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Freshness Preservation of Canadian Atlantic Crab (*Chionoecetes opilio*), Scallop (*Placopecten magellanicus*), Squid (*Illex illecebrosus*) and Sea Cucumber (*Cucumaria frondosa*)

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FRESHNESS PRESERVATION OF CANADIAN ATLANTIC CRAB (*Chionoecetes opilio*), SCALLOP (*Placopecten magellanicus*), SQUID (*Illex illecebrosus*) AND SEA CUCUMBER (*Cucumaria frondosa*)

by

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ABSTRACT

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Freshness enhancement studies for Atlantic queen crab *(Chionoecetes opilio)*, scallop *(Placopecten magellanicus)*, squid *(Illex illecebrosus)* and sea cucumber *(Cucumaria frondosa)* have been comprehensively investigated in terms of handling, grading, and of various related operations and technical improvements. This report contains four independent papers of the above four species in terms of holding method evaluations as well as various physical, organoleptic and scientific grading guidelines based on post-mortem biochemical deterioration, discolouration, and time/temperature effects. In conclusion, it is aimed that this report should provide up-to-date information and technology on the Atlantic queen crab, scallop, squid and sea cucumber in order to improve the overall fresh quality and handling operations for our fishing industry.

RESUME

Des études sur l'amélioration du degré de fraîcheur du crabe des neiges *(Chionoecetes opilio)*, du pétoncle géant *(Placopecten magellanicus)*, de l'encornet nordique *(Illex illecebrosus)* et du concombre de mer *(Cucumaria frondosa)* ont porté sur la manutention, le classement et les diverses opérations ou améliorations techniques qui s'y rattachent. Le présent rapport est constitué par quatre articles préparés indépendamment sur ces espèces. On y évalue pour chacune les méthodes de stabulation ainsi que les divers critères physiques, organoleptiques et scientifiques fondés sur la détérioration biochimique post-mortem, le changement de couleur et les effets température/temps. En conclusion, le rapport veut fournir à notre industrie halieutique une information et une technologie à jour sur ces quatre espèces dans le but d'en améliorer la qualité générale et les opérations de manutention.

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(A) ATLANTIC QUEEN CRAB *(Chionoecetes opilio)*

A.1 INTRODUCTION

To secure the supply of excellent quality live crab for processing, and to maintain the initial top quality for the period between catching and processing, it becomes particularly important in the queen crab fishery, as well as part of the overall national Quality Enhancement Program.

Live crab should be handled as carefully as possible after capture. They should not be removed from the traps by their claws or legs, since these are easily shed when a crab senses that it is trapped, resulting in a mutilated specimen. Crab left exposed to sun and wind on deck will rapidly become weakened and may die. If possible, the crab should be put into boxes or other suitable containers, and chilled immediately onboard and maintained in a chilled condition during transport.

There are many improved techniques claimed to maintain quality and reduce the incidence of crab injury and mortality, such as the use of refrigerated seawater tanks. However, the application of these improved handling procedures to our crab fishery is not well developed. Therefore, some emphasis on technology transfer and/or development, and even mandatory adoption of improved handling procedures for queen crab should be considered, in order to improve the overall crab quality problem.

The aim of this report is to describe the problems in our crab handling operations, and to re-investigate the suitability for holding queen crab alive by various techniques. With the present limited data, the tentative analysis has been made, and it is believed that various changes in crab handling and holding procedures should be taken for quality assurance of Atlantic queen crab prior to marketing and processing.

A.2 INVESTIGATIONS ON HOLDING TECHNIQUES

The holding investigations were conducted on five separate holding techniques: icing, non-contact icing (NCI), refrigerated seawater (RSW), chilled moist air (CMA), and circulating aerated seawater (CAS). The CAS technique was employed as the control similar to that employed by Ke et al. (1979). The crab specimens used for these tests were landed in 1980-1982. All crabs were healthy and active upon arrival at the station.

Fifty crabs were used in each holding test. Three sample lots (20 crabs in each) of the controlled injured crabs were prepared by cutting the second or third leg (not on the same side) with a pair of scissors, and by dropping the crabs approximately 1 m onto a wooden floor. All tests were conducted for a 10-day period. It should be noted that a seasonal variation study has not been investigated.

(1) Contact Icing: Crabs were held in an insulated container (90 x 56 x 50 cm) fitted with a 3-cm diameter side drain and iced in a 2:1 ratio of crab to ice. The melt water was drained and the crabs were re-iced daily. The average temperature at the centre of the container was approximately 2°C.

(2) Non-Contact Icing (NCI): Crabs were held in the container as in (1). Slush ice was placed in the plastic bags (45 cm x 120 cm) around and on the top of the crab box to keep the crabs at 2°C to 5°C.

(3) Refrigerated Seawater (RSW): An RSW unit, complete with refrigerated insulated tank (80 x 80 x 90 cm) and circulating pumps, was employed for this study. The aeration was accomplished using a small air pump, at a flow rate of approximately 100 ml per second. The temperature was maintained at 6-8°C. The total volume of seawater was about 300 litres in this closed circulation system.

(4) Chilled and Moist Air (CMA): Four layers of crabs were kept in a plastic box for this test in a cool moist atmosphere. The air relative humidity was 90-100% and maintained at 3-7°C.

(5) Control Circulating Aerated Seawater Holding Tank (CAS): This part of the test was made in the Halifax Laboratory. The holding tanks (90 x 90 x 60 cm) containing about 25 crabs each were operated at the following conditions: 6°C (42°F), filtered seawater, water flow rate: 1 litre per minute, and air flow rate 20 ml per second.

A.3 RESULTS ON CHILLING OPERATION

A comparison of the five holding techniques for queen crab, over a 10-day period, is presented in Table 1 in terms of mortality rates. The NCI and RSW are the best methods for holding queen crab for less than 30% mortality over a 10-day period, and the direct icing technique can only keep crab for no more than three days to maintain a 74% survival rate. The chilled air may be practical for holding crabs onboard and during transportation for up to six days, with a survival rate of 80%.

The mortality rate of crabs injured to varying degrees and held in chilled air at 5°C is reported in Table 2. The results confirm again that the careful handling of crabs is the single most important factor for maintaining crab quality.

The circulated, aerated seawater control tank maintained under ideal laboratory conditions had a mortality rate of about 5% for six months.

This may be recommended for the crab industry to supply live crab for the market.

A.4 GUIDELINES ON QUALITY ASSESSMENT

Quality changes for crab samples held at 3°C and 23°C in terms of FFA, EPN, TVB and pH have been studied. Production of FFA and TVB at 23°C is very rapid, reflecting the rate of spoilage at this temperature. Increases in FFA and TVB were much slower at 3°C showing only a gradual rise up to two days, but increasing sharply after three days storage. Generally increases in TMA values closely paralleled those of TVB tests.

pH increases were higher at 23°C than 3°C, paralleling the increase in basic compounds. Similarly, EPN values showed a large decrease at 23°C and a smaller rate of reduction at the lower temperature.

In organoleptic testing, crabmeat quality was divided into three classes: 1) Grade A - good quality; taste panel score 4-5; 2) Grade B - acceptable quality; taste panel score 3; 3) Grade F - unacceptable, reject quality; taste panel score 1-2 (see Table 4).

It was relatively easy to establish Grade A, good quality and Grade F, rejection quality. However, differentiating Grade B, acceptable quality, from Grades A and F, was more difficult. A correlation between sensory and chemical data is shown in Table 3. Chemically-derived limits are presented for each grade.

Free fatty acid levels of less than 42 μmole/10 g of meat and EPN of more than 1.50 mg-N/100 g have been tentatively suggested for good quality crabmeat. Grade B or acceptable quality was set at values of 42-50 μmole FFA/10 g for FFA and 1.00-1.50 mg-N/100 g for EPN. Rejection quality was from meat containing FFA values above 50 μmole FFA/10 g and EPN values below 1.00 mg-N/100 g. It was difficult to set firm limits in Grade B since some scattering in the data was encountered.

From the above data, FFA is suggested as the method of choice for quality assessment because it is a simple, precise, reliable assay requiring minimal equipment. Another method which shows promise as a quality indicator is EPN, but it seems limited by a cumbersome procedure and greater deviation in results. A more extensive study to simplify and increase the accuracy of this procedure must be completed before the EPN data can be applied objectively to the assessment of crab quality. TVB and pH measurements are alternative (simpler) methods than EPN for quality assessment.

A.5 SUMMARY

A holding experiment employing the RSW, CMA and icing was carried out and assessed by measuring the mortality rate of the specimen crabs. The NCI, RSW and CMA were shown to be the most suitable methods for holding queen crab up to six days with less than 25% mortality. The direct icing method may be used satisfactorily for short periods of up to three days in total, prior to processing. Since this study was conducted without a systematic plan, and the sample size was very limited, no conclusions or recommendations can be made without some further, more statistically significant results. We also would recommend the use of a scientific grading system by employing two chemical methods such as FFA and EPN which can be correlated with the results of the sensory analyses. The recommended procedures and guidelines have been tested satisfactorily in our laboratory, and can be applied to assess the quality of crabmeat.

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TABLE 1. Incidence of Queen Crab Mortality Held by Various Techniques

Holding Method	Mortality % (Accumulated)		
	3 days	6 days	10 days
ICE (direct contact, about 2°C) *	26	84	100
NCI (non-contact icing, 2-5°C)	4	18	30
RSW (aeration 6-8°C, closed circulation)	6	14	28
CMA (chilled and moist air, 5°C)	10	20	30
Control Seawater Holding Tank (flow filtered seawater, 8-10°C, aeration)	2	3	3

* About 5% mortality rate has been recorded for the crabs held in our laboratory seawater tank for two months with daily feeding.

TABLE 2. Comparison of the Mortality Rates of Queen Crab Subjected to Varying Degrees of Injury

Holding Method (CMA)	Mortality % (Accumulated)	
	3 days	6 days
Control* (uninjured)	10	20
Less one leg**	20	55
Less two legs**	50	95
Dropped** (1 m high)	30	45

* 50 crabs were used as the control.

** 20 crabs were used for the tests, respectively.

TABLE 3. Comparison of Recommended Chemical Guideline Values For Assessing the Quality of Crabmeat and Results From Organoleptic Tests

Grade	FFA (μmole/10 g)	EPN (mg-N/100 g)	Organoleptic Results		
			A (%)	B (%)	F (%)
A	42	1.50	93.8	6.2	-
B	42-50	1.00-1.50	12.5	50.0	37.5
F	50	1.00	-	25.0	75.0

TABLE 4. Taste panel sheet used in the organoleptic analysis of fresh queen crab meat.

NAME: ______________ DATE: __________

Please evaluate the quality of these crab samples, using the table below. Check which description best describes the sample.

Odour Sample #	Pleasant, characteristic crab odour	Sl. characteristic to neutral	Sl. turnipy to vegetable-like	Stale, sl. sour, turnipy, sl. ammonia	Sour, stg. ammonia, putrid
*Colour Sample #	(leg) Pigment, pink-red Meat, creamy white, bright, glistening	(leg) Pigment, sl. dull Meat, creamy white, loss of sheen	(leg) Pigment, dull Meat, dull or sl. grey, sl. yellow discoloration	(leg) Pigment, dull, bleached no pigment, Meat, yellow discoloration, greyness	(leg) Pigment, dull, bleached; Meat, yellow or green discoloration
Texture Sample #	Fi[illegible] elastic, moist Lo[illegible] fibres in leg me[illegible]t	Firm, elastic moist	Loss of elasticity shredded or grated appearance	Soft, limp, soggy, chalky; shredded or grated appearance	Mushy, slimy
Flavour Sample #	Characteristic crab flavour, mild, sl. sweet	Sl. characteristic to neutral	Sl. turnipy, sl. bitter after-taste	Stale, sl. sour turnipy, bitter after taste	Sour, very stale, very unpleasant after taste, putrid
	A5	A4	B3	F2	F1

* Evaluate the colour of both leg or body meat.

(B) SCALLOP *(Placopecten magellanicus)*

B.1 INTRODUCTION

The major producing countries of scallops in the world are Japan (32%), the United States (30%), Canada (23%), France (3%), the United Kingdom and Iceland. The total landed round scallops in 1979 was 382,040 t. The meat weight and meat with roe weight was 12 and 15% of the round weight, respectively. In 1980, Canada produced 70,472 t (round) with a value of about $70 million. Most of the Canadian catch was exported. In 1980, Canada exported 7,300 t of scallop meat representing about 83% of total production of 8,800 t of scallop meat to the United States. Another 2% was exported worldwide. France is the major importing country in Europe - nearly 8,000 t annually. The product most commonly consumed in Europe is scallop with roe, with only a very small demand for meat alone. The approximate weight of roe is 3% of the round scallop. If the freshness preservation for the meat with roe is to be improved, it would not only be improving the utilization of scallop but also increasing the production from 12 to 15%. Various technical considerations for handling and keeping scallop meat and meat with roe are described in this report based on our recent tests and investigations.

The sea scallop can be found from the northern Gulf of St. Lawrence to Cape Hatteras, North Carolina where it is found only in cooler water below a 60-metre depth. The most important area in Canada is Georges Bank, although other beds are located in the Gulf of St. Lawrence, the Northumberland Strait, Bay of Fundy and off Newfoundland near St. Pierre-Miquelon.

The most well known portion of the scallop is the white disk-shaped "meat". This is the adductor muscle which accounts for about 10-14% of the scallop's total weight. The simple anatomy of scallops is illustrated in Figure 1. Approximate ranges of the weight percentage and the water contents are listed in Table 5.

B.2 SHUCKING OPERATION

A. Manual Shucking

Scallop quality deterioration starts from the moment it is lodged in the rake. Great care must be taken for various handling, chilling and shucking operations in order to preserve the freshness quality. Overall, shucking is the most important step because of bacteria contamination, enzymatic effect and yield changes.

In recent studies, Commar Management Consultants has made a comprehensive survey and time/motion study, and the manual scallop shucking operations for the meat and the meat with roe have been summarized in Tables 7A and 7B respectively.

B. Automatic Shucker

Within the past few years, a number of mechanical shucking machines have been designed to shuck scallop meats. Several use hot water to provide a thermal shock. These heat-shock methods can partially cook the scallop meat and hence are generally not considered to produce a high-quality product for the market.

A mechanical shucker which can produce a quality meat at the rate of 60 scallops per minute has been developed by the Fisheries Development Branch of the Department of Fisheries and Oceans in Halifax. It uses high-pressure water jets to cut the meat from the shell and to separate the viscera from the meat (Figure 2).

Although primarily designed to shuck meats only, it may well be possible to shuck meats with rim and roe by adjusting the cuts made by the circular saws which "standardize" each scallop prior to action of the water jets. Details of the automatic scallop shucking machine were reported by W. K. Rodman in 1980 at the Atlantic Fisheries Technological Conference in Newfoundland (Appendix A).

C. Shucking Speed and Meat Yield

The number and product weight per minute per shucker were used for the evaluation of the scallop shucking operation. The results for various scallop tissues shucked, both by manual and mechanical operations, were compared in Table 8. The number of scallops shucked per minute by manual and mechanical operations are 23 and 60 respectively. The unit weight yield from manual shucking indicated to be about 4% higher than automatic shucking on the meat recovery.

By using manual shucking operations alone, the shucking speeds for meats, meats with roe and meats/roe/rim together are also listed in Table 8. Since more work and care are required for the shucker to produce good quality scallop meats with roe etc., the shucking rate was only one third of the normal shucking for the meat alone. However, the overall yield was still about 50% of the production of the meats alone. In contrast, the product yield for meats/roe/rim compares favourably with the yields for meats alone, being almost 97%. Even its shucking speed was decreased to half of the rate of the meat shucking operation.

B.3 QUALITY CONSIDERATIONS

The physical and organoleptic qualities, based on colour, odour, texture, flavour and saltiness, are very important for scallop meat. Since the scallop meat is considered to be a luxury seafood, the overall acceptability and freshness requirements are very high. Therefore, handling operations for scallops must be carefully conducted in order to keep the excellent freshness quality. Canadian scallops *(Placopecten magellanicus)* have roe which is either white (male) or reddish (female) in colour. So the colour preservation for scallop meat with roe becomes a major factor of quality grading for this type of product. Size differentiation is another major quality consideration. The larger scallop meats are preferred - usually starting at 8-12 size (8-12 scallop meats/pound) and following with 12-18, 18-30, 30-50 and 40-60.

The guidelines of the five-point taste panel, attached in Table 9, are recommended for the organoleptic evaluation for scallop meats. The guidelines were recommended based on texture, colour, flavour and eating criteria etc. The simple physical grading standards were also developed (Table 10) for selling point or dockside grading assessment. Those standards are mainly based on physical appearance and smelling tests, but they are very practical and easy to be adopted for preliminary evaluation.

Various laboratory evaluations using hypoxanthine, trimethylamine and free fatty acids as the indicators were conducted. The freshness data showed that FFA content may be employed for both meats and roe samples on their quality control and assessment (Figure 3). However, specific FFA value for the evaluation on scallop quality has not been completed.

B.4 FRESHNESS PRESERVATION

Shucked scallop meats are currently packed in cotton bags and iced in the ship's hold prior to landing and further processing. This preservation system is adequate for storing meats but Bourne and Read (1965) state that meats with roe "will require new and more specialized handling methods". Among suggestions for further research antibiotic dips (now prohibited) and refrigerated brine or freezing at sea were mentioned. Freezing at sea is one method of ensuring that a high-quality product is landed. The concept of onboard freezing of scallops has been discussed from time to time, however, none of the vessels in the Canadian fleet presently utilizes this technology.

The advantages of refrigerated seawater (RSW) systems are that the product is rapidly cooled and held at consistently low temperature and crushing and bruising are avoided. The main disadvantage of such systems is that they are expensive. A far cheaper alternative is to use seawater and ice in combination. Such holding systems are normally referred to as chilled seawater (CSW) systems and also have shown to be effective in preserving quality.

In order to better define the problems involved in storing scallop products, a series of preliminary shipboard trials were conducted. The results of these trials delineated further tests which were conducted in the more controlled environment of the laboratory and taste panel evaluations.

4A. Shipboard Preservation Trials

A variety of scallop products were prepared and preserved aboard the "M.V. Charlotte Louise" in May 1981 (Table 11). Approximately 10 kg of each shucked product was prepared and placed in cotton bags or plastic bags on ice in the hold and in CSW. In addition, a wire basket and two feedbags of whole scallop in the shell were placed in ice live to test lasting quality. Samples were evaluated at the Port Mouton fish plant in terms of odour, texture, colour and rim reaction. Live scallops had normal rim pigmentation and reacted to touch, while older scallops did not react to touch and had pigments which rubbed off. Spoiled scallops had lost all rim pigmentation and a brown slime covered the samples.

It was found, surprisingly, that good quality whole scallops in the shell can be landed live after three to four days on ice. Scallop meat can be kept in cotton bags iced with good quality and freshness for seven days. Rims-roe-meat could be kept for up to four days in cotton bags on ice. These results reconfirmed the findings of Bourne and Read (1965), and indicated some direction of further study, especially using CSW.

4B. Laboratory Preservation Trials

Whole scallops from Georges Bank were obtained from the "M.V. Barbara Louise" and trucked to Halifax on ice. Scallops were generally in very good condition with the caught age of about two days. Scallop meat with roe and rim was shucked and stored on ice. Immediately after shucking, a control sample was frozen and stored at $-40^{\circ}C$. Each preservation sample consisted of at least eight male and eight female scallops with rim, roe and meat. Chilled seawater samples were placed in a plastic 1.5-litre jar which had holes punched in the lid to allow for air exchange. Scallop to seawater-with-ice ratio was 1:1. Refrigerated seawater samples were identical to CSW samples except that the refrigerated seawater was used. Cotton bags (CB) were used for holding the samples for the above chilling tests.

Taste panels were conducted on three, five and seven days. On each test, scallops from a different storage period were tested. Five panelists evaluated the scallop meats and roe according to the criteria as shown in Table 10.

Biochemical evaluation of the stored scallop products was also undertaken by the staff of the Fisheries Development Branch. Levels of free fatty acids (FFA) were determined for stored scallop meat and roe respectively. Free fatty acid provides a good indication of lipid breakdown which occurs during spoilage and leads to decreased quality and nutritive value.

To evaluate taste panel results, the meat scores were pooled with those from the roe. Mean scores of overall acceptability for the meat and roe samples have been presented and compared in Figures 4 and 5. After three days of storage, the cotton bag samples were not significantly more acceptable than CSW meats and the meat with roes, however, their texture was rated higher. After five days, the general acceptability of CSW scallop meat and roe scored significantly higher than the cotton bag samples. Chilled seawater flavour was rated highest even surpassing the control sample.

The meat alone can be preserved for seven days in ice, RSW and CSW with acceptable quality. However, the meat with roe scored poorly after seven days by all storage methods.

A number of other observations was also made:

1. Meats from female scallops were slightly pink compared to meats from male scallops. However, this may not be due to storage since similarly coloured meat was in the control sample and has been noted at fish plants.

2. Chilled seawater and RSW samples were perceived as having a pleasant, slightly salty taste which may mask some bad flavour.

3. Red roes decrease in quality faster than white gonad, perhaps due to their higher fat content. They had a stronger flavour.

4. All storage methods produced meats which were tougher to cut than the freshly frozen control sample.

B.5 SUMMARY

The holding and shucking operations for fresh scallop meat and the meat with roe have been evaluated and compared. The guideline of physical grading, as well as organoleptic tests, have been described and used for this investigation. The yield, shucking rate and the production from both manual and automatic scallop shucking operations have been conducted and compared in this report. The shucking speeds by manual and mechanical operations are 23 and 60 respectively. The meat samples can be preserved at good freshness quality in ice, RSW and CSW for not less than seven days. However, for the meats with roes, their shelf-life can only be kept for about five days at acceptable quality. Various quality considerations for scallop products are also discussed.

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TABLE 5. APPROXIMATE WEIGHT PERCENTAGES OF WATER CONTENT IN MAJOR PARTS OF SCALLOPS

	Round	Meats	Roes	Rims
Weight (g)				
Male	215-315	28-41	12-28	13-17
Female	261-369	34-48	12-26	13-18
Mean Value	325	42	19	17
% of round	100	13	6	5
Water content (%)	——	77-81	75-85	85-90

TABLE 6. SIZE AND YIELD DISTRIBUTION OF SCALLOPS TOWED SELECTED TOW FROM GEORGES BANK, JULY 1981

Size (mm)	No. Caught	% of Tow	Meat Yield (g)	% Total Yield
60	11	8	22	1
70	6	4	28	1
80	13	10	94	4
90	28	20	304	13
100	42	30	828	35
110	23	17	499	21
120	10	7	294	12
130	5	3	195	9
140	2	1	101	4
Total	140	100	2,365	100

TABLE 7A. SCALLOP SHUCKING FOR THE MEAT ONLY

Step 1	A knife is inserted between the shells where they gape, near the wings.
Step 2	The knife pries the flatter shell slightly up from the more convex shell.
Step 3	The muscle is severed from the flat shell.
Step 4	The point of the knife is hooked into the rims.
Step 5	The flat shell is removed along with the rims and viscera.
Step 6	The meat is scraped off the convex shell and into a bucket.

TABLE 7B. SCALLOP SHUCKING FOR THE MEAT WITH ROE

Step 1	Remove round shell.
Step 2	Remove upper frill and gill.
Step 3	Lift up roe and cut through mantle around the muscle from beneath the roe to the intestine keeping close to the edge of the muscle.
Step 4	Cut across foot portion of roe and between liver and meat.
Step 5	Scrape off roe and meat into bucket.

TABLE 8. SHUCKING RATE AND PRODUCT YIELD FOR VARIOUS SCALLOP SHUCKING OPERATIONS

Shucking Operation	Automatic Shucking Meats Only	Manual Shucking		
		Meats	Meats/Roe	Meats/Roe/Rim
Shucking rate (No./minute)	60	23	7	12
Average weight (yield) (g/scallop)	41	42	61	78
Production rate (g/minute)	2,460	966	427	936

% CHANGE IN COMPARISON WITH THE STANDARD MANUAL MEAT SHUCKING

Shucking rate	260%	100%	30%	52%
Yield	97%	100%	145%	185%
Production rate	254%	100%	44%	97%

TABLE 9. ORGANOLEPTIC TEST FORM AND GUIDELINES FOR SCALLOP MEATS

SCALLOP TEST PANEL
(BL 1981)

NAME: ______________________ DATE: ____________

Please evaluate the quality of these scallop samples, using the table below. Check which description best describes the sample.

	5	4	3	2	1	
Odour Sample #	Medium, sweet butterscotch odour or fresh steamed fish odour.	Slight sweet, slight steamed fish odour.	Neutral, no definite odour.	Slight ammoniacal slight stale fish slightly sour or turnipy, musty, porridge-like.	Sour, ammoniacal spoiled fruit odour. Putrid.	Comments
____ ____ ____ ____	____ ____ ____ ____	____ ____ ____ ____	____ ____ ____ ____	____ ____ ____ ____	____ ____ ____ ____	
Colour Sample #	Creamy, white and glistening.	Creamy, white.	White, loss of sheen.	Slightly dull or somewhat greyish.	Colour range from white through bleached white, grey or brown.	Comments
____ ____ ____ ____	____ ____ ____ ____	____ ____ ____ ____	____ ____ ____ ____	____ ____ ____ ____	____ ____ ____ ____	
Saltiness Sample #		Not salty	Slightly salty	Moderately salty	Very salty	Comments

. . . /2

Texture Sample #	Firm, elastic (chewy but not tough).	Slightly soft. Slightly dry.	Slightly tough. Loss of elasticity	Somewhat tough. Somewhat putty-like.	Texture range from slightly soft to tough or putty-like.	Comments
____	____	____	____	____	____	
____	____	____	____	____	____	
____	____	____	____	____	____	
____	____	____	____	____	____	
Flavour Sample #	Sweet, characteristic of cooked fresh shellfish.	Slightly sweet	Very, slight aftertaste.	Vegetable-like. Old herring spoil-fruit. Slight sharpness or sourness, strong after-taste	Very bitter, sour, turnipy. Unpleasant aftertaste.	Comments
____	____	____	____	____	____	
____	____	____	____	____	____	
____	____	____	____	____	____	
____	____	____	____	____	____	
Overall Acceptability Sample #	Very Good	Good	Fair	Slightly spoiled	Spoiled	Comments
____	____	____	____	____	____	
____	____	____	____	____	____	
____	____	____	____	____	____	
____	____	____	____	____	____	

GENERAL COMMENTS:

TABLE 10. PHYSICAL GRADING STANDARDS FOR SCALLOP MEATS

Excellent Quality (A)	Good Quality (B)	Acceptable Quality (C)	Unacceptable (F)
- Cream white meats - Bright red in roes - Sweet odour - Firm, elastic	- White in meats - Red in roe - Natural odour - Slightly soft	- White, loss of sheen - Slightly fishy odour - Slightly tough	- Dull white; greyish - Fishy odour; objectional odour - Putty-like; tough and dry

TABLE 11. SHIPBOARD PRESERVATION TESTS OF VARIOUS SCALLOP PRODUCTS STORED IN ICE

Product	Storage Method	Days Stored	Odour	Texture	Rim Colour Loss
Whole scallop in shell	feedbag	3	slight	alive	slight
	wire basket	4	none-slight	alive	none
Meat only	cotton bag	5	none	firm	-----
	cotton bag	7	slight	firm	-----
Meat-roe-rim	cotton bag	4	none	firm	none
	cotton bag	5	strong	firm	slight
	cotton bag	5	strong	roe - flaccid	slight
	cotton bag	6	strong	soft	total
	cotton bag	7	strong	soft	total
	plastic bag	6	strong	firm	total
Meat-roe	cotton bag	7	strong	soft	-----

Fig. 1 Anatomy of Sea Scallop

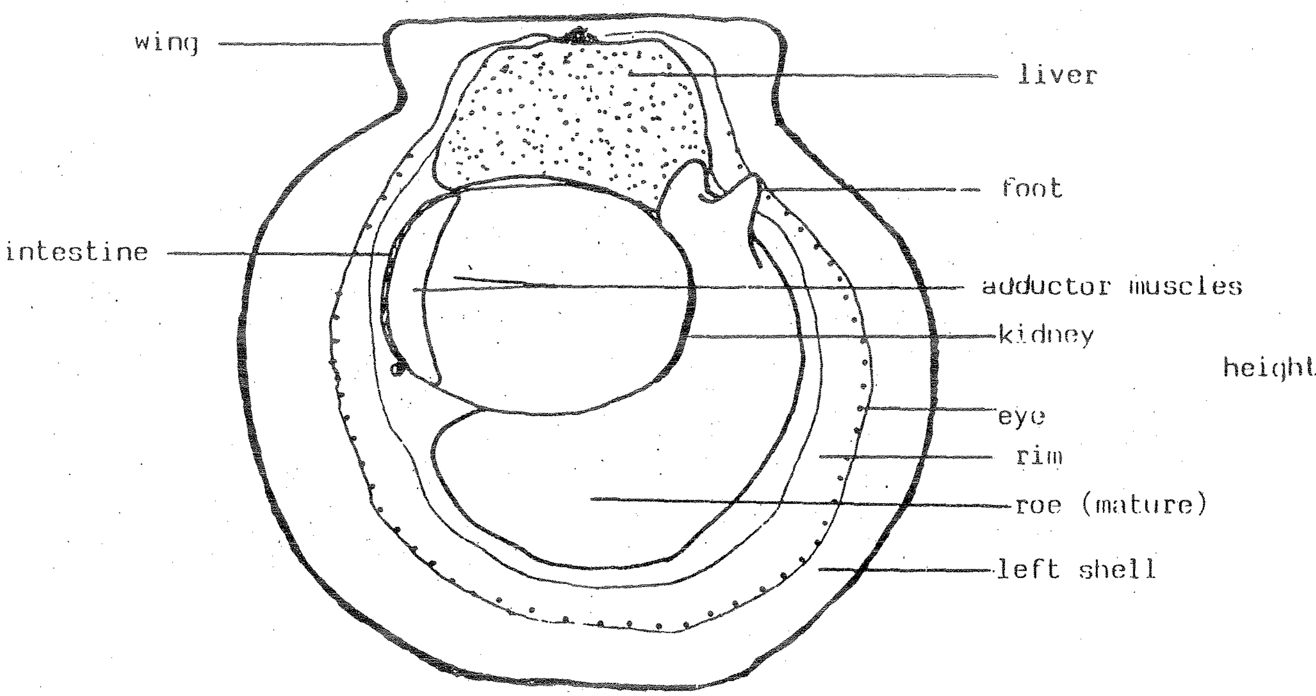


FIGURE 2.
AUTOMATIC SCALLOP SHUCKING MACHINE DESIGNED BY DEPARTMENT OF FISHERIES AND OCEANS

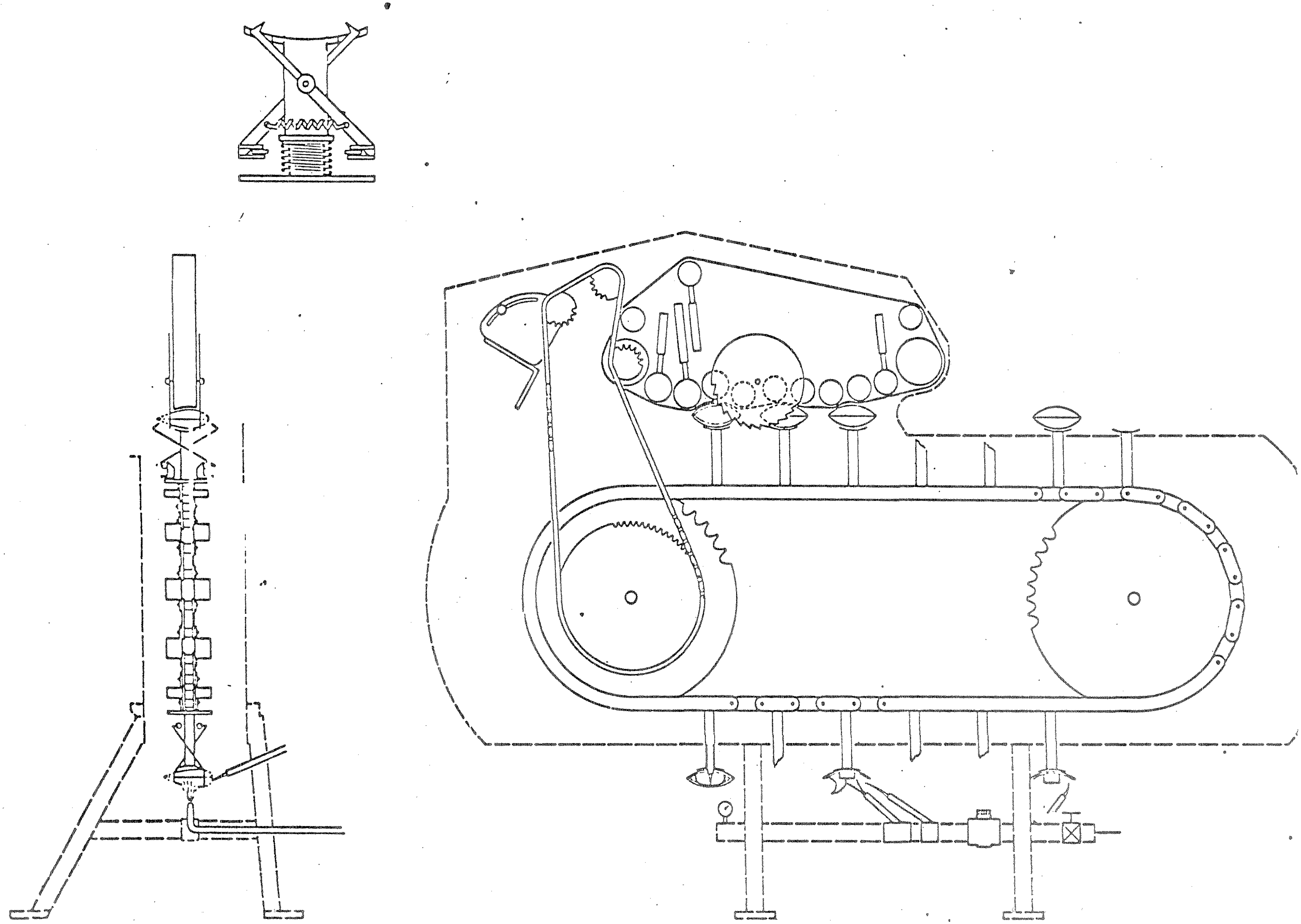


Figure 3.

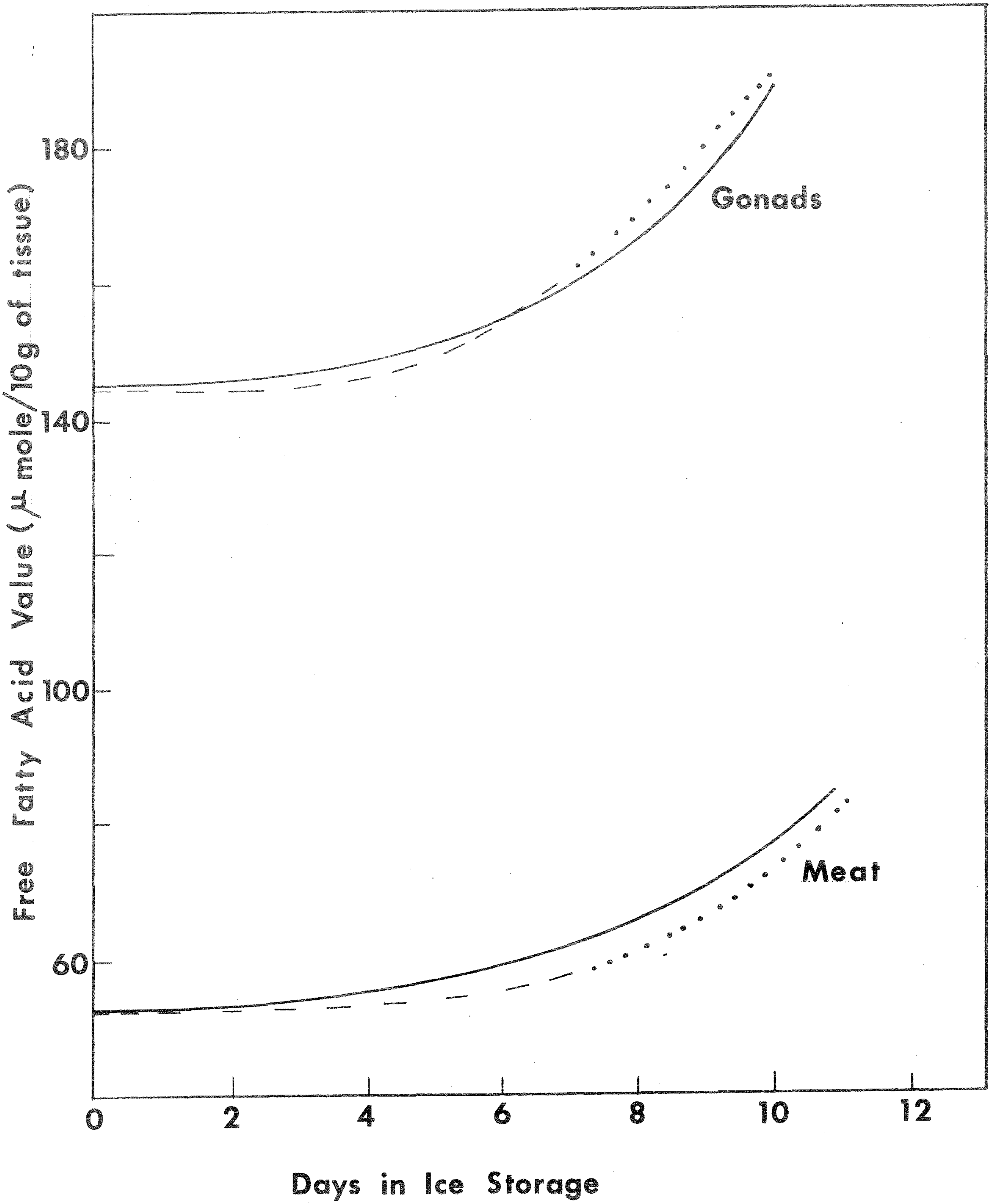

Free Fatty Acid Value (μ mole/10g of tissue)
180
140
100
60
Gonads
Meat
0
2
4
6
8
10
12
Days in Ice Storage

Figure 4. Meat Sample Taste Panel (% Grade)

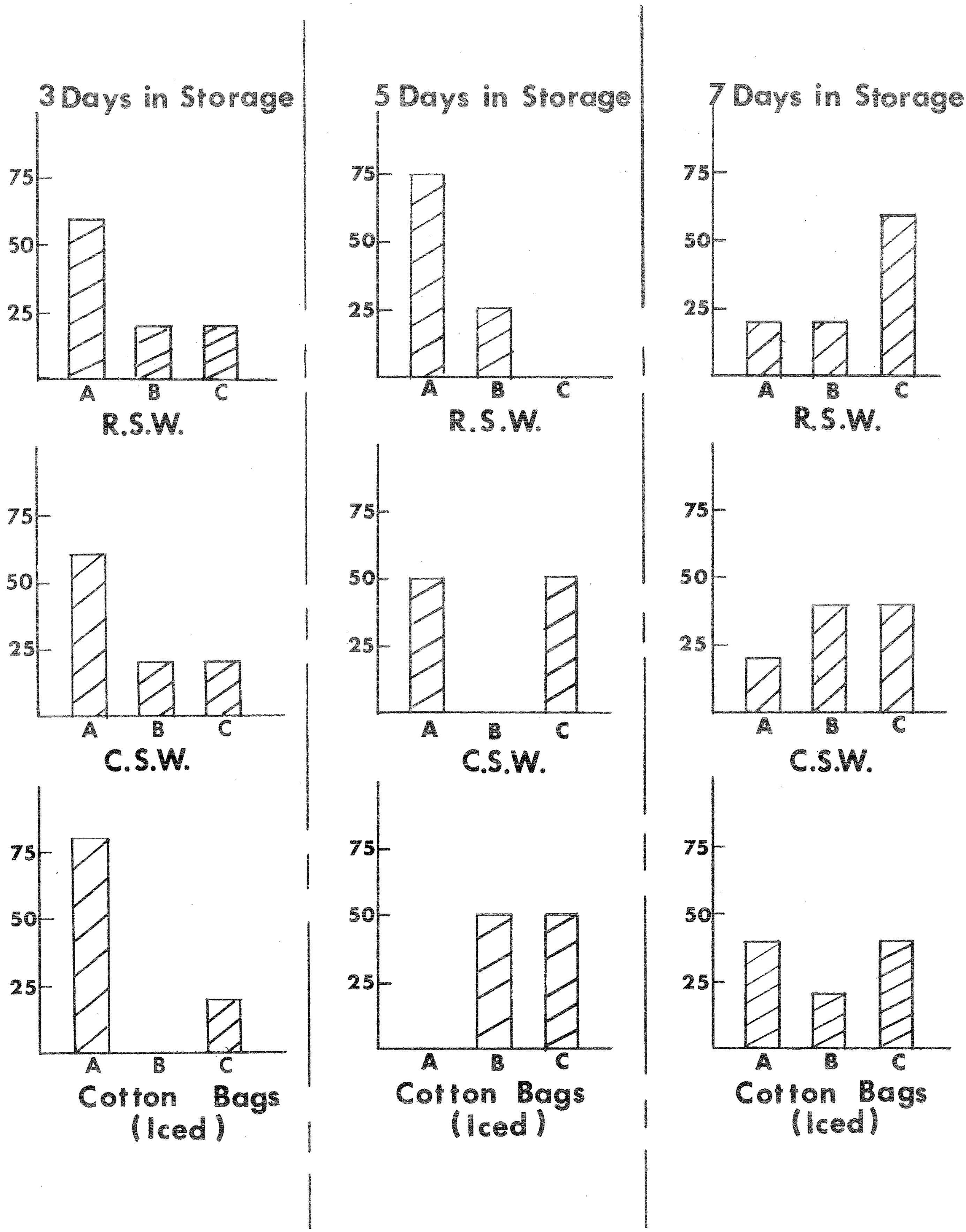
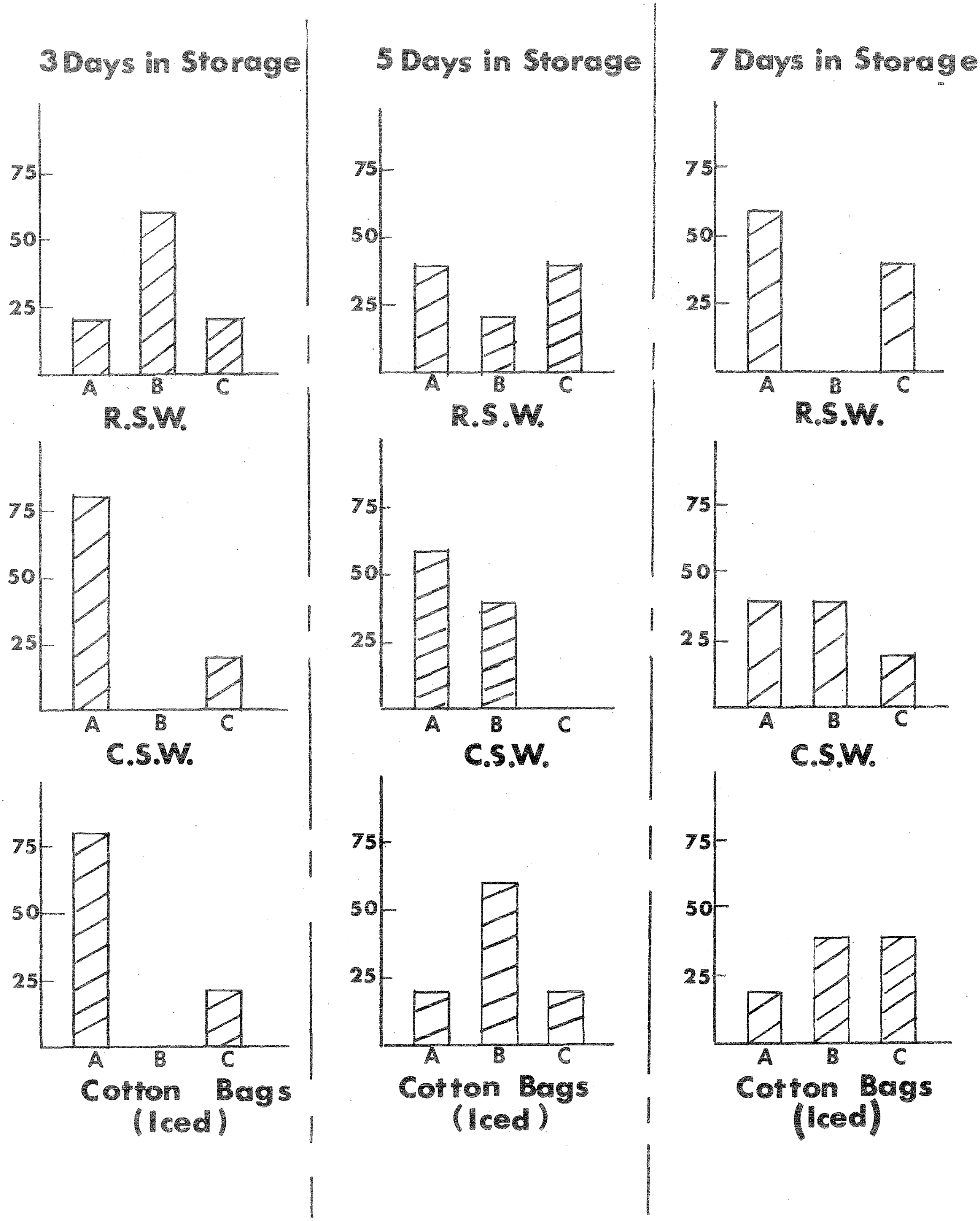


Figure 5. Roe Taste Panel (% Grade)



AUTOMATIC SCALLOP SHUCKING MACHINE (REVISED)

JANUARY, 1981

By

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Paper presented at the Atlantic Fisheries Technology conference in St. John's, Newfoundland - August, 1980

AUTOMATIC SCALLOP SHUCKING MACHINE

Introduction

The scallop fishery represents the single most valuable fishery resource in Atlantic Canada and it is only partially utilized. The resource consists basically of two species. The Sea Scallop harvested principally on George's Bank by offshore draggers and the underutilized Icelandic Scallop found in colder waters such as those off the west coast of Newfoundland.

The principal reason the Icelandic scallop resource is underutilized is due to the great difficulty to manually shuck this type of scallop. Upon comparative examination of these two types of scallops it soon becomes evident that nature provided the Icelandic scallop with a very tight fitting shell with no easy access hole as is the case with the Sea Scallop, thus the great difficulty to hand shuck the Icelandic Scallop and thus the lack of a significant commercial fishery. The resource availability is being studied by the Newfoundland Region Industrial Development Division.

The need for a mechanical aide was therefore established if the Icelandic Scallop resource were ever to be commercially harvested. To further complicate the problem, the device had to be small and inexpensive if it were to be practical for the small outports servicing only a few day boats for a portion of the year. The "thermal shock" shuckers clearly did not suit the local need due to the high cost and large size of the equipment.

In 1976, the late Mr. Wilfred Gionet of Pidgeon Hill, N.B. approached the Department with an idea for a shucker. We supported his idea and approximately a year later he delivered his shucker for laboratory demonstrations. The device successfully

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eviscerated scallops but due to a variety of problems with the shucking knives and the solenoid operators, the actual meat removal was unsuccessful. Carriers were redesigned so that they clamped the bottom shell firmly and air cylinders were substituted to provide more control over the length of stroke and the applied force on the knife. In order to securely clamp the shell, it was decided to make two parallel cuts through the scallop to standardize them so that the machine could reliably clamp and control the scallop.

At about this time, Mr. Gionet suffered a fatal heart attack and work on the machine ground to a halt for a period of several months.

It was decided to continue the development using our own limited resources. The design arrangement was changed to allow loading of scallops onto a moving series of 29 carriers spaced about 6 inches apart on an endless conveyor. The scallop shell is oriented with the hinge facing away from the operator and must be large enough to overhang the concave carrier on both the hinge side and the opposite side. This is necessary as the scallop shell is first clamped by a spring-loaded belt conveyor and then conveyed past 2 parallel circular sawblades. The blades cut the hinge away and expose the scallop interior on both sides. This "standardizes" the width of the scallop shell which facilitates clamping and provides access to the meat. The bottom shell is then securely clamped by the spring-loaded clamping fingers and is conveyed to the first of a series of water jets that first remove the unclamped shell, then eviscerate and wash the meat or abductor muscle and finally sever the meat from the clamped shell.

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The first water jet is a solid beam or pencil of high pressure water that enters the opening provided by the saw cut opposite the hinge. The beam of water hits the unclamped shell, places a load on the muscle and conforms to the shell curvature perfectly severing the muscle from the shell. This unattached shell then drops away and the clamped shell with the meat and viscera still attached proceeds to the eviserator section.

The eviscerator section is a series of low pressure water fan jets that literally peel the viscera from around the abductor muscle. During this process, the muscle is thoroughly washed and the viscera and roe, which one day may be as valuable as the meat, is removed undamaged.

The meat now attached only to the clamped shell and having been eviscerated and washed is conveyed through the final water jet. This operation is a high pressure fan jet which directs a thin fan of high pressure water on the scallop shell where it conforms to the shell curvature and severs the meat perfectly from the shell. The meat then drops away to be collected. The shell is released and the carrier returns to the loading station to repeat the cycle.

It is our belief that this machine has been developed to the point where private enterprise can continue its refinement and be in a position to demonstrate under actual commercial conditions within 18 months.

To this end, we have demonstrated the prototype machine to approximately 16 potential manufacturers and are confident that further development will result

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in an efficient reliable aide to the scallop industry in general and potentially re-establish a profitable inshore Icelandic scallop fishery.

The net benefits that we feel will encourage the machines widespread application are as follows:

1. The machine's ability to shuck either Icelandic or Sea Scallops results in the freedom to fish either or both resources with equal ease. In the past, the Icelandic scallops resource has been largely ignored due to the extreme difficulty to manually shuck this type of scallop. The simplicity of the machine suggests that it will be extremely reliable and easily maintained. The only component presently requiring periodic maintenance apart from routine lubrication and cleaning is the circular sawblades.
2. There are no switching circuits to fail, and in its final form, little or no adjustments will be required due to variation in scallop size or type. The fact that the machine occupies so little space and requires only minimal power and water services suggests that the machine could be employed aboard the smallest of the scallop dragger fleet with little or no vessel modification.
3. The improvement in yield estimated to be in the order of 5 to 10% indicate that the machine could be justified on that basis alone. If one assumes a 5% yield improvement, $3.50 scallop meat value and a capital cost of $25,000 it can be shown that the capital cost could be recovered after processing approximately 143,000 pounds with the machine. What this means in simple terms is that if 143,000 pounds are landed using the machine, only about 136,000 pounds would have been landed without the

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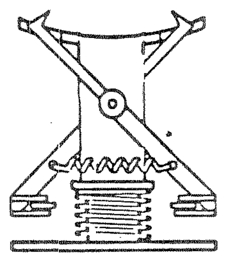
machine. The difference or 7,000 lbs. of scallop meat, valued at about $25,000 would have been discarded over board by the manual shuckers.

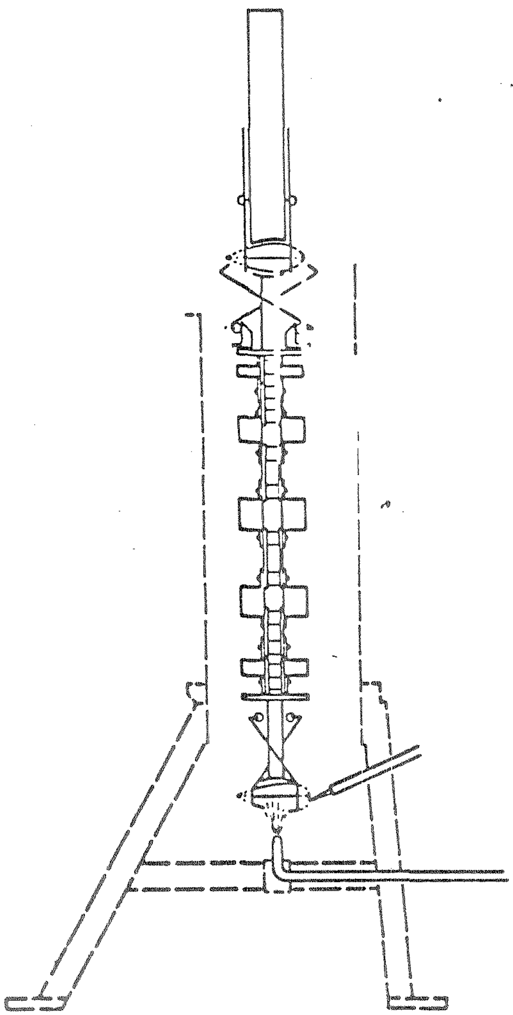
4. The fact that the scallop roe is removed undamaged suggests that it could be utilized at some future date for increased revenue with some additional manual handling and separation required. Apparently there are some limited European markets available but this requires further clarification and market research.

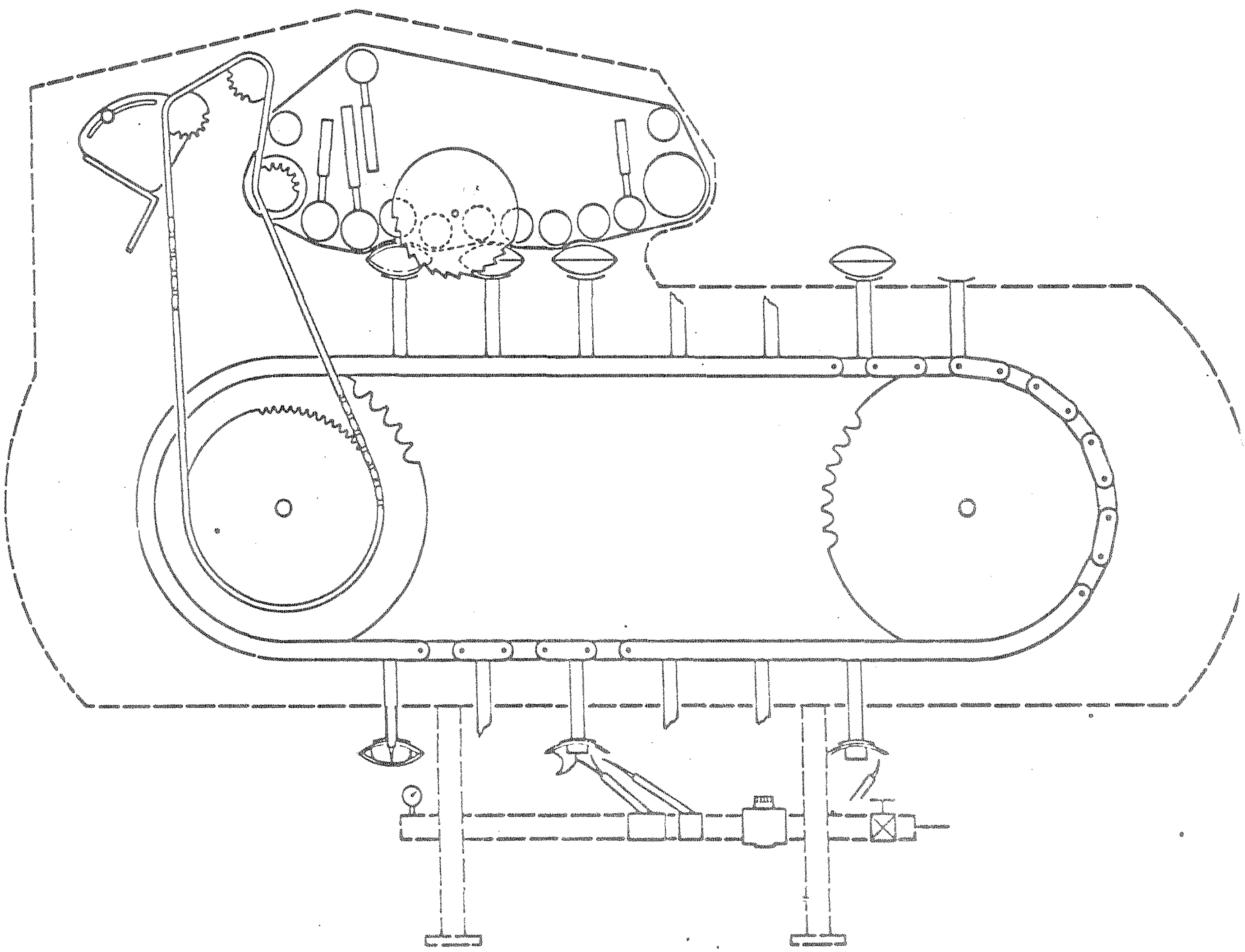
5. The fact that the scallops can be more rapidly shucked and thoroughly washed in the process cannot help but improve the overall quality of the landings. Often large volumes of scallops are left exposed to the sun and the elements for hours at a time eventually to be shucked and some hours later washed and bagged. By this time, the sand and grit are firmly embedded and the temperature of the meat is certainly much higher resulting in more rapid spoilage.

6. Finally, the manual shucking effort would be dramatically reduced for the offshore vessels in particular where it is not uncommon to find the entire crew including the captain and cook taking their turn at the shucking box for as long as 16 hours a day, 7 days a week, for up to 10 days at a time.

In short, we are very enthusiastic about the potential for the machine and are confident that it can be used to advantage.







AUTOMATIC SCALLOP SHUCKING MACHINE

SPECIFICATIONS

SIZE:	6'6" L x 2'0" W x 4'6" H
WEIGHT:	800 LBS.
CAPACITY:	60 SCALLOPS/MINUTE
	(90 LBS. MEAT/HR., ASSUMING 40 MEATS/LB.)
POWER REQUIREMENTS:	6 H.P.
WATER REQUIREMENTS:	8 G.P.M.
COST:	$25,000 (ESTIMATED COMMERCIAL UNIT COST)

AUTOMATIC SHUCKING MACHINE

BENEFITS

1. ABILITY TO SHUCK ICELANDIC OR SEA SCALLOPS
2. SIMPLICITY OF OPERATION AND MINIMAL SPACE AND ENERGY REQUIREMENTS
3. IMPROVED YIELD BY 5 - 10%

   ON A YIELD IMPROVEMENT BASIS THE CAPITAL COST OF THE MACHINE COULD BE RECOVERED AFTER PROCESSING APPROXIMATELY 143,000 LB. OF MEAT

   ASSUMING: 5% IMPROVEMENT IN YIELD
   $3.50/LB. SCALLOP MEAT
   $25,000 CAPITAL COST OF MACHINE
4. REMOVAL OF SCALLOP ROE UNDAMAGED

   THERE IS A POTENTIAL MARKET OF SCALLOP ROE IN EUROPE
5. IMPROVED MEAT QUALITY

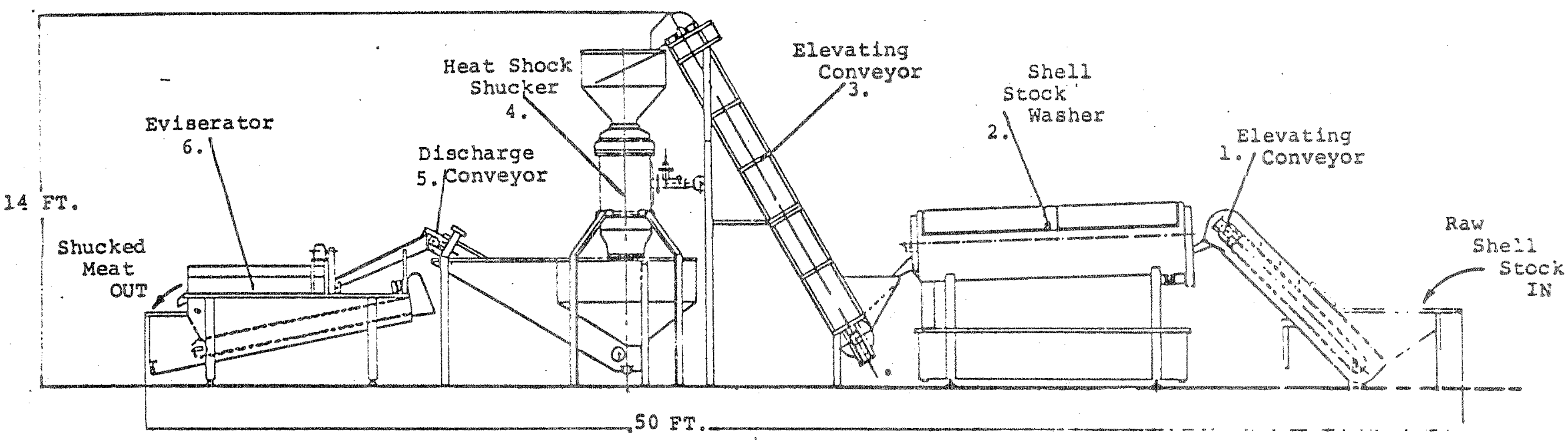
   DUE TO MORE RAPID SHUCKING AND THOROUGH WASHING
6. REDUCTION IN MANUAL SHUCKING EFFORT

   OFFSHORE SCALLOPS OFTEN WORK 16 HRS. A DAY, 7 DAYS A WEEK FOR UP TO 10 DAYS AT A TIME

TYPICAL "THERMAL SHOCK" SHUCKER

CAPACITY 6,000 LB./HR.

COST $150,000 +



(C) ATLANTIC SHORT-FIN SQUID *(Illex illecebrosus)*

C.1 INTRODUCTION

Changing international trade patterns and the new jurisdiction have radically affected the size and diversity of the Atlantic squid fishery. In the past decade, the squid fishery has evolved from a small bait fishery into an export-oriented food industry with expected landings of more than 100,000 metric tons in 1979. To realize the full potential of this underutilized resource, it is essential that the appropriate methods of harvesting, handling, preservation, and quality assurance be acquired and adapted.

The preservation of the fresh skin colour and of the eating quality of the meat are important factors in the Japanese squid market. Tentative guidelines for judging the quality of squid have been proposed (Woyewoda and Ke, 1979). In this report, the physical and simplified organoleptic methods used for this evaluation are described, and applied in investigating the relative effectiveness of chilled seawater (CSW) and non-contact icing (NCI) in preserving the quality of squid.

C.2 CHILLING INVESTIGATIONS

Squid caught by trap nets or hand jiggers and landed in the coastal area of Nova Scotia from July to October, were used for this study. The size of squid was 35-45 cm and the weight ranged from 150-300 g. The squid were landed onshore less than two hours after catching. They were transported to the laboratory and the plants and used in the experiment within 30 minutes after landing.

A polyethylene "Ship-to-Shore" tote box (79 cm long x 46 cm wide x 28 cm deep; made by Can-Am Containers, Ltd., Nova Scotia) and a fiberglass container with top cover, insulated with 1.8 cm foam urethane (90 cm long x 56 cm wide x 50 cm deep; made by Bartek Ltd., Nova Scotia) were used for storage of samples. Both containers were equipped with 1 1/4-inch side drains and plugs.

Handling Procedures

Round squid were held in chilled seawater (CSW), in non-contact ice (NCI), in fresh water ice (CON-1) and without ice at room temperature (CON-2), for our investigations.

A. Non-Contact Icing of Squid

Squid were chilled by non-contact icing (NCI) in the described containers by placing a 2-ml plastic film between the ice and two layers of squid. The ratio of squid to ice was 2:1. The melt water was drained without contacting the squid. Each container held three sets of squid of about 40 kg between four layers of ice. Thus, NCI-1 refers to storage of squid using the tote box; NCI-2, to similar storage in the insulated box; and NCI-4, is the same as NCI-2, but 1 litre of seawater or brine was added on each of the squid layers.

B. Chilled Seawater Storage

CSW-1 and CSW-2 refer to storage of squid in chilled seawater in the tote box and in the insulated container, respectively. About 15 kg (33 pounds) of ice and 15 litres (3.5 gallons) of seawater or brine were added to the container and mixed well, then about 45 kg (99 pounds) of squid were added. The ratio of squid/ice/seawater was maintained at about 3:1:1 as in the previous report (Lemon and Regier, 1976). The temperatures of the top and bottom inside the CSW unit at commencement of storage were -1 and -0.5°C. Both temperatures increased to about 1.0°C on the top part and 2.5°C at the bottom of the container after two days storage when ice was added to the CSW container. No mixing was provided in the CSW containers since the purpose was to keep the squid in the simplest manner suitable for the inshore fishery.

C.3 COMPARISON OF HANDLING AND STORAGE METHODS

In order to develop some simple and practical storage methods for squid during the period of holding and transportation after catching, some investigations with CSW and NCI were made (Table 12). For a holding time of up to five days, the quality of fresh squid kept by CSW and NCI in the insulated containers has been evaluated and compared by using the recommended physical and organoleptic methods. By applying the proposed grading guide, the percentages of squid of excellent quality at different sampling times in CSW and NCI have been determined and compared in Table 13. The data indicated that, under the same operating conditions, NCI can hold the fresh whole squid at Grade A quality for a longer time than CSW storage. But CSW holding with air mixing should increase the keeping time as reported previously. However, the described methods for handling squid in CSW and NCI in this report can satisfactorily meet the requirements to give a keeping time of two days as excellent quality, and more than three days as acceptable squid.

The contact-icing of squid directly with fresh water ice is not a proper means for handling squid since some disadvantages could arise, such as catalyzing the skin discolouration, changing the texture, flavour, etc. The results (CON-1, Table 12) have shown that the squid kept in contact-icing were decolourized in less than 12 hours and could not be considered as acceptable for food use for more than one and a half days. Squid kept at room temperature without refrigeration (CON-2, Table 12), lost the reddish-brown colour within four hours, and the quality became unacceptable after 10 hours of storage. On the other hand, the holding squid in chemically modified seawater can slightly improve the keeping time and preserve the quality, but this would involve additional operating costs.

By using the proposed guidelines, the keeping times estimated for the squid in various CSW and NCI tests are presented in Table 5. The best handling method for fresh squid (NCI-4) was non-contact icing in the insulated box and adding a small amount of seawater to each squid layer. This method may extend the keeping time of Grade A squid by about 100% compared to NCI (NCI-1). The modified NCI holding method with added seawater can be advantageous in that it evens out storage temperature, increases the ionic strength to inhibit the colour changes, and reduces weight losses. Comparing the results from NCI-1 with NCI-2, and CSW-1 with CSW-2, the data show that the storage life of squid in the insulated containers (NCI-2, CSW-2) was about 50% longer than in the tote box, and more than six times longer than in contact-icing (CON-1). In general, NCI holding of squid can preserve the quality slightly better than CSW storage. But both NCI and CSW, with the insulated or uninsulated box, can be used for holding squid for at least two days in excellent quality and skin colour, and for more than three days at acceptable quality.

C.4 QUALITY EVALUATION PROCEDURES

During the storage, a sample consisting of 12 squid was taken randomly and evaluated for physical and organoleptic quality. The sample then was placed in a plastic bag and stored at -25°C until further analysis. Chemical analyses, such as total volatile bases (TVB), free fatty acids (FFA), trimethylamine (TMA), and thiobarbituric acid value (TBA), etc. were used occasionally and the results were presented in other reports.

(1) Physical Method

The samples taken from the holding container were placed on a white plastic cutting board without washing or other treatments and examined by three judges. Evaluation of squid quality was based on the skin colour, texture, mantle conditions and odour. The guidelines and working sheet on squid quality evaluation by the physical method is described in Table 14. The average, with standard deviation calculated from these data, was used in the present investigations.

(2) Organoleptic Method

The sample preparation for organoleptic evaluation was similar to that described earlier (Botta et al., 1979; Woyewoda and Ke, 1979). Five round frozen squid were placed in a plastic bag and thawed in water (20°C) for two hours. The skinless mantles were cleaned and placed on the top of a perforated baffle (one cup of water beneath the baffle) in a pan, and then steamed for 36 minutes. The cooked mantles were subdivided and kept warm for the taste panel evaluation. A panel of five judges rated the quality of samples by a three-grade and five-point scale as described in Table 15.

C.5 PROPOSED SQUID QUALITY STANDARDS

Recently we have developed some objective methods for the evaluation of the quality of squid in field and laboratory, and these have been satisfactorily used for our various investigations of squid development projects and tested by experienced fish inspectors. The recommended physical quality method is based on a combination of the texture, skin colour, mantle stain formation and odour. It can be applied to examine the quality of fresh and frozen squid by anyone without requiring any scientific skills.

The correlation of the results between physical and organoleptic is good. However, the utilization of a taste panel, even when using the simplified procedure, was found to be time consuming and not suitable for field use. But the described organoleptic test method is recommended for quality assessment when routine evaluations need confirmation. For the advanced research and laboratory studies, chemical methods of quality evaluation could be more suitable.

The recommended guidelines for assessing the overall acceptability of squid in terms of physical data (Table 14) and taste panel results (Table 15) have been employed successfully for various investigations. We believe that the proposed standards can be used by the Canadian squid fishery for assessing and grading the quality of fresh and frozen round squid. The more detailed five-point scale shown in Tables 6 and 7 is only used as a reference scale in this report. For all experiments in this study, a three-grade system - Grade A (excellent; 4-5 points); Grade B (acceptable; 3 points); and Grade C (unacceptable; less than 2 points) - was used for estimating the storage life by various handling methods.

C.6 QUALITY GRADING FOR DRIED SQUID

The grading operation for dried squid is very difficult for our fishing industry because it is a non-traditional species. The summarized procedures and guidelines are presented in Table 16. The details of this assessment can be obtained from the previous Canadian Technical Report of Fisheries and Aquatic Sciences, No. 900, published in 1979.

C.7 SUMMARY

Methods of quality evaluation and handling of fresh Canadian Atlantic squid *(Illex illecebrosus)* are described. A physical quality examination based on skin colour, texture, mantle condition, and odour has been developed and recommended to the squid fishery for routine quality grading in the field. An organoleptic test procedure is also presented. Simplified guidelines for a three-grade system based on each procedure have been applied satisfactorily in various squid studies.

By using the proposed guidelines, the keeping time of squid in various handling methods using chilled seawater (CSW) and non-contact icing (NCI) have been estimated. Non-contact icing handling can preserve the quality of squid slightly better than CSW storage. A modified NCI method, with some seawater added to the squid, gave the longest keeping time. Both NCI and CSW, with various containers, can be used for holding squid for at least two days with excellent quality and skin colour, and for more than three days with acceptable quality. Standards for evaluating dried squid are also recommended.

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TABLE 12. Comparison of the Keeping Time For Squid With Various Handling Methods

Handling Method*	Keeping Time (Day)	
	A Grade	B Grade
Non-contact Icing		
NCI-1	2.0	3.0
NCI-2	3.0	4.0
NCI-4	4.0	5.0
Chilled Sea Water		
CSW-1	2.0	2.5
CSW-2	2.5	4.0
Controls		
CON-1	0.5	1.5
CON-2	0.2	0.4

TABLE 13. Quality Preservation of Squid by Using CSW and NCI Assessed by Physical Method

Time (Day)	% of Grade A Squid $\pm$ SD	
	CSW-2	NCI-2
1	100 $\pm$ 1	99 $\pm$ 1
2	82 $\pm$ 2	90 $\pm$ 2
3	59 $\pm$ 7	68 $\pm$ 8
4	39 $\pm$ 9	46 $\pm$ 8
5	28 $\pm$ 6	35 $\pm$ 5

TABLE 14. Grading Guide to Evaluate the Quality of Round Squid

Grade	Point	Overall Quality	Criteria: Skin Colour	Texture	Inside Mantle	Odour
A	5	Excellent	sheen, red-brown	elastic, firm	sheen off-white	squid odour
	4	Good	red-brown	firm	slight sheen, no stains	squid odour
B	3	Acceptable	grey-white	reasonably firm	few yellow stains	slightly fishy odour
F	2	Unacceptable	some pink spots	slightly soft	some brown-green stains	offensive odour

TABLE 15. Simplified Guidelines Used For the Organoleptic Tests to Evaluate the Quality of Squid

Grade	Point	Overall Quality	References of Standards
A	5	Excellent	- sheen, off-white colour - firm, rubbery texture - fresh squid (seawater) flavour
	4	Good	- creamy to yellowish appearance - rubbery, slightly chalky texture - slight cabbage flavour and odour
B	3	Fair and Acceptable	- yellow to light brown colour - sticky (outside) and crumby (outside) - stronger cabbage flavour and odour
F	2	Unacceptable	- no sheen, brown colour - slight mushy, slimy texture - unpleasant ammonical odour
	1	Spoiled	- pinkish brown colour - offensive odour - very mushy and curdy texture - very bitter and cheesy flavour

TABLE 16. The Proposed Standards For Assessing the Quality of the Dried Canadian Squid

Grade	Overall Quality	Physical Appearance	%, Moisture Content	Total Volatile Bases, mg%	Rehydration Tests
A	Excellent	- sheen, amber colour - very flat and symmetric - fresh squid odour - a little white powder - 50 g or over	18-22%	Less than 140 ± 5	- soft but elastic - about 50% water
B	Acceptable	- brown colour - fair flat - white powder over surface more than 20% - strong squid smell - between 30-50 g	17-23%	140-200	- soft but less rubbery - 40-50% water
F	Unacceptable	- blackening or reddening over more than 20% of surface - white powder over surface - objectionable smell - not flat or bad shape - less than 30 g	$<$17% or $>$23%	200	- too soft or not soft - bad smell - less than 40% water

(D) ATLANTIC SEA CUCUMBER *(Cucumaria frondosa)*

D.1 INTRODUCTION

A number of harvestable, apparently abundant marine species remain underutilized in the Atlantic provinces due to unacceptability in the local market and lack of developed export markets. Of recent note is the squid fishery which has developed over the last several years from primarily an inshore bait fishery to an offshore fishery, selling the product as a consumer food item in Asian and European markets. Local industry now processes squid, harvested partly by domestic inshore fishermen, for export. Thus, the exploitation of one previously underutilized species has contributed to increased development in the Maritime fisheries industry.

Recent interest has been shown by a fisherman and at least one processor in developing a sea cucumber fishery for export to the Orient where it enjoys great popularity as a consumer food item.

A major difficulty encountered in development of unconventional fisheries is in establishing objective quality criteria for the marketed product. This is especially important for products destined for export to markets in which established consumer satisfaction levels exist. Inshore fishermen must maintain a quality level equal to that obtained by offshore factory freezer trawlers to allow local packers and processors to penetrate foreign markets. Handling methods and objective quality criteria pertinent to the sea cucumber fishery were developed and described.

D.2 EXPERIMENTAL HARVESTING

Four hundred and twenty-four (424) sea cucumbers were obtained with the aid of a local fisherman in St. Mary's Bay off Saulnierville, Nova Scotia on November 18, 1980. Two one-metre Digby scallop drags were utilized in a tandem offset configuration in 9-11 metres depth at low tide. The cucumbers were transported to the regional Fisheries Laboratory in Halifax in a truck-mounted seawater tank and held in 500-litre tanks supplied with filtered seawater at ambient temperature and aeration. Stocking density was 30-40 cucumbers per tank. Animals used in experiments were selected randomly from all tanks.

D.3 HOLDING EVALUATION

Two seven-day experiments were carried out to determine optimum handling techniques for sea cucumber. In the first experiment, 23 live cucumbers were placed on trays, covered with plastic food wrap and held in a 5°C cold room. Each day, morphometrics and physical characteristics (odour, colour, texture, hardness, mucus buildup) were noted and separate samples of body meat and viscera were obtained for chemical analysis.

The second experiment utilized six treatments with 10 sea cucumbers in each group. Two groups were placed in trays and covered with plastic wrap; one was placed, as before, in a 5°C cold room (5°C air), another at room temperature (20°C air). The third group was left in non-circulating, un-aerated seawater (SW) with a mean temperature of 10.8°C. This treatment was terminated at day 3 when aeration and seawater flow were inadvertently resumed by aquarium room staff. The fourth group, cold seawater (CSW), was placed in an insulated container of 50% crushed fresh-water ice and 50% seawater. A fifth group, contact ice (CI), was layered within crushed, fresh-water ice in an insulated container. In the sixth group, non-contact ice (NCI), sheets of polyethylene separated the cucumbers from surrounding layers of fresh-water ice in an insulated container. The latter three groups were all kept in the 5°C cold room for the duration of the experiment.

The results of various holding tests are summarized in Tables 17 and 18. Cold seawater holding for sea cucumbers proved to be the best handling method, maintaining the animals alive for the duration of the experiment. Contact ice storage resulted in frostbite and death due to osmotic shock after the fresh-water ice melted. Non-contact ice handling delayed contact with fresh water, but frostbite was evident and eventual flooding of the layers containing the sea cucumbers resulted in death. Even though the animals were of acceptable quality in CI and NCI groups at the end of the experiment (excluding those with frostbite), the meat was wrinkled and water content higher due to osmotic imbalance. Animals may be maintained in non-circulating, un-aerated seawater (SW group) for one or two days before becoming unacceptable. The cold seawater treatment (CSW) owes its success to the hypo-saline tolerance of sea cucumbers and low temperature.

Holding round specimens in room temperature air was utilized only a a control group and is unacceptable as a handling procedure. Although specimens may be held in 5°C air for up to five days, this is not a practical method for fishing industry use.

Three methods of pre-processing handling have merit. Cold seawater (CSW), in insulated containers, is practical where ice is available for inshore fishermen. The inshore fishery might also make use of floating, slatted lobster pounds to hold cucumbers prior to shipment in CSW containers. Major fish plants might make use of existing large-scale refrigerated seawater facilities to hold cucumbers for a day or two prior to processing. In any case, it is recommended that cucumbers not be held for periods longer than a week prior to processing in order to maintain excellent quality.

D.4 QUALITY CRITERIA

Approximate composition of sea cucumbers is listed in Table 19. The physical and chemical guidelines for quality assessment of sea cucumbers is summarized and presented in Table 20.

The ranges of biochemical quality indicators are affected by the original biochemical composition of the organism. The restricted ranges of TVB and FFA for sea cucumber, compared to those for squid tissue, may be explained by lower percent values of crude protein and crude fat and higher percent water content for sea cucumber meat. As an example, the percent crude protein for sea cucumber meat was about 12% of weight, about two-thirds of that for clam and oyster meat. This may be attributed to the comparatively high collagen content (about 3% of total nitrogen) in the meat portion of sea cucumbers, at least three times the values found for fish and about equal to values for squid.

Considering both the results of Tanikawa (1955) and this study, preliminary quality levels for meat based on TVB (mg-N/100 g) are recommended as outlined below:

EXCELLENT QUALITY (GRADE A) - 10
ACCEPTABLE QUALITY (GRADE B) - 10 TVB 15
UNACCEPTABLE QUALITY (GRADE F) - 15

Good on-sight criteria for quality assessment of sea cucumbers are physical criteria of odour, skin and mucus colour and mucus viscosity (Table 20). Rigor-mortis may be identified by comparative stiffening of the body meat. Odour, colour and mucus viscosity are the best physical quality assessments since they require no serial comparison over time to be used effectively. Frostbite destroys tissue so quickly that once observed, the meat is already unacceptable due to local physio-chemical deterioration (a faint sulphur smell may be noticeable from the frostbite wound). Similarly, wounds incurred in harvesting deteriorate quickly and rapidly make the meat unacceptable.

Advanced spoilage seems to be well correlated to sulphide odour and purple discolouration which could be caused by anaerobic bacterial action or accumulation of mercaptens. This aspect warrants further microbiological and biochemical investigation and development of a chemical test for mercaptens that could prove useful as a quality assessment tool. In addition, wound or frostbite discolouration should be microbiologically and biochemically investigated.

D.5 EXPERIMENTAL PREPARATION OF DRIED SEA CUCUMBER (DSC)

Fifty fresh, live sea cucumbers were eviscerated by making a longitudinal cut and removing viscera by hand. Intestines were carefully separated from gonad and both were retained for weighing and further processing. All pieces of body meat were boiled for 60 minutes in 3% NaCl using a commercial steam cooker. The meats were then cooled and dried by one of two methods. A few samples were placed in a vacuum drying oven at room temperature ($20^{\circ}C$); the remainder was placed on racks in an operating fume hood at room temperature. Moisture content was subsequently determined in a vacuum drying oven at $60^{\circ}C$. Figure 6 is a process flow diagram of this operation.

Salting of gonad and intestines was also investigated, treating three samples of each separately. After draining off excess water, samples were covered with 20% NaCl by weight and allowed to stand 20 minutes at room temperature ($20^{\circ}C$). Excess water removed in the salting process was drained off and weighed.

The weight balance of dried sea cucumber production of each step of operation is summarized and listed in Table 21. The overall yield of DSC from live weight is about 5%.

D.6 SUMMARY

Handling, quality evaluation criteria and utilization of sea cucumbers *Cucumaria frondosa* (holothuria), were investigated to provide a preliminary data base for a potential fishery. The study indicated chilled seawater was the best handling method for maintaining quality prior to processing of sea cucumbers. Various quality indicators have been tested for evaluating the quality changes during various holding studies. Total volatile bases (TVB), however, are proposed to be used for grading sea cucumber quality. Total volatile bases levels below 10 mg-N/100 g indicate unacceptable meat quality. Physical criteria for quality assessment were also developed, based primarily on appearance, colour, odour and mucus condition. Chemical criteria compare well with physical results and may complement each other in quality assessment of sea cucumbers.

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TABLE 17. First Occurrence of Physical Criteria (in at Least Two Individuals Per Group). Day Criterion First Observed Shown

* - indicates only two individuals exhibited criterion

B - acceptable grade

F - unacceptable grade

TREATMENT	Frostbite Blemish (F)	Mucus Viscous (B)	Sloughing off Mucus, Skin (F)	Respond Slowly to Stimulus (B)	No Response to Stimulus (F)	Sour Odour, Sliced Open (B)	Odour; Strong Sulphide Sliced Open (F)	Purple Colour to Skin, Mucus (F)
5^{o} C Air		3	5	3		3	5	5
20^{o} C Air		1	3			1	3	2
CSW	3*							
NCI	1			2				7
CI	1				7			
SW		2	3			3		3

TABLE 18. Percent Moisture and Mean Whole Weight of Sea Cucumbers in Various Holding Experiments

PERCENT MOISTURE

DAY		0	1	2	3	4	5	6	7
5^o C Air	M	83	83	84	80	-	80	-	80
5^o C Air	V	81	91	72	78	-	77	-	-
20^o C Air	M	80	83	83	82	82	-	-	-
CSW	M	-	86	86	85	84	-	-	85
NCI	M	-	83	84	83	86	-	-	85
CI	M	-	82	86	84	87	-	-	84
SW	M	-	84	83	85	-	-	-	-

"M" denotes meat portion; "V" denotes viscera

MEAN WHOLE WEIGHT (grams)

DAY	0	1	2	3	4	5	6	7
5^o C Air	356	352	-	328	-	294	281	276
CSW	450	511	472	450	447	-	-	437
NCI	437	394	365	353	341	-	-	346
CI	391	360	353	377	376	-	-	370
SW	430	405	530	555	-	-	-	-

TABLE 19. Approximate Composition of Sea Cucumber Meat and Viscera

COMPONENT	MEAT	VISCERA
% of round S.C.	52	
Crude protein %[1]	13.8	12.4
Fat %[2]	0.7	7.8
Ash %[3]	2.7	
Water %[4]	82.0	80.1

[1]Protein was determined on an automated Kjeldahl analyzer (Technician Instrument Co. Limited)

[2]Fat was determined by the chloroform-methanol extraction method of Blight & Dyer (1959).

[3]Samples were ashed at 525°C. until weight was constant.

[4]Water was measured by heating samples at 60°C. in a vacuum over until the weight was constant.

TABLE 20. Physical and Chemical Indicators For *Cucumaria frondosa* Quality

		Excellent A	Acceptable B	Unacceptable F
Round Product	PHYSICAL	-wet, glossy appearance to skin surface -mucus generally does not stick to fingers -responds immediately to touch by contraction -slight fresh fish smell	-mucus thicker, sticky -relaxed and limp when picked up, with slow contraction response -sour milk odour -sour or slight sulphide (rotten egt) odour when cut open	-no resp. to touch; rigor-mortis -may have ejected internal organs anteriorly without being disturbed -slight sulphide odour to meat -strong sulphide odour to viscera -reddish-purple blemishes from frostbite if kept in CSI, NCI or CI -mucus sticks to fingers; skin and mucus sloughing off -purplish colour in mucus, on skin, esp. on ventral
Viscera Blended	PHYSICAL	-watery, runny consistency -orange colour (bright) -unobnoxious fresh fish odour (slightly sweet)	-pasty consistency -darker orange colour -sour or slight sulphide odour	-pasty consistency -further darkening of c-lour -strong sulphide odour
Meat Blended	PHYSICAL	-as for viscera, but grey colour	-pasty consistency -sour odour	-pasty consistency -sulphide odour
Meat	CHEMICAL	TVB 10 mg-N/100 g	15 mg-N/100 g	15 mg-N/100 g
	CHEMICAL	FFA 2 u moles/g	5 u moles/g	5 u moles/g

TABLE 21. Summary Table For Drying Experiment

	% of Live Weight	Weight of (kg) Sample
Meat not sliced - 30 animals		
Step 1. live weight	100	13.8
2. eviscerated		
- meat	36	4.9
- gonad	17	2.3
- intestine	3	0.39
- water	47	6.4
3. remove muscles		
- meat	25	3.4
4. boil for 60 minutes		
- meat	13	1.8
5. dried until inflexible in fume hood		
- meat	5	0.66

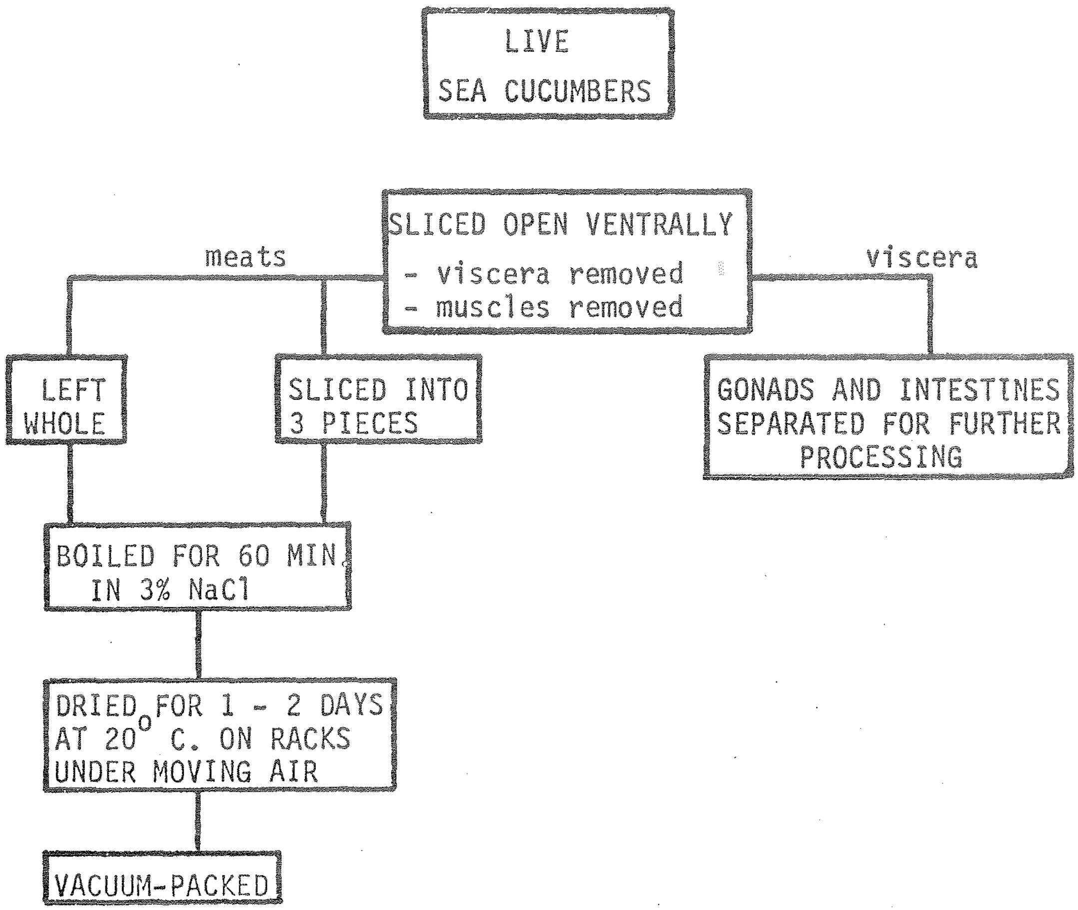

Figure 6. - Flow diagram of drying process for Dried Sea Cucumber (DSC).