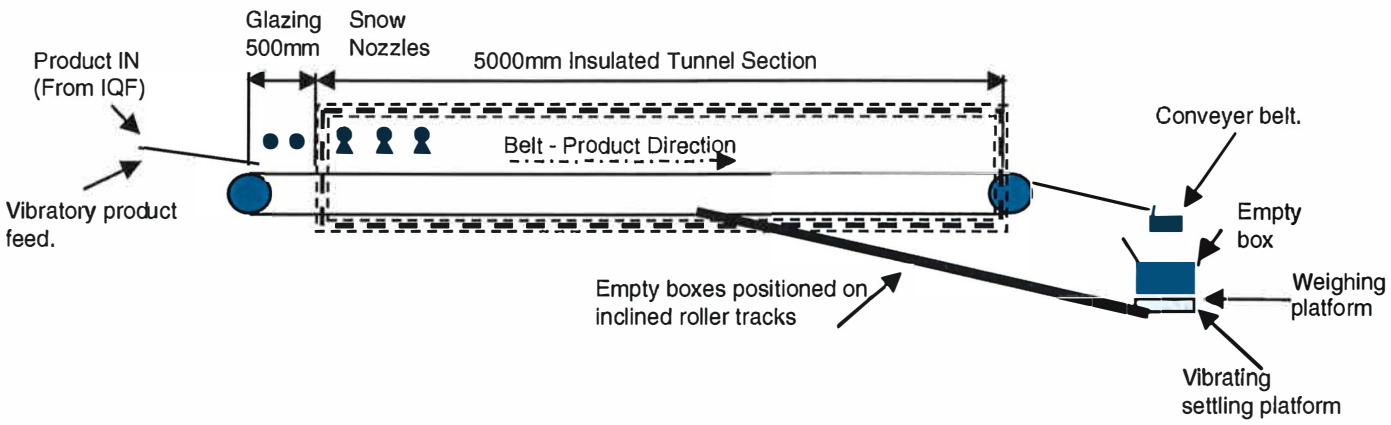
The spray of CO_2 was staggered as two applications of snow for 1½ minutes allowing the melting snow to remove heat from the product between snow applications. No significant difference between prawns subjected to CO_2 treatment and standard brine frozen prawns was noted under standard triangle test conditions.

FIGURE 4 *Temperature record of prawns during freezing in brine and/or ethanol with CO2 finishing*



The CO_2 spray operation can be automated using a tunnel and belt system. Generic designs have been prepared but the technical specification of a system would be dependant on the processing parameters of the establishment. A number of issues would affect the building of an automated freezing line such as product throughput and hence belt size, capacity and speed. The layout of ancillary equipment such as product feeders, weigh stations and hoppers would need to be considered in relation to the specific processing facilities. Both the set up and operating costs would be subject to these conditions. An example freezing tunnel design is shown in Figure 5.

FIGURE 5 *Side view of an example freezing tunnel and ancillary equipment layout*



In this diagram, product is fed into the tunnel from the brine immersion freezer over a vibratory belt or tray. This would settle the product out into a layer of prawns. The glaze is applied from sprays both top and bottom of the belt and a short period is left to remove excess glaze water. Position and spacing between the CO_2 sprays is dependant on the belt speed; and hence product throughput.

A wide range of options are available for packaging the product from the freezing tunnel. This diagram shows a basic set-up where an inclined roller feeds empty boxes onto a weighing / settling platform. Automating the glazing and CO_2 finishing process using conveyor belts in an insulated tunnel will provide greater savings in labour to producers.

In the interest of technical performance and OH&S regulations, it is recommended that technical assistance is obtained from a gas service provider in the design and building of a freezing tunnel.

An example of running cost calculations of a CO_2 tunnel is attached at Appendix 1. This calculation is based on the assumptions stated and of course will not be applicable for all processing establishments, but does provide and indication of what expenses will be involved with running the freezing tunnel.

Section 2. Sensory assessment and storage of frozen product

The quality of frozen prawns was assessed over a 12mth period. Microbial assessments and regular taste panels were performed on the products.

Methods

Frozen storage life

Frozen cooked tiger prawns were defrosted in ambient fresh water gently agitated for 10mins before each trial. Tasters were supplied with a sample from each treatment and a brine (control) frozen sample.

Tasters were asked to rate the appearance, flavour, texture and odour of the samples using standard rating test procedures (AS2542.2.3). They were also asked to rate the overall acceptance of the product. Numerical scores of 0 and 100 were assigned to all scales on the questionnaire, with 0 representing the left-hand end (= none) and 100 the right hand end (= very much) of the characteristic labelled on the scales. Results were analysed using one way analysis of variance (ANOVA) and pairwise comparison of means for those attributes that showed a significant ($p<0.05$) difference between freezing treatments. Product characteristics were profiled with standard descriptors for the flavour, texture and odour of samples. Tastes were performed at 0, 2, 4, 6 and 12 months frozen storage.

Microbial Evaluation of Thawed Product

Samples were removed from frozen storage and thawed in a coolroom (2°C) over 24h and stored for the 14 trial days. Daily samples from each treatment were aseptically removed from chilled storage and submitted for mesophilic and psychrotrophic counts. Coliform counts were performed on the first day, then every second day through the trial and finally on the last day of the trial.

Sample Preparation

Composite samples of three prawns from each freezing treatment were roughly chopped. The whole prawn was used with shell and head left on. Samples were macerated for 60 seconds in a Seward BA6021 type stomacher with peptone diluent. Serial dilutions were made as appropriate dependant on number of trial days elapsed.

Microbial Enumeration

Psychrotrophic & mesophilic enumeration.

Approximately 15ml of nutrient agar at 45°C - 50°C was mixed with 1ml aliquot's of sample dilution in Petrie dishes and allowed to set. Incubation was at 30°C for 72h to enumerate mesophilic and at 4°C for 14 days to enumerate psychrotrophs. Plates were counted and the number of organisms recorded as colony forming units per gram (cfu/g).

Coliform enumeration

Approximately 5mL of Violet Red Bile Agar (VRBA) was poured into Petrie dishes and allowed to set. 1ml aliquot's of the diluted sample was mixed with approximately 10ml of VRBA at 45°C -50°C in the Petrie dish and allowed to set. Incubation was at 30°C for 72h to enumerate coliform bacteria. Plates were counted and the number of organisms recorded as colony forming units per gram (cfu/g).

Market Evaluation Trials

Two and a half kilo samples were frozen in brine, spray glazed and sprayed with 2, 1½min CO_2 snow applications and were shipped to 5 seafood retailers and wholesalers with a questionnaire sheet (participants are listed in Appendix 2). Respondents were given a list of instructions with the survey sheets. Survey participants were required to assess the product in comparison to the product currently purchased.

The survey of 16 questions consisted of a mixture of open ended, multiple choice and "Likert" scale questions. "Likert" scales ranged from 1 to 5, 5 being like very much, much better than or very important and 1 being don't like at all, much worse than, or not important at all (a full survey questionnaire is supplied in Appendix 2). Multiple choice questions provided a range of answers for respondents to choose and provided space for specifying other appropriate answers. Results were collated into a spreadsheet program (Microsoft Excel 7.0) and evaluated.

Results and Discussion

Frozen shelf life

Taste tests after freezing (storage time=0) indicated a difference between treatments in the "other odour" and "saltiness" attributes (Table 1). The CO_2 and brine treatments were significantly different from both ethanol treatments in other odours and the CO_2 + ethanol treatment was rated as being more salty than the other samples. There was no difference in the overall quality of the samples between treatments.

TABLE 1 Mean taster scores assigned to treatments at 0mths frozen storage

Attributes	Mean taster scores (0mths storage)			
	Control (brine)	CO_2	Ethanol + CO_2	Ethanol
Appearance	82.83	84.17	82.75	83.92
Typical Odour	61.58	60.92	52.75	46.96
Other Odour	12.92[a]	13.21[a]	31.25[b]	38.00[b]
Firmness	71.33	71.58	72.67	74.83
Moistness	67.75	70.33	65.75	63.75
Typical Flavour	71.67	70.75	63.67	62.50
Saltiness	51.67[a]	46.42[ab]	40.75[b]	46.33[ab]
Sweetness	52.58	55.75	51.67	50.83
Other flavour	26.83	27.75	30.83	35.67
Overall Quality	76.67	72.58	65.67	67.75

[ab] samples followed by different letters are significantly different at P<0.01 (1%)

The appearance of the CO_2 treated samples were given the highest mean score which could be due to the snow application freezing the glaze before packaging and maximising it's protective quality. The product samples frozen using CO_2 sprays appeared to sustain less damage to feelers and legs and were easily removed from the pack after frozen storage. This freezing method could provide a convenient product that can be taken in the required amount from the package while still frozen.

The profiles of the products from each freezing treatment using standard descriptors indicates that ethanol was apparent in the odour of the products when they were initially frozen. This is comparable to the results of triangle tests performed during freezing trials. Prawns that were frozen with the ethanol treatments were described as having a chemical

odour / flavour and being chewy / rubbery with more frequency than the other treatments. Some tasters described all the treatments as having a chemical flavour, including the brine frozen control samples.

Over the 12mths frozen storage, the mean rating scores showed a typical pattern, reducing for all freezing treatments across all attributes. After 2mths frozen storage (Table 2) the significant difference between treatments in the "saltiness" attributes was no longer apparent. Both ethanol and / CO_2 treatments had significantly higher "other odour" present at 2mths storage. The control sample was rated as having a significantly better "typical flavour" than the ethanol treatment but by 4mths storage (Table 3) no difference in the "typical flavour" or "other odour" was noted between treatments.

TABLE 2 MEAN TASTER SCORES ASSIGNED TO TREATMENTS AT 2MTHS FROZEN STORAGE

Attributes	Mean taster scores (2mths storage)			
	Control (brine)	CO_2	Ethanol + CO_2	Ethanol
Appearance	82.50	83.75	82.58	84.42
Typical Odour	60.50	59.92	50.92	47.33
Other Odour	15.25^{a}	14.17^{a}	31.33^{b}	32.67^{b}
Firmness	75.42	70.25	72.42	77.50
Moistness	66.50	69.50	64.00	62.08
Typical Flavour	71.50^{a}	68.83^{ab}	61.42^{ab}	56.25^{b}
Saltiness	44.58	48.75	44.83	46.67
Sweetness	50.17	49.25	49.67	45.58
Other flavour	27.25	27.50	36.83	38.75
Overall Quality	75.67	71.58	64.42	64.58

^{ab} samples followed by different letters are significantly different at P<0.01 (1%)

The CO_2 treated samples showed lower levels of "other flavour" than the ethanol treated samples after 4mths storage.

TABLE 3 Mean taster scores assigned to treatments at 4mths frozen storage

Attributes	Mean taster scores (4mths storage)			
	Control (brine)	CO_2	Ethanol + CO_2	Ethanol
Appearance	81.42	84.25	81.50	84.67
Typical Odour	59.33	55.67	51.92	51.83
Other Odour	17.67	19.42	25.58	27.83
Firmness	69.25	70.17	70.75	69.58
Moistness	64.92	64.83	60.08	59.83
Typical Flavour	65.75	66.83	60.75	55.58
Saltiness	45.92	47.17	42.33	48.75
Sweetness	47.75	48.50	48.75	44.58
Other flavour	33.75^{ab}	24.33^{a}	34.00^{ab}	38.17^{b}
Overall Quality	69.00	69.33	61.17	63.67

^{ab} samples followed by different letters are significantly different at P<0.01 (1%)

At 4 to 6mths storage the development of other flavours and odours could be expected. Prawns typically become slightly drier, discolouration around the head occurs and flavour loss is noted. The taste test results show that at 6mths storage (Table 4) the CO_2 treated samples had significantly less other flavours present that the control, ethanol and ethanol+CO_2 treatments, and this continued through to the end of the storage trial. The CO_2 treated samples were also rated as retaining more moisture than the ethanol treatment. There was no difference between treatments in the appearance of the samples until after 6mths frozen storage, when the brine treatment was rated significantly lower than the other treatments.

After 12 months (Table 5) the prawns from all treatments were rated as being softer and less moist than at the start of frozen storage. The appearance likewise degraded. There was no significant difference in the overall rating between the treatments at the end of the tested storage period.

TABLE 4 *Mean taster scores assigned to treatments at 6mths frozen storage*

Attributes	Mean taster scores (6mths storage)			
	Control (brine)	CO_2	Ethanol + CO_2	Ethanol
Appearance	66.83^{a}	77.25^{b}	77.00^{b}	79.50^{b}
Typical Odour	56.83	55.67	47.75	48.00
Other Odour	21.67	19.42	23.17	25.33
Firmness	64.92	70.17	71.08	69.58
Moistness	61.83^{ab}	64.83^{a}	58.67^{ab}	54.75^{b}
Typical Flavour	59.00	66.83	56.58	55.58
Saltiness	44.33	47.17	41.50	47.33
Sweetness	42.67	48.50	48.75	42.67
Other flavour	32.08^{ab}	24.33^{a}	30.08^{ab}	38.17^{b}
Overall Quality	62.17	68.83	59.75	64.50

^{ab} samples followed by different letters are significantly different at P<0.01 (1%)

TABLE 5 *Mean taster scores assigned to treatments at 12mths frozen storage*

Attributes	Mean taster scores (12mths storage)			
	Control (brine)	CO_2	Ethanol + CO_2	Ethanol
Appearance	59.75^{b}	62.75^{a}	58.75^{b}	57.33^{b}
Typical Odour	46.92	46.33	42.17	44.75
Other Odour	52.17^{b}	40.58^{ab}	47.17^{a}	25.25^{c}
Firmness	57.50	57.33	55.08	61.00
Moistness	50.25	52.17	51.58	49.67
Typical Flavour	50.00^{b}	53.50^{a}	49.58^{b}	49.58^{b}
Saltiness	30.67	38.17	34.25	40.50
Sweetness	46.83	49.58	44.67	48.75
Other flavour	36.08^{b}	31.58^{a}	33.58^{ab}	33.58^{ab}
Overall Quality	49.33	53.83	48.50	48.50

^{ab} samples followed by different letters are significantly different at P<0.01 (1%)

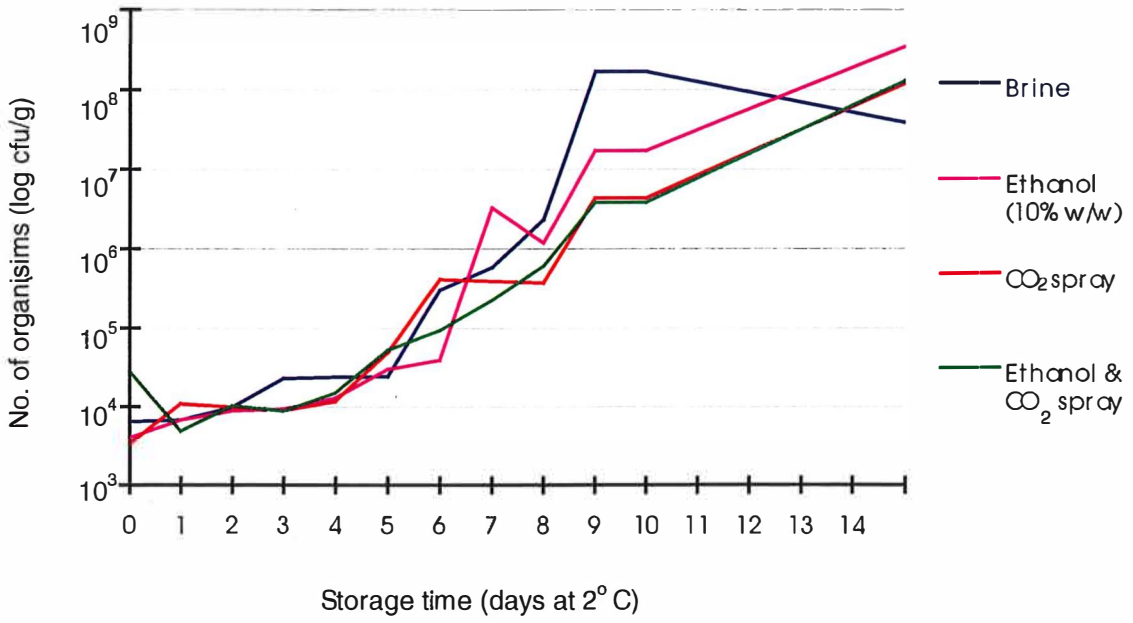
The control (brine) treatment was given a significantly lower appearance and overall quality rating after 6mths storage whereas the other treatments ratings did not significantly decrease until the 12mths storage time. The taste test results demonstrate that quality can be maintained over an increased period when product is rapidly frozen and low, stable temperatures are maintained.

Microbial analysis of thawed product

The microbial population on the green tiger prawns followed a typical growth pattern for prawns held at chill temperatures. The brine frozen (control) prawns had mesophilic bacteria reaching levels indicative of spoilage at 9 days storage, while ethanol and / CO_2 treated prawns showed retarded population growth (Figure 4). Both CO_2 spray treatments caused greater retardation of bacterial growth than ethanol treatment. The combination of ethanol

and CO_2 spray treatment resulted in similar growth rates to the CO_2 only treatment, indicating no accumulative inhibitory effect of ethanol and CO_2

FIGURE 7 Mesophilic load of thawed green tiger prawns (P. monodon)



The psychrotrophic population of the green prawns grew at a similar rate for all treatments applied (Figure 7). Again, CO_2 treatment appeared to have a slightly greater inhibitory effect than ethanol.

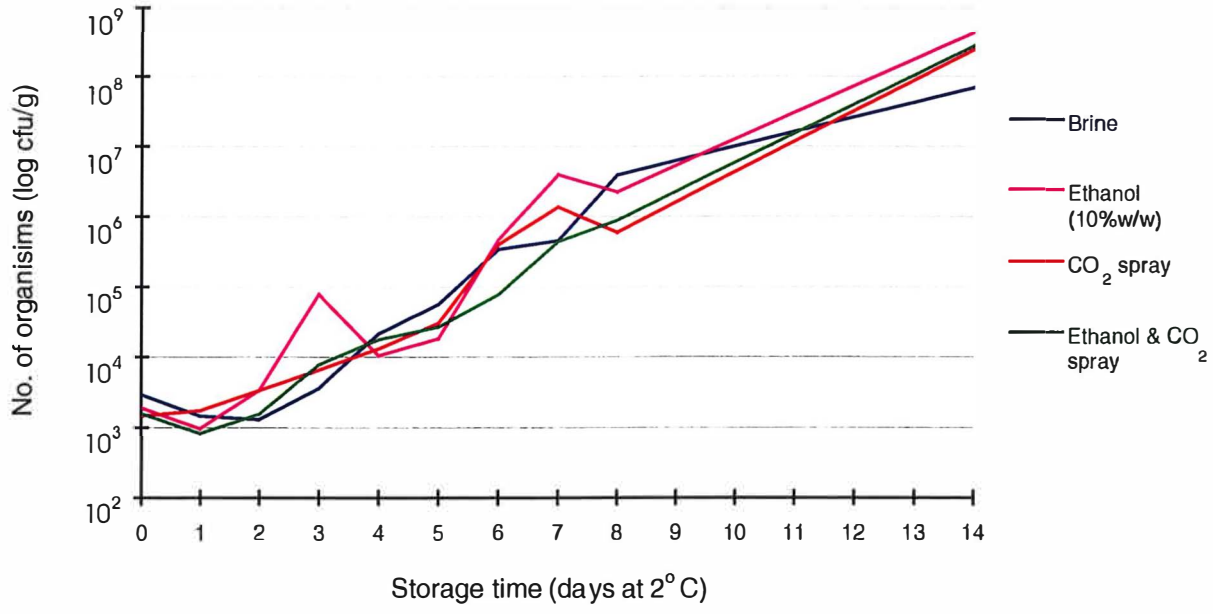


Figure 8 Psychrotrophic load of thawed, green tiger prawns (P. monodon)

The microbial load on the cooked prawns increased in a typical growth pattern for chilled prawns (Figures 5 & 6). Growth rates of the mesophilic bacteria were retarded by the combined treatment of ethanol and CO_2, while psychrotrophic population increase was inhibited by both CO_2 treatments.

FIGURE 9 Mesophilic load of thawed, cooked tiger prawns (P. monodon)

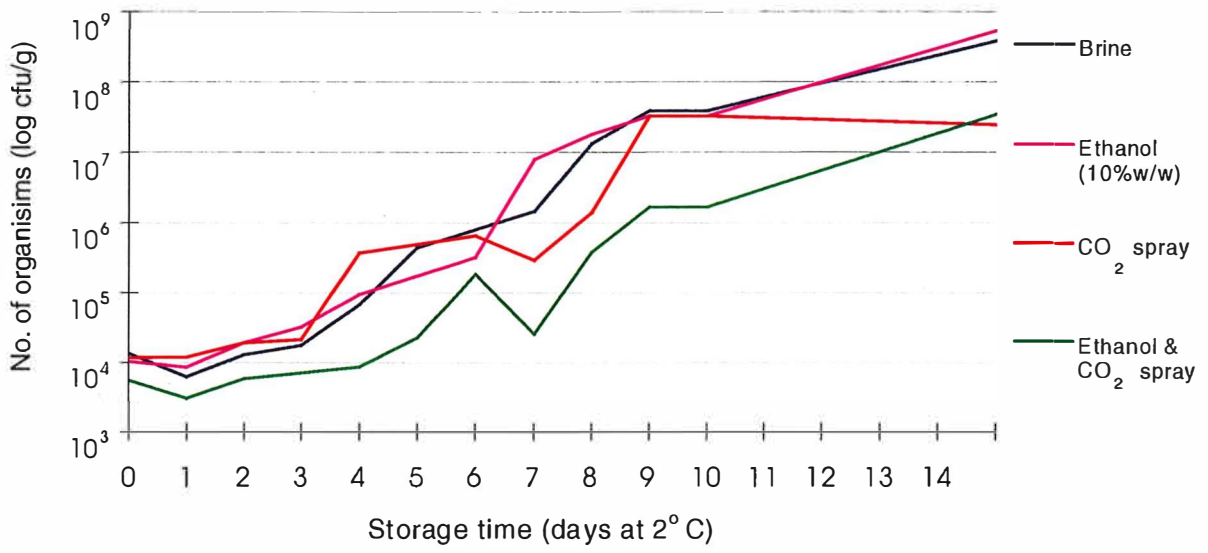
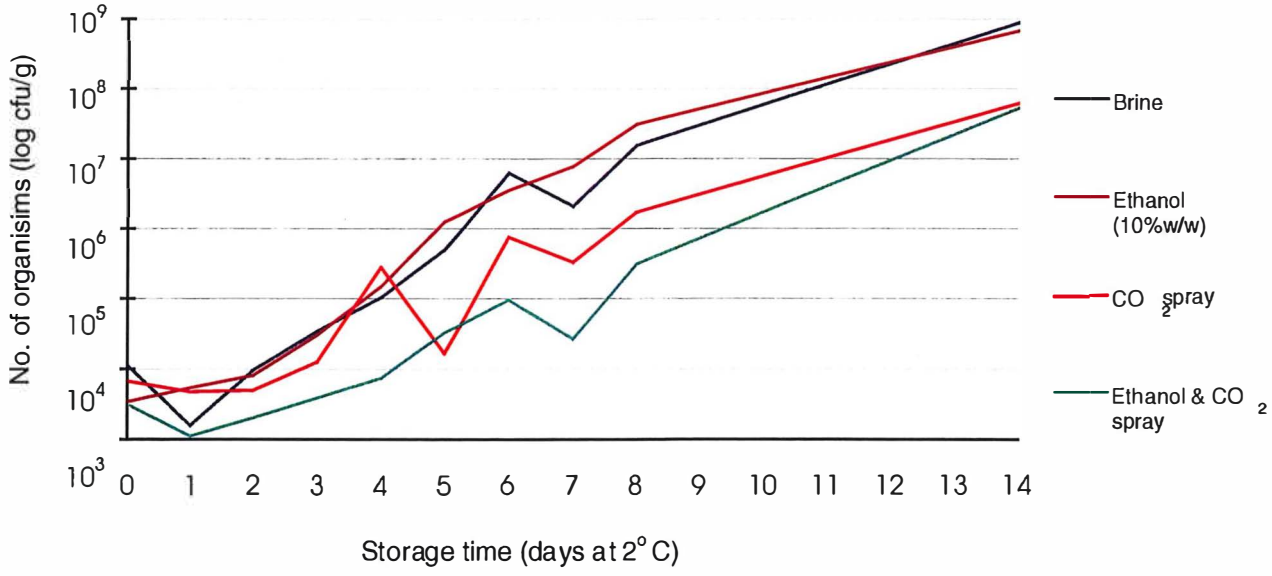


Figure 10 Psychotropic load of cooked, thawed tiger prawns (P. monodon)



The greater inhibitory effect of bacterial loads on cooked prawns compared to green prawns implies that the cooking process has altered the bacterial population species composition and that those species present on the cooked prawns were more susceptible to the effect of

CO_2. This is a valid assumption from the bacterial numbers determined, but was not confirmed by bacterial identification within this project.

Based on psychrotroph numbers present, results indicate that cooked tiger prawns frozen with ethanol and CO_2 spray treatments would be likely to have a longer storage life than prawns frozen under other treatments.

Pre-market test trials

Questionnaires were returned from 1 small retailer, 2 large retailers and 1 large wholesaler. One medium retailer failed to return the survey questionnaire. Product was purchased both frozen and fresh by all respondents and all respondents indicated that product quality was the most important consideration in purchasing prawns. One retailer also indicated that using the same supplier was important.

Overall, the samples rated well when assessed frozen. Table 6 presents the ratings given to the frozen sample products for each attribute. Similar ratings were given to the thawed product (Table 7). The flavour and texture of the samples was rated as being appealing to very appealing by all the survey respondents. Only 1 respondent indicated they disliked the appearance and packaging (likert score = 2) of the samples and felt the appearance was much worse than product regularly bought by the company. The respondent stated that IQF products were not usually purchased as damage could occur during handling and transport.

The sample products were rated as having appealing to very appealing smell and colour and appearance by most respondents in comparison to products regularly purchased (Table 8).

TABLE 6 Ratings given to the provided frozen samples for each attribute

Attribute	Frequency				
	Like very much	**Like**	**Neither like or dislike**	**Dislike**	**Dislike very much**
Smell	3	1			
Colour		3	1		
Packaging		2	1	1	
Appearance		3		1	

TABLE 7 Ratings given to the thawed samples sensory attributes

Attribute	Frequency				
	Like very much	**Like**	**Neither like or dislike**	**Dislike**	**Dislike very much**
Typical prawn flavour	3	1			
Sweetness		4			
Saltiness	1	3			
Moistness	1	3			
Firmness	1	3			

TABLE 8 *Sample ratings in comparison with product currently purchased.*

Attribute	Frequency				
	Like very much	Like	Neither like or dislike	Dislike	Dislike very much
Smell	3	1			
Colour		4			
Packaging		3	1		
Appearance	1	2			1

All respondents said they liked the colour and smell when compared to product they currently purchased. The appearance was rated as much better by 1 respondent and better by 2 respondents than product already purchased. A respondent, who didn't purchase IQF products disliked the appearance very much in comparison to what they currently purchase. The evenness of the glaze and number of prawns sticking together was highly rated by the survey respondents (Table 9).

TABLE 9 *Rating scores given to glaze quality on frozen sample products.*

Attribute	Frequency				
	Like very much	Like	Neither like or dislike	Dislike	Dislike very much
Thickness	2	1		1	
Coverage		2	1		1
Product Clumping	3	1			
Evenness	2	2			

The majority of respondents preferred the thickness and coverage of the glaze on the samples to what they currently buy. One respondent said the glaze coverage was much worse than his current products and this may be because of the thin coating which was able to be achieved with the spray system. The information which was supplied by the survey respondents indicates that the prawn quality was not compromised by the cryogenic application, and the convenience of IQF prawns can be enhanced through using the spray glazing system instead of the common dip glaze.

Section 3. Packaging development

Packaging was designed and costed and assessed for robustness and suitability by the retail / wholesale seafood sectors. Export packaging was performance tested.

Methods

Product packaging

Visy Board Pty Ltd was contacted to obtain advice on the required packaging specifications and from this, packaging dimensions and sample boxes were produced.

Sample boxes were packaged with frozen product in two size grades, 16-20 count/lb and 30-40 count/lb to ensure the volume of each size grade would fit into the boxes at the correct weight. The suitability and performance of the packages were tested during storage of frozen product and through pre-market test trials.

Packaging assessment

Information on packaging was collected from 5 seafood companies during pre-market test trials of the product. The results of this survey are discussed in greater detail under section 2 in this report but the comments and responses pertinent to the packaging sizes are discussed below.

The questionnaire required the respondents to provide information on their current purchasing habits, package size preferences and their purchase volumes during peak and off peak seasons.

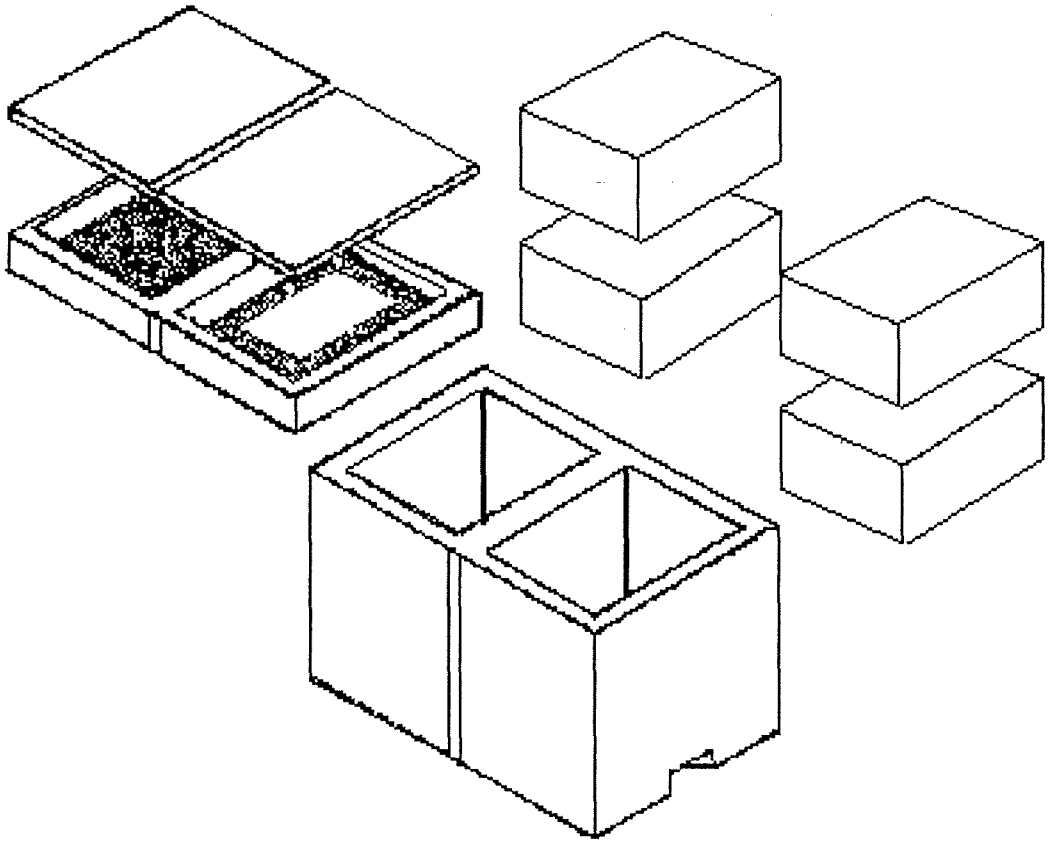
Export packaging trials

Immersion frozen prawns were packaged into 2½ kg waxed boxes and fitted, two boxes per side, into the expanded polystyrene outer package designed for export of live prawns (Figure 1). Solid blocks (250mm*125mm*125mm *ca.*3.0 Kg) of CO_2 (dry ice) was placed in the coolant section of the EPS outer box.

Boxes were held in an ambient temperature of approximately 22°C (room temperature) Temperature was monitored over 24h using an external datalogger (Datataker DT-500) programmed to record temperature every fifteen minutes. Thermocouples were strategically placed in each inner wax box and the boxes were placed into the polystyrene outer carton. Thermocouples were also located to monitor the air temperatures within the polystyrene package, the coolant section and outside ambient air.

Logged data was downloaded into a spreadsheet program (Microsoft Excel 7.0) and standard graphs were produced.

PLATE 1 *Configuration of 2.5 Kg waxed boxes in expanded polystyrene outer pack.*



Results and Discussion

Packaging

The following factors were taken into account in the design of the waxed boxes;

- Palletising configuration and efficiency of the packages.
- Versatility with all product sizes and volumes.
- Storage freezer shelf spacing of commercial premises
- Ease of packaging for producers, associated labour costs
- Durability of packaging (eg. handling, moisture contact, labelling)

Packaging is an important aspect of product development. Packaging needs to be protective, attract the buyer and provide the required size and configuration of product to the customer. The 15-18 kg waxed boxes that are commonly used to package frozen aquaculture prawns may not suitable for the whole market. The large domestic market in food service, catering and seafood retail would find these volumes of product inconvenient. For example, supermarkets purchase frozen prawns in 5 kg boxes to minimise waste from thawed, unused

product (Laudani 1997 pers. comm). Farmers could also take greater advantage of the export market through producing smaller package sizes.

Recently, producers have received requests from purchasers in the United States to package frozen product in 10 kg boxes. Japanese buyers have made similar requests for smaller boxes (Herbst 1988 pers. comm).

A site visit with Woolworths Queensland Ltd. allowed samples of packaged frozen products to be viewed. A small number of sample boxes in both the 2½ and 5 Kg sizes were produced and frozen product was packaged into these during processing trials. The waxed corrugated cardboard box sizes for 2½ and 5Kg were, 300x210x113mm and 304x204x230 respectively.

Packaging Survey

From the 5 surveys distributed only 3 respondents provided information on packaging. The importance of packaging in buying decisions was rated from undecided to very important. Appearance, colour, texture, smell and consistency of supply were also rated as being very important factors in purchasing decisions. Price was rated as being slightly important to not important at all. Peak season (summer) purchases of prawns ranged from 300 - 800Kg/week for wholesale businesses and 100 - 300Kg/week for retail businesses.

The 5kg wax boxes were rated as being very attractive by 1 retailer surveyed. This retailer already purchases prawns in five kilo boxes and stated he was happy with these package sizes. Additionally, 1 wholesaler indicated a preference for boxes between five and ten kilograms. The retailers stored frozen prawns for up to 5mths, while the wholesalers stored for a maximum of a month.

Product was currently purchased in volumes of ten kilos or greater and this may be because of the limited options in packaging sizes available. Both of the wholesalers stated they would prefer another package size. One of the wholesalers purchased prawns in large packages (>15 Kg) but indicated in their comments that the preferred package size was dependant on the product being purchased and indicated this is related to the quality and likely volume of sales of the different prawn species. Concern was expressed by 1 respondent with the extra amount of packaging waste from smaller box sizes.

The results from the surveys suggest that the 5kg boxes would be particularly suitable for the retail market and a small proportion of the wholesale market, particularly with high quality products.

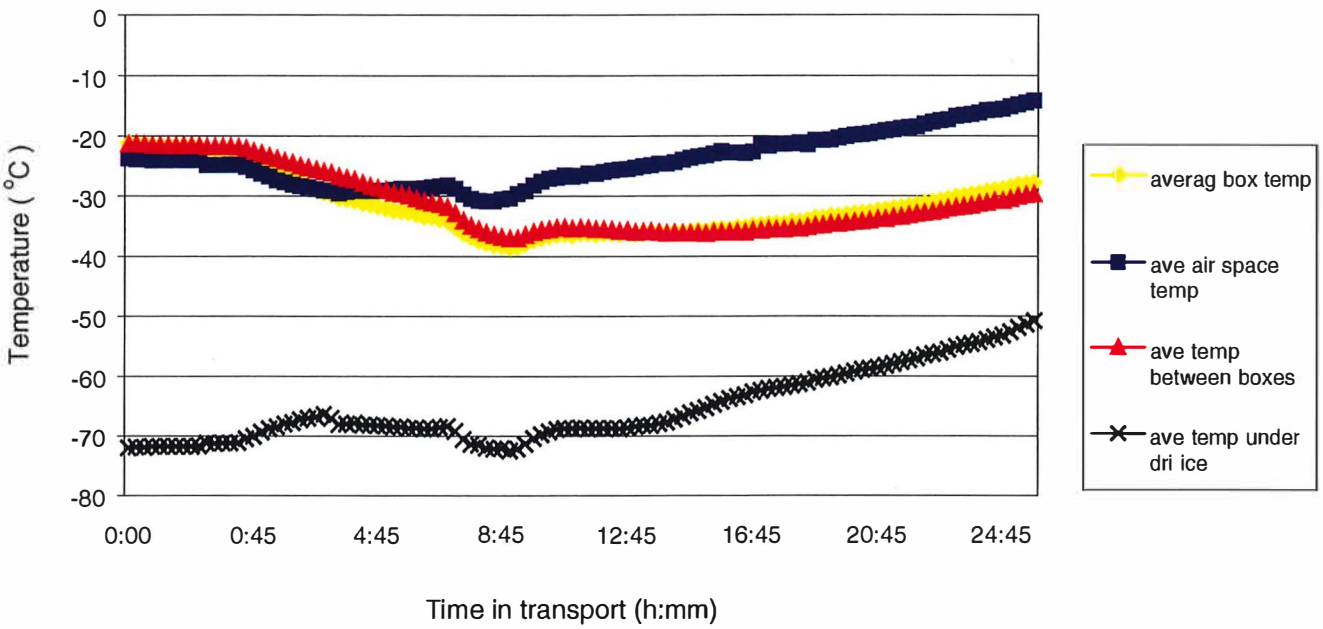
Export packaging

Product temperature in the polystyrene box is maintained through the coolant section fitted into the lid. Although the package has been designed for the transport of live animals and as such the only required cooling, the gel coolant blocks can be substituted with more suitable substances which are able to maintain lower product temperatures.

Performance testing of the polystyrene outer package over a 24 hr period indicated the current configuration would not be effective for the transportation of frozen prawns without added insulation. The temperature within the waxed boxes was not sufficiently maintained for transport. The trial was repeated with 1" Styrofoam sheeting added to all sides of the EPS package. When extra insulation was added, the average temperature inside the box was approximately -30°C after 24 hours (Figure 1). This suggests that only a small increase to the overall thickness of the polystyrene walls and base of the package would be required to provide an adequate insulation for 24hrs transport.

All areas in the waxed boxes remained at a sufficiently low temperature for the 24hr trial period. Thermocouple probes were not inserted into the product during these trials so it is not possible to determine the core temperature of the product. Observation of the product after 28 hours indicated that it appeared frozen and the ice glaze visible. After 36hrs the dry ice completely evaporated.

FIGURE 1 Temperature record of polystyrene outer package and 1" extra insulation over 24h.



Blocks of dry ice provide an ideal coolant to maintain frozen product temperatures. As the ice evaporates, it goes directly to the gaseous state. The gas is heavier than air hence flows downwards and around the packages containing the frozen product. Additionally, there is no liquid after the evaporation which eliminates the problems of package degradation through wetness, liquid spills and some of the problems of corrosion. Dry ice is easily accessible and relatively cheap to purchase. It can also be readily stored in established freezers. Unfortunately, due to airline regulations the option of dry ice as a coolant is only viable for domestic road transport.

The polystyrene outer box costs approximately $6.50 (dependant on purchase numbers) in its current configuration. Prices for the inner cartons vary substantially with the number ordered and the choice of printing colours. For 5000 pieces the prices are $696.00 per thousand and $353.00 per thousand for the 5Kg and 2½ Kg boxes respectively. Blocks of solid CO_2 (dry ice) are inexpensive and easy to source and store for limited periods.

CONCLUSIONS

Both cooked and green tiger prawns appear to have longer thawed and frozen shelf life when treated with CO_2 cryogen after glazing. The appearance of CO_2 treated prawns were rated higher on all occasions over the shelf life testing. CO_2 treatment has been demonstrated to retard microbial growth after thawing on both cooked and green product, indicating a likely increase to thawed shelf life.

On average the product temperature was lowered to -25°C with a 3min application of the cryogen. Further improvements to the efficiency have been gained from glazing product with fine sprays as opposed to the industry standard dip glazes. Ethanol added to the brine solutions was successful in lowering the temperature of the prawns after glazing, but the required concentrations resulted in noticeable effects to the prawns flavour, odour and texture by taste panellists. Slight improvements were noted with levels as low as 10%, but the added compliance costs may negate the benefits to processing efficiency.

Packaging weights between 5 and 10Kg were determined as the most likely to be acceptable to larger retailers and wholesalers. It is likely that the foodservice industry would require packaging between 2½ and 5Kg. Waxed boxes are required for robustness during frozen storage and transport. Solid blocks of CO_2 were shown to provide adequate cooling to keep product frozen for 24hrs during transport. This method is particularly applicable for the local domestic market and is a clean and cheap method of cooling.

BENEFITS

The implied benefits of this research are highlighted in the summary and individual discussions of results but may quickly be summarised as follows;

Treatment with cryogens such as CO_2 after glazing reduce product temperature sufficiently to maintain product quality. The method is cost effective, as the cryogen is only required to remove specific heat from the product, latent heat being removed by the brine immersion freezer. The temperature reduction before packaging removes the requirement for double handling by processing establishments and hence improves efficiency.

Shelf life, both frozen and thawed, was enhanced in CO_2 treated prawns, resulting in benefits to the retail, wholesale and foodservice sector. Further market potential will be available to processors as a result of offering suitable package weights for these industry sectors.

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Appendix1. CO_2 tunnel operating costs

Operating costs to run a CO_2 tunnel for post glazing temperature reduction of prawns.

Processing establishment variables

Processing times

weeks/yr	*days/week*	*hrs/day*	*Product throughput/hr*
16	5	8	250 Kg

Specific heat variables

Specific heat below freezing (prawns)	0.45	Kcal / KG / deg C
Required temperature change	15	Degrees (-10°C to -25°C)
Specific heat to be removed	6.75	Kcal / KG
Specific heat of liquid CO_2 (LCO_2)	66.9	Kcal / KG
Usage Rate	0.100897	KG / KG product
Assumed system losses	25	%
Usage Rate with losses	0.126121	KG/ KG prawns

Liquid CO_2 usage rates

Operating hours per year	640	hours
Usage LCO_2 / hr	31.53027	KG
Monthly Usage LCO_2	5044.843	KG
Annual Usage LCO_2	20179.37	KG

CO2 tunnel operating costs

Total prawns processed	160000	Kg/yr
Delivered price LCO_2	260	Dollars/1000 KG
Annual cost	5246.637	dollars
Rental cost LTH 6 tonne vessel	6960	Dollars/mth
Total annual cost	12206.64	dollars
Total Monthly Cost	3051.659	dollars
Total cost per KG prawns	0.087	Dollars/Kg

Appendix 2. Survey participants and questionnaire sheet

Survey participants and sample questionnaire sheet

Laurie Cerasa
Lauries Quality Seafoods
Hawthorne Rd
Hawthorne QLD 4170

Peter Michaels
Peter Michaels Seafoods
Sydney Fish Markets
Pyrmont NSW

Denis Poulos
Poulos Bros. Seafoods
Sydney Fish Markets
Pyrmont NSW

T. Costi
Fairfield Fish Markets
Fairfield NSW

Charis Seafoods
6 Marine Pde
Harley Park
Labrador QLD 4215

IMPORTANT: Please read before opening packs and filling in surveys

This survey is being conducted by the Queensland Department of Primary Industries (Centre for Food Technology) as part of a research project on refining the freezing techniques used with brine immersion freezers.

The purpose of this research is to improve the quality of frozen prawns and to develop a more convieniently packaged product, both for you, the buyer, and for the producer.

The prawns you have received are aquacultured black tiger prawns (P. *monodon*). They have been individually quick frozen using a new method developed by the seafood research group at the Centre for Food Technology (a section of the Queensland Department of Primary Industries).

These handling procedures are designed to keep the prawns at temperatures low enough to sustain high product quality at all times throught the freezing process.

The purpose of the questionnaire is to obtain feedback from buyers and users of prawns about the freshness and quality of the product in relation to what you currently use. We are not interested in species or size differences.

This questionnaire will take you through a number of steps. You will be required to thaw and taste the prawns provided during this survey. It is important to answer all questions and follow the instructions so that the survey results remain valid.

Questions will be related to the steps involved in the process from opening the package through to thawing and tasting the prawns, then providing your comments.

If you have any questions regarding any of this information, please contact Jacquie Edwards on (07) 3406 8504

Please return the survey in the envelope provided by the 8th of June or fax back to (07) 3406 8698.

FROZEN PRAWN SURVEY SHEET

The product you are assessing are farmed black tiger prawns (P. *monodon*). They have been individually quick frozen using a new method developed by the seafood research group at the Centre for Food Technology (a section of the Queensland Department of Primary Industries).

Please answer the following questions in order, opening and thawing the prawns when prompted.

Name _____

Company _____

Date _____

Please answer the following questions **before** opening the package of sample prawns you have been provided.

Question 1

In what form do you usually purchase prawns?

- ☐ Fresh
- ☐ Frozen
- ☐ Don't usually buy
- ☐ Other

If other; please specify _____

Question 2

Please rate the level of importance of the following elements listed below when buying prawns (**Please circle the number**).

	Very important				Not important
Smell	5	4	3	2	1
Colour / Appearance	5	4	3	2	1
texture	5	4	3	2	1
Packaging	5	4	3	2	1
Price	5	4	3	2	1
Consistent supply	5	4	3	2	1
Shelf life	5	4	3	2	1
Current supplier	5	4	3	2	1

Question 3

What is the most common package weight of the prawns your company currently buys? (**Please tick the appropriate box**)

- ☐ 1-3 Kg
- ☐ 5 Kg
- ☐ 10 Kg
- ☐ 15 Kg
- ☐ >15 Kg
- ☐ Other

If other; please specify _____

Question 4

Is this package weight the most suitable or would you choose another size if available ?

☐ Yes ☐ No

If yes; what product weight would be more convenient?

- ☐ 1-3 Kg
- ☐ 5 Kg
- ☐ 10 Kg
- ☐ 15 Kg
- ☐ >15 Kg
- ☐ Other

If other; please specify _____

Question 5

Is the package of sample prawns convenient for handling and storage

☐ Yes ☐ No

If no; please explain and suggest improvements

Please open the box you have been provided and answer the following questions on the quality of the sample prawns.

Question 6

The sample prawns have been coated with a glaze for protection during frozen storage Please assess the quality of the glaze on the sample prawns

	Very good				Very poor
Glaze coverage	5	4	3	2	1
	Very thick				Very thin
Glaze thickness	5	4	3	2	1
	Very good				Not poor
No of prawns sticking together	5	4	3	2	1
	Very even				Very patchy
Evenness of glaze	5	4	3	2	1

Do you have any comments on the quality of the glaze on the sample prawns you have been supplied? _____

Question 7

Please rate the acceptablity of the following elements of the sample prawns on the scale below: (Please circle the number)

	Very appealing				Not appealing
Smell	5	4	3	2	1
Colour	5	4	3	2	1
Appearance	5	4	3	2	1
Packaging	5	4	3	2	1

Question 8

How do the sample prawns compare to prawns you currently buy?

	Very appealing				Not appealing
Smell	5	4	3	2	1
Colour	5	4	3	2	1
Appearance	5	4	3	2	1
Packaging	5	4	3	2	1

Question 9

Product thawing: How do you usually thaw the prawns you purchase frozen? **(tick the box corresponding to your answer)**

- ☐ In refrigerated air
- ☐ In room temperature air
- ☐ In fresh water
- ☐ In salted water

Please thaw the sample product in the manner you have indicated above

Question 10

Please rate the acceptability of the following elements of the thawed prawns on the scale below: **(Please circle the number)**

	Very appealing				Not appealing
Smell	5	4	3	2	1
Colour	5	4	3	2	1
General Appearance	5	4	3	2	1

Question 11

How do the thawed prawns compare to prawns you currently buy? **(Please circle the number)**

	Very appealing				Not appealing
Smell	5	4	3	2	1
Colour	5	4	3	2	1
General Appearance	5	4	3	2	1

Please peel and taste some of the sample prawns provided. Answer the following questions on the quality of the prawns.

Question 12

Please indicate your level of satisfaction with the following **(please circle the number)**

Flavour

	Very appealing				Not appealing
Typical prawn flavour	5	4	3	2	1
Sweetness	5	4	3	2	1
Saltiness	5	4	3	2	1

Continued over page

Texture

	Very appealing				Not appealing
Firmness	5	4	3	2	1
Moistness	5	4	3	2	1

Question 13

How does this compare to the prawns you currently buy? **(please circle the number)**

Flavour

	Very appealing				Not appealing
Typical prawn flavour	5	4	3	2	1
Sweetness	5	4	3	2	1
Saltiness	5	4	3	2	1

Texture

	Very appealing				Not appealing
Firmness	5	4	3	2	1
Moistness	5	4	3	2	1

Question 14

What quantity of frozen prawns do you use / buy each week? **(specify if kg or tonnes)**

Question 15

Do you keep prawns in frozen storage?

☐ Yes

☐ No

If yes; what is the average period of storage?

Question 11

Are you willing to pay more for higher quality products?

☐ Yes

☐ No

Please state reason _____

Thank-you for participating in this survey. The other side of the page has been left blank for any comments you wish to make on either the sample product or the survey.

Appendix 3. Best practise handling manual

Best practise manual for freezing prawns in IQF systems with CO_2 snow application.

BEST PRACTICE MANUAL FOR PRODUCING INDIVIDUALLY QUICK FROZEN (IQF) PRAWNS

October 2000

B. Goodrick, J. Edwards, S. Grauf & D. Leighton

CENTRE FOR **FOOD TECHNOLOGY**

Queensland Government
Department of Primary Industries

SEAFOOD SERVICES
AUSTRALIA

TABLE OF CONTENTS

Background

Prawns have a relatively short shelf life in the fresh state. The frozen shelf life on the other hand can be substantial if all the processes of handling, packaging and storage are combined with good freezing techniques.

In a well run brine immersion system (IQF), where brine concentration is monitored and temperature of the solution is maintained, it is possible to achieve freezing times of 15 to 20 minutes. The rapid freezing time, due to total and direct contact between the product and freezing solution, can produce excellent quality frozen products. Although the immersion freezer is particularly suited for freezing smaller products that tend to clump, such prawns (Montgomery 1968), when the product is removed from the freezer for glazing and packing the temperature can rise substantially. Smaller products reach a higher temperature than larger ones because they are hit by a large volume of glaze water in relation to their body mass (Montgomery 1968). If the temperature is not lowered after glazing and packing products face the possibility of quality losses in frozen storage.

Recent research at the Centre for Food Technology has demonstrated that treatment with cryogens such as CO_2 after glazing effectively reduces product temperature. The method is cost effective, as the cryogen is only required to remove specific heat from the product, latent heat being removed by the brine immersion freezer. The temperature reduction before packaging removes the requirement for double handling by processing establishments and hence improves efficiency. On average the product temperature was lowered to -25°C with a 3min application of the cryogen. Further improvements to the efficiency have been gained from glazing product with fine sprays as opposed to the industry standard dip glazes.

Both cooked and green tiger prawns appear to have longer thawed and frozen shelf life when treated with CO_2 cryogen after glazing. The sensory scores for the appearance of CO_2 treated prawns were consistently higher than that for prawns frozen in brine over the storage period. CO_2 treatment has been demonstrated to retard microbial growth after thawing on both cooked and green product, indicating a likely increase to thawed shelf life.

Generic designs of cryogenic freezing tunnels have been prepared by seafood researchers at the Centre. The basic tunnel set-up is used after brine immersion freezing and includes fresh water glaze sprays and subsequent cryogenic treatment before packing. Ancillary equipment can be added to automate packing. Processors should be aware that their individual processing facilities and product throughput's will determine the exact layout and costs of operating a CO_2 tunnel and it is recommended that a gas service provider is consulted for the design, cost and placement of the tunnel and gas supply lines / tanks.

This manual will provide information on the best practise operation of brine immersion freezers and cryogenic treatment of prawns. The sections will run through the freezing operation from harvest to chilling, freezing, packing and storage.

General conditions

Establishments wishing to process prawns need to be aware of and follow the requirements of food processing establishments. In order to export seafood products, Australian Quarantine and Inspection Service (AQIS) registration as an export facility is also required. Good hygiene practices should be maintained at all times throughout the processing area.

Product quality before freezing is of vital importance. Prawns should be fresh in order for high quality frozen prawns to be produced. Freezing should take place as rapidly as possible after harvesting or catching before bacterial and enzymic damage occurs. Prawns should be stored at low temperatures and iced as soon as possible after harvesting. Cooked prawns should be stored on ice after cooking and allowed to completely cool before freezing.

Brine Immersion Freezing

General description

The most common method of brine immersion freezing is using a solution of common salt at a concentration of *ca.* 26.4% which can be maintained at a temperature of -21°C without freezing.

Freezer Preparation

Care should be taken with the addition of salt to the freezer, as increasing the salt content will not produce a colder freezing solution. The salt content of the solution should be validated with a hydrometer / salinometer and the reading should be monitored regularly to ensure the immersion freezer operates at optimum temperatures.

The freezer should be turned on and the brine solution circulating. The brine solution should be at the operating temperature of at least -21°C before freezing commences.

Freezing Baskets

Approximately 15 kilograms of washed, chilled product are weighed into freezing baskets. Freezing times vary with product size and weight but as a guide, freezing large prawns (10-20 count/lb) and smaller prawns (30-40 count/lb) for approximately 15 and 13mins respectively is adequate to freeze below -18°C.

Freezing times can be determined for each size grade with a digital thermometer inserted into a prawn whilst freezing and monitoring internal product temperature. Alternatively, product should remain in the freezer until hard frozen.

Immersion Freezing cycle

The baskets containing the prawns are closed, the lid fixed into place and the baskets placed into the freezer. If freezing to a specific time, a stopwatch or timer should be started as soon as the product is in the freezer. During freezing, the brine solution should be circulated

rapidly around the tank to ensure uniform and constant freezing. The temperature of the brine solution should be monitored throughout freezing and maintained at -18°C/ -21°C.

Once the product is satisfactorily frozen, it is removed from the freezer and allowed to drain for approx. 1 - 2mins.

Glazing

Glazing should take place immediately after product draining. It is important that the glazing water is as cold as possible to minimise temperature increases.

Dip glazing is achieved by plunging the product, while still in the freezing baskets, into the tub of chilled fresh water. The dipping should be performed as rapidly as possible as this will also minimise temperature increases and ensure that the ice glaze is not deposited thickly and unevenly. Once glazed, gently shake the basket of prawns to remove excess water and transfer prawns to the package immediately

Packaging

General

Waxed boxes are usual for packing frozen prawns as the wet environment of a freezer and processing room does not damage them. The carton should be an adequate size for the weight of prawns to be packed or extensive damage could occur due to crushing of the product. A plastic liner should be placed in the carton. The liner can be lifted and gently shaken to settle the contents of the box. The lid of the box is then closed and stapled.

Care should be taken to avoid rough handling at this stage as the prawn's feelers; legs and other body appendages are susceptible to damage when frozen

Waxed boxes of appropriate size are to be constructed prior to commencing freezing. Boxes are placed in an area accessible from the brine immersion freezer, ensuring that adequate boxes are available. A poly liner is placed in the package and product from the freezing basket is transferred to the box. The filled package is gently agitated to settle the contents and the lid closed and fixed into place.

Packaged product should be regularly transferred to the freezer storage to minimise temperature increases in the product.

Cryogenic treatment

General description

The CO_2 unit consists of an insulated tunnel and conveyor belt. Product is fed into the tunnel from the brine immersion freezer over a vibratory belt or tray (Figure 1). This would settle the product out into a layer of prawns. The glaze is applied from sprays both top and bottom of the belt and a short period is left to remove excess glaze water. Position and spacing between the CO_2 sprays is dependant on the belt speed; and hence product throughput.

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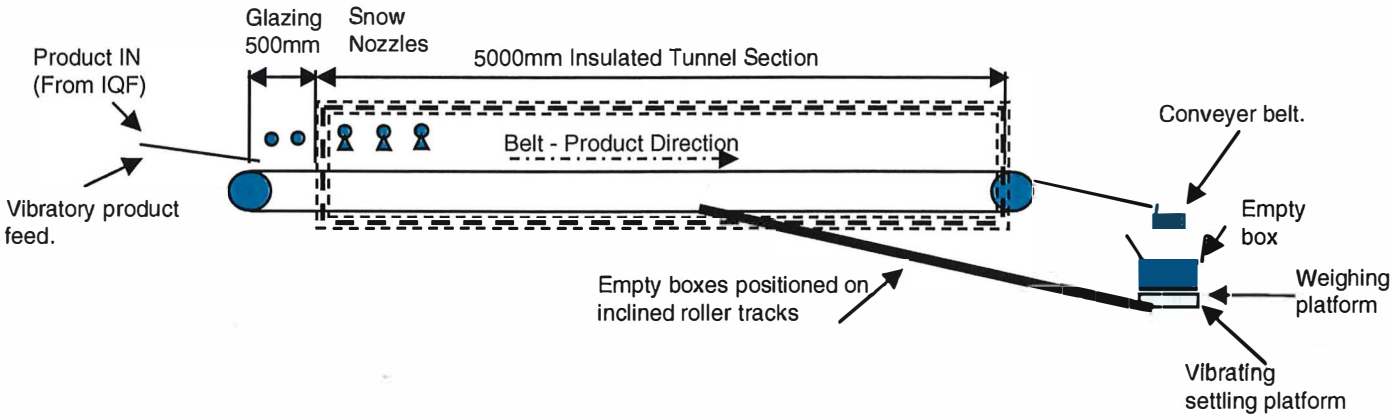
FIGURE 1 Side view of an example freezing tunnel and ancillary equipment layout



The design and construction of the tunnel should be carefully planned and a gas supply company should be consulted to ensure efficient operation of the tunnel.

Freezer preparation

The CO_2 tunnel should be turned on and the belt allowed to rotate through the unit at least once while operating to reduce the tunnel temperature. Ensure that the fresh water supply for spray glazing is connected to the unit and turned on.

Cryogenic tunnel operation

The immersion freezing process occurs as above. Product should still be hard frozen in the immersion freezer to maintain the freezing tunnel efficiency. The immersion freezer removes the latent heat from the product in an economical and efficient manner, therefore ensure that freezing is completed before putting product into the CO_2 finishing unit.

The frozen prawns are transferred to a settling hopper, which feeds them onto the tunnel belt in a single layer. It is important that the prawns form a single layer to ensure than an even coating of glaze water is achieved.

Once in the settling hopper the pawns are allowed to travel through the tunnel and then packaged. The hopper should be monitored to ensure that all prawns are being fed into the freezing tunnel at an adequate speed.

weight of prawns to be packed or extensive damage could occur due to crushing of the product. A plastic liner should be placed in the carton. If necessary, the liner can be lifted and gently shaken to settle the contents of the box. The lid of the box is then closed and stapled.

Care should be taken to avoid rough handling at this stage as the prawn's feelers; legs and other body appendages are susceptible to damage when frozen

The product form the freezing tunnel can be automatically or manually packed depending on the actual tunnel set-up. The procedure for both packaging methods from the CO_2 tunnel is as follows;

Manual packing

A set of scales should be employed to maintain accuracy in packaging weights. A liner is put into the box and it is placed onto the scales. Product from the freezing tunnel is allowed to flow into the package until the desired weight is achieved. The freezing tunnel is then paused, the package closed and another box is placed onto the scales.

Ensure an adequate supply of boxes with liners in place is available before freezing commences

Automated packing

The boxes are placed onto the roller feeder to be automatically fed onto weight scales under the end of CO_2 tunnel. The roller feeder works using gravity to move the boxes along the line to the scales.

Product from the freezing tunnel flows into the box and once the box is filled to the correct weight, an automatic arm will push the package onto the settling platform. The vibratory base will allow the product to settle into the box without damage. The box should then be closed and the lid fixed into place.

Frozen Storage

The storage freezer used should include an external digital thermometer so that the freezer temperature can be monitored. A stable frozen storage temperature should be maintained. It is recommended that the storage freezer be operated at approx. -27°C to maintain product quality.

References

Montgomery, W. A. S., G. S. (1968). "Prawn preservation and processing." Australian Fisheries Newsletter January: 7-11.