FINAL REPORT

FIRDC PROJECT

WATER CONTENT OF SAUCER SCALLOPS *(AMUSIUM BALLOTI)*

International Food Institute of Queensland
Queensland Department of Primary Industries

FISHING INDUSTRY RESEARCH AND DEVELOPMENT COUNCIL

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(*Amusium balloti*)

Project DAQ1Z

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Water content of saucer scallops (*Amusium balloti*).

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SUMMARY

1. The natural moisture content of saucer scallops (*Amusium balloti)* varied with season and with size of the adductor muscle. Scallops had a higher moisture content in winter (79.5%) than in summer (76.4%); moisture content increased as scallop meats decreased in size. Studies on the effect of geographic location on moisture content were inconclusive.

2. The changes in moisture content of unshucked scallops during storage on different vessels were variable. For freezer and refrigerated trawlers, the average increase in scallop moisture was 1% after 4 to 8 days storage. Scallops from brine spray trawlers showed less than 1% increase, but few samples were tested. High increases in moisture (up to 3.6%) were recorded for storage in melting ice.

3. Processing of scallops on barges and land-based establishments added a further 1% to the moisture content, giving a post-harvest minimum increase in moisture content of about 2%. This increase would apply to the majority of Queensland's catch which is obtained by freezer boats.

4. Water absorption by fresh scallops was lowest after soaking in 3.5% sodium chloride solution (100% seawater) and highest after soaking in fresh water. However, thawed scallops when soaked in 3.5% sodium chloride, usually absorbed more water than fresh scallops. Shucked scallops always absorbed more water than unshucked scallops. Water absorption was significantly reduced at low temperatures (below 4°C).

5. Drip loss from soaked scallops (fresh and thawed) was minimal if the salt concentration of the soaking solution was greater than 3.0%, irrespective of the amount of water absorbed during soaking. Highest levels of drip loss were obtained with water-soaked scallops. Freezing fresh and thawed scallops, after soaking in solutions containing less than 2.5% salt, increased the amount of thaw drip loss.

6. A 5% polyphosphate dip was effective in reducing drip loss from scallops soaked in water and 1% salt, but was ineffective on scallops soaked in 3.5% salt. Residues of polyphosphate could be detected by phosphorus analysis after scallops were soaked for 15 minutes in the dip.

7. Histological studies showed the scallop adductor muscle was comprised of cross-striated myofibrils, with one myofibril representing the cell unit. The cells were ribbon-shaped rather than cylindrical. A comparison of soaked and live specimens, using electron microscopy, illustrated complete rupture of the myofibrillar membrane after soaking in water, but little membrane damage after soaking in 3.5% salt.

8. A rapid float test for measuring the moisture content of scallops was developed. The test was based on the flotation of whole scallops in a solution containing an appropriate concentration of salt. The measurement of moisture by this method was acccurate to $\pm$1%. An instructional brochure and a video on the float test were produced.

9. Alternative rapid methods for moisture analysis of scallops were provided by microwave oven drying and an infra red moisture balance. Both methods gave satisfactory results and could be completed in about 15 minutes.

10. The development of a single specification for moisture content was not considered practical due to the natural variability in moisture content. The moisture levels reported in this study should be used as a guide for the setting of quality standards for the scallop industry. These moisture levels are not more than 79% for the period from November to March, and not more than 82% from April to October.

PROJECT OBJECTIVES

The objectives of the project were:

1. To establish the natural moisture content of saucer scallops taking into account seasonal, geographic and size variation.

2. To examine the effects of all aspects of scallop handling on water content.

3. To devise and validate a simple and reliable test for determining whether scallops have been soaked.

4. To develop specifications for scallops with regard to water content to assist in the setting up of an appropriate quality control programme

INTRODUCTION

The saucer scallop, *Amusium balloti*, is fished commercially off the central Queensland coast from about 21°S to 25°S (Williams and Dredge, 1981). The major scallop landing ports for this region are Bundaberg, Urangan, Tin Can Bay, Yeppoon and Townsville. A fishery for *A. balloti* is also located in waters off Western Australia between 25°S and 30°S (Heald and Caputi, 1981) with the main areas being Shark Bay and Abrolhos Islands. Other scallop species such as *Pecten fumatus* are found in southern waters of Tasmania and Victoria, but these fisheries suffer large stock fluctuations and currrently are less commercially important than those of *A. balloti*.

The Australian saucer scallop industry is presently worth around $40 million per year in export revenue. About 80% of the scallop catch is exported, the major markets being Hong Kong and Singapore. A summary of scallop exports from Queensland and Western Australia for the last three years is shown in the following table.

Saucer scallop exports for Queensland and Western Australia.

Year	Queensland		Western Australia	
	Quantity (tonnes)	Value ($m)	Quantity (tonnes)	Value ($m)
1989/90	982	18.1	594	7.4
1989/90	931	23.5	171	2.5
1990/91	1349	30.4	645	10.3

Data supplied by Australian Quarantine and Inspection Service, (Brisbane and Perth)

These figures relate to export scallops and do not represent total catch. In 1990/91, for example, the total scallop catch for Western Australia was considerably higher than the quantity exported.

The price obtained for saucer scallops from buyers in Hong Kong and Singapore may exceed $20 a kilo. This price is extremely attractive and about double that available from the United States. Meeting the quality requirements of the Asian markets is therefore an important consideration for fishermen and processors.

A quality problem which can significantly reduce the price obtained for scallop meat relates to high moisture content. It is known that scallops, when allowed to soak, will significantly increase their weight by absorbing water. For example, Sumner *et al.* (1985)

reported an 86% increase in scallop weight after soaking scallops (*P. fumatus)* in fresh water for 30 hours. The inferior quality of soaked scallops is often reflected in a high drip loss on thawing and an excessive release of water on cooking. Flavour and texture may also be adversely affected. Most importantly, overseas buyers are unwilling to pay for added water.

In 1986, the unfavourable reaction of Hong Kong buyers to high moisture scallops highlighted the need for more information on the natural variation of scallop moisture and on water uptake by scallops during acceptable practices of storage and processing. One area of concern was that "on-board" processing procedures used by some fishermen and operators of processing barges resulted in scallops being soaked for excessive periods. In Queensland, legislation was introduced in 1988 to minimise on-board processing so that around 90% of the scallop catch is now processed by land-based operators. In Western Australia, however, the majority of processing is conducted on-board trawlers where shucked scallops are frozen for direct export, or frozen and then repackaged for export by land-based processors.

The natural moisture content of different scallop species has not been widely studied. Naidu and Botta (1978) reported a natural moisture of 78.5% for *Placopecten magellanicus* caught in Canadian waters. Sumner (1986) reported the same moisture content (with a maximum of 81.0%) for *P. fumatus* caught off Tasmania and Victoria. In the latter study, however, samples were obtained from processors and not from live scallops. No studies have been reported on the natural moisture content of *A. balloti.*

At present no regulatory standards exist in Australia with respect to the moisture content of scallops. According to the Australian Quarantine and Inspection Service (AQIS), the practice of soaking scallops is not recommended, but is condoned if the product is labelled with the appropriate trade description of "water added" (AQIS, 1988). In relation to soaking of scallops and assessment of the final product the regulations state:

- if scallops have been soaked, they should be drained for a minimum of 30 minutes prior to packing; and

- to be elegible for export the average thawed and drained weight of the samples must be equal to or greater than the declared net weight. No sample will have a drained weight less than 95% (for packs less than 5 kg) or 98% (for packs of 5 kg or more) of the declared net weight. (For the thaw drain test a drainage time of two minutes applies).

Within the regulations requiring an appropriate trade description for soaked scallops, a problem arises for the secondary processor who receives shucked scallops to package and freeze for export. The secondary processor may not know if scallops contain added water, since scallops which have been soaked in high concentrations of salt or dipped in polyphosphate solutions may not exhibit any drip loss. In order to give the correct trade description the processor should test the product for moisture content. Monitoring incoming consignments for excessive moisture would enable processors to reject high moisture scallops and provide quality assurance for their export product.

Testing of export scallops for moisture content is not practised by the majority of processors. Rapid tests such as the cook test and the pressure test have been developed for determining moisture levels in scallops (Sumner *et al.* 1985). The cook test assesses the loss in weight of whole scallops after boiling for 60 s while the pressure test measures the amount of exudate when homogenised scallop is pressed between two filter papers. For the latter method, a moisture zone on the filter paper gives a measure of the moisture content. With samples containing more than 30% added water the tests showed high correlations with oven moisture, but only low correlations for samples with less added water (Sumner, 1986). Differences in water holding properties of the scallops due to variations in tissue pH and salt concentration would limit the reliability of these tests, and alternative rapid tests which can be used by processors are required.

This report provides data on the natural moisture content of *A. balloti* and information on the water absorption properties of these scallops when subjected to various handling and soaking treatments. Rapid methods for moisture testing of scallops were also investigated in order to develop a test suitable for use by the seafood industry.

MATERIALS AND METHODS

Samples for natural moisture content

Samples of scallop adductor muscle were obtained from live scallops (*A. balloti*) within 1 h of landing a shot. Scallops were kept alive during this period in deck boxes containing running seawater. Immediately after shucking, scallops were blotted dry on paper towelling and individual scallops placed in separate 60 ml screw-capped containers. The samples were then frozen and kept at -20°C until moisture content was tested in the laboratory. For each survey 50-200 samples were obtained from one or two shots taken in close proximity. All samples were collected by Department of Primary Industries staff on commercial or DPI trawlers.

The above sampling procedures were used in surveys to investigate the effects of season, size and location. Most surveys were conducted during November to March (summer) or in July (winter) over a two-year period. Scallops were sampled mainly in the Hervey Bay area; other areas surveyed were Bustard Head, Yeppoon, and Bundaberg. A summary of the sampling dates and locations for all surveys is shown below:

Date	Location	No. of samples
10.12.88	Bustard Head	58
14.7.89	Bustard Head	60
14.7.89	Yeppoon	57
15.11.89	Hervey Bay	148
15.2.90	Hervey Bay	148
13.7.90	Hervey Bay	172
13.7.90	Bustard Head	151
13.11.90	Hervey Bay	189
23.4.91	Bundaberg	140

Monthly samples of live and dead scallops were obtained in the Hervey Bay region over a period of 26 months by a commercial trawler skipper. The trawler was equipped with dry refrigeration operated at 0-1°C. On each sampling occasion, approximately 30 scallops from one shot were shucked live, blotted dry and divided equally into three 120 ml containers. The samples were then frozen in the sealed containers. Another 30 unshucked scallops from the same shot were placed in an open mesh bag and stored in the hold with the main scallop catch for 4-8 days until reaching port. These dead scallops were then shucked and placed in sealed containers. Both live and dead scallops were stored frozen until tested for moisture content.

Samples for laboratory trials

Scallops for laboratory trials were obtained mainly from the Hervey Bay area by the skipper of a commercial trawler. The unshucked scallops were kept at 0-1°C (unfrozen) and were forwarded to the laboratory in an unfrozen state within 1-2 days of catching. At the laboratory, the samples were shucked, quickly rinsed in cold saline (1%) and used immediately as "fresh" scallops or were stored in 500 g packs at -20°C for subsequent trials. For experiments where the history of the scallops was not important (for example, rapid moisture testing), samples were obtained as shucked scallops from local secondary processors.

Scallop size

In studies on natural moisture content, scallop size was taken as the weight of individual scallop meats measured in the laboratory prior to moisture testing. In this report the term size, therefore, does not necessarily relate to shell size. The classification of meat sizes was largely based on those used in the industry.

Scallop weight (g)	No. of meats/kg
<7.5	>133
7.5-11.4	89-133
11.4-15.1	67-88
15.1-22.8	44-66
>22.8	>44

Trawler storage

Refrigeration

To examine the effect of refrigerated storage on scallop moisture content, 19 paired samples of scallops shucked live and dead were obtained from a commercial trawler. The latter samples were stored 4-8 days at 0°C before shucking. Sampling methods are described previously in the section on sampling for natural moisture.

Freezing

Two trials were carried out on a DPI trawler. Ten replicates of 5 scallops were used in each trial. Unshucked scallops were frozen within 30 minutes of catching and stored in the hold in mesh bags at -20°C for 4 days. After this period scallops were thawed 2-3 h at room temperature before shucking. Samples of frozen live-shucked scallops from the same catch were used as controls.

Brine spray

Samples were obtained from a commercial trawler on two occasions. Paired samples of live and dead shucked scallops comprised 3 replicates of 10 meats. Unshucked scallops were stored 4-8 days in a mesh bag in the brine spray hold at approximately -2°C. These scallops were then shucked and frozen prior to testing. The live-shucked scallops were frozen immediately after shucking.

Ice and refrigeration

To simulate trawler storage, unshucked scallops were held in crushed ice in a large esky stored at 0°C for 4 days. Scallops (2 replicates of 10 scallops) were sampled from the middle and bottom of the esky and immediately shucked and frozen in sealed containers. Moisture content of the scallops was compared with live-shucked controls.

Trawler surveys

Thirty unshucked scallops were sampled from each trawler during unloading. Sampling was carried out at Bundaberg, Gladstone and Rockhampton. Scallops were shucked, blotted dry and placed in 120 ml sealed containers to give 3 replicates of 10 scallops. In the case of freezer boats, samples were thawed at air temperature before shucking. The sealed samples of shucked scallops were frozen and transported to the laboratory for testing.

Processing plants

During line surveys at processing plants the following samples were taken where possible:

- unshucked scallops
- shucked scallops
- after spray wash
- after first brine wash
- after second brine wash (sampled after 5 min draining prior to packaging)

Samples at each location consisted of 40 scallops (4 replicates of 10) which were blotted dry, placed in sealed containers and frozen if necessary.

Moisture testing

The convection oven drying method was used as the standard procedure for determining moisture content. The method was used for individual scallops and for homogenised samples.

Individual scallops

Each frozen scallop (from natural moisture surveys) was partially thawed at room

temperature and, before any exudate appeared, weighed into aluminium foil dishes (diameter bottom 35 mm, top 60 mm, height 20 mm). The scallop surface was incised several times with a scalpel blade to facilitate drying. Scallops were dried at 100±2°C to constant weight which required approximately 24 h. For large scallops (>20 g), drying time was extended to 48 h.

Homogenised scallops

Bulk scallop samples (usually 5-10) were homogenised in a plastic beaker using a Bamix blender. Any free water in the sample container was carefully incorporated into the total homogenate. A 5-6 g sample was weighed into an aluminium foil dish and spread evenly over the bottom of the dish. Samples were dried at 100±2°C for at least 5 h to constant weight or, in most cases, allowed to dry overnight (20 h). All homogenates were tested in duplicate. For a typical sample of 3 replicates (each comprised of 10 homogenised scallops), the mean moisture content was obtained from six moisture determinations.

Salt concentration

A sample of 2-5 g of homogenised scallop was dispersed in 100 ml distilled water in a beaker using a Bamix blender. The salt (sodium chloride) concentration in the suspension was determined by electrometric titration, using a silver/silver chloride electrode, against 0.1 N silver nitrate. The end point was taken at -133 mV (Standards Association of Australia, 1970). For analysis of salt solutions, an appropriate dilution was used to give a titration of 10-20 ml.

Water absorption and drip loss

All experiments on water absorption and drip loss were carried out using 15-20 scallops for each treatment (3-4 replicates of 5 scallops). Conditions for individual experiments are described in the figure legends in the Results and Discussion section. Soaking experiments were carried out in 500 ml beakers (or larger containers for unshucked scallops) in which scallops were immmersed in at least five volumes of soaking solution. To determine drip loss, scallops were drained by suspending the scallops in plastic mesh (flyscreen) in an empty 500 ml beaker which was then sealed with parafilm. Water absorption and drip loss was determined from the change in weight of scallops after blotting the surface moisture.

Phosphorus determination

The phosphorus content of scallops was determined colorimetrically using a modified molybdovanadate procedure (AOAC, 1984). Molybdovanadate reagent was prepared as follows: (a) dissolve 40 g ammonium molybdovanadate in 400 ml of hot water and cool; (b) dissolve 2 g ammonium vanadate in 250 ml hot water and cool; (c) add the two solutions and dilute to 2 litres in distilled water.

To determine phosphorus, 2 g of wet homogenised scallop was oven dried at 100°C in silica crucibles and ashed at 525°C. The ash was dissolved in 15 ml of 20% perchloric acid and heated till fuming. On cooling, the solution was transferred to a 100 ml

volumetric flask and made up to 100 ml with distilled water. A 5 ml aliquot of the solution was pipetted into a 50 ml volumetric flask, 10 ml of molybdovanadate reagent added and the volume made up to 50 ml with distilled water. After 15 min the absorbance of the solution was read at 400 nm.

A 1 mg/ml phosphorus standard contained 4.394 g potassium dihydrogen orthophosphate and 20 ml concentrated perchloric acid per litre. A 5 ml aliquot of a 10-fold dilution of this stock solution was made up to 50 ml with distilled water, 10 ml molybdovanadate reagent and 1.5 ml 70% perchloric acid. The final concentration of the standard was 0.01 mg P/ml. Phosphorus concentration of the test solution (mg/ml) was calculated from the linear relationship with the standard, and the percentage phosphorus (w/w) in the dried scallop sample determined as follows:

$$\% \text{ Phosphorus} = \frac{\text{mg P/ml} \times 100}{\text{Dry weight (g) of sample}}$$

The natural levels of phosphorus in scallops were determined on homogenised samples of 10 scallop meats. The scallops were obtained from the Hervey Bay region during surveys on natural moisture content.

Polyphosphate dipping

Trials on the use of polyphosphate to reduce drip loss from scallops were carried out by dipping soaked scallops in 5% Brifisol 512 (Hoechst Australia) for 15 min. The scallops (3 replicates of 5 scallops) were previously soaked in 0, 1 and 3.5% NaCl for 21 h at 5°C and, after dipping in Brifisol, were frozen overnight at -20°C. The scallops were then thawed and drained for 24 h at 5°C in sealed beakers. Water absorption was determined from the change in weight of the scallops.

Measurement of extracellular fluid

Individual scallops were soaked for 3 h at 5°C in 50 ml of solutions containing 0-3.5% NaCl and 0.025 µCi of the radioisotope ^{14}C-inulin. After soaking, scallops were blotted dry and a 0.5 g representative wedge of scallop tissue excised. The tissue was solubilised in 3 ml of soluene and the radioactive count determined after mixing with 10 ml of scintillant. The count on 1 ml of soaking solution was also measured after adding 10 ml scintillant. A ratio of the tissue counts/g and the solution counts/ml was taken as the proportion of extracellular fluid in the scallop.

Penetration of water and ^{14}C-inulin into the scallop muscle was measured for horizontal and vertical sections of the tissue sampled as in the schematic diagram in Figure 15. Each individual section was duplicated within each slab of scallop tissue. The mean moisture content of each section was estimated for six scallops and the amount of absorbed water estimated from the average moisture content of 20 untreated scallops in the batch. Inulin levels were expressed as counts/g.

Light Microscopy

Studies were carried out on live animals transported to the laboratory in aerated seawater at 18-20°C. After shucking, the adductor muscle was dissected longitudinally and a slab 2 mm thick cut from across one half. Muscle sections 2 mm long and 1 mm x 1mm were taken midway along the scallop radius and about 3 mm below the point of attachment to the shell. This process was carried out as quickly as possible (2-3 min) and sections were then fixed in 5% glutaraldehyde in sodium cacodylate buffer pH 7.4 at room temperature. After dehydration in ethanol and treatment with xylene, the sample was embedded in paraffin wax at 55°C. Sections were stained with haematoxylin and eosin and examined under an Olympus BD microscope.

Electron Microscopy

A live scallop was shucked and sampled as described in the procedure for light microscopy. Scallops from the same shot as the live animal were soaked for 20 h at 5°C in distilled water and 3.5% NaCl. Small sections (1 mm cubes) were rapidly frozen against a cold gold-plated copper mirror cooled with liquid nitrogen to -170°C under vacuum. This process was carried out using a Life Cell CF 100 Cryofixation apparatus. The water (ice) was removed from the frozen specimen by freeze substitution in 2% osmium tetroxide in dried acetone at -80°C for 50 h. The temperature of the specimen was raised slowly to -20°C over 16 h and to 2°C in 2 h. After 4 x 20 min washes in dried acetone, the specimen was embedded in Spurrs resin which was polymerised at 50°C overnight. Sections 60 µm thick were mounted on copper grids and stained with Reynolds lead acetate for 30 s, aqueous uranyl acetate for 1 min and lead acetate for another 30 s. Sections were examined under an Hitachi H-800 electron microscope.

Float test

The full procedure for the float test is described in the Results and Discussion section.

Float test development

Factors affecting the float test were examined in the following experiments:

Scallop temperature

The effect of scallop temperature on the float test was investigated using scallops at 2±1°C and at room temperature (22±4°C). The salt solutions for the float test were at room temperature. Cold scallops were maintained at 2°C by dividing the scallops into 5 lots of 10 and placing these into separate plastic bags. The bags were immersed in an ice slurry and the internal temperature of the scallops monitored before subjecting the scallops to the float test. No temperature adjustment was necessary for scallops equilibrated to room temperature. Different batches of scallops were used for the experiments at 2°C and 22°C.

Temperature of salt solutions

The design for this experiment was 4 temperatures x 10 scallops x 15 replicates. The 600 scallops were obtained from the same bulk supply at a local processing plant. Salt solution temperatures were 15, 20, 25 and 30°C, while the scallops were equilibrated to room temperature (22°C). The temperatures of the solutions were adjusted after testing 50 scallops. Analysis of variance was used to compare mean float counts (out of 10) at each solution temperature.

Repeated use of salt solutions

This experiment was conducted at a processing plant where 1,2 and 5 batches of 50 scallops were immersed in three separate beakers each containing 800 ml of 9.5% salt solution. For each batch, scallops were added and removed from the solution in lots of 10, simulating the float test procedure. The salt concentration of the solution was determined after adding the respective number of batches.

Microwave oven drying

A sample of 6-10 scallops (75-90 g) was weighed onto a microwave plate. The scallops were placed in a circle and, to prevent splattering, were covered with a circle of paper towel with the centre removed (Figure 24c). Drying was carried out in a commercial microwave oven (National Genius NE 7090) which had a maximum output of 650 W. The oven was programmed for 11 min drying time with the following settings: 4 min HIGH (650 W), 3 min MEDIUM-HIGH (580 W) and 4 min MEDIUM (450 W). After drying, scallops were reweighed hot on a top-pan balance accurate to 0.01 g. A tissue wedge (about 25% of the total) was removed from each scallop prior to weighing for microwave drying. Each wedge was dried by convection oven at 100$\pm$2°and the average moisture of the wedges compared with the moisture determined by microwave drying.

Infra red moisture balance

An homogenised sample of 2-5 g was spread over a tared dish and dried isothermally at 160°C on a Sartorius infra red moisture balance (Model YTC014). The instrument was programmed to print percentage moisture at 0.5 min intervals and the end point for drying was taken when the moisture increased by less than 0.1% per min.

Ultrasonics

About 12 whole scallops were compressed into a rectangular perspex chamber (width 40 mm) taking care to remove major air spaces. The ultrasound sensor was placed against the side of the container with a layer of transmission gel to ensure adequate coupling. A backfat tester (Meritronics Livestock Grader), for measuring thickness of fat on livestock, was used to generate the sound pulse and to detect the reflected pulse. Resolution was 0.1 µs, sufficient to detect a change of 2.8 m/s in sound velocity. After carrying out the ultrasound test on 27 lots of scallops, the same scallops were homogenised and tested for moisture by the convection oven method. The salt concentration was also determined on

moisture by the convection oven method. The salt concentration was also determined on the homogenate.

Statistical methods

The significance of the difference between treatment means was tested by an analysis of variance. Least significant differences were used to identify if treatments differed at the 1% or 5% levels of probability.

Linear regression analysis was used to determine the relationship between variables. Prediction intervals (90 and 95%) for the regression analyses were used to assess the accuracy of the rapid moisture tests.

RESULTS AND DISCUSSION

NATURAL MOISTURE

The natural moisture content of live-shucked *A. balloti* is shown in Table 1. For all scallops (n=1125) the average moisture content was 77.9% and ranged from 73.4 to 82.9%. No previous data on moisture levels have been reported for authentic samples of live-shucked *A. balloti*. The average moisture content reported here (77.9%) is slightly lower than the level of 78.5% reported by Sumner (1986) for *Pecten fumatus* caught in southern waters of Australia.

Table 1. Natural moisture content of scallops.

Parameter	All surveys	Summer	Winter
Average moisture, %	77.9	76.4	79.5
Range, %	73.4 - 82.9	73.4 - 80.2	77.2 - 82.9
n	1125*	544	441
SE	0.04	0.05	0.04

n, number of samples; SE, standard error; Summer (November to March); Winter (July)
* Data include 140 samples taken in April 1991.

Effect of season

Natural moisture levels varied with season (Table 1). During summer (November to March) moisture content was significantly lower ($P<0.01$) than in winter (July) with a difference of about 3%. The cyclic variation in natural moisture content is demonstrated in Figure 1. Although the peaks and troughs in the cycle did not occur in corresponding months for each year, it was evident that high moisture levels occurred mainly in winter (April to October) while low moisture levels occurred mainly in summer (November to March). Continued seasonal monitoring would be necessary to establish these cyclic patterns more clearly, since aberrations may occur from one year to the next.

The seasonal variations in moisture followed the reproductive cycle of *A. balloti*. Studies on gonad development in *A. balloti* (Dredge, 1981) caught off the central Queensland coast showed that the spawning period occurred from April to October. In Western Australia spawning of *A. balloti* occurred in a similar period in Shark Bay (Joll, 1987) although further south at Albrolhos Bay, the spawning period occurred later in the year from August to February. Joll (1987) also reported that changes in adductor muscle condition for *A. balloti* were closely related to the reproductive cycle, and that minimum meat condition (high wet weight) corresponded to the time of maximum gonad index.

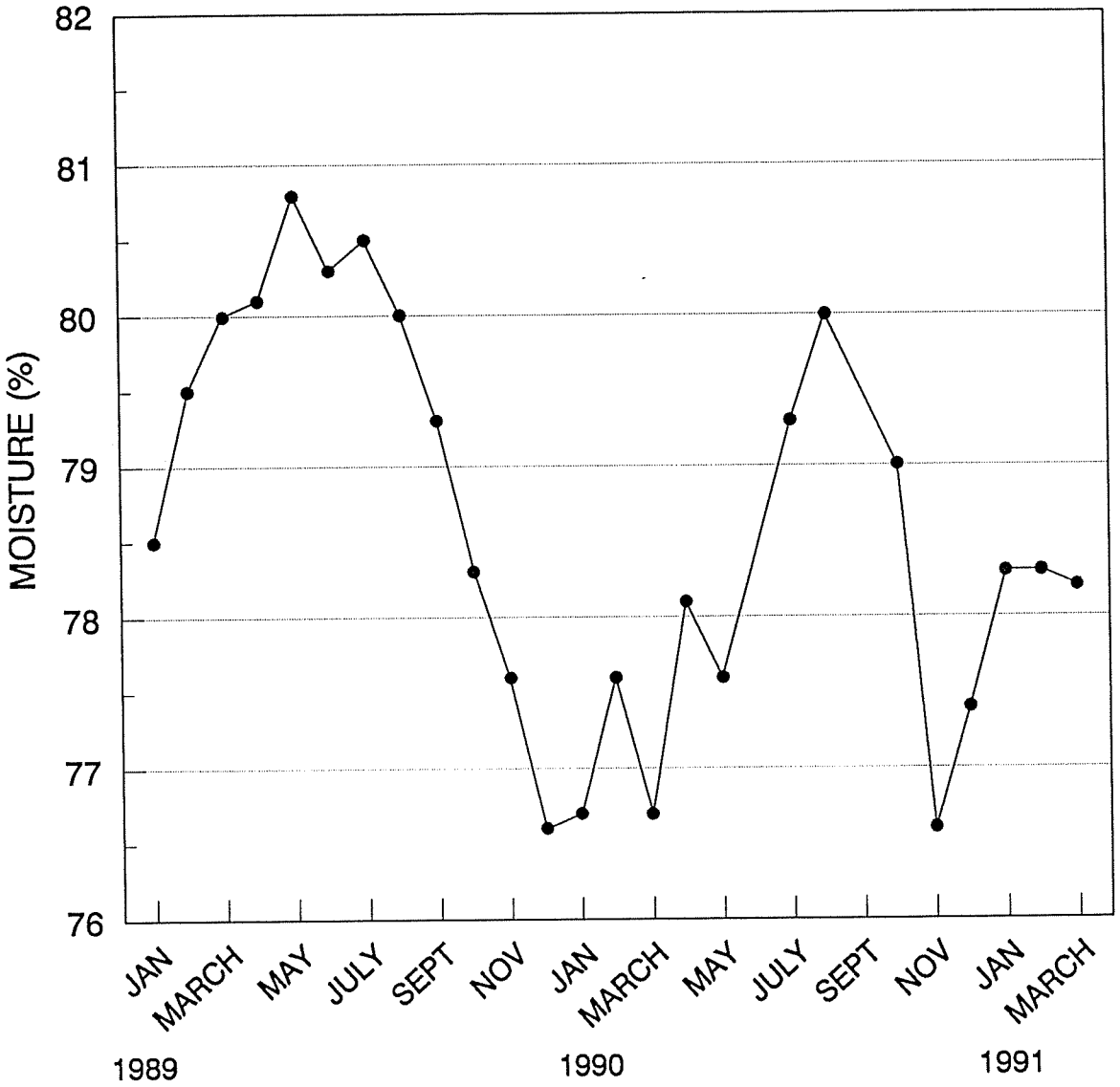


Figure 1. Seasonal variation in natural moisture content of scallops

In Queensland, processors have noted that minimum meat condition occurs around August/September when scallop meats are distended, exhibit fluid loss and are easily damaged during shucking. Figure 1 shows that moisture levels peaked in May during 1989 but peaked later (August) in 1990. The early peak in moisture levels in 1989 was related to an abnormal shift in the reproductive cycle, as processors observed early gonad development in that year.

The period of highest demand for Australian scallops, in particular Queensland scallops, by Hong Kong buyers is during September to December. At the start of this period the natural moisture content of scallops is likely to be high, and fishermen and processors need to be vigilant in minimising water uptake by scallops at this time.

Effect of size

The natural moisture content of scallops increased with decreasing scallop size irrespective of season (Tables 2, 3, 4; Figures 2, 3). These results provide useful information to industry in showing that small scallops (high count meats) have a higher natural moisture content than large scallops (low count meats). Most export scallops have meat counts in the range 44-133/kg. In the summer months the average moisture levels for scallops with these counts were in the range 75.9-76.8 (Table 3), while in winter, the range was 78.9-79.4 (Table 4). This data provides the base levels for setting quality standards for moisture content of export scallops, although an allowance will need to be made for water absorption during storage and processing.

The reason for high moisture levels in small scallops is unknown. A possible explanation is that immature scallops may have different osmotic properties from the mature animal, allowing a greater uptake of water intracellularly. A higher moisture in small scallops could also be associated with a higher metabolic activity during growth. Evidence for such biological events could not be found in the literature.

Table 2. Effect of size on natural moisture content of scallops.

Parameter	Size (no. of meats/kg)				
	<44	**44-66**	**67-88**	**89-133**	**>133**
Average moisture, %	75.3[a]	76.4[b]	77.5[c]	78.2[d]	79.2[e]
Range, %	73.5-79.2	74.2-80.8	74.4-80.7	73.4-81.5	75.6-82.9
n	28	146	249	439	263
SE	0.26	0.12	0.10	0.07	0.08
Average size (no/kg)	39	57	77	104	170

Means followed by the same letter are not significantly different (P>0.01).

Table 3. Effect of size on natural moisture content of scallops in summer.

Parameter	Size (no. of meats/kg)				
	<44	**44-66**	**67-88**	**89-133**	**>133**
Average moisture, %	74.9[a]	75.9[b]	76.4[c]	76.8[d]	77.2[e]
Range, %	73.5-76.7	74.2-79.0	74.4-79.5	73.4-80.2	75.6-78.5
n	25	120	146	189	64
SE	0.16	0.09	0.09	0.07	0.08
Average size (no/kg)	39	57	77	102	166

Means followed by the same letter are not significantly different (P>0.01)

Table 4. Effect of size on natural moisture content of scallops in winter.

Parameter	Size (no. of meats/kg)				
	<44	**44-66**	**67-88**	**89-133**	**>133**
Average moisture, %	-	78.9[a]	79.1[ab]	79.4[c]	80.0[d]
Range, %	-	78.1-80.8	77.9-80.3	77.5-81.5	77.2-82.9
n	-	15	63	190	173
SE	-	.19	.07	.05	.06
Average size (no/kg)	-	61	78	106	173

Means followed by the same letter are not significantly different (P>0.05)

Effect of location

Insufficient data were obtained to conclusively determine the effect of geographical location on natural moisture content. Restricted availability of the DPI trawler did not allow an adequate sampling programme to be carried out. Limited data for two different locations were obtained in July 1989 (Bustard Head and Yeppoon) and in July 1990 (Bustard Head and Hervey Bay). No difference was obtained for the 1989 trial (P>0.01) but there was a significant difference (P>0.01) in moisture levels between Bustard head

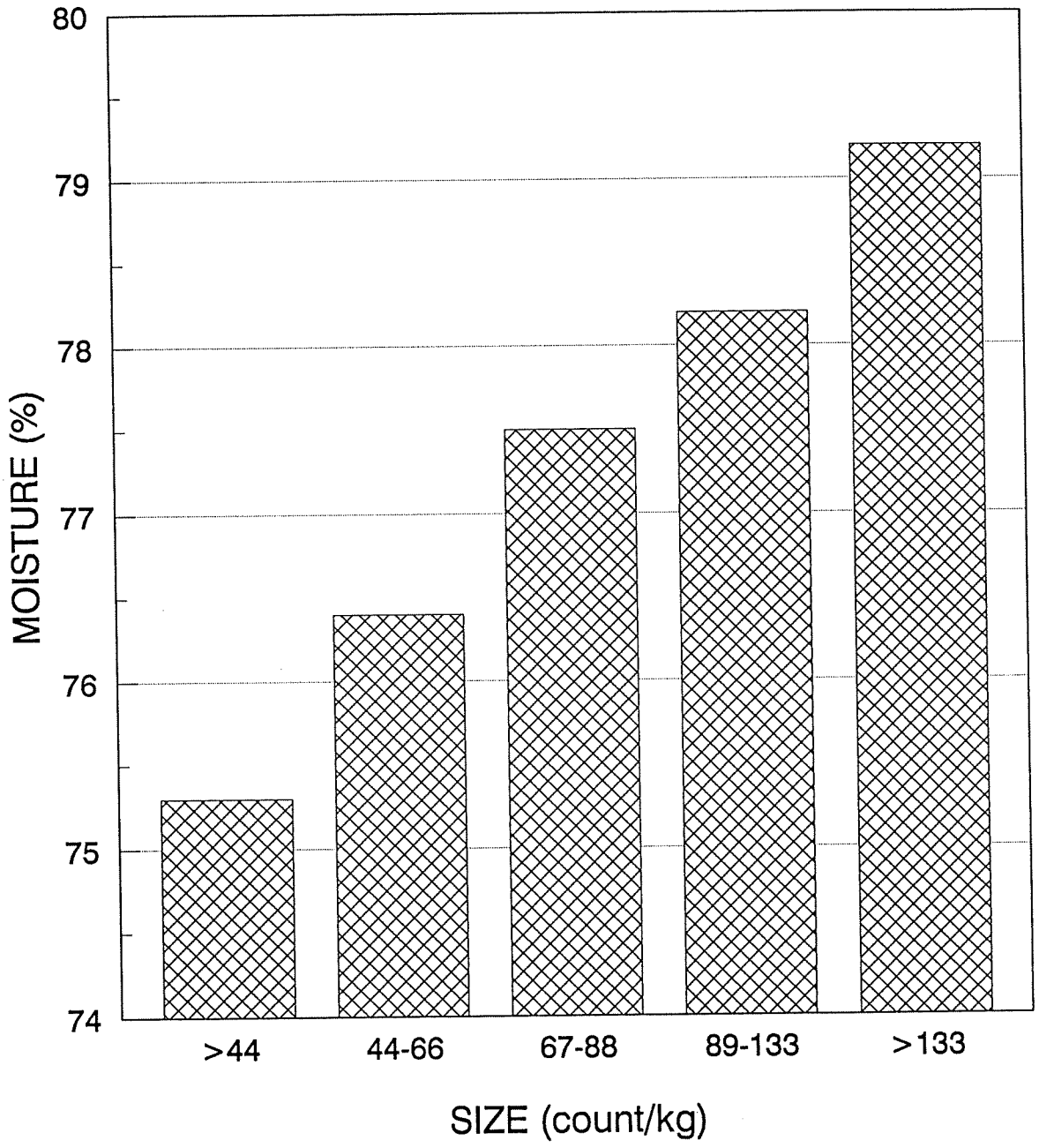


Figure 2. Effect of meat size on natural moisture content of scallops

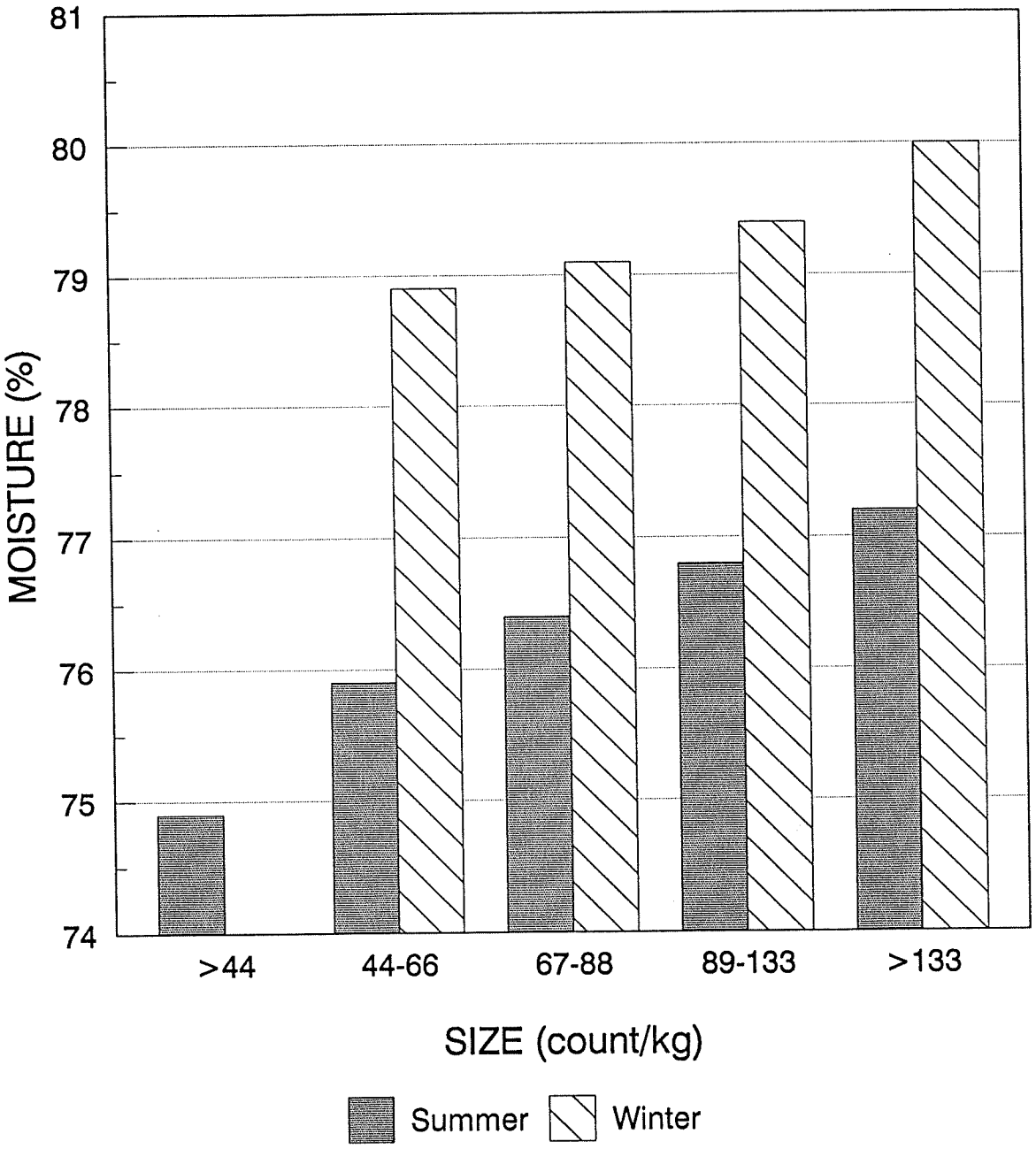


Figure 3. Effect of meat size on natural moisture content of scallops during summer and winter

and Hervey Bay in 1990 (Table 5). However, this difference was only 0.6% and may be of no practical importance to the industry.

Table 5. Effect of geographic location on the natural moisture content of scallops.

Time of Sampling	Moisture, %		
	Bustard Head	**Yeppoon**	**Hervey Bay**
July 1989	79.9[a]	80.1[a]	-
n	60	57	
July 1990	79.7[a]	-	79.1[b]
n	151		172

Within each sampling time, means followed by the same letter are not significiantly different (P>0.01).

Dredge (1981) found that scallop gonad weights peaked at slightly different times over relatively small distances (between Bustard Head and Bargara). Therefore, it is feasible that differences in reproductive stage could cause variations in natural moisture levels between different locations.

STORAGE AND PROCESSING

This section reports on the post-harvest absorption of water by scallops during trawler storage and subsequent processing. Data relating to uptake of water during storage on commercial trawlers were limited since adequate samples of both live-shucked and stored scallops were difficult to obtain. Attempts to have skippers from "freezer" and "brine" trawlers obtain the necessary paired samples were mostly unsuccessful, although one skipper from a "refrigerated" trawler was able to collect monthly samples over a two-year period.

Trawler storage

Refrigeration

The average moisture content of unshucked scallops stored on a refrigerated trawler at 0°C for 4 to 8 days increased by 0.9%. This result was obtained from 19 paired samples of live and dead scallops from different trips, each sample containing 30 individual meats (Figure 4). The increase in moisture content on storage was possibly due to absorption of residual seawater held in the shell or absorption of fluid from the surrounding viscera. Continual dripping of seawater from fresh scallops being added to the hold could also contribute to moisture increase. It was found that scallops which were suspended in mesh bags in the hold above the main scallop catch showed a net loss of moisture due to evaporation.

Freezer

Two trials were carried out on a DPI trawler to examine the effect of storage at -20°C for 4 days. Moisture content of the frozen scallops increased by 0.3 and 1.1% in the respective trials. Again it appeared that some moisture was absorbed from entrapped seawater in the shell or from the fluid of the viscera before or after the scallop was frozen. These results are in contrast with observations by processors and fishermen who generally observe a slight loss of moisture from evaporation in freezer holds.

Brine spray

In two trials on a commercial trawler, the moisture content of scallops chilled by brine spray increased by only 0.2%. These samples were not collected by DPI staff. Although industry opinion is that scallops from brine spray boats would show greater water absorption than scallops from freezer boats, this was not confirmed in the relatively few samples obtained in these trials.

Ice and refrigeration

No data was obtained from commercial trawlers. Unshucked scallops immersed in crushed ice in a large esky held at 0°C for 4 days were used to simulate trawler storage. Scallops obtained from the upper and middle sections of the esky showed increases in

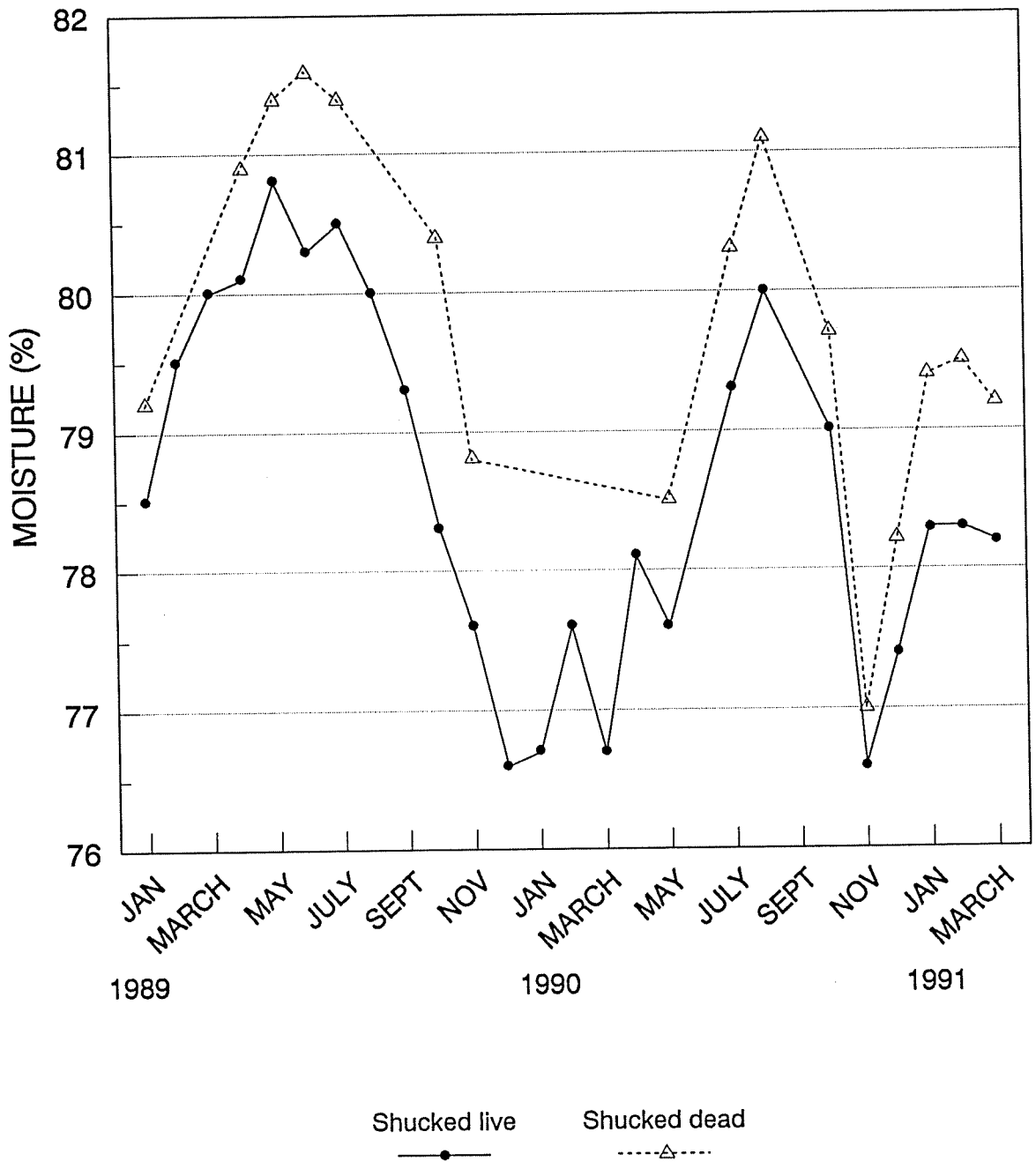


Figure 4. Water absorption by scallops during refrigerated storage at 0°C on a commercial trawler

moisture of 1.8 and 2.6%, while those in the slurry at the bottom of the esky showed an increase of 3.6%. The high amount of water absorption could be attributed to the osmotic action of unfrozen scallop tissue absorbing low ionic strength water from the melted ice.

Except for the data from the refrigerated trawler, the results for frozen, brine spray and ice storage may be questionable because of limited sample numbers. A summary of the amounts of water absorbed by the different storage procedures based on the present data is follows:

Trawler	Average increase in moisture	Range
Freezer	0.7%	0.3 - 1.1%
Brine spray	0.2%	0.1 - 0.2%
Refrigerated	0.9%	0.1 - 1.4%
Ice	2.7%	1.8 - 3.6%

Trawler survey

The moisture content of scallops from different trawlers sampled during unloading is shown in Table 6. The samples were taken in the period November 1989 to April 1990. These results illustrate the moisture levels in scallops submitted for processing. Because there were no live-shucked samples for comparison, no conclusions can be drawn regarding the most suitable trawler storage method.

Table 6. Moisture content of unshucked scallops ex trawlers before processing.

Parameter	Trawler Storage		
	Freezer	Brine	Ice
Moisture, %	78.2	78.7	78.0
n	7	12	5
SE	0.24	0.13	0.25

Processing

The changes in moisture content of scallops sampled during line surveys of processing plants is shown in Tables 7 and 8. The procedures used in primary processing differed between plants with regard to use of spray washing and the number of brine tank washes before final chilling, draining and packaging. A typical process operation used a brine

tank wash (15 min at 2°C), a drain time of 5 min, a brine chill (-3°C for 20 min) and and a final drain time of 30 min. Scallops were then packaged into 2 or 10 kg packs. Between shucking and packaging, the changes in scallop moisture levels varied from an increase of 1.8% to a decrease of 0.6%. The average increase in moisture content for the 13 plants was 1.1%, which corresponds to about 5% increase in scallop weight (Table 7).

Table 7. Moisture content of scallops during primary processing.

Processor	Moisture, %			
	Shucking	Spray Wash	Brine Wash 1	Brine Wash 2
1	81.0	82.0 (1.0)	-	82.0 (0)
2	77.5	-	78.3 (0.8)	79.2 (0.9)
3	79.5	-	-	80.9 (1.4)
4	82.4	83.3 (0.9)	-	83.2 (-0.1)
5	82.6	82.7 (0.1)	-	83.5 (0.8)
6	78.5	-	78.4 (-0.1)	78.8 (0.4)
7	78.0	-	78.0 (0)	79.8 (1.8)
8	79.5	-	80.3 (0.8)	81.1 (0.8)
9	78.4	-	79.3 (0.9)	80.0 (0.7)
10	79.8	-	80.9 (1.1)	80.8 (-0.1)
11	83.0	-	-	82.4 (-0.6)
12	79.7	-	-	80.4 (0.7)
13	79.9	-	81.6 (1.7)	81.7 (0.1)
Mean, %	80.0			81.1

Numbers in brackets indicate change in percent moisture from previous step.

Table 8. Moisture content of scallops during secondary processing.

Processor	Moisture, %		
	Initial	Brine Wash	Grading
1	83.7	-	83.9 (0.2)
2	80.1	-	80.6 (0.5)
3	79.5	80.5 (1.0)	80.5 (0)
4	79.5	80.4 (0.9)	80.4 (0)
5	83.4	-	83.1 (-0.3)
6	82.8	-	82.2 (-0.6)
Mean, %	81.5		81.8

Number in brackets indicate change in per cent moisture from previous step.

Secondary processing operations usually involved little use of water during the sorting and repackaging of unfrozen scallops (10 kg) to smaller 2 kg packs for export. The average increase in moisture was 0.3% although variations between plants were high.

In summary, trawler storage and processing each contributed about 1% to the natural moisture content of scallops (Figure 5). These average contributions can be expected to vary considerably depending on the method of trawler storage and the washing times and temperatures used during processing. Based on the data for natural moisture content and an increase in moisture content of up to 2.5% for acceptable handling practices during storage and procesing, scallops should contain no more than 79% moisture in "summer" (November to March) and 82% moisture in "winter" (April to October). Obviously there will be certain months of the year when intermediate moisture levels may apply, for example, during March/April and October/November.

The variation in moisture content with season makes it impractical to set a single moisture specification. The use of seasonal quality standards may be a suitable alternative.

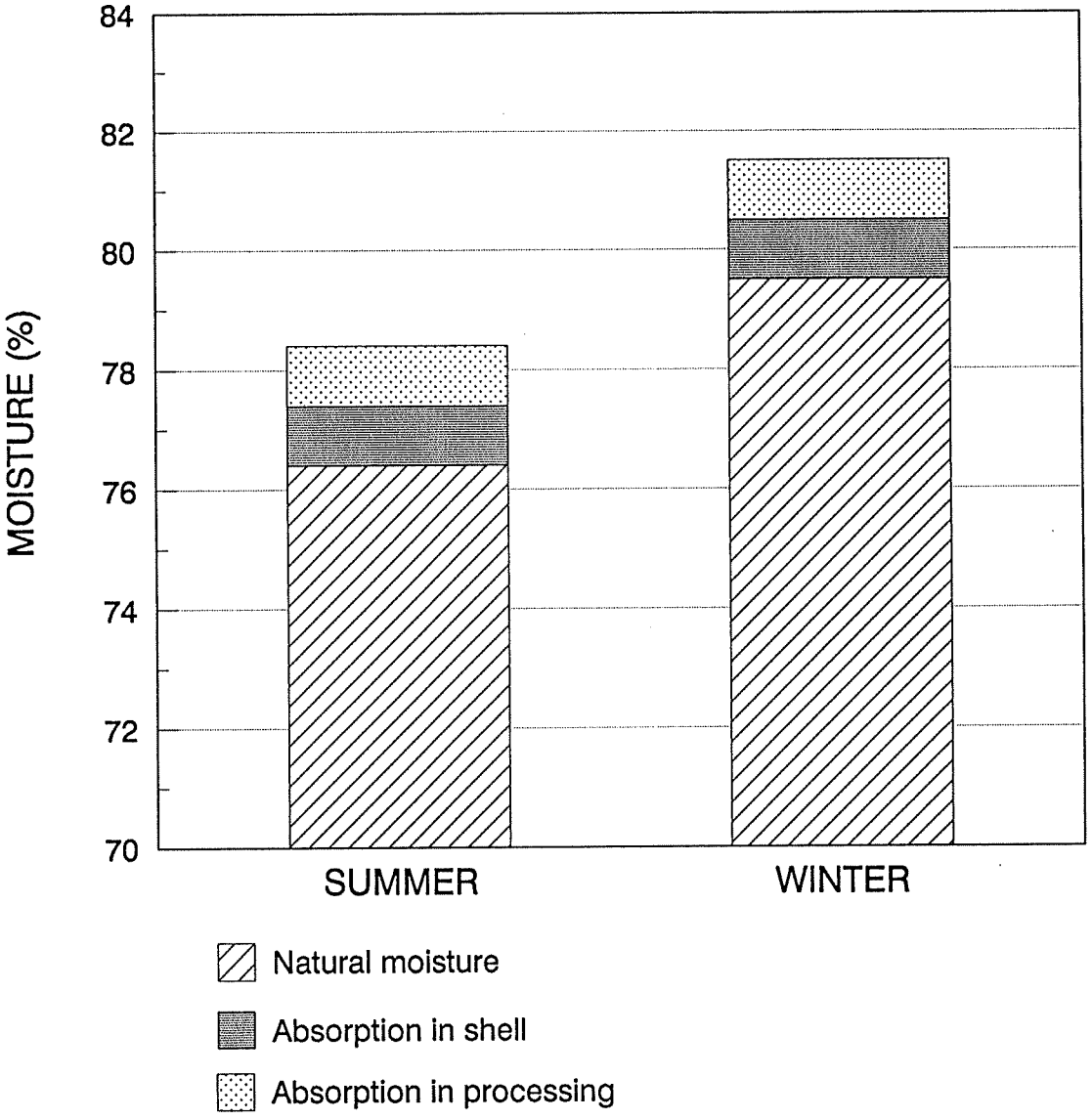


Figure 5. Changes in moisture content during storage and processing

WATER ABSORPTION

Theoretical considerations

The theoretical relationship between moisture content of scallops and added water is shown in Figure 6. For a known increase in moisture content, the percentage added water can be calculated from the formula:

$$\text{Added water (\%)} = \frac{M_2 - M_1 \times 100}{100 - M_2}$$

where M_1 = initial moisture (%)

M_2 = final moisture (%)

Alternatively, the final moisture content resulting from a known addition of water is given by:

$$M_2 = \frac{W + M_1 \times 100}{W + 100}$$

where W = added water (%)

The assumption in these formulae is that the change in weight of scallops is due only to loss or gain of water having a specific gravity of 1.0. Hence the accuracy of the calculations may be affected slightly by a net exchange of fluid with a different specific gravity due to soluble protein or electrolytes.

An appreciation of the relationship between added (or absorbed) water and moisture content (Figure 6) is helpful in following the experiments in this section. As a guide, a 5% increase in weight of scallops corresponds to about 1% increase in moisture content.

Water absorption

A typical example of water absorption by scallops is shown in Figure 7 where fresh scallops were soaked for 18 h at 5°C. The rate of water absorption was high during the first hour and gradually decreased during the soaking period. However, the amount of water absorbed was affected significantly by the salt concentration of the soaking solutions. After 1 h, scallops soaked in water increased in weight by about 10%, compared to an increase of only 5% for scallops soaked in 3.5% NaCl. After 18 hours, water-soaked scallops absorbed 45% water which was almost three times the amount absorbed by scallops soaked in 3.5% NaCl. The fact that water absorption did occur in

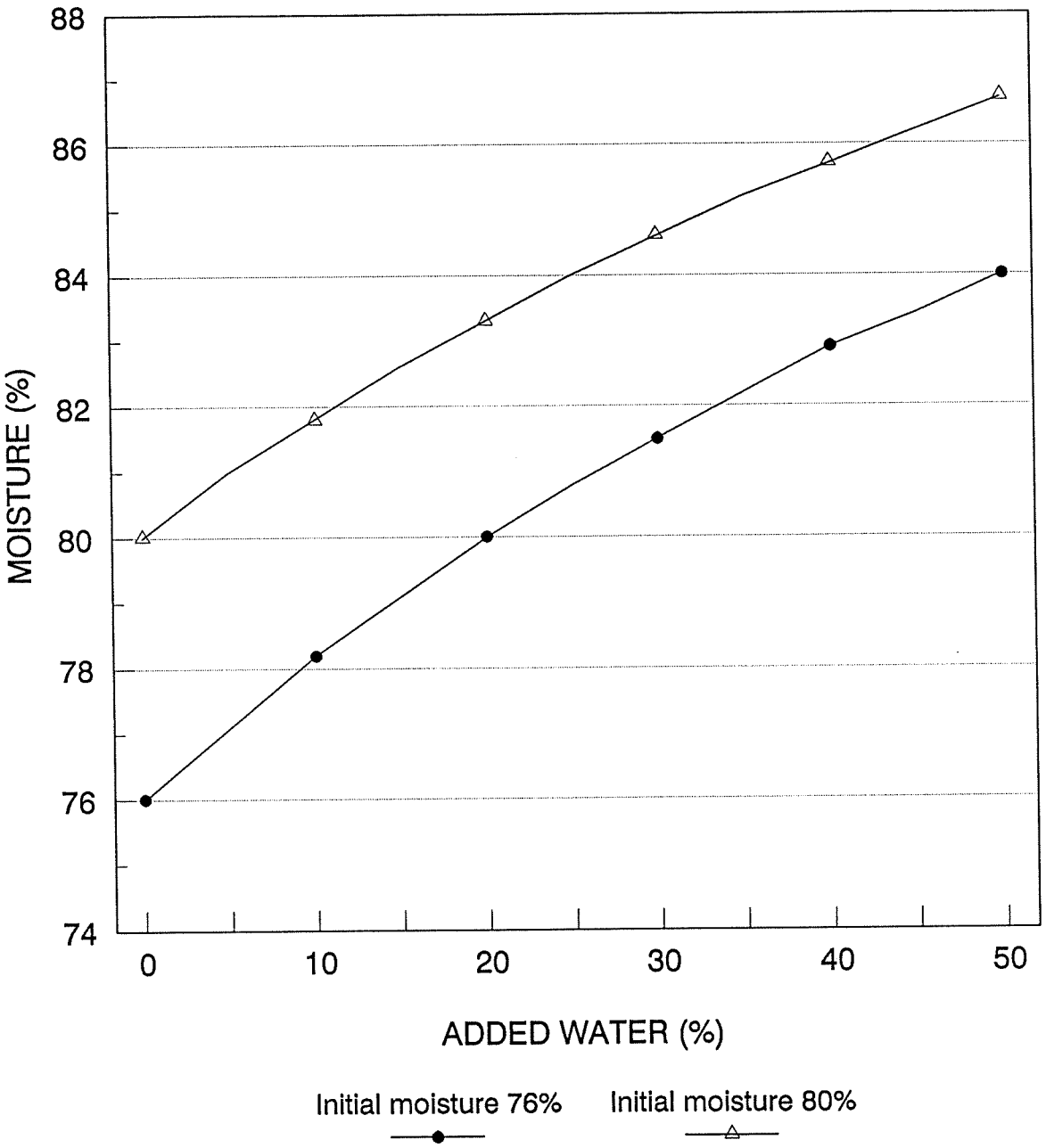


Figure 6. Relationship between moisture content and added water

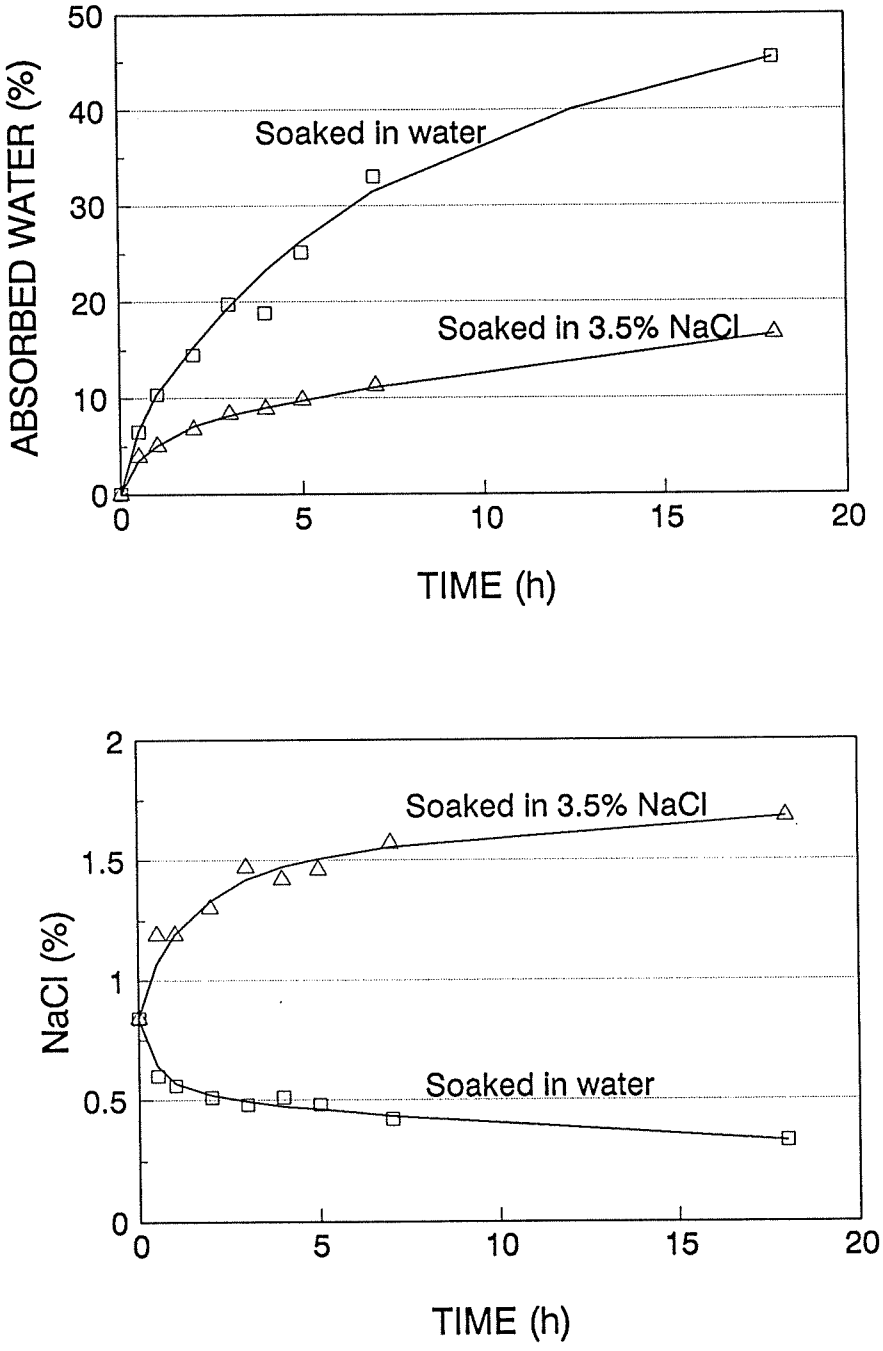


Figure 7. Water absorption and changes in salt levels for fresh scallops after soaking in water and 3.5% sodium chloride at 5°C

the 3.5% NaCl and that the NaCl content of the tissue increased, indicated that water uptake from this solution occurred primarily by permeation of the solution between the muscle cells and not by osmosis. Subsequent absorption of this extracellular water by the cells was presumed to be under osmotic control, which would explain the high water absorption after soaking in solutions of low ionic strength (*i.e.* low salt levels).

Figure 8 compares the absorption profiles for fresh and thawed scallops from the same shot. An important difference was that thawed scallops absorbed more water than fresh scallops after soaking in high levels of salt. This result indicates that the use of seawater for processing operations will not necessarily reduce water absorption in the case of thawed scallops. A possible explanation is that cell damage caused by freeze-thawing enables the salt solution to permeate more easily into the scallop and become bound electrostatically to membrane and muscle proteins. Similar binding may not occur at low ionic strength. Another observation in Figure 8 was that the fresh scallops absorbed much less water than those used in the experiment in Figure 7. This variation, although not fully investigated, was attributed to a seasonal effect where scallops showed a higher capacity for absorbing water during winter.

The effects of shucking and temperature of soaking on water absorption is shown in Figure 9. Shucked scallops absorbed 5-10 times more water than unshucked scallops demonstrating the effectiveness of the intact mantle in unshucked scallops in restricting influx of water from the soaking solution. For water soaked scallops, water uptake at 2°C was about 40% lower than at 18°C. For scallops soaked in 3.5% salt, the reduction in water uptake was less pronounced. These results demonstrate the importance of using low temperatures for washing procedures during processing.

Thawed scallops, previously frozen at -20°C for 2 days, also showed more water absorption after being shucked (Figure 10). In this experiment it was noted that absorption at high ionic strength was less than that for water soaking. In most trials the reverse occurred as in Figure 8. The degree of cell damage due to freeze-thawing may be a critical factor in the net absorption of fluids at different ionic strengths.

Water retention

Fresh scallops which had been soaked in water for 24 h lost about 70% of their absorbed water when drained for 24 h at 5°C (Figure 11). Drip loss was greatly reduced by increasing the salt concentration of the soaking solution. Approximately half of the drip loss occurred within 2 h. After draining for 24 h, the level of absorbed water retained by the scallop was similar (about 10%) for most soaking treatments.

For thawed scallops soaked in low ionic strength solutions (<1% NaCl), all absorbed water was lost on draining (Figure 11). At high ionic strength (greater than 2.5% NaCl), the level of absorbed water increased but drip loss was low. These results indicate that although seawater is the appropriate choice in processing operations for avoiding drip loss, net water absorption by thawed scallops can be greater with seawater than with fresh water. It is important, therefore, to minimise contact time with the brine solutions during processing.

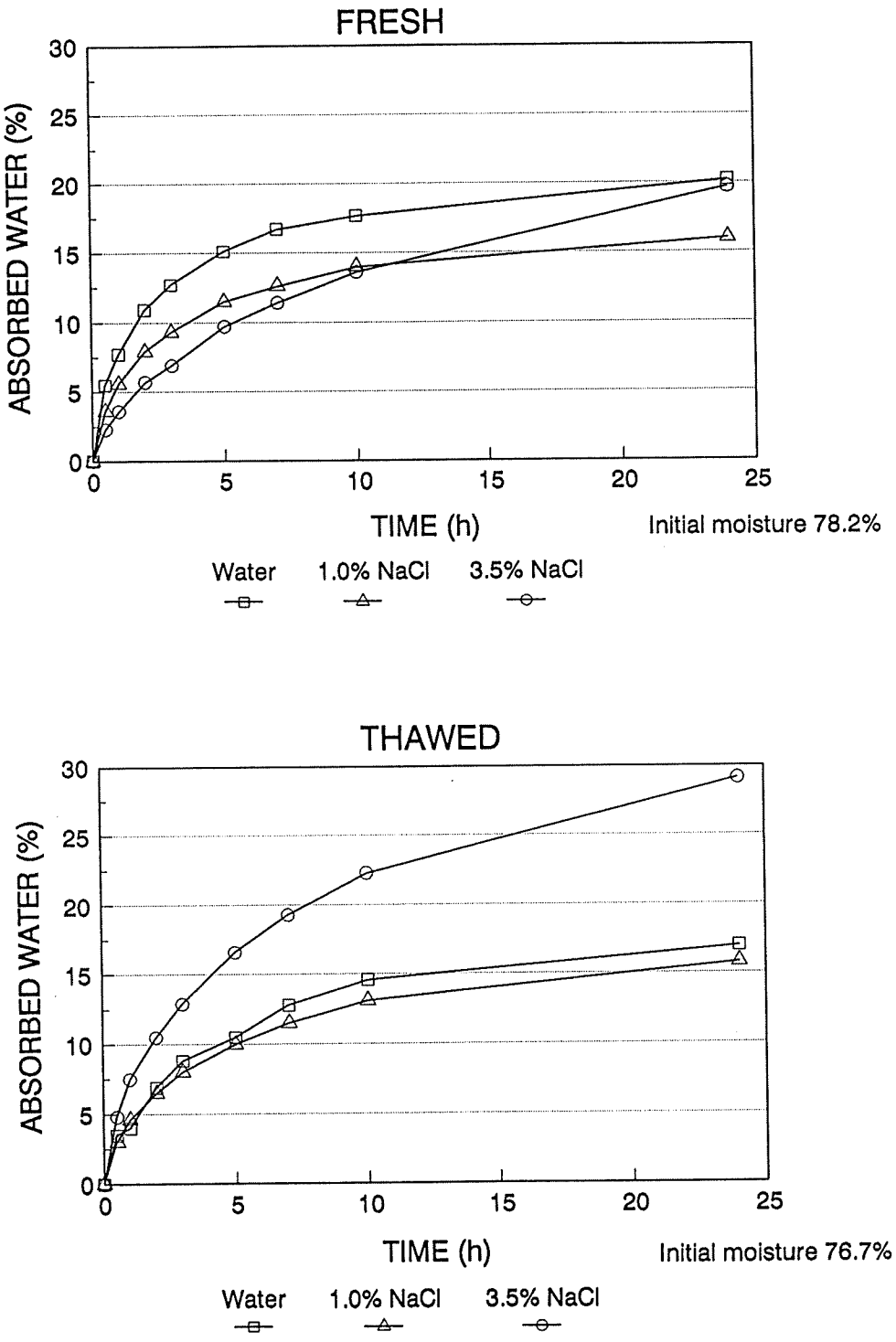


Figure 8. Water absorption by fresh and thawed scallops from different catches after soaking in various concentrations of sodium chloride at 5 °C

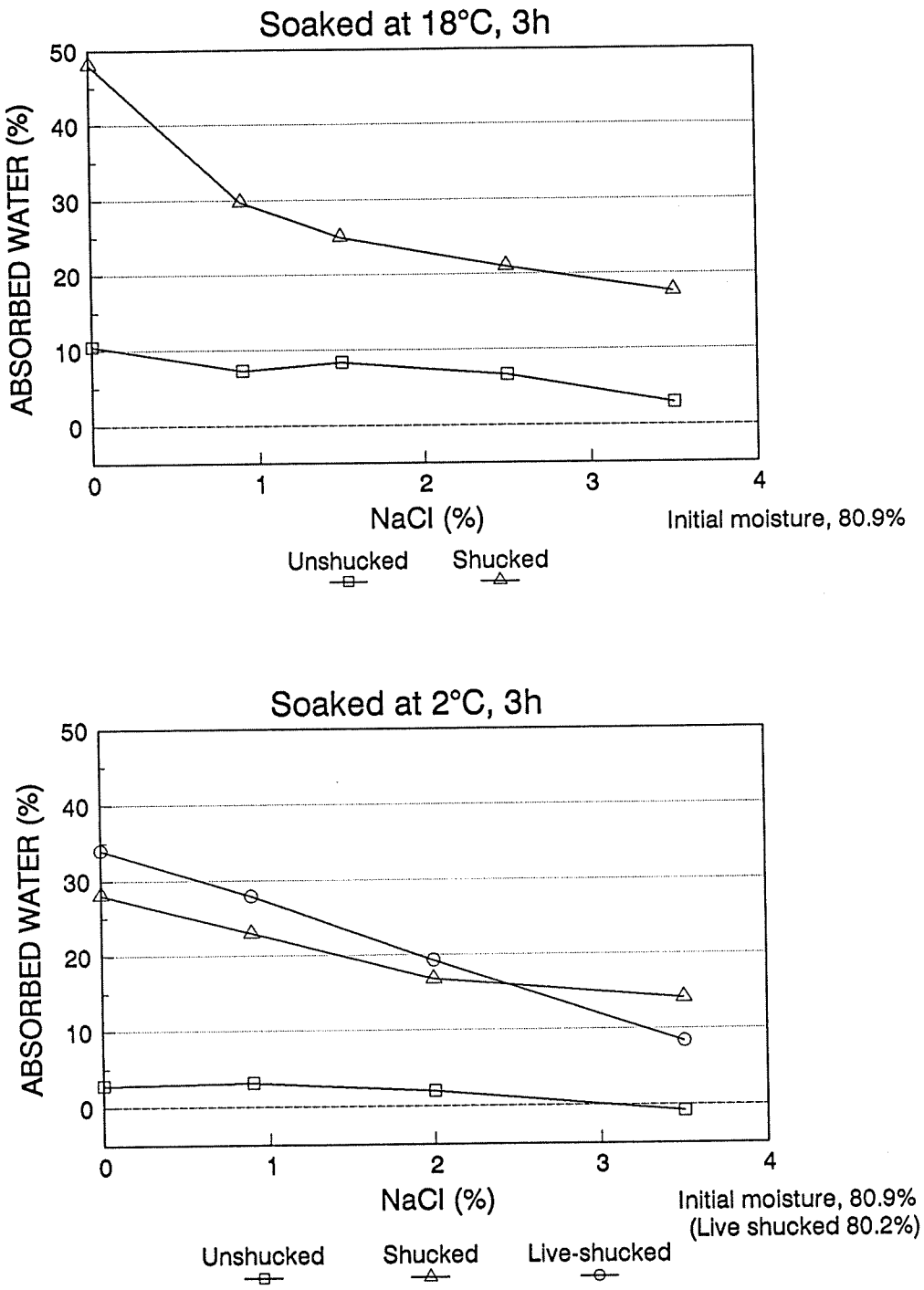


Figure 9. Water absorption by fresh scallops (unshucked and shucked) after soaking in different concentrations of sodium chloride for 3 h at 18 °C and 2 °C

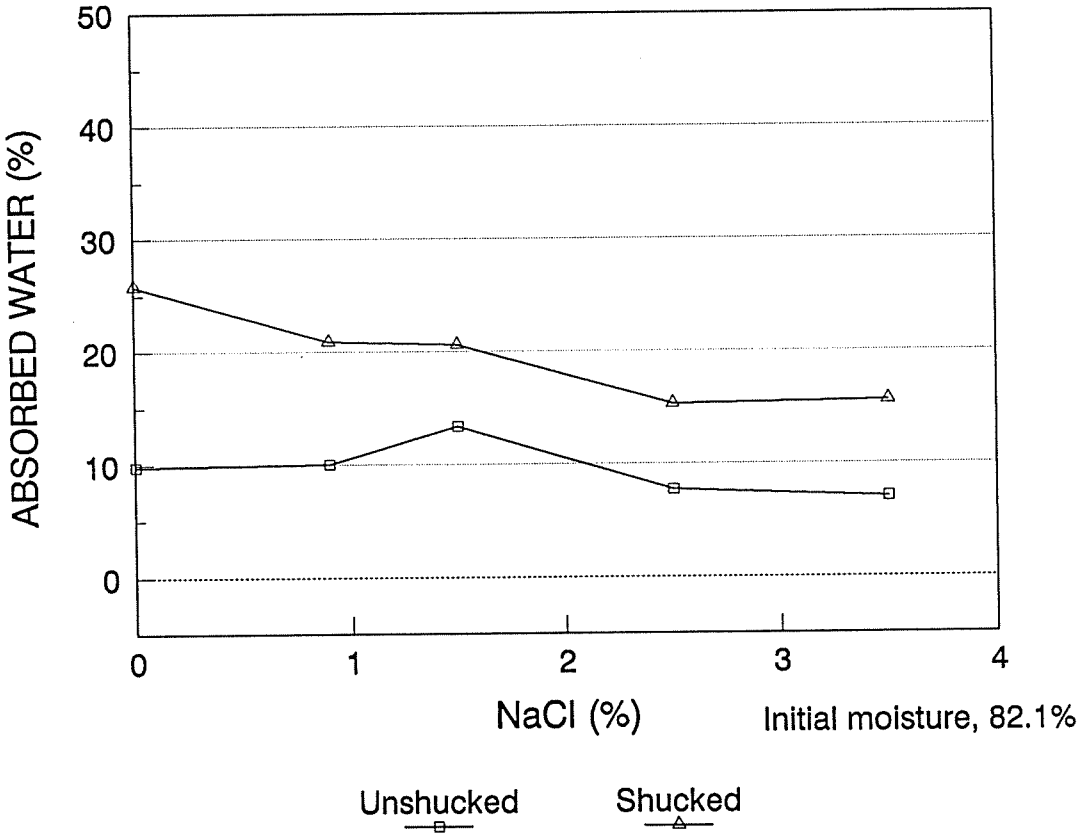


Figure 10. Water absorption by thawed scallops (unshucked and shucked) after soaking in different concentrations of sodium chloride for 3 h at 18 ℃

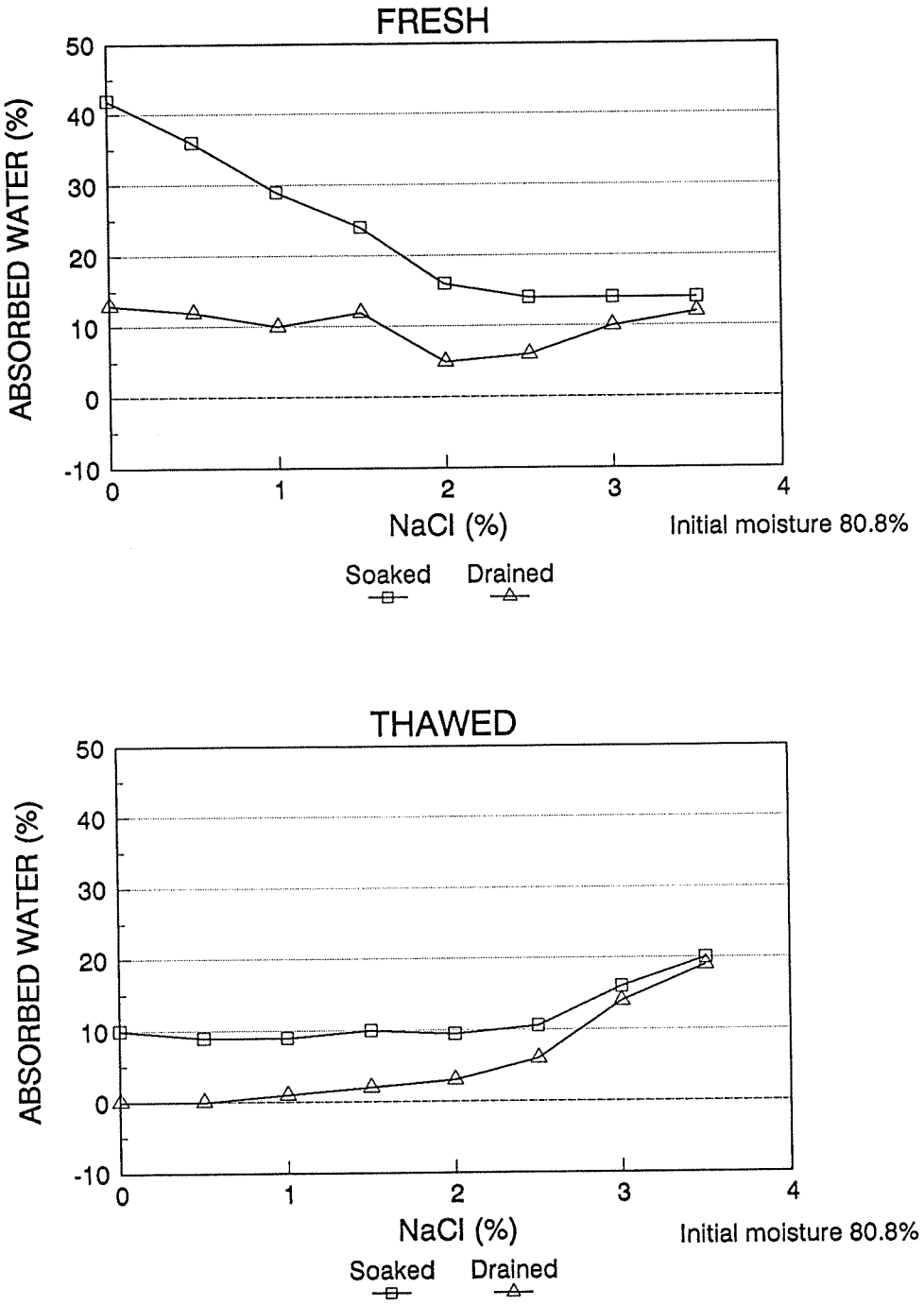


Figure 11. Water absorption and water retention in fresh and thawed scallops from the same catch after soaking in various concentrations of sodium chloride at 5°C for 24 h and draining at 5°C for 24 h

Drip loss from scallops was increased if the scallops were frozen after being soaked in low concentrations of salt (Figure 12). However minimal drip loss occurred after soaking scallops in solutions containing greater than 3.0% NaCl. This experiment relates to the situation where export scallops are thawed on reaching overseas markets. Drip loss should be minimal if seawater has been used in processing operations.

The amount of water retained by scallops reached a maximum at soaking concentrations of 4% NaCl (Figure 13). Above this salt concentration, water absorption and retention was relatively constant and virtually no drip loss occurred. Since seawater has a concentration of around 3.3% NaCl, most processors are fortunate in having an abundant supply of this water which has a near optimal level of NaCl for preventing drip loss in their product.

The industry practice of using chilled seawater instead of fresh water in processing operations was validated in the present investigations. Although thawed scallops may absorb more water when using seawater, problems with drip loss will be minimised.

Polyphosphate dipping

Dipping scallops in polyphosphate solution (5% Brifisol) effectively reduced drip loss by about 60% from scallops which had been soaked in water and 1% NaCl (Figure 14). However, scallops soaked in 3.5% NaCl showed an increased drip loss after dipping in polyphosphate. This result was confirmed in a similar trial where soaked scallops were not frozen before draining. It appears that the high salt concentration on or near the surface of scallops after soaking in 3.5% NaCl interferes with the water binding action of polyphosphate.

Polyphosphate dips (usually a mixture of hexametaphosphate and tripolyphosphate) can be used to retain water and flavour in seafoods and other meat products (Mahon and Schneider,1964; Gibson and Murray (1973); Teicher, 1990). The present study has shown that the use of polyphosphate dips during scallop processing offers no advantage over the use of chilled seawater for reducing drip loss. While polyphosphate dipping of scallops is not illegal provided its use is stated on the product trade description, the dip may adversely affect the quality by causing a sticky meat surface and a metallic taste when used at high levels (Teicher, 1990).

Natural phosphorus levels in live-shucked scallops were investigated to determine if polyphosphate residues from dipping could be detected as phosphorus. For 18 samples of homogenised scallops, natural phosphorus levels (on a dry weight basis) was 1.55% with a range of 1.39 to 1.70% and a standard error of 0.025%. Repeatability of the test performed on the same homogenised scallop sample was high (mean, 1.52%; standard error, 0.003%) and recovery of phosphorus using standard addition of Brifisol was 95%.

Phosphorus levels in processed scallops which had been dipped in 5% Brifisol at 5°C for various times are shown in Table 9. Because of the natural variation in the phosphorus content of scallops (1.39-1.70%), phosphorus residues from Brifisol dips would not be detectable for dip times less than 15 min. Alternative polyphosphate products may give different residue levels but these products were not investigated.

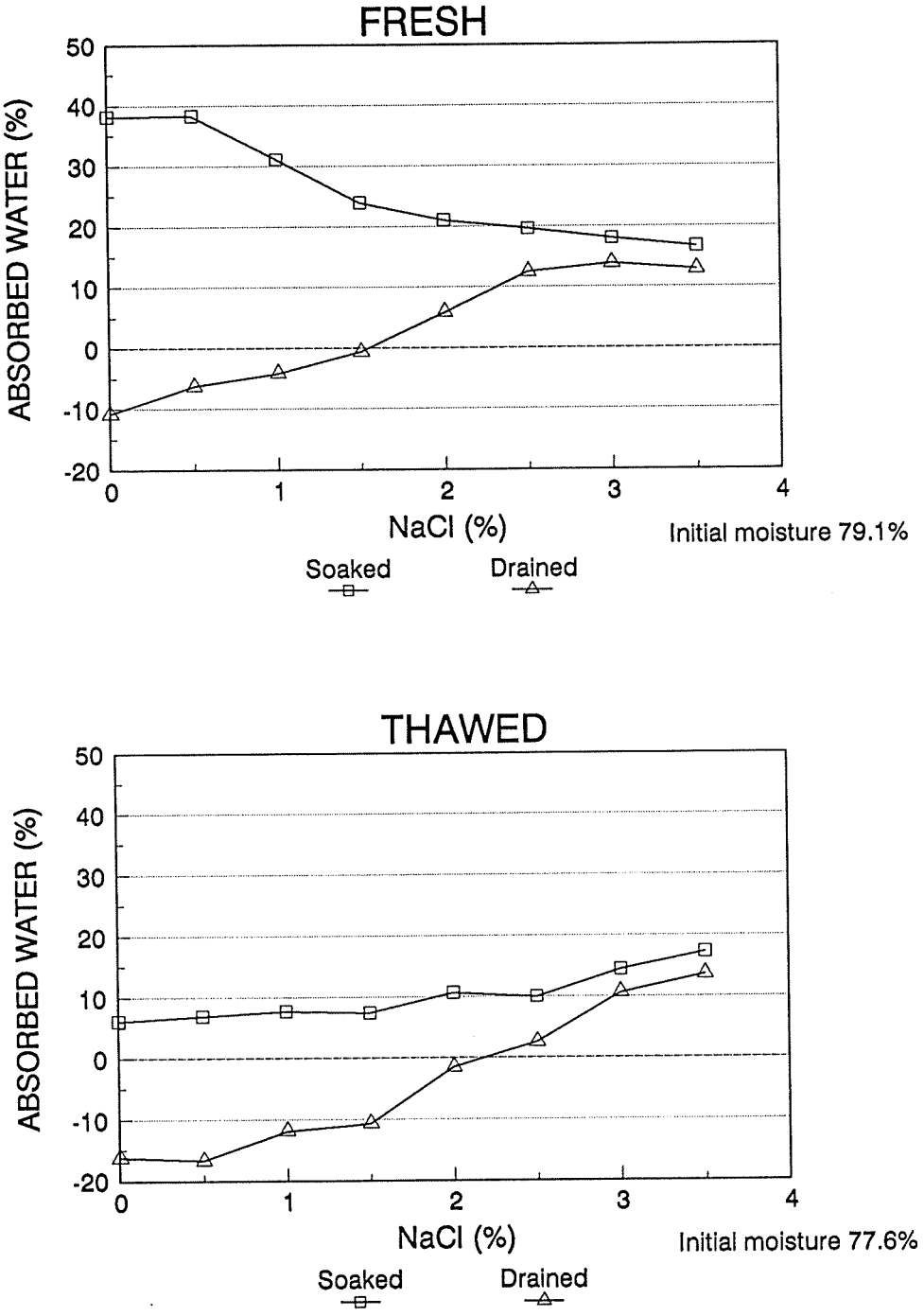


Figure 12. Water absorption and water retention in fresh and thawed scallops from the same catch after soaking in various concentrations of sodium chloride at 5°C for 24 h, freezing at −20 °C for 24 h, and draining at 5°C for 24 h

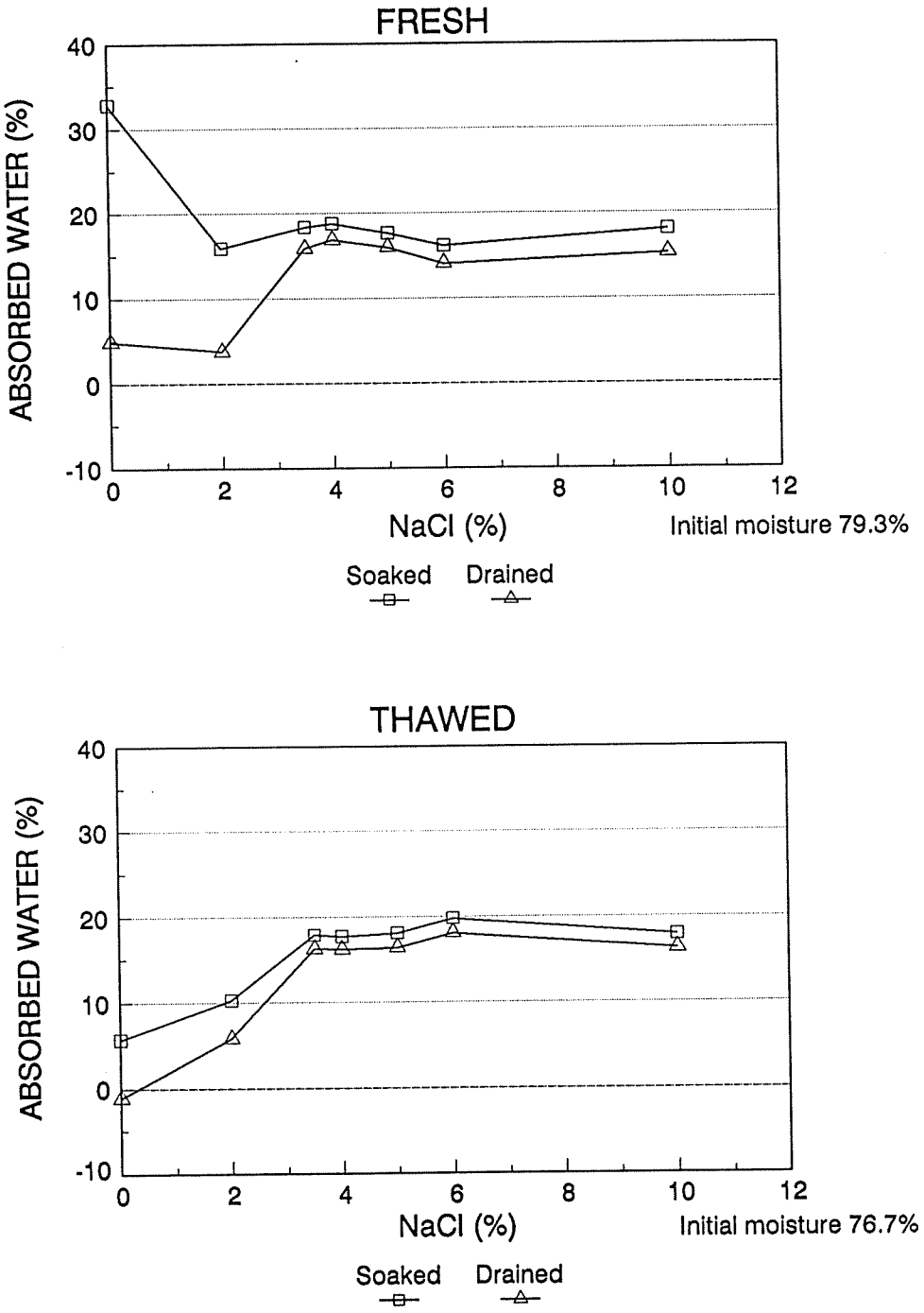


Figure 13. Water absorption and water retention in fresh and thawed scallops from different catches after soaking in various concentrations of sodium chloride at 5°C for 24 h and drained at 5°C for 24 h

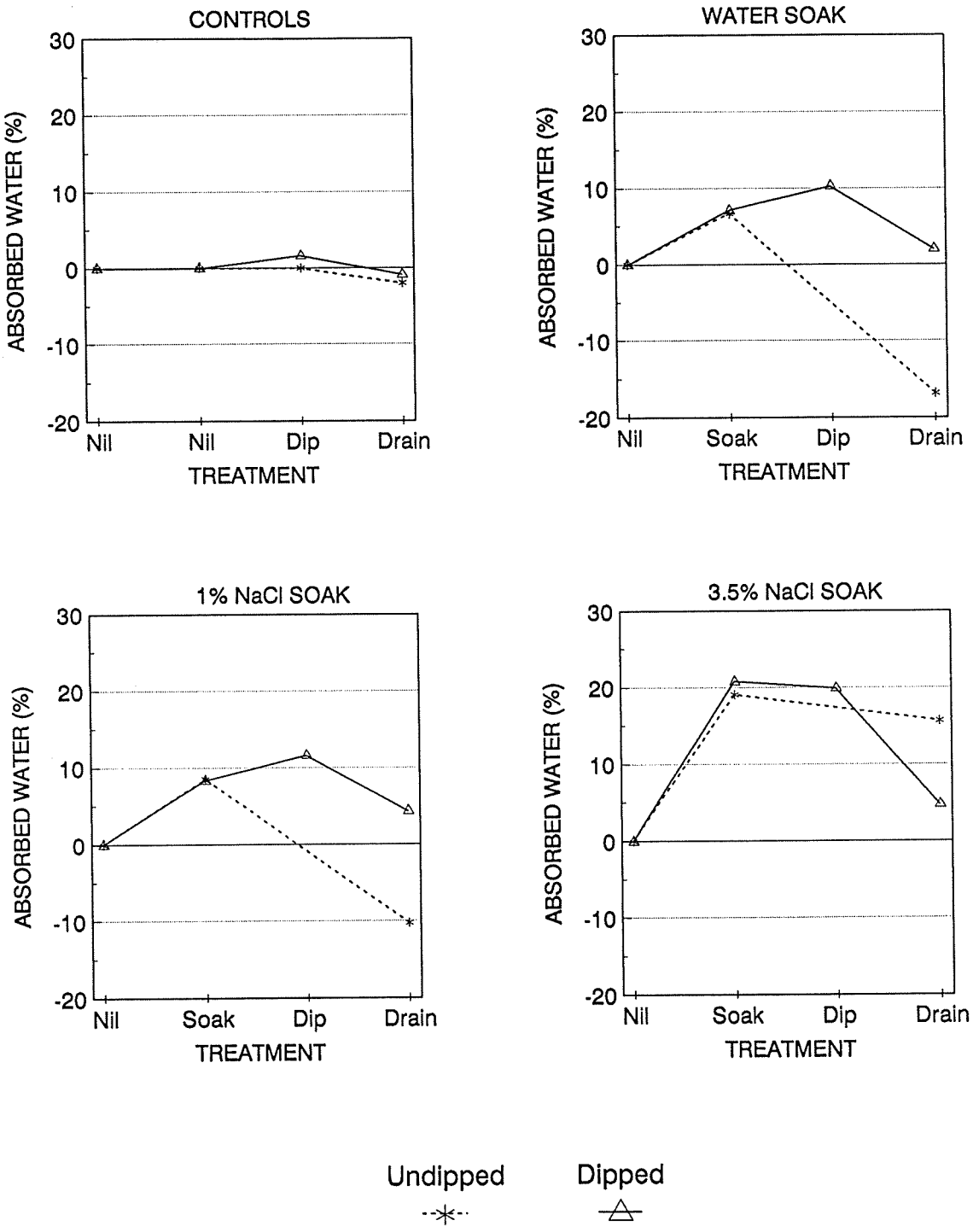


Figure 14 Changes in levels of absorbed water in scallops after soaking for 21 h at 5°C, dipping in polyphosphate (5% Brifisol) for 15 min at 5°C, freezing for 20 h at −20°C and draining for 24 h at 5°C

Table 9. Phosphorus levels in scallop muscle after dipping in 5% polyphosphate (Brifisol) solution at 5°C.

Scallop Sample	Phosphorus (% dry weight)				
	Dip time (min)				
	0	2	5	15	30
Fresh	1.42	1.60	1.67	1.80	1.75
Thawed	1.50	-	1.79	-	1.99

Measurement of extracellular fluid

Attempts to determine the extent of extracellular and intracellular absorption of fluid by scallop adductor muscle after soaking were largely unsuccessful. The approach involved the use of a radiolabelled polysaccharide, ^{14}C-inulin, which was added to the soaking solutions. When absorbed by the scallop, inulin should remain in the extracellular fluid (ECF) since the molecule is too large to penetrate the membrane of the muscle cells. The assumption is that the inulin concentration in the ECF is equilibrated with the soak solution, so that ECF% can be determined from a ratio of the scintillation count in a tissue sample to the count in the soaking solution.

High variability in tissue scintillation counts precluded meaningful results. This was caused mainly by a non-uniform penetration of inulin (and water) into the muscle tissue. Figure 15 shows the gradient of inulin concentrations and the levels of absorbed water in the tissue in vertical and horizontal directions after soaking for 3 h. Extended soaking up to 24 h did not remove the gradient in absorbed water between the outer and central portions of the scallop which remained at about 10%. No differences in moisture levels were obtained between the various sections of the scallop prior to soaking. These results indicate that water does not readily penetrate the muscle but is restricted in its movement by the network of muscle fibres. When scallops are soaked for a short period most of the water would remain near the surface. On draining, some of the water may be lost while the remainder will permeate further into the scallop and be retained.

Microscopy

Light microscopy of longitudinal and transverse sections of scallop muscle from a live animal are shown in Figure 16. The longitudinal section (Figure 16a) showed cross-striated muscle and associated banding. The cells (myofibrils) were of variable thickness although the majority were 1-2 µm. The open spaces between the cells and the wavy structure may be attributed to artefacts caused by contraction of the muscle fibres during the fixation procedure. Other longitudinal sections (not shown) revealed significant cross-linking by division of a cell into two strands. The transverse section of the muscle (Figure 16b) showed the elongated nature of the myofibrils.

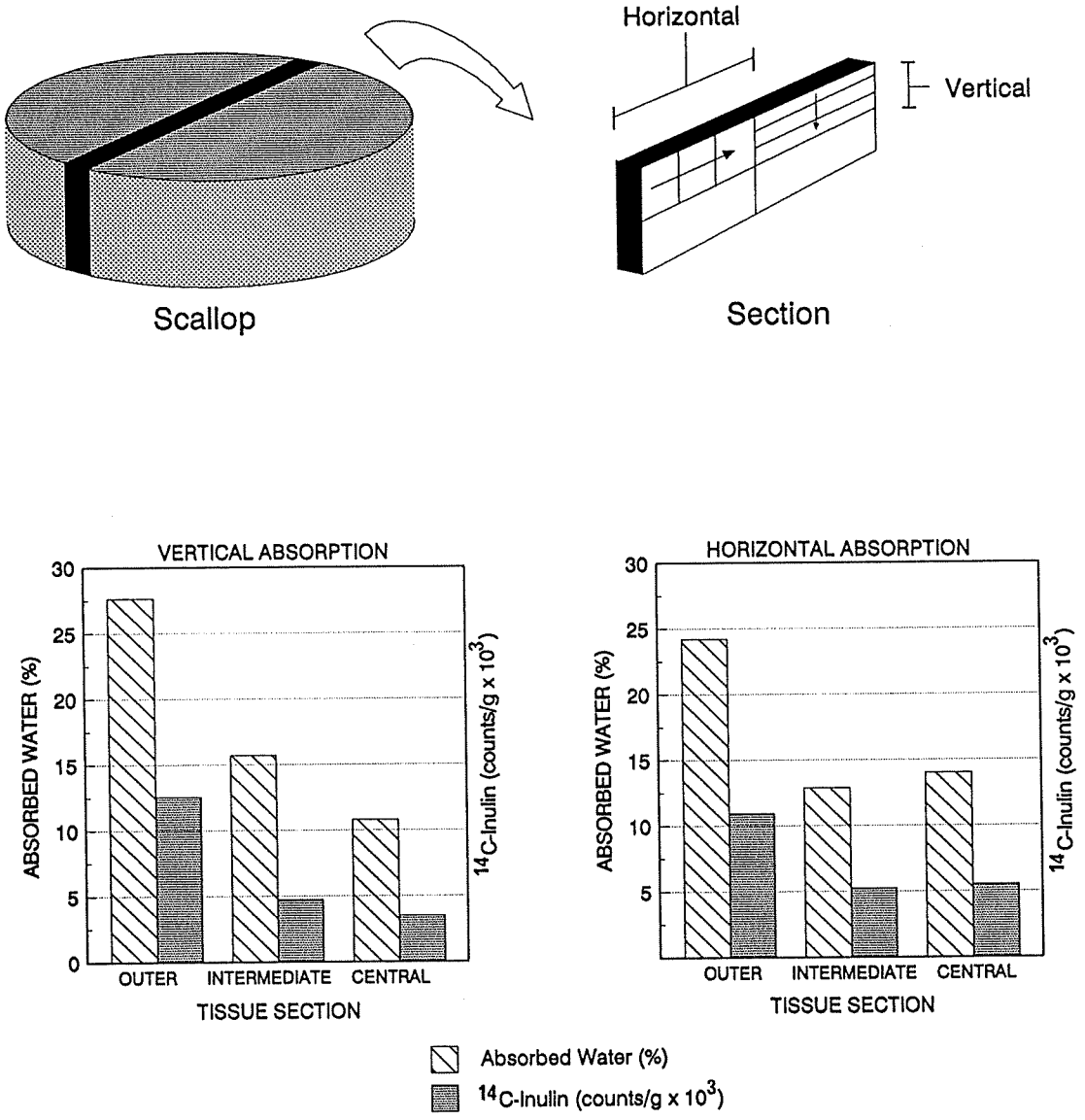
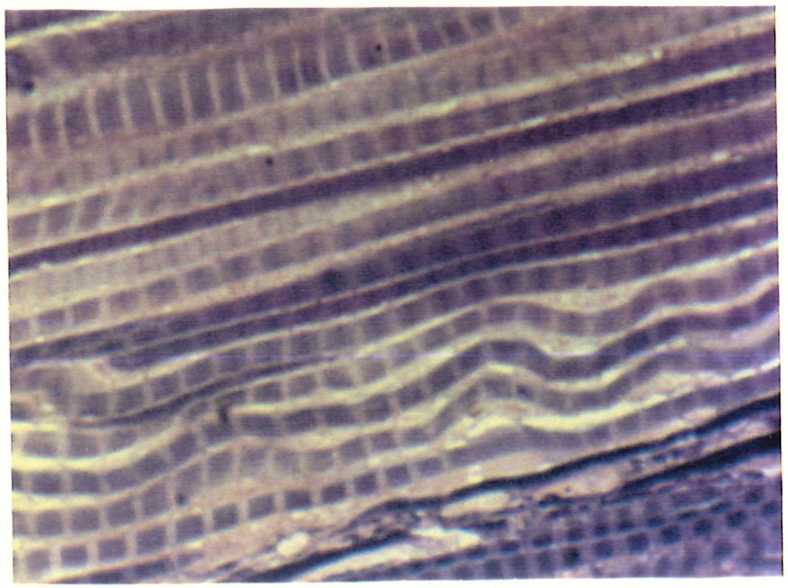


Figure 15. Penetration of water and ^{14}C–inulin into thawed scallops along vertical and horizontal axes after soaking in water for 3 h at 5°C. Scallops were dissected as shown in the schematic representation.

a



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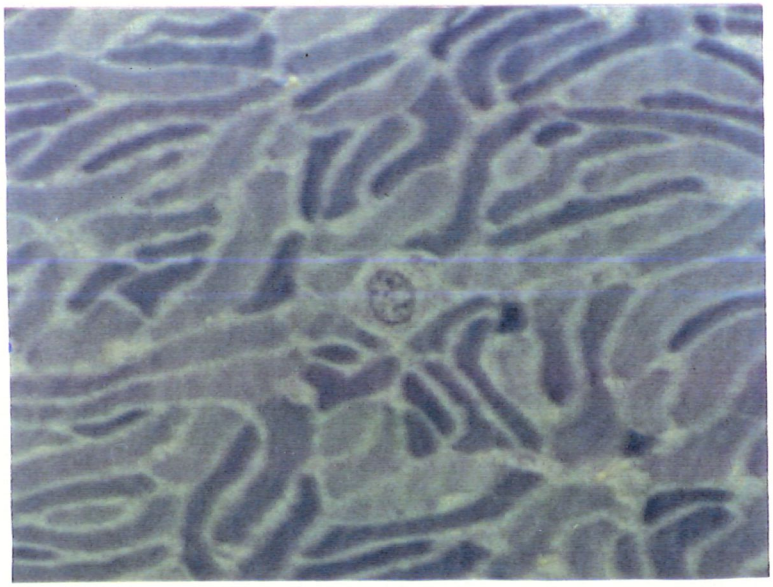

Figure 16. Light microscopy of scallop adductor muscle. (a) longtitudinal section (X1900); (b) transverse section (X1900). Sections were stained with haematoxylin and eosin.

Most studies on the microscopy of scallop muscle have been on *Aequipecten irradians, P. magellanicus* and *P. maximus* (Nunzi, 1981; Rall,1981; Chantler, 1983). According to these reports, scallop muscle cells are ribbon-shaped and are less than 2 mm long, about 1 µm thick, and 3-10 um wide. Each cell contains a single myofibril (rather than a bundle of myofibrils) surrounded by a sarcoplasmic reticulum or cell membrane. The cell should contain a single nucleus although none was observed in the present study.

Electron micrographs of longitudinal sections of live and soaked scallops from the same shot are shown in Figure 17. To overcome the possible problems of artifacts during conventional fixation of sections, the processes of rapid cryofixation and freeze substitution were used. Both the live scallop (Figure 17a) and the scallop soaked in 3.5% NaCl (Figure 17c) showed intact myofibrillar membranes and an absence of extracellular spaces. For the salt soaked sample, the presence of voids beneath the membrane may represent pockets of water which had accumulated under the influence of high extracellular ionic strength. In contrast, the water soaked scallop (Figure 17b) showed a complete absence of cell membranes along with large extracellular spaces containing vesicles (supposedly cell membrane fragments). This micrograph represents visible evidence of rupturing of the cell membrane after water is absorbed osmotically by fresh scallop. Thus soaking in water destroys the cell membrane and hence weakens the structural intregity of the flesh.

Mechanism of water absorption

Based on the results obtained in the present investigation, and on reports found in the literature, the mechanisms for water absorption and retention in scallops are considered to be as follows:

1. Water is primarily absorbed by permeation or diffusion of water into the extracellular spaces between the muscle cells (myofibrils). This process appears to be independent of the ionic strength of the soaking solution. At low temperatures permeation is restricted by muscle shrinkage.

2. In fresh scallops, extracellular water of low ionic strength is absorbed osmotically by the myofibrils. In actively taking up water by this process, the myofibrils swell and rupture, causing intracellular fluid to be released into the extracellular matrix. Conversely, extracellular water of high ionic strength draws water out of the myofibrils and the net water absorption by the scallop is limited to that of the permeation process.

3. In thawed scallops, the osmotic movement of water into or out of the myofibril is reduced because of cell membrane damage. Absorption of water from high and low ionic strength solutions is due mainly to permeation. However, in the absence of intact myofibrils, the muscle proteins become accessible to ions from the soaking solution. Interaction of the ions (Na^+, Cl^-) with charged groups on the proteins enhance the formation of hydrophilic regions where water is immobilized to the protein (Pearson and Young, 1989). If this is an active process, more water

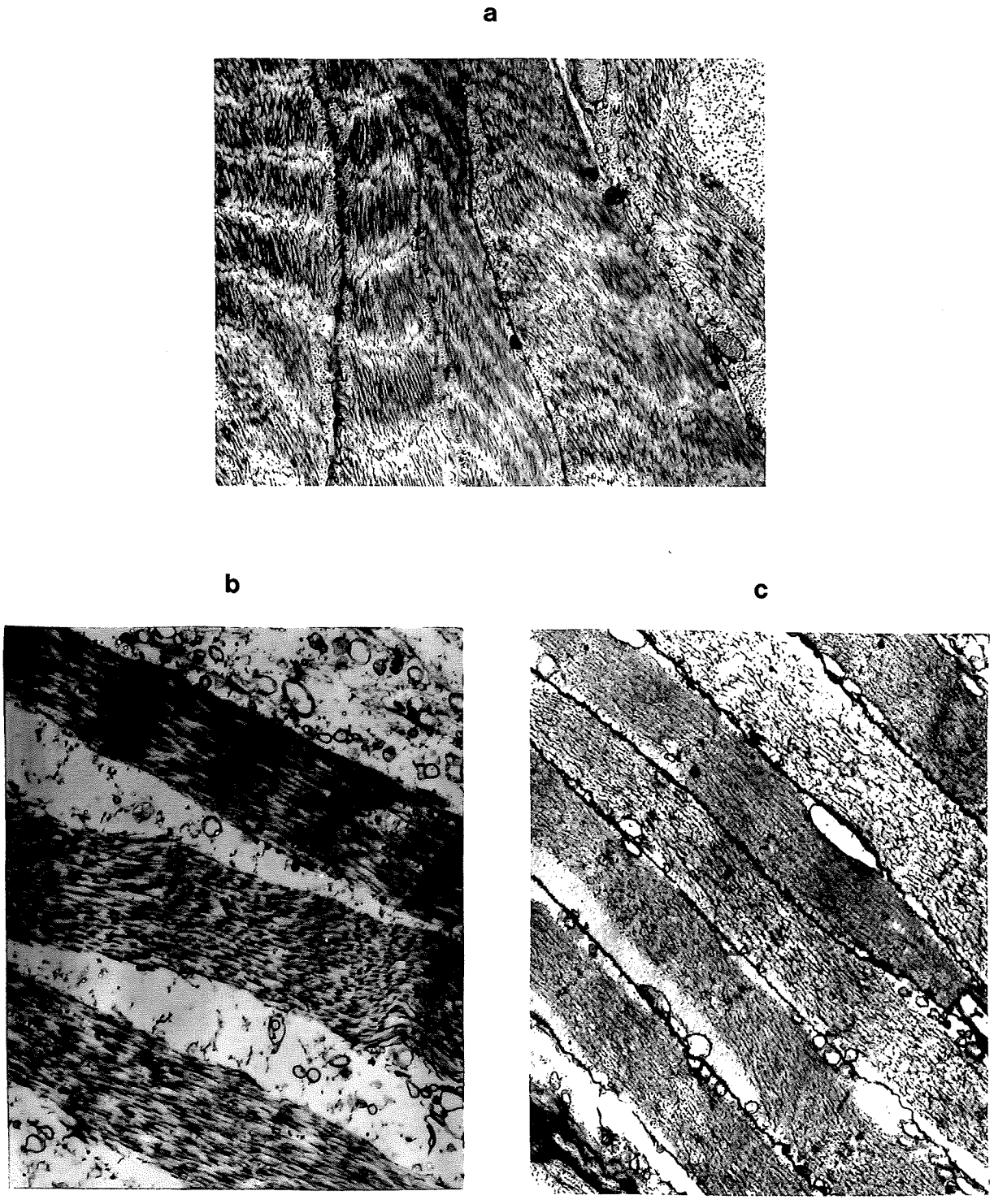

Figure 17. Electron micrographs of scallop adductor muscle in longitudinal section. (a) live animal (X7000); (b) live-shucked and soaked in water for 20 h (X12500); (c) live-shucked and soaked in 3.5% NaCl for 20h (X12500).

may be absorbed after soaking in high ionic strength solutions than in low ionic strength solutions.

4. Drip loss relates to the loss of low ionic strength extracellular fluid from the scallop. The amount of this fluid will be increased by slow freezing and soaking at low ionic strength, and will be decreased by rapid freezing and soaking at high ionic strength.

5. In slow freezing, extracellular water freezes more rapidly than intracellular water because it has a lower solute concentration. During freezing, the solute concentration of the unfrozen extracellular fluid increases and draws water out of the myofibrils. Large extracellular ice crystals are formed which can cause mechanical damage due to volume changes. On thawing, the extracellular fluid is easily lost as drip. Fast freezing results in small ice crystal formation both intra- and extracellularly, resulting in little movement of water from the myofibril and less cell damage (Forest *et al.* (1975).

6. The action of salt and polyphosphate in reducing drip loss is most likely due to interaction of chloride and phosphate ions with charged groups on sarcoplasmic and myofibrillar proteins which increases the capacity of these proteins to bind water (Lawrie, 1979).

7. The water holding capacity of muscle is reduced by several factors such as low pH (*e.g.* with onset of rigor mortis), increased levels of divalent cations (Mg^{++}, Ca^{++}) and loss of ATP (Lawrie, 1979; Pearson and Young, 1989). These factors were not studied in the current project.

RAPID MOISTURE TESTS

The rapid moisture tests investigated in this section were evaluated against the standard convection oven procedure (Materials and Methods). The accuracy of this method was checked by carrying out 20 moisture tests on one homogenised scallop sample. Mean moisture content was 77.85% and standard error 0.012%, indicating low variability in individual results.

The Float Test

The highlight of the project was the development of a simple float test for measuring the moisture content of scallops. The principle of the test is that the density of a scallop decreases as it absorbs water, so that in an appropriate salt solution, scallops with a high moisture will float while those with a low moisture will sink. The moisture content of scallops can be estimated from the relationship between scallop moisture and the salt concentration of a solution in which scallops partially float.

The float test can be used in two ways:

- a pass/fail method for rapid screening to check compliance with a given quality standard for moisture. One salt solution is used.

- a series method where several salt solutions are used to estimate percentage moisture content.

Float test procedures

Pass/fail method

1. Sample 50 scallops from each batch and place in a leakproof plastic bag.
2. Warm the scallops to room temperature (22±4°C) by placing the bag in a tub of running water for about 30 minutes.
3. Blot the scallops dry on a paper towel.
4. Drop 10 of the scallops into a 1 litre beaker containing about 800 ml of the salt solution* at room temperature.
5. Stir the scallops briefly and then stop the movement.
6. Wait 10 seconds. Count and record the number of scallops which float.
7. Remove the scallops from the beaker.
8. Repeat steps 4 to 7 with the remaining scallops testing 10 at a time.
9. Total the number of scallops which float out of 50.

* The concentration of the salt solution depends on the selected quality standard for moisture content. This concentration can be obtained from the relationship

between scallop moisture content and the concentration of the salt solution in which more than 50% of scallops float:

$$\text{Salt\%} = \frac{102 - \text{moisture\%}}{2}$$

Interpretation:

All scallops float - FAIL (high water content)
All scallops sink - PASS (low water content)
Some scallops sink - Suspect PASS

Series method

A series of salt solutions is required between 8.0% and 12% in increments of 0.5% (i.e. 8.0, 8.5, 9.0 up to 12%). This range of solutions corresponds to scallop moistures from 86% to 78%.

1. Sample 60 scallops and warm to room temperature (22±4°C) in a plastic bag placed in a tub of running water.
2. Take 10 of the scallops and, progressing from high to low salt concentrations, find the "cut-off" solution in which some of the scallops sink. (Blot the scallops dry between solutions).
3. Discard the 10 scallops.
4. Divide the remaining scallops into 5 lots of 10.
5. Carry out the pass/fail method using the above "cut-off" solution. Blot the scallops dry before and after testing.
5. Total the number of scallops which float out of 50.
6. If less than 25 scallops float, repeat the test on the same 50 scallops using the next highest strength salt solution.

Interpretation:

Moisture content is estimated from the salt concentration of the solution in which between 25 and 50 scallops float. The regression relationship between moisture and salt percentages is shown in Figure 20. An approximation of this regression for simple calculation of moisture content is as follows:

$$\text{Moisture} = 102 - (2 \times \text{salt\%})$$

Test development

Sample size. The moisture content of individual scallops within a bulk sample varied considerably. For samples of 50 scallops taken from two different processing plants after shucking, the moisture range was about 4% with standard deviations of 0.7 to 0.9%

(Figure 18). Based on this variation in moisture levels a sample size of 50 scallops was chosen for the float test.

Temperature of scallops. The float test was affected by the temperature of the scallops. Cold scallops, being more dense, required a slightly higher strength salt solution for flotation than that required to float the same scallops equilibrated to room temperature. Figure 19 shows the effect of temperature on the relationship between moisture content and the concentration of the salt solutions which gave greater than 50% flotation.

Temperature of the salt solutions. Increasing the temperature of the salt solutions from 15°C to 30°C in 5°C intervals significantly decreased the number of scallops that floated ($P<0.05$) (Table 10). However, the float test gave the same moisture result for temperatures between 15°C and 25°C, but gave a lower moisture result at 30°C. It is recommended that the test be carried out with both the scallops and the salt solutions at room temperature (22 ± 4°C) to minimize temperature changes during testing.

Table 10. Effect of temperature of salt solution on flotation of scallops.

Parameter	Temperature of solution (°C)*			
	15	**20**	**25**	**30**
No. float per 10 scallops	9.7[a]	8.1[b]	7.0[c]	3.9[d]
n	15	15	15	15
Estimated scallop moisture**(%)	84	84	84	<84

* NaCl concentration, 9.0%

** Moisture content by oven drying, 83.8%

Means followed by the same letter are not significantly different ($P>0.05$).

Repeated use of salt solutions. Using the same 800 ml of salt solution for testing more than one batch of 50 scallops resulted in a dilution of the salt concentration even though scallops were blotted dry before testing. The mean decrease in salt concentration was 0.2% for each batch of 50 scallops. From these results it is considered necessary to discard the salt solution after testing each lot of 50 scallops.

Water absorption during testing. During the float test each lot of 10 scallops is usually immersed in the salt solution for approximately 1 min before being removed and blotted. After soaking for 2 min and 5 min in a 10% salt solution at 25°C scallops increased in weight by 0.7 and 1.0% respectively. For scallops with an 80% moisture, these values give an increase in moisture content of about 0.2% which would not be detectable by the float test. Hence for normal immersion times, the slight water absorption during testing should have no effect on the float test result.

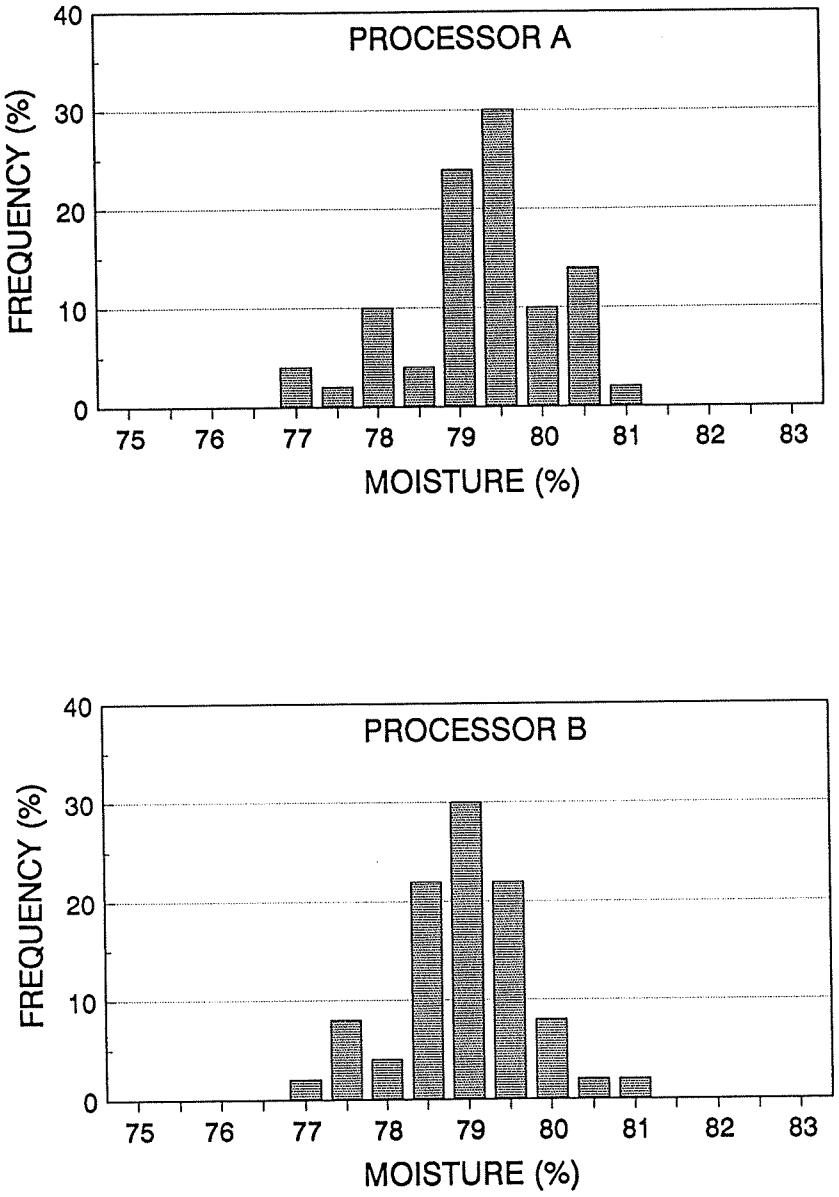

Figure 18. Variation in moisture content of individual scallops within bulk samples of 50 scallops collected after shucking

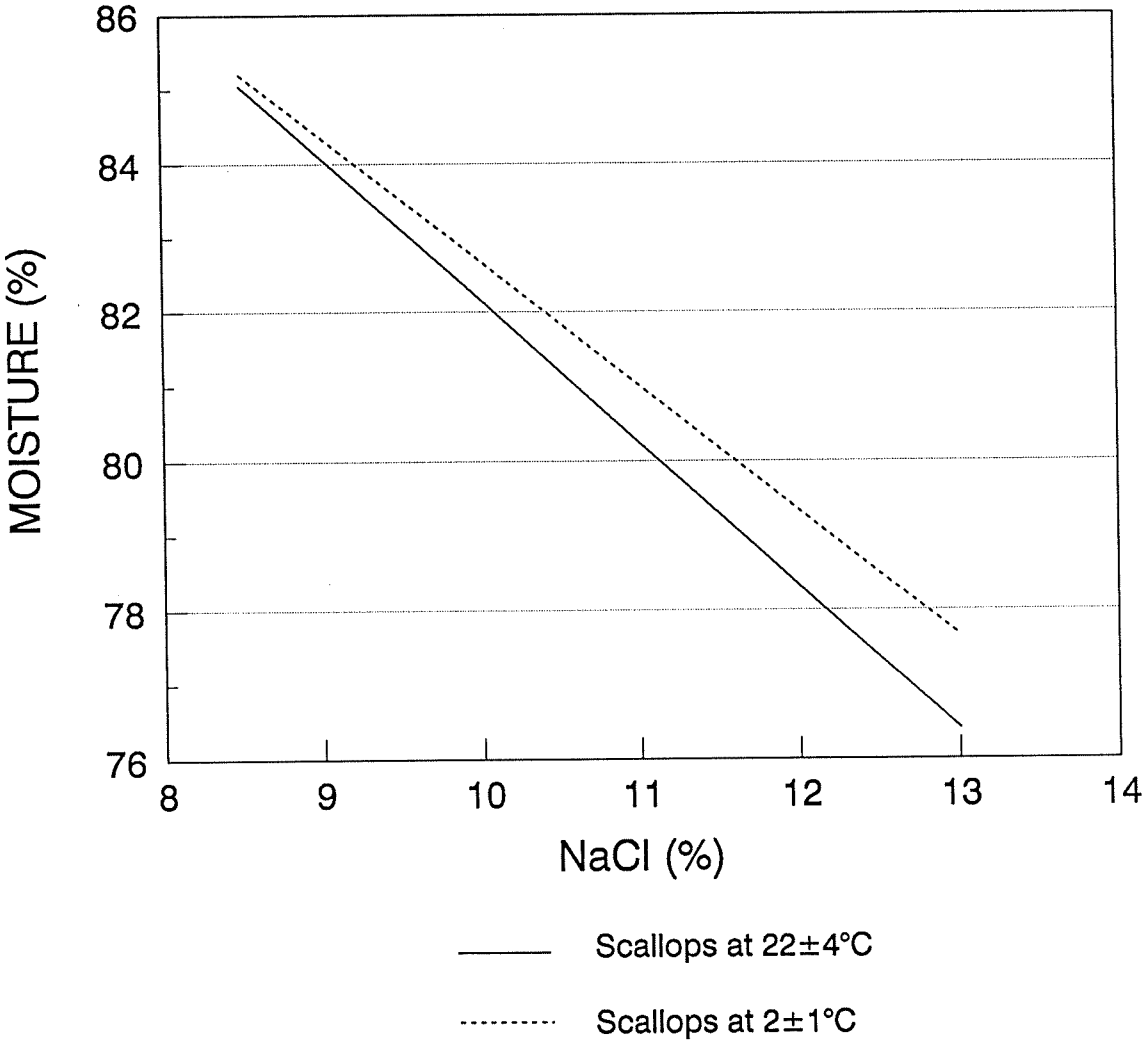

Figure 19. Effect of scallop temperature on the relationship between scallop moisture content and salt concentration of solutions used in the float test

Statistical evaluation of the float test

In order to use the float test to estimate water content, a "cut off" solution must be reached in which less than 100% of the scallops float. All batches of 50 scallops gave partial flotation in at least two solutions of salt differing in concentration by 0.5%. A flotation criterion (that is, a percentage flotation) was therefore necessary to define the correct cut off solution for the test.

The regression between scallop moisture (by oven method) and NaCl% (concentration giving partial float) was analysed for various float criteria from 10-100% to 90-100%. Using the NaCl% at the top of the range for each float criteria gave no significant difference ($P>0.05$) between moistures determined from each of the regressions. However, in using NaCl% at the bottom of the range for each float criteria, those regressions for criteria below 70-100% gave significantly lower moistures ($P<0.05$) than those for the top of the range. Hence it was decided that only top of the range NaCl concentrations would be used for the standard curve. Since less than 10% of the data had top of the range NaCl% corresponding to less than 50% flotation, the float criterion for the test was taken as 50-100% (that is, more than 25 scallops to float out of 50). If two NaCl solutions met this criterion, the solution showing the highest float percentage would be used in the estimation of moisture.

The regression for the 50-100% float criterion for 55 batches of 50 scallops is shown in Figure 20. This regression represents data for the float test carried out at room temperature (22 ± 4°C). The regression coefficient was 0.90 indicating a satisfactory correlation between moisture and salt concentration. To simplify the estimation of moisture from this regression line we have recommended, in an industry brochure, use of the following formula to approximate the regression equation:

$$\text{Moisture (\%)} = 102 - (2 \times \text{salt\%})$$

The accuracy of the test is illustrated by the prediction intervals for the regression which were ±1.1% at 90% and ±1.3% at 95% predictability. Therefore, a single moisture determination by the float test will predict the moisture result to within ±1.1% in 90% of cases.

Similar analysis of the float test was carried out for cold scallops. The regression line for the 50-100% float criterion is shown in Figure 21. Prediction intervals were larger (*e.g.* ±1.6 at 90%) than those calculated for the relationship at room temperature. Fewer samples ($n=18$) would have contributed to the lower accuracy.

Comparison of the regression lines for cold and ambient scallops showed that the slopes of the two lines were not significantly different ($P>0.05$) but the intercepts were different ($P<0.01$). Therefore the two lines should be used separately according to the temperature of the scallops. It is recommended that the test be adopted at room temperature to avoid temperature changes in the scallops and salt solution during testing.

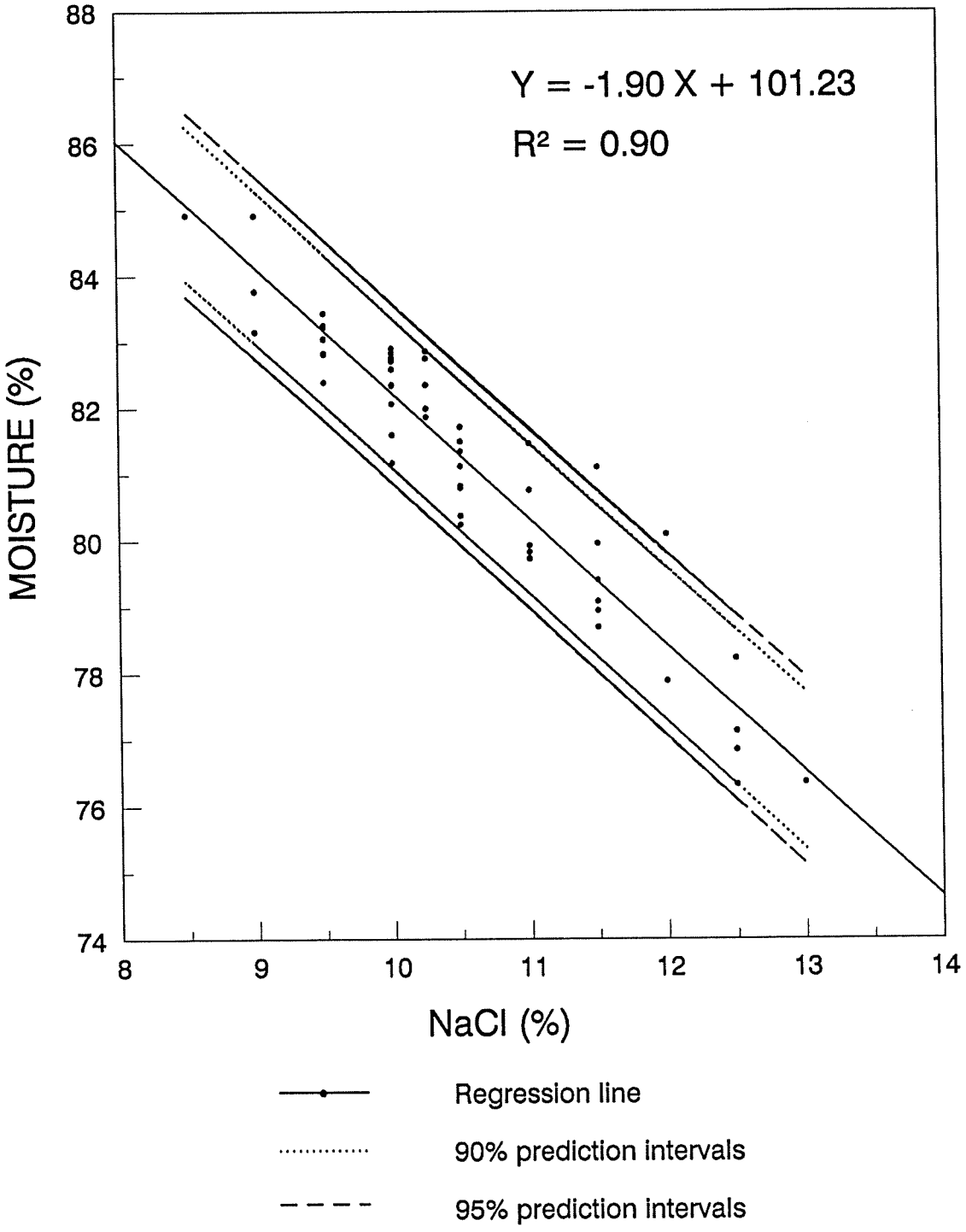

Figure 20. Relationship between moisture content of scallops and salt concentration of solutions for the float test carried out on scallops prewarmed to room temperature

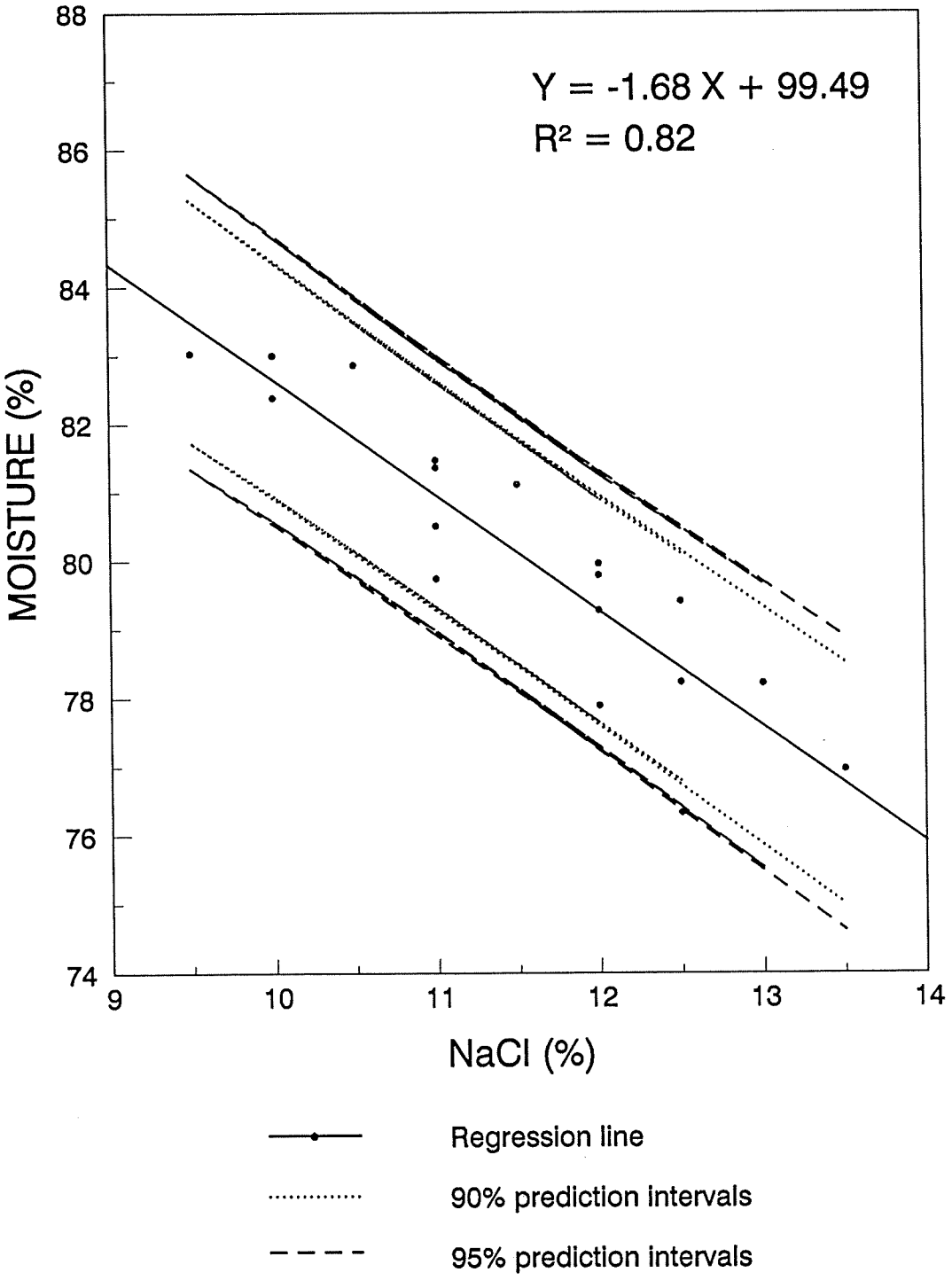

Figure 21. Relationship between moisture content of scallops and salt concentration of solutions for the float test carried out on scallops held at 2°C

Attributes of the float test

The float test is intended as a field procedure which can be performed by seafood processors. The pass/fail method can be carried out in 5 minutes while the series method requires 10 to 15 minutes. The test is simple, non-destructive and inexpensive. No capital outlay is required apart from a weighing balance ($1000) for preparing the salt solutions. Commercial grade salt can be used which gives a consumables cost of 4 cents per litre for a 10% salt solution.

A disadvantage of the test, particularly the series method, is the need for preparation and storage of salt solutions of different concentrations. With experience, the number of salt solutions required may be reduced to match the moisture range of the incoming scallops (for example, a range of 79-82% moisture requires four salt solutions). Solutions can be prepared in bulk (10 litres) and stored at room temperature.

Measurement of moisture by the float test is accurate to only $\pm 1\%$ and consequently the test cannot be recommended as a standard method. More accurate procedures are provided by convection oven, microwave oven and infra red drying.

Field evaluation

Nine scallop processors were provided with test kits for the float test and asked to evaluate the procedure. Although many were initially enthusiastic about the test, few have adopted it in their quality management. In the absence of a specification for scallop moisture there is no real incentive to use the test. However, one secondary processor has recognised the usefulness of the test for monitoring the moisture content of all incoming consignments which are packaged for export. He has trained staff for this purpose and follows up on consignments containing excessive moisture. A sample of the processors float test records is provided in Appendix 1.

Extension material

A brochure entitled "Testing scallops for moisture using the float test" (Appendix 2) was produced and is currently available to industry from the Queensland Department of Primary Industries and the Australian Quarantine and Inspection Service.

A training video (Appendix 3) on the float test was also produced, but screen quality was considerably reduced after copying the super VHS master to standard VHS tapes. The video has been made available to industry on a free-loan basis and should be viewed in conjunction with the float test brochure. Consideration will be given to improving the screen quality of the video pending available funds.

Microwave oven drying

A microwave oven drying method enabled the moisture content of whole scallops to be determined in less than 15 min. Moisture results correlated closely (R^2=0.95; n=38) with those obtained by convection oven drying. The 90% prediction intervals of $\pm 0.9\%$

indicated the microwave oven method was slightly more accurate than the float test (Figure 22).

The main difficulty with the microwave procedure was optimising the heating programme in order to prevent charring or incomplete drying. A heating programme of 650 W for 4 min, 580 W for 3 min and 450 W for 4 min was suitable for most scallops provided the total sample weight of 6-10 scallops was less than 90 g. For high moisture scallops (>84%) an extra minute on the final setting was usually adequate. Although the test is destructive on samples it has the advantage that whole scallops can be used. Capital costs include a commercial microwave oven ($400) and a weighing balance ($1000) accurate to $\pm$0.1 g.

Infra red moisture balance

The infra red moisture balance provided a suitable method which could be completed in about 15 min. In the comparison with oven drying, the regression coefficient R^2 was 0.98 on 24 samples and the 90% prediction interval was $\pm$0.75 . Optimal sample size for the test was 2-3 g which usually dried to constant weight in under 15 min (Figure 23). The balance could be programmed to switch off after a certain time or when weight loss reached a predetermined rate. Satisfactory end points for drying could also be determined from the continuous printout when moisture readings increased by less than 0.1% per min.

A disadvantage of the infra red drying method was the need to homogenise the scallop sample before testing. In addition the capital cost of the balance was moderately high at approximately $5000.

Ultrasonics

The ultrasonic method was not sufficiently accurate for measuring the moisture content of scallops. The regression of pulse time against oven moisture gave an R^2 of 0.52 for 27 samples. The test was affected by salt content of scallops and inclusion of this variable in the regression analysis gave an improved R^2 of 0.76.

The principle of ultrasound measurement is that the velocity of sound through a material is proportional to the density of that material. Ultrasound was considered initially to have potential in measuring the moisture content of scallops since moisture changes were known to affect the density of the muscle.

Infra red reflectance

A moisture analyser based on infra red reflectance showed the most potential for rapid measurement of scallop moisture. With this equipment analysis can be carried out in a few seconds although the sample must be homogenised. A small trial on four samples conducted by Rofin Australia, Melbourne, showed close agreement ($\pm$0.2%) with standard oven results. However, the company was unable to carry out a large scale trial to properly

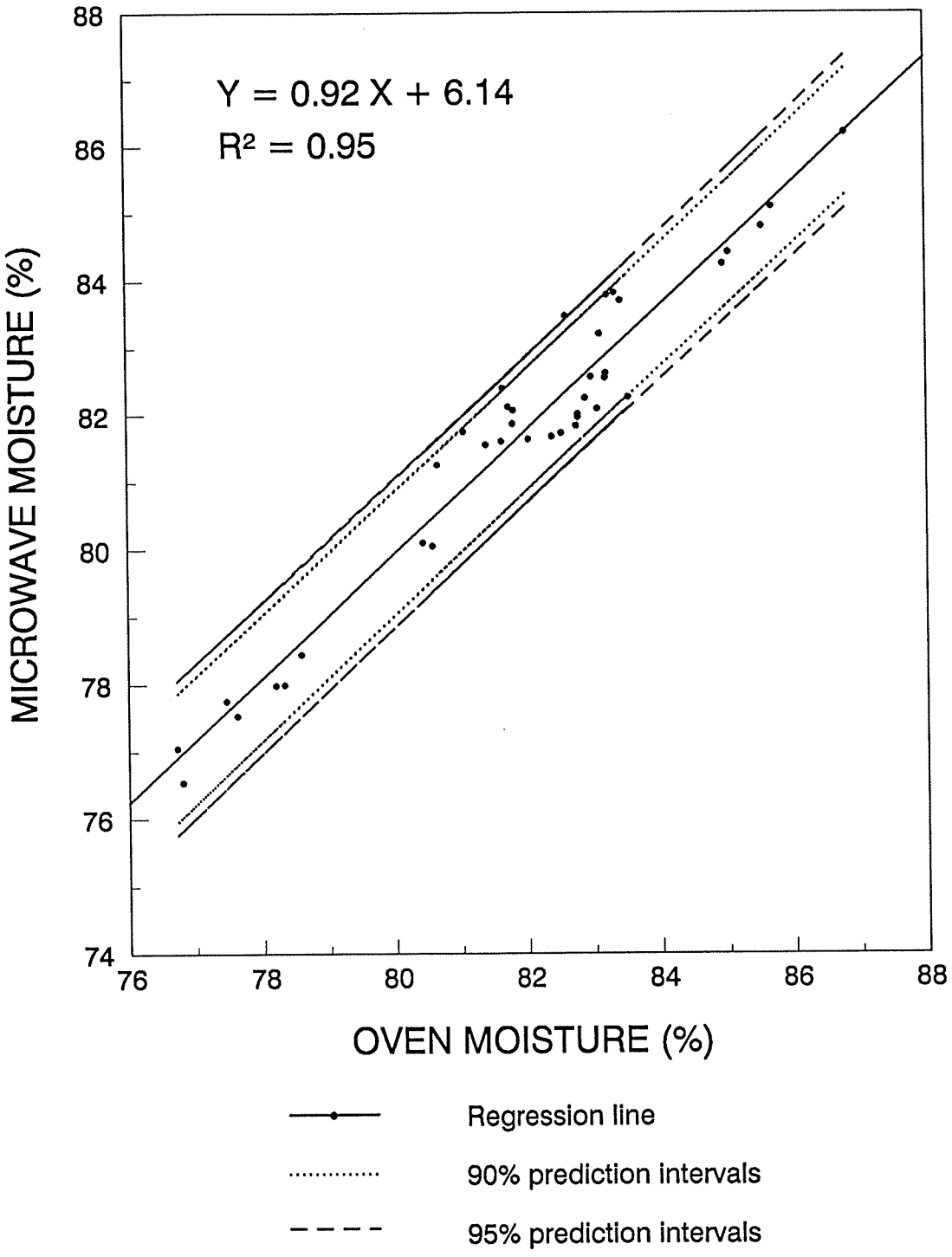

Figure 22. Relationship between microwave oven and convection oven methods for the determination of moisture content of scallops

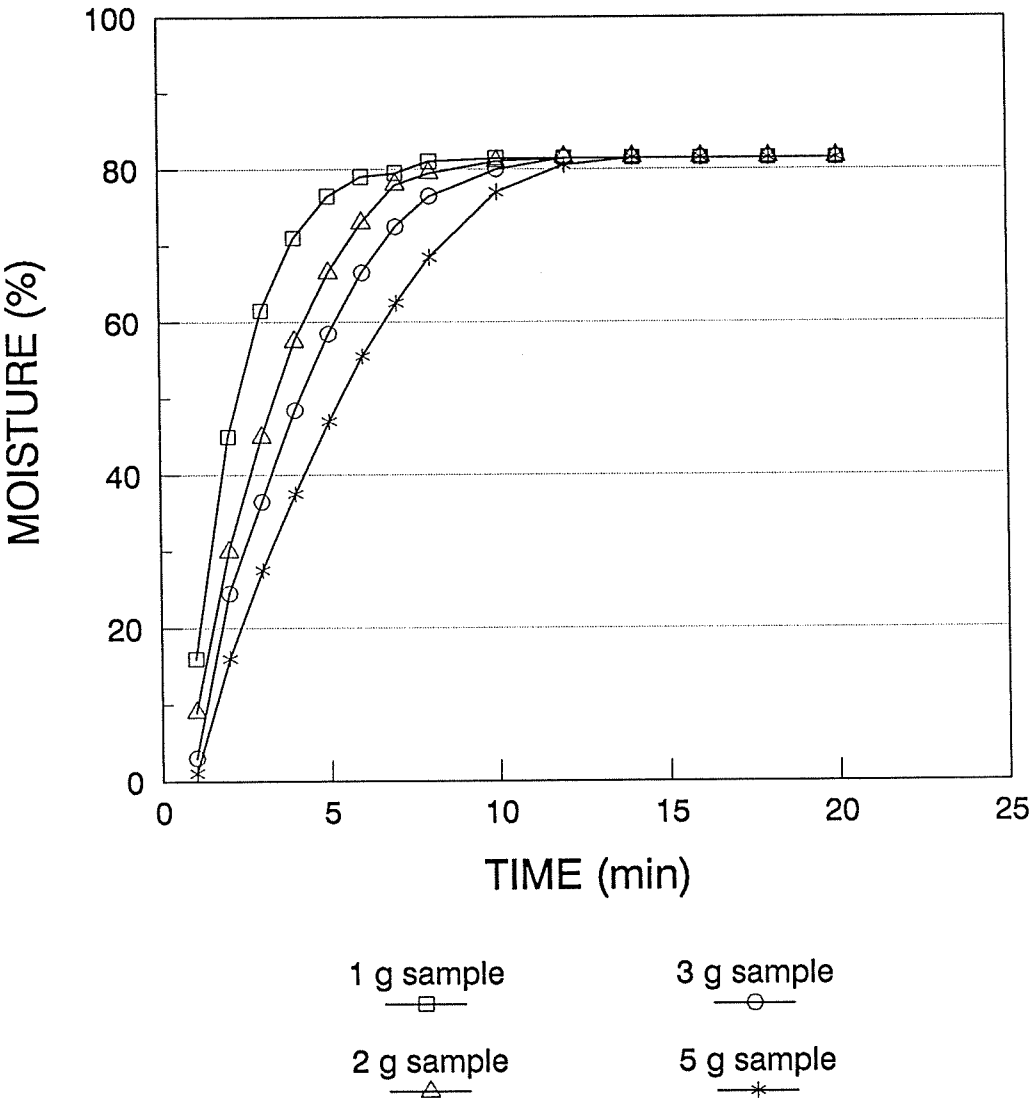

Figure 23. Time profiles for the drying of scallops by infra red moisture balance

evaluate the equipment. A major disadvantage of the method was the capital cost of approximately $20 000.

In summary, the rapid moisture tests found to be suitable for determining scallop moisture content were microwave oven drying, the infra red moisture balance and the float test (Figure 24). Attributes of these testing methods are shown in Table 11. The infra red method showed the highest accuracy with a 90% prediction interval of 0.75%, but required the sample to be homogenised. Whole scallops could be used in the microwave and float test procedures and, although the microwave had improved accuracy, the float test had the advantage of being non-destructive and less expensive.

Table 11. Comparison of rapid moisture tests with convection oven procedure

Test Attribute	Test method			
	Float test	**Microwave drying**	**Infra red balance**	**Convection oven**
Scallop sample	whole	whole	homogenised	homogenised
Sample size	50 scallops	90g	3g	6g
Time	5 min[a]	15 min	15 min	5h
R^2	-	0.95	0.98	-
Capital cost	$1000[b]	$1400	$5000	$2500
Prediction interval	1.13%	0.90%	0.75%	-

[a] Pass/fail method, 5 min; series method, 10 min.
[b] Cost of weighing balance for preparing salt solutions.
[c] Prediction interval (90%) at sample mean.

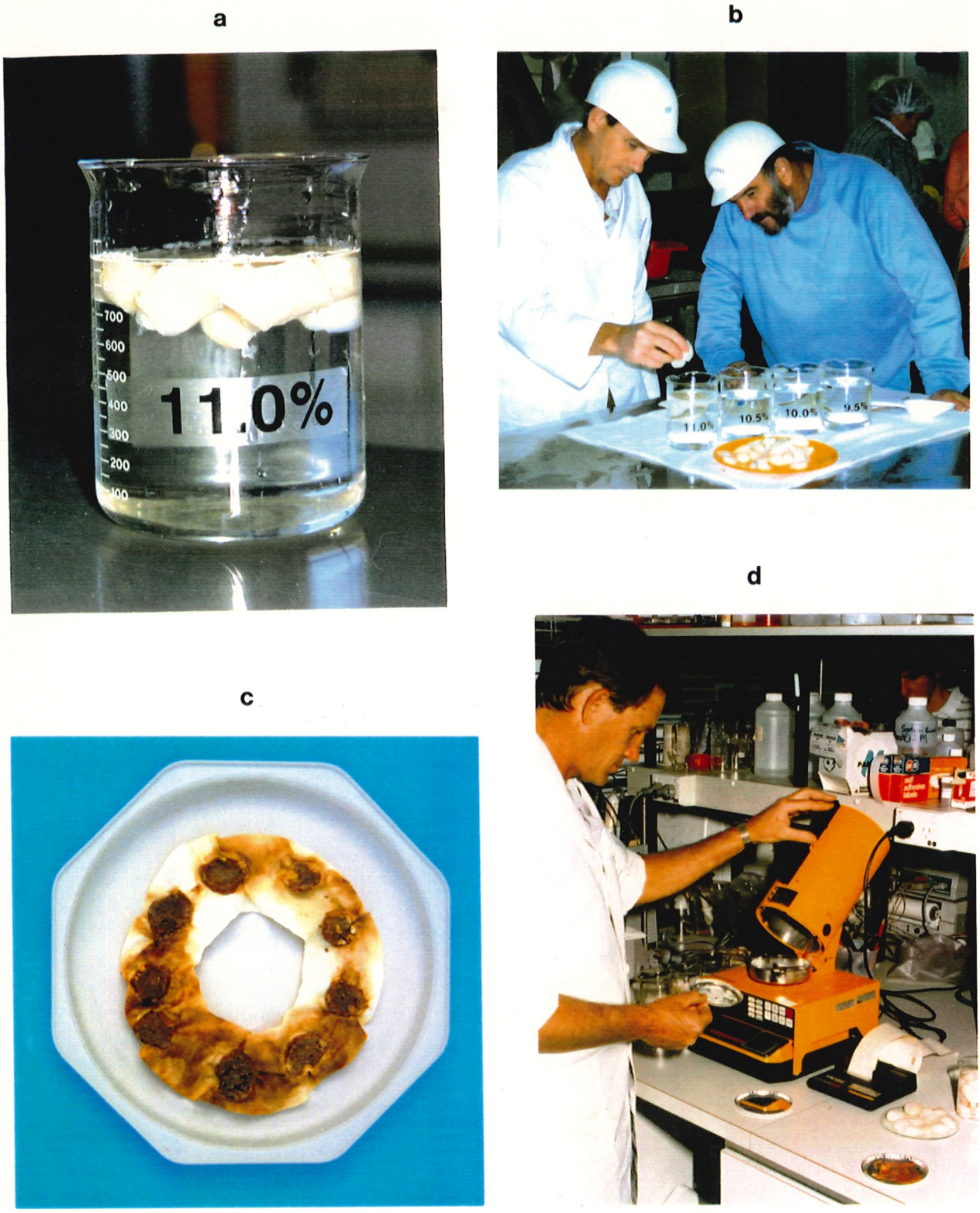

Figure 24. Rapid tests for moisture content of scallops.
(a) float test (pass/fail method)
(b) float test (series method)
(c) scallops dried by microwave oven
(d) infra red moisture balance

CONCLUSIONS

Survey data on the natural moisture content of live-shucked scallops (*A. balloti)* showed that moisture content varied in a cyclic fashion with time of year. Highest levels were recorded during winter, which coincided with the scallop spawning period. The size of scallops also influenced moisture content, with small scallops having a significantly higher moisture content than large scallops in both summer and winter. Such variability in natural moisture levels precludes the setting of a single moisture specification for scallops.

Post-harvest handling of scallops increased their moisture content by about 2% above the natural moisture level. Individual contributions from trawler storage and processing were each approximately 1%. Storage on trawlers using ice and refrigeration contributed more than 1% moisture, but these trawlers represent a small minority of the scallop catch. This information on scallop handling, together with data on natural moisture content, enabled quality standards for moisture content to be defined for processed scallops on a seasonal basis.

The most effective way to minimise water absorption and drip loss problems during processing operations is to use cold, UV-treated seawater or a 3.0-3.5% salt solution. Fresh water is least effective in this regard. Dipping scallops in polyphosphate significantly reduces drip loss, but use of this product is not recommended.

Fresh (unfrozen) scallops showed different water absorption properties to thawed scallops. An effective osmotic system in fresh scallops results in greater water absorption from low ionic strength solutions. Processors who handle fresh scallops need to be aware of the potential for high water absorption and subsequent drip loss from this product. Thawed scallops, while absorbing less water than fresh scallops in low ionic strength solutions, usually absorb more water than fresh scallops when soaked in high ionic strength solutions (*e.g.* seawater), due to increased electrostatic interaction of salt with muscle proteins.

A rapid float test was developed for measuring the moisture content of scallops. Although the accuracy of the test is limited to $\pm 1\%$, the method is suitable for use by processors in monitoring scallops for excessive moisture content. Other rapid methods such as microwave oven drying and infra red drying are also suitable for moisture determinations, but such methods are destructive and equipment is more expensive.

With the exception of studies on the variation in natural moisture content of scallops due to geographic location, all objectives for this project were achieved. The adoption of a single moisture specification for scallops was not considered practical in view of the variations due to season and scallop size. However, achievable moisture levels for summer and winter periods have been defined, and these can be used in conjunction with rapid moisture tests to determine if scallops contain excess water.

RECOMMENDATIONS

Trawler storage

The method of trawler storage will affect the water absorption and water retention properties of scallops. In general, slow freezing or continual freeze/thawing of scallops will increase subsequent thaw/drip loss. Such problems can be minimised if scallops are kept unfrozen and not in contact with fresh water. However, since storage times for unshucked, unfrozen scallops is limited to several days, freezing on-board for several weeks is considered to be more economical and is the storage method practised by the majority of trawler operators. Recommendations for storage of unshucked scallops on trawlers using different refrigeration methods are as follows:

Freezer. Scallops should be drained and frozen in shell as rapidly as possible at -30°C (or lower) and kept below -20°C at all times. Scallops added to the hold should not be sprayed with chilled water as this will partially thaw previously frozen scallops and may cause ice formation between scallops. Large blocks of frozen scallops are difficult to thaw for processing.

Brine spray. Chilled seawater sprays should be used in refrigerated holds kept at -2°C to -4°C. Lower temperatures may cause partial freezing. Holds should be adequately drained to avoid immersion of scallops in water.

Refrigeration. Scallops should be chilled to 0°C. Avoid partial freezing to prevent ice crystal damage.

Ice and refrigeration. Ice boxes should be well drained to avoid immersion of scallops in fresh water. This method of storage is least recommended.

Processing

1. Minimise contact time with water at all stages of processing. In particular, unshucked scallops should not be thawed for extended periods in water. Shucked scallops should not be held in brine wash tanks for more than 5 minutes and in the final chilling tank for more than 15 minutes. Extended storage in these salt solutions will increase sodium content and could adversely affect consumer acceptance of the product.

2. Keep wash water as cold as possible (<5°C).

3. Use UV-treated seawater or 3.0-3.5% salt water. Avoid using fresh water or ice. This is particularly relevant if scallops are shucked live on-board.

4. Spray wash systems with conveyor belt transport are preferable to wash tanks.

Moisture specifications and testing

1. A single specification for moisture content of scallops is not recommended because of seasonal fluctuations in natural moisture levels. An alternative would be for the seafood industry to set appropriate quality standards based on attainable moisture levels for different times of the year. Recommended standards are not more than 79% during November to March and not more than 82% for April to October. Scallops whose moisture levels exceed the relevant quality standard should be rejected for export.

2. The thaw/drain test and the pressure test should not be used to monitor the trade description "water added" because of possible variations in the water holding properties of processed scallops.

3. Processors should adopt a method of moisture testing such as the float test in order to screen incoming consignments for excessive moisture content and provide quality assurance for their export product.

DISSEMINATION OF INFORMATION

Communication with industry

During this project support was provided by the Australian Quarantine and Inspection Service in dissemination of research information to the seafood industry. In September 1990, a seminar entitled "Improving the quality of Queensland scallops" was held at the AQIS headquarters in Brisbane. This seminar was well attended by seafood processors, fishermen and associated industry groups. A research report on the findings of the scallop project was presented along with a demonstration of the float test. Subsequently, DPI officers in Brisbane, Bundaberg and Rockhampton approached all major processors and provided them with test kits and individual instruction on carrying out the float test.

Extension material

A brochure and a video each entitled "Testing scallops for moisture " were prepared in order to provide details of the float test procedure (Appendices 2 and 3). This extension material will be made available to the seafood industry, FIRDC, AQIS and QDPI.

Publications

It is anticipated that two articles will be submitted for publication in *Australian Fisheries* in the near future. These articles will report on the float test procedure and on the natural water content of scallops including effects of post-harvest handling.

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APPENDICES

APPENDIX 1

Float test result sheet from a seafood processor

FLOAT TEST FOR SCALLOP MOISTURE.

DATE	TIME	TRAWLER PROCESSOR.	BATCH NO. BOAT NAME.	SALT % -	NO. FLOAT (PER 10 SCALLOPS.)					TOTAL FLOAT	% FLOAT	EST. MOISTURE %
22-11-90	9:00			10.0%	8	8	10	10	10	46	92	82%
				9.5%	5	0	3	3	6	17	34	
22-11-90	9:15			10.0%	9	8	10	8	7	42	84	82%
22-11-90	9:25			10.0%	9	9	10	9	8	45	90	82%
22-11-90	11:40			10.0%	4	1	3	2	1	11	22	
				10.5%	1	5	4	4	3	17	34	
				11.0%	8	10	9	7	8	42	84	80%
22-11-90	12:40			10.0%	3	4	3	3	4	17	34	
				10.5%	7	7	7	9	6	36	72	81%
22-11-90	12:50			10.0%	4	0	4	5	4	17	34	
				10.5%	7	3	6	6	8	30	60	
				11.0%	10	9	10	9	10	48	96	80%
22-11-90	12:15			10.0%	8	7	6	8	7	36	72	82%
23-11-90	8:35			10.0%	0	1	3	1	4	9	18	
				10.5%	3	5	6	5				

APPENDIX 2

Brochure: **"Testing scallops for moisture using the float test"**

Testing scallops for moisture using the float test

QL91019

International Food Institute of Queensland

Queensland Department of Primary Industries

Why test for moisture?

Saucer scallops are a valuable export, especially to Asian countries such as Hong Kong. To maintain high returns from these markets, scallops must be of high quality.

One quality problem which needs to be controlled is excessive moisture content. This problem occurs when scallops are soaked. Buyers are reluctant to pay a high price for added water.

The natural moisture content of Queensland scallops varies with season. After processing, scallops should not contain more than 79% moisture in summer and 82% in winter.

The *float test* described in this pamphlet is a simple method for measuring the moisture content of scallops.

How the float test works

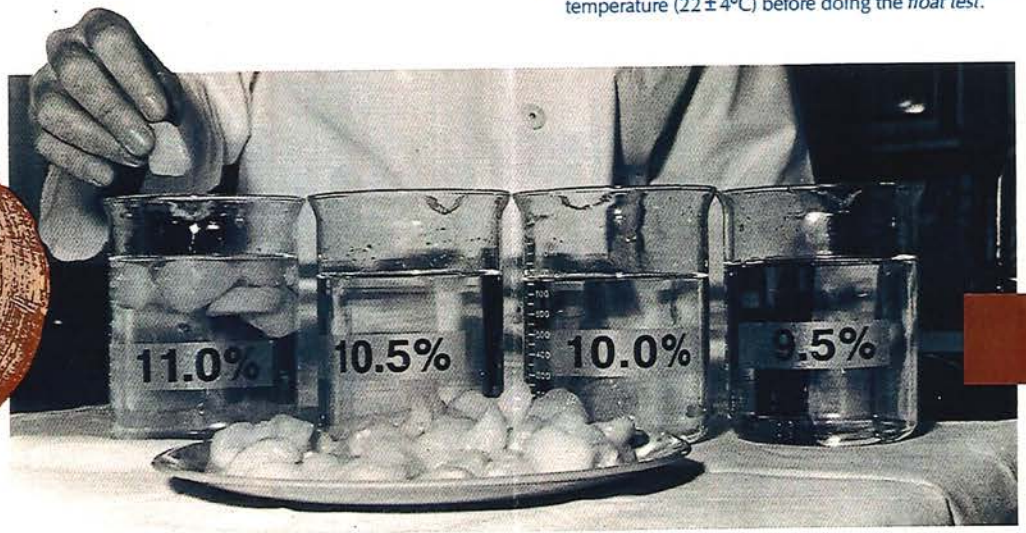
The *float test* is based on the decrease in density of scallops as they absorb water. In a selected salt solution, scallops with a high moisture content float, while those with a low moisture content sink.

The *float test* can be used in two ways:

- pass/fail method — for rapid screening
- series method — to estimate moisture content.

Notes on the *float test*

- The accuracy of the test is about ±1%. Hence the *float test* should not be used as a standard method.
- Discard the salt solution after testing each batch of 50 scallops to avoid dilution effects.
- Ensure scallops and salt solutions are close to room temperature (22 ± 4°C) before doing the *float test*.



Estimating scallop moisture content using the series method.

Getting started

Equipment required

- beakers
- measuring cylinder
- storage bottles
- thermometer
- scoop
- weighing balance accurate to ±1 gram

Preparing salt solutions

Salt solutions are prepared from commercial grade salt (sodium chloride). For a 10% solution, weigh 100 g of salt and completely dissolve in 900 mL of tap water. Make up to 1 litre in a measuring cylinder and store at room temperature in a screw-cap container.

Float test procedures detailed overleaf ►

The float test

Pass/fail method

The pass/fail method shows if moisture exceeds a selected quality standard. A single salt solution is used. Its concentration depends on the quality standard and is obtained from the formula:

$$\text{salt\%} = \frac{102 - \text{moisture\%}}{2}$$

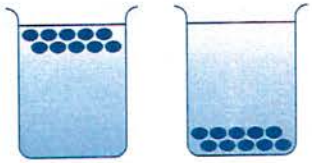
For a standard of 79% moisture, the salt concentration is 11.5%; for 82%, it is 10%.

Test procedure

1. Sample 50 scallops from each batch and place in a leakproof plastic bag.
2. Warm the scallops to room temperature (22 ± 4°C) by placing the bag in a tub of cold running water for about 30 minutes.
3. Blot the scallops dry on a paper towel.
4. Drop 10 of the scallops into a 1 litre beaker containing about 800 mL of the salt solution.
5. Stir the scallops briefly and then stop their movement.
6. Wait 10 seconds. Count and record the number of scallops that float.
7. Remove the scallops from the beaker.
8. Repeat steps 4 to 7 with remaining scallops, testing 10 at a time.
9. Total the number of scallops that float.

Interpreting the results

- all scallops float — fail (high moisture)
- all scallops sink — pass (low moisture)
- some scallops sink — suspect pass



Series method

The series method estimates the percentage moisture content of scallops. A series of salt solutions is required, ranging from 8.0 to 12.0% in increments of 0.5% (e.g. 8.0, 8.5, 9.0 up to 12%). This range of solutions corresponds to scallop moistures from 86% to 78%.

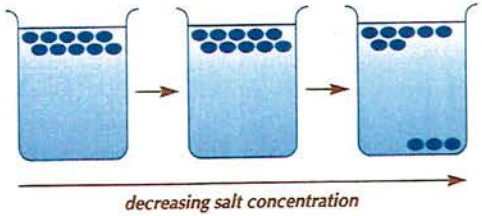
Test procedure

1. Sample 60 scallops from each batch and place in a leakproof plastic bag.
2. Warm the scallops to room temperature (22 ± 4°C) by placing the bag in a tub of cold running water for about 30 minutes.
3. Take 10 of the scallops and, progressing from high to low salt concentrations, find the 'cut-off' solution in which some of the scallops sink. (Blot the scallops dry between solutions.)
4. Discard the 10 scallops.
5. Divide the remaining scallops into five lots of 10.
6. Carry out the pass/fail method using the 'cut-off' solution obtained in step 3. Blot the scallops dry before and after testing.
7. Total the number of scallops that float.
8. If less than 25 scallops float, repeat the test on the same 50 scallops using the next highest strength salt solution.

Interpreting the results

Moisture content is estimated from the salt concentration of the solution in which between 25 and 50 scallops float:

$$\text{moisture\%} = 102 - (2 \times \text{salt\%})$$



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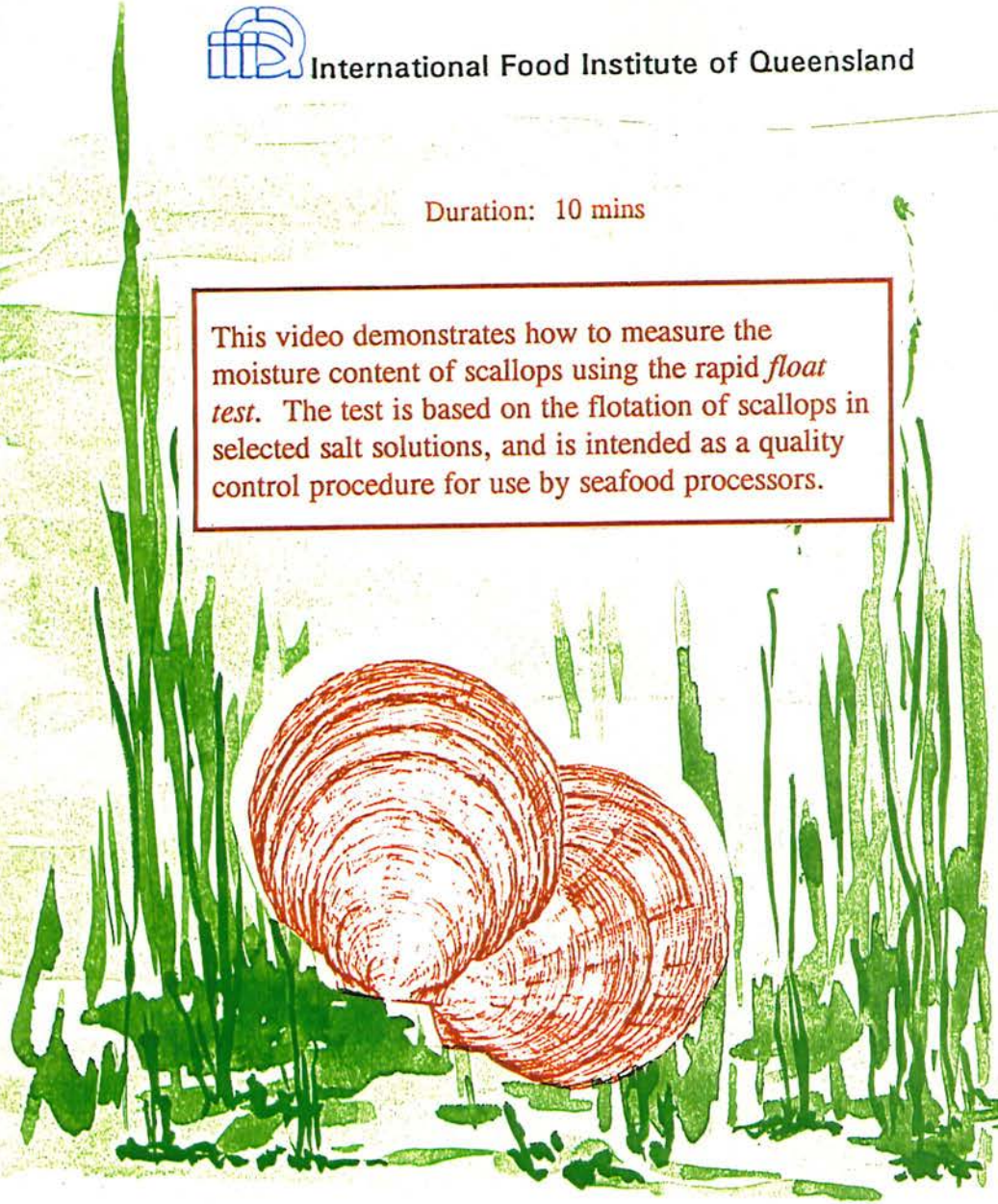
International Food Institute of Queensland

Duration: 10 mins

This video demonstrates how to measure the moisture content of scallops using the rapid *float test*. The test is based on the flotation of scallops in selected salt solutions, and is intended as a quality control procedure for use by seafood processors.

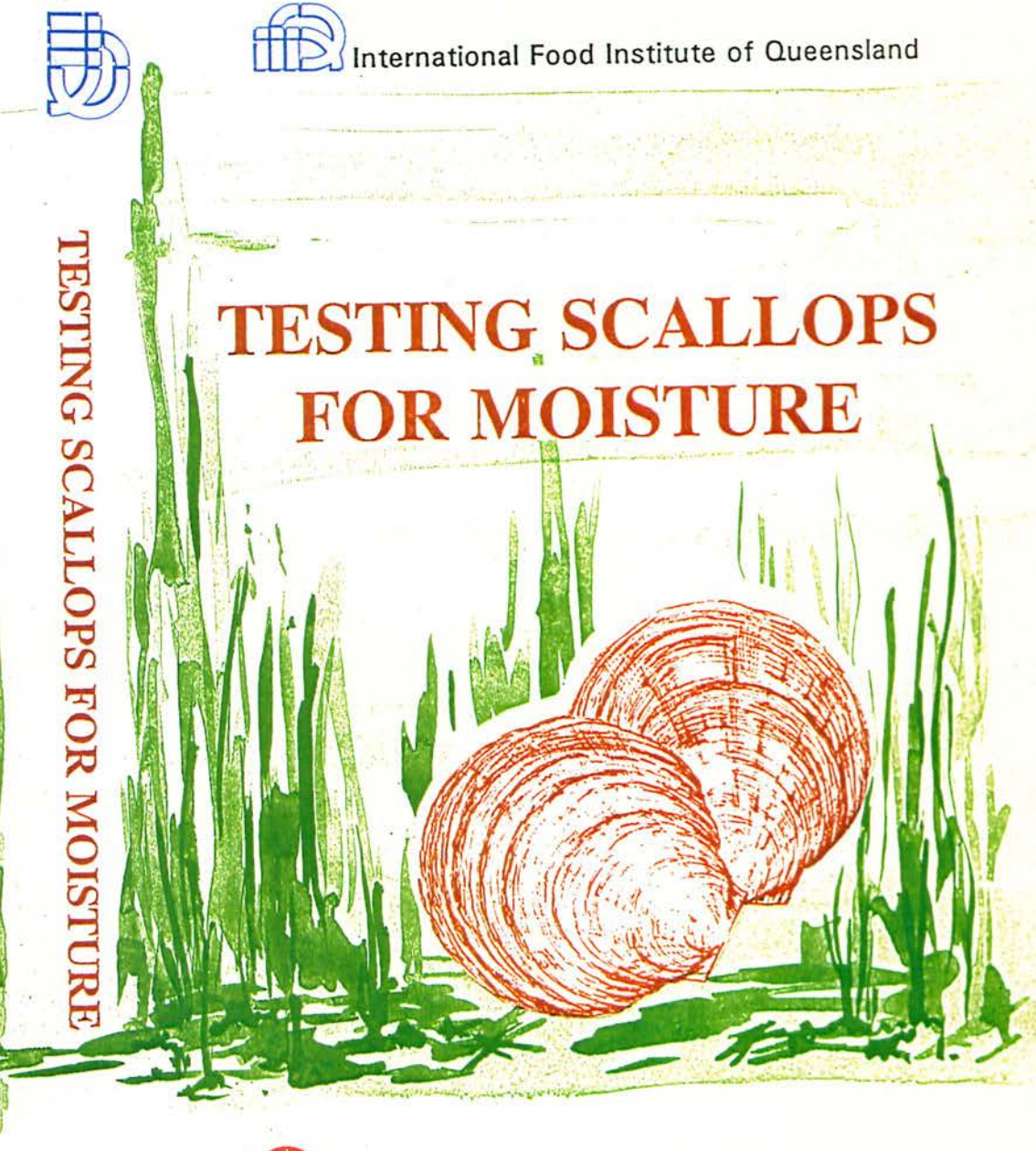


Department of Primary Industries, Queensland

TESTING SCALLOPS FOR MOISTURE

International Food Institute of Queensland

TESTING SCALLOPS FOR MOISTURE



Department of Primary Industries, Queensland

APPENDIX 3

Video: **"Testing scallops for moisture"**

Narration

VIDEO NARRATION

TESTING SCALLOPS FOR MOISTURE

Introduction

The saucer scallop industry in Australia is worth about $30m in export revenue per year. The scallop fishery is located along the coast of Queensland and also Western Australia. Our seafood processors have an excellent reputation for producing a quality product and we want to maintain that reputation.

The saucer scallop is favoured by overseas buyers in Hong Kong and Singapore because of its attractive white colour and crunchy texture. About 80% of our scallops are exported to these markets at prices generally higher than $20 a kilo.

It is important therefore to maintain a consistently high quality product to stay ahead of our competitors and continue to provide profitable returns to the fishermen and processors.

Scallops can absorb significant amounts of water if allowed to soak. Typically their weight will increase by 20-30% after 24 hours of soaking. This results in an inferior product for our overseas markets.

At the Hamilton laboratories of the International Food Institute of Queensland, scientists have been studying the problem of water absorption by scallops.

Why is it a problem? Well - firstly the buyer doesn't want to pay a high price for water. Then there is the possible problem of excessive drip loss on thawing which detracts from the visual quality of the scallop. There may also be problems with soaked scallops splattering and shrinking when cooked.

The Institute has developed a simple non-destructive test which processors can use to screen their product. It's called the FLOAT TEST. It's based on the decrease in density of scallops as they absorb water. So in a particular salt solution, scallops with a high moisture content will float while those with a low moisture content will sink.

Here at the Sea Traders seafood processing plant in Brisbane the float test is being used routinely to monitor the moisture content of export consignments of scallops. Quality assurance is now an integral part of processing scallops for export.

Float Test Preparation

Before you can do the float test, you'll need to prepare salt solutions of known concentrations, and you'll need some basic equipment such as beakers, a measuring cylinder, storage bottles, a scoop, thermometer and a weighing balance.

The salt solutions are prepared by weighing out commercial grade salt on a balance which

should be accurate to ±1 g. For a 10% solution, 100 g of salt is dissolved completely in about 900 mL of tap water.

The solution is made up to 1 litre and stored at room temperature.

Scallop Preparation

A sample of at least 50 meats without roe is required from the main batch. The 50 scallops are placed in a leakproof plastic bag.

The scallops are allowed to warm to room temperature.

This can be speeded up by placing the bag in a container of running water at room temperature.

The Float Test

In its simplest form the float test is done with one salt solution to give a PASS or FAIL result.

This graph shows how the salt solution and the scallop moisture are related. Using the graph select a salt solution which corresponds to the required quality standard for moisture. If you have selected a quality standard of 80% then the corresponding salt solution will be 11%. This solution is then used for the PASS/FAIL test.

Before doing the test, blot the external moisture from the scallops with a paper towel. This prevents diluting the salt solutions.

Drop 10 scallops into about 800 mL of salt solution. Stir briefly and then stop the movement.

Allow about 5-10 seconds and then count the number which float. Repeat this step 4 times until all the scallops have been tested. Count up the total number that floated.

If no scallops float, the test is a PASS. If all scallops float, the test is a FAIL (that is, the scallops contain more than 80% moisture).

If more than 25 (or half) of the scallops float, the water content of the scallops will be approximately 80%.

Using Float Test to Estimate Water Content

To estimate the actual water content of the scallops, several salt solutions are required. Here 5 salt solutions differing by 0.5% have been prepared in the range 9-11%.

Take at least 60 scallops from the main batch and prewarm to room temperature.

Take 10 of these scallops and find the first salt solution in which some of the scallops sink. Here we see that in starting at a concentration of 11%, all of the scallops float.

Now progress to lower concentrations of salt to find the "cut off" solution.

Here, some of the scallops sink in the 9.5% solution. Discard the 10 scallops after reaching this point.

Now carry out the float test on 5 lots of 10 scallops using the same 9.5% cut-off solution. Count the total number of scallops which float out of 50. If between 25 and 50 scallops float, then you have reached the correct cut-off solution for estimating moisture content.

From our graph, the corresponding moisture is 83%. This moisture level is considered excessive and, at Sea Traders, the scallops would be rejected for export.

If less than 25 scallops float, repeat the test on the same 50 scallops at the next highest strength solution, in this case, 10.0%. This solution should give a float count of between 25 and 50. The corresponding moisture will then be 82%.

The moisture content can also be estimated from this formula:

Remember, make sure the scallops are blotted dry before testing in each salt solution. Discard the salt solution after testing each batch of 50 scallops.

The accuracy of the test is about $\pm 1\%$. The test should be considered as a screening method only, and not regarded as a standard method.

The natural water content of scallops varies with season and size of the scallop, so it is difficult to estimate the amount of added water. However using data based on natural water levels and on water uptake during handling and processing, it should be possible to achieve less than 79% moisture in summer and less than 82% moisture in winter.

A brochure detailing the procedure for the float test can be obtained from the Queensland Department of Primary Industries or the Australian Quarantine and Inspection Service.