QUALITY IMPROVEMENT INVESTIGATIONS FOR ATLANTIC QUEEN CRAB (CHIONOECTES OPILIO)

A. OBSERVATIONS ON HANDLING AND HOLDING OPERATIONS.

B. POST-MORTEM DETERIORATION, DISCOLORATION AND TIME/TEMPERATURE EFFECTS.

C. OBJECTIVE METHODS FOR QUALITY GRADING.

D. REVIEW AND SUMMARY OF VARIOUS TECHNICAL INFORMATION.

P. J. KE, B. SMITH-LALL AND A. B. DEWAR

AUGUST 1981

FISHERIES AND MARINE SERVICE
TECHNICAL REPORT NO. 1002

Government of Canada Fisheries and Oceans
Gouvernement du Canada Pêches et Océans

Canadian Technical Report of Fisheries and Aquatic Sciences

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Can. Tech. Rep. Fish. Aquat. Sci.
~~Fisheries and Marine Service~~

Technical Report

No. 1002

AUGUST 1981

QUALITY IMPROVEMENT INVESTIGATIONS FOR ATLANTIC QUEEN CRAB (*CHIONOECTES OPILIO*)

A. Observations on Handling and Holding operations.

B. Post-mortem deterioration, Discoloration and Time/ Temperature effects.

C. Objective methods for Quality Grading.

D. Review and summary of various Technical Information.

BY

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ABSTRACT

Ke, P. J., B. Smith-Lall, and A. B. Dewar. 1981. Quality Improvement Investigations for Queen Crab (*Chionoecetes opilio*). Can. Tech. Rep. Fish. Aquat. Sci. 1002: 74p.

Quality enhancement studies for Atlantic Queen Crab (*Chionoecetes opilio*) fishery have been comprehensively carried out in terms of handling, grading, and of various related operations and technical improvements. This publication contains four independent reports: (A) Preliminary observations on handling and holding operations for Atlantic queen crab prior to processing; (B) Quality assurance investigations on Atlantic queen crab, in terms of post-mortem biochemical deterioration, discoloration, and time/temperature effects; (C) Objective scientific methods for assessing freshness and quality of queen crab; and (D) Review and summary of various technical information concerning Atlantic queen crab and related crab species. Reports A, B, and C, including experimental results and technical discussions, are the original work of this laboratory. Report D is a comprehensive literature review, but some selected papers have been completely summarized in the attached appendices. In conclusion, it is aimed that this publication should provide up-to-date information on the Atlantic queen crab fishery in order to improve the overall quality and operations.

Key words:

RÉSUMÉ

Ke, P. J., B. Smith-Lall, and A. B. Dewar. 1981. Quality Improvement Investigations for Queen Crab (*Chionoecetes opilio*). Can. Tech. Rep. Fish. Aquat. Sci. 1002:

On a mené des études d'ensemble sur l'amélioration de la qualité du crabe des neiges de l'Atlantique (*Chionoecetes opilio*) dans ses aspects manipulation, classification et les diverses opérations et améliorations techniques qui s'y rattachent. La présente publication contient quatre rapports indépendants; (A) Observations préliminaires sur la manipulation et la conservation du crabe des neiges avant transformation; (B) Recherches sur la qualité du crabe des neiges en termes de détérioration biochimique postmortem, décoloration et effets de la relation temps-température; (C) Méthodes scientifiques objectives d'évaluation de la fraîcheur et de la qualité du crabe des neiges; et (D) Revue et résumé des connaissances techniques sur le crabe des neiges de l'Atlantique et autres espèces apparentées de crabes. Les rapports A, B et C, y compris résultats expérimentaux et discussions techniques, découlent de travaux originaux de ce laboratoire. Le rapport D contient une revue d'ensemble des travaux publiés; certains articles ont toutefois été entièrement résumés en annexes. Comme conclusion, le but de la présente publication est de fournir une information à jour sur le crabe des neiges de l'Atlantique et améliorer de cette manière la qualité et les opérations dans leur ensemble.

(A) PRELIMINARY OBSERVATIONS ON HANDLING AND HOLDING OPERATIONS FOR ATLANTIC QUEEN CRAB PRIOR TO PROCESSING

INTRODUCTION

Some quality problems have been experienced over the past few years in the Atlantic crab industry. The production of consistently high quality crab finished products is dependent on the initial quality of raw queen crab prior to processing. Therefore, 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 becomes particularly important in 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 on board and maintained in a chilled condition during transport.

The handling methods for providing top quality crab (live crab) to the industry have been thoroughly discussed in the 1969 meeting on Atlantic Crab Fishery Development (Anon., 1969). 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 (Longard and Regier, 1970). However, the application of these improved handling procedures to our crab fishery is very limited (Varga *et al.*, 1969; Stewart, 1970). Therefore, some emphasis on technology transfer and/or development, 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 these preliminary observations and report is to describe the problems in our crab handling operations, and to reinvestigate 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 processing.

INVESTIGATIONS AND EXPERIMENTAL HOLDING TECHNIQUES

(a) Handling obervations: Four lots of Atlantic queen crab (*Chionoecetes opilio*) landed in the Maritimes area during the interval from June to September, 1980 were examined. The selection of landing area, time, dockside inspection or in-plant inspection prior to processing, were tentatively made without a systematic program. The limited results from these observations and examinations on the initial quality of queen crab are, in fact, the by-products of our present crab study project. The lots A, B, C and D containing 120, 161, 115 and 74 crabs respectively, were examined. However, the individual size and weight of the specimens were not recorded. The incidence of dead crab and a quality evaluation for lots A,C and D were conducted approximately 30 minutes after the crab were unloaded from the capture vessel. Lot B was examined immediately after the truck transport arrived at the processing plant. The details of each lot have been described in Table 1.

(b) Holding tests: The holding investigations were conducted on four separate holding techniques: icing, refrigerated sea water (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) using squid. The crab specimens used for these tests were landed in June of 1980 in N.E. New Brunswick. 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 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 center of the container was approximately 2°C.

(2) Refrigerated sea water (RSW): A 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/sec. The temperature was maintained at 6-8°C. The total volume of seawater was about 300 liters in this closed circulation system.

(3) 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.

(4) 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: 8-10°C, filtered seawater, water flow rate: 1 ℓ/min, and air flow rate 20 ml/sec.

RESULTS AND DISCUSSION

The preliminary observations of mortality and the degree of injuries of queen crabs landed from June to September of 1980 are listed in Table 1. The mortality rates varied from 12 to 58% when the crab were examined. About 10 to 20% of crabs were injured, and the mortality rate of those injured crabs was much higher than the undamaged crabs. In fact, only 5% or less of all the crabs examined that had lost 2 legs or suffered a broken shell were alive. The mortality rate of crabs injured to varying degrees and held in chilled air at 5°C, is reported in Table 3. The results confirm again that the careful handling of crabs is the single most important factor for maintaining crab quality.

The data reported here are very limited and was obtained from our other studies. No conclusions should be drawn from the present results in order to avoid misunderstandings with our crab fishery. However, these observations do indicate that there may be some problem in our crab handling techniques, and a systematic investigation is certainly needed.

A comparison of the four holding techniques for queen crab, over a 10 day period, is presented in Table 2 in terms of mortality rates. The RSW is the best for holding queen crab for less than 25% mortality over a 10 day period, and the direct icing technique can only keep crab for no more than 3 days to maintain a 74% survival rate. The chilled air may be practical for holding crabs onboard and during transportation for up to 6 days, with a survival rate of 75%.

The circulated, aerated seawater control tank maintained under ideal laboratory conditions had a mortality rate of about 16% for 10 days, but this could not be recommended for the crab industry. The present results agree with previous investigations.

We believe that with RSW and CMA, crabs can be held for periods up to and possibly longer than 6 days with about 25% mortality. This would allow the capture vessels a 3-5 day fishing trip, and land a top quality crab for processing. The direct icing technique, however, may be only satisfactorily used for inshore fishing operations of short duration and subsequent road transport to the processing plant.

SUMMARY

For Atlantic queen crab landed in 1980, a preliminary investigation has been made with 4 sample lots, measuring the incidence of mortality and injuries. The percentage of mortality and injury are between 12% to 58% and 12% to 20%, respectively. Crabs injured to varying degrees were held in chilled moist air for 6 days. The results of this test and field observation, both showed that no more than 5% can survive the loss of 2 legs. A 50% survival rate was observed for the crabs that had lost 1 leg or had been dropped 1 m. A holding experiment employing the RSW, CMA and direct icing was carried out and assessed by measuring the mortality rate of the specimen crabs. The RSW and CMA were shown to be the most suitable methods for holding queen crab up to 6 days with less than 25% mortality. The direct icing method may be used satisfactorily for short periods of up to 3 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.

ACKNOWLEDGMENTS

The authors wish to thank Messers. K. Rodman (Fisheries Development Branch), D. Casavechia and F. Rahey, Jr. (Support Services Branch), and W. Wilford and G. Doucette (Field Services Branch) for their assistance on this investigation.

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SECTION A

TABLE 1. Preliminary observations of the landed quality of queen crab in 1980.

Samples	%, L (Live)	%, D (Dead)	% of total crab, L+D (D)			
			-1 leg	-2 legs	broken shell	soft shell
A (June/80, 3-day fishing trip, unlaoded, dockside, [1]NE-NB, 120 crabs)	75	25	9 (5)	3 (2)	1 (1)	0 (0)
B (June/80, fishing trip, duration unknown, trucked 6-8 hrs, in plant [2]E-NB, 161 crabs)	46	54	12 (7)	3 (3)	2 (2)	1 (1)
C (August/80, 1-day fishing trip, unloaded, dockside [3]BSL, 115 crabs)	88	12	7 (4)	2 (2)	0 (0)	2 (2)
D (Sept./80, fishing trip, duration unknown, unloaded, dockside, [4]N-NB, 74 crabs)	42	58	12 (8)	5 (3)	3 (3)	4 (4)

1. North-east New Brunswick
2. East New Brunswick
3. Baie St. Lawrence
4. North New Brunswick

TABLE 2. 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
RSW (aeration 6-8°C closed circulation)	8	14	22
CMA (chilled and moist air, 5°C)	16	26	48
Control Seawater Holding Tank (flow filtered seawater, 8-10°C, aeration)	10	12	16*

*About 40% mortality rate has been recorded for the crabs held in our laboratory seawater tank for 2 months with daily feeding.

TABLE 3. 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	16
Less 1 leg**	20	55
Less 2 legs**	50	95
Dropped** (1 m high)	30	45

*50 crabs were used as the control
**20 crabs were used for the tests, respectively.

(B) QUALITY ASSURANCE INVESTIGATIONS ON ATLANTIC QUEEN CRAB (*CHIONOECETES OPILIO*) IN TERMS OF POST-MORTEM BIOCHEMICAL DETERIORATION, DISCOLORATION AND TIME/TEMPERATURE EFFECT

INTRODUCTION

Atlantic queen crab (*Chionoecetes opilio*) fishery has become one of our important renewable resources in the Gulf area. From 1969, some reports have been published for improving and evaluating frozen and canned crab products (Dewar *et al.*, 1969; Varga *et al.*, 1969; Varga and Anderson, 1971; Dewar *et al.*, 1972; George, 1973). However, because of the lack of comprehensive information and technical data, there are wide gaps in our knowledge and understanding of the post-mortem quality changes of this resource during the period between catching and processing, with respect to the quality demands of the world market.

The present investigation attempts to identify the major quality deterioration problems for post-mortem crabs, prior to processing with regards to the development and establishment of the requirements for some practical handling operations. In this report, we have completed a comprehensive study on post-mortem biochemical, enzymatic and autolytic changes for round crab kept from 3 to 23°C after death. Various quality parameters were employed for monitoring the protein degradation and deterioration, fat hydrolysis and oxidation, discoloration as well as the formation of off-flavours, during the post-mortem stage. Based on the present findings, the selected conditions for handling of crab based on the time/temperature effects on the quality preservation have been described.

EXPERIMENTAL

SAMPLE PREPARATION

Queen crabs (*Chionoecetes opilio*) caught in St. Lawrence Gulf were used for this study. Three shipments landed in June, July and September, about 300 lbs of each shipment, were delivered to the Halifax Laboratory. The crabs were transported to Halifax by truck with RSW tank; about 50% of the crabs were alive and active upon arrival. The live crabs were kept in the tank with flowing seawater and aeration, at 8-10°C for at least 3 days before use. The live crab were killed by using thermal vacuum operation at 45°C for 30 minutes. All fresh killed round crabs were cooled in the low temperature laboratory (3°C) for 20 minutes before various post-mortem quality investigations were conducted after holding at 3, 13 and 23°C. At a certain time interval, about 4 crabs were taken and sectioned. The guts were combined to be used for some analysis. The crab sections were washed with running freshwater, and the body meat and leg meat were separated immediately from the uncooked sections. The body and leg meat samples were pooled together (respectively) and blended for various quality evaluations.

DISCOLORATION EVALUATION

Two different qualities of queen crab were used for the discoloration tests. The whole crab, the washed sections, the body meat (not blended) and the viscera in the shell after the sections were removed, were placed on the table with reasonable room light and air flow. The examination was made hourly for six hours for those crab samples at 3 and 23°C, respectively. All samples were examined by three judges using a modified 10-point scoring system as from the previous report by Varga and Dewar.

QUALITY ASSESSMENT BY VARIOUS BIOCHEMICAL INDICATORS

The body meat sample was used for all tests of the post-mortem crab quality at temperatures of 3, 13 and 23°C. The leg meat and viscera samples were tested also for a few investigations at 3°C. The six quality indicators used in this study were extractable protein nitrogen (EPN), thiobarbituric acid value (TBA), free fatty acids (FFA), total volatile base (TVB), pH and trimethylamine (TMA). The operating procedures for above determinations have been described in the previous reports (Ke and Woyewoda, 1979; Woyewoda and Ke, 1980; Part C of this report).

RESULTS AND DISCUSSION

By applying 6 biochemical quality parameters, the quality deteriorations of the post-mortem queen crabs held at 3, 13 and 23°C for 4 days have been measured and presented in Fig. 1. The enzymatic and autolytic changes as well as protein denaturation were measured by the increases of TMA, and FFA and EPN decreases as the curves shown in Fig. 1f, 1d and 1a, respectively. The changes of FFA (Fig. 1d), pH (Fig. 1b) and TVB (Fig. 1e) were used for the estimation of quality deteriorations from chemical decomposition, and enzymatic degradation in the crabmeat during the post-mortem time. The TBA value change is only used for rancidity and oxidative deterioration (Fig. 1c) (Ke *et al.* 1977). The changes of all quality indicators have shown non-linear curves as a function of the keeping time. These quality change curves have clearly shown an induction period prior to a rapid meat quality change, taking place by biomolecular reactions, except for TBA value and pH as shown in Fig. 1b and 1c. The rates of changes for all quality parameters are temperature dependent as shown in Fig. 1. The small negative change in TBA value may be due to some interfering reactions from carbohydrate in the crabmeat (Lauer *et al.*, 1974).

After comprehensive tests of various body meat samples and the correlation from the organoleptic results, two quality indicators, FFA and EPN, have been selected to be recommended for the quality assessment and grading of Atlantic queen crab prior to cooking or other processing. The applicable procedures and the proposed guidelines have been described in a separate report.

The reason for using body meat to study the quality changes is simply because it directly contacts the viscera, which contains various biochemical catalysts and microorganisms. However, the differential quality changes in body meat, leg meat and viscera at 3°C, were also investigated for the comparison as shown in Fig. 2. As shown in Fig. 2a, the production of FFA in guts is much faster than in body and leg meat samples. However, the FFA change in viscera cannot be used satisfactorily for quality evaluation uses due to poor reproducibility from this sample type. The irregular decrease of EPN and the relatively fast formation of TMA in leg meat samples may be caused by some catalytic reaction from its pigments.

The results of the black discoloration in various types of crab samples held at 3 and 23°C were summarized in Table 1. The rate of discoloration of the body meat under the same conditions, showed the order as; the crab section > the separated body meat > the whole crab. This may indicate that the discoloration is an oxidative reaction as reported previously (Boon, 1975). In comparing the data for crab of same initial quality but held at different temperatures, it may be concluded that the black discoloration in queen crab is certainly temperature dependent. Furthermore, the rate of discoloration on the crab meat is highly related to the initial quality. The low quality crab will give a very fast color change even at 3°C. Based on these results, we suggest that the crab should not be sectioned until cooking. In general, the discoloration in the round crab kept at 3°C takes place relatively slowly. The normal meat color can be preserved for more than 24 hours for good quality round crab held at 3°C.

The overall quality evaluations on Atlantic queen crab are based on post-mortem quality deterioration and black discoloration. Since both changes are temperature dependent, a proposed time/temperature relationship on the keeping quality of the post-mortem crab has been described and tested satisfactorily in our laboratory by using both chemical parameters and organoleptic examination. Post-mortem queen crab can be preserved at an acceptable grade for about 30 and 10 hours at 3 and 13°C, respectively. However, if the keeping temperature increased to 23°C for 2 hours or less, the crab meat would be certainly unacceptable for food uses.

SUMMARY

By applying 6 biochemical quality indicators and a 10-point discoloration scoring system, the comprehensive post-mortem quality deterioration of Atlantic queen crab has been investigated. Both biochemical and enzymatic changes in body meat samples are non-linear as a function of holding time at 3, 13 and 23°C. All quality changes in the post-mortem period are temperature dependent. Therefore, the crab meat quality can be preserved by using various chilling operations. A time/temperature relationship on post-mortem quality of queen crab has been described and tested in the laboratory. In order to keep the crab meat at an "acceptable" quality level for about 30 hours prior to processing, the round crab must be held at 3°C or lower.

ACKNOWLEDGEMENTS

The authors are grateful to Mr. Sandor Varga for his valuable discussion, and Mr. G. Landry and Mrs. J. Hingley for their technical assistance.

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SECTION B

TABLE 1. Discoloration in queen crab meat at various quality and keeping conditions.

Sample/quality/conditions		Discoloration point*					
		0	½	1	2	4	6 hour
Excellent quality at 3°C	whole	10	10	10	10	10	10
	sections	10	10	9	8	6	2
	body meat	10	10	10	9	8	5
	guts	10	10	8	6	2	-
Good quality at 3°C	whole	10	10	10	9	8	4
	sections	10	10	9	7	4	2
	body meat	10	10	10	9	7	4
	guts	10	9	7	4	2	-
Borderline quality at 3°C	whole	10	9	-	9	8	-
	sections	9	7	5	1	-	-
	body meat	10	10	8	5	3	-
	guts	9	6	2	-	-	-

*The 10-points scoring system is used to assess the development of blue discoloration; 10, no discoloration present; 9, slight trace of discoloration or evidence of graying of blood; 8, reasonably free of black discoloration; 7, black discoloration in one location; 6, slight black discoloration throughout the whole sample; 5, moderate discoloration through the whole sample; 4, excessive discoloration; 3-0, discoloration black (Varga, S., A.B. Dewar, and W.E. Anderson, 1969. Effect of citric acid on quality of heat processed crab. Dept. Fisheries & Oceans, In Proceedings for Meeting on Atlantic Crab Fishery Development, Can. Fish. Report No. 13: 169-174).

TABLE 2. Time/temperature effects on post-mortem quality of queen crab prior to processing.

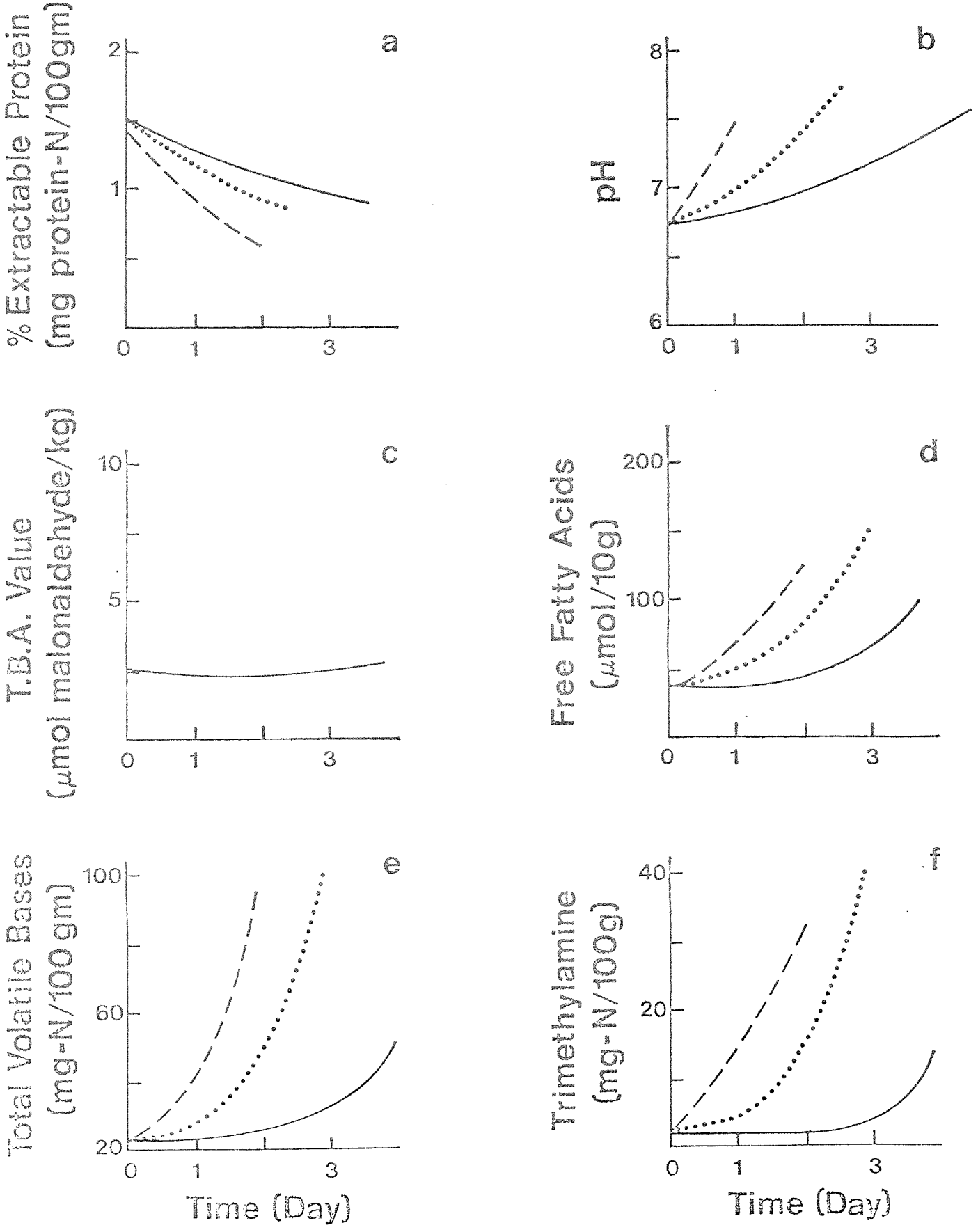
Temperature °C	Keeping time (hour)		
	Acceptable	Borderline	Unacceptable
3	<30	48	>48
13	<10	18	>18
23	-	2	> 2

SECTION B

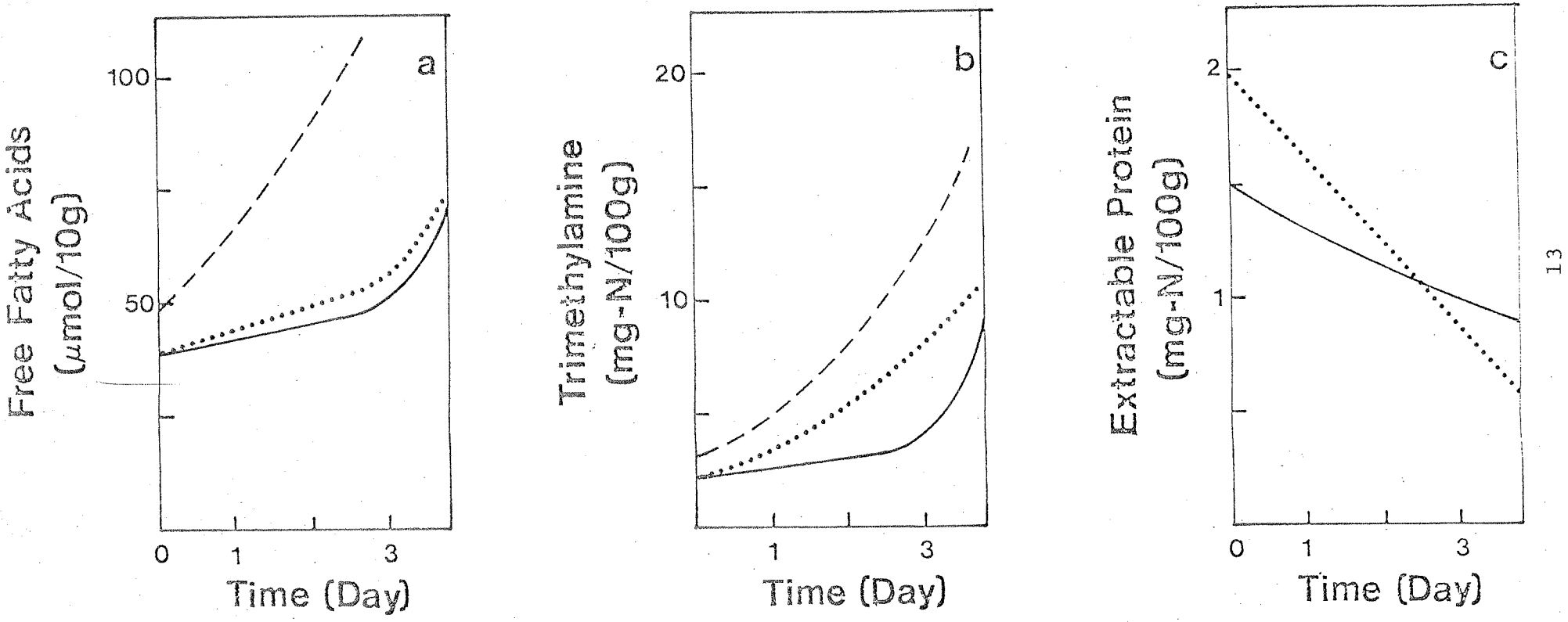
FIGURE 1. The post-mortem changes of various quality indicators in queen crab kept at 3 (——), 13 (·····) and 23°C (----).

FIGURE 2. The post-mortem quality changes of FFA, TMA and EPN in the body meat (_____), leg meat (·····) and viscera (----) from the crab held at 3°C).

SECTION B - FIGURE 1



SECTION B - FIGURE 2



(C) OBJECTIVE SCIENTIFIC METHODS FOR ASSESSING FRESHNESS AND QUALITY OF QUEEN CRAB (*CHIONOECETES OPILIO*)

INTRODUCTION

The production of consistently high quality Queen crab (*Chionoecetes opilio*) meat products is dependent on the quality of crab used. However, to date only physical and organoleptic assessments have been used to grade crab meat. These methods are time and labour intensive and are subjective in nature. An objective scientific method could give a more reliable and specific assessment of crab meat before it is processed.

Crab body meat is composed of approximately 16.0% protein, 0.86% fat, 1.71% ash and 82.9% water. The quality degradation occurs bacterially, enzymatically and chemically during post-mortem storage of crab meat. Of prime importance is bacterial degradation. While living, all organisms have protective mechanisms barring the entrance of bacteria. When an organism dies, bacteria from the environment and the digestive tract quickly invade the body and secrete enzymes that begin digestion of tissues.

Another source of degradation or spoilage is through enzyme action. Enzymes are proteins which serve as catalysts and are responsible for metabolic processes which occur in living tissue. A delicate state of enzyme equilibrium and control maintained by body regulators exists in living organisms however. After death, this system no longer functions and enzyme reactions proceed unhindered. Enzyme degradation reduces the structural proteins to smaller submits producing the familiar foul smelling substances associated with spoilage.

Chemical reactions also occur resulting in the breakdown of tissue and further accumulation of degradation products. The rates of both autolytic and enzymatic reactions increases with temperature.

An investigation of the rates of accumulation of these compounds formed by degradative processes and their effects on the product was undertaken by this laboratory to develop scientific objective methods for the assessment of crab meat quality. The fat content of crabmeat is very low and although fat oxidizes during storage to produce off-flavours, the overall effect on crabmeat quality is probably minimal. Fat oxidation (chemical spoilage) is often monitered by the determination of malonaldehyde, one of the many reaction products. Enzymatic and autolytic degradation of fat produces free fatty acids (FFA) as one of the end products. In lean fish with fat contents similar to that of crabmeat, FFA accumulation during both fresh and frozen storage has been used as in index of quality deterioration. Therefore, the FFA content was monitored in our experiment. After death, (TMAO) trimethylamine oxide is readily attacked by bacterial enzymes to produce trimethylamine (TMA), a volatile fishy smelling compound. In fresh fish, the formation of TMA has been correlated to organoleptic tests and used as a fairly reliable indicator of bacterial fish spoilage. TMAO may also be degraded either enzymically or chemically to produce dimethylamine and formaldehyde. This reaction causes protein denaturation, excessive water loss and textural changes in the meat.

In this report, the following quality parameters such as FFA, extractable protein (EPN), total volatile bases (TVB), and pH measurement were used to monitor the quality changes of Atlantic queen crab prior to processing. The guidelines of the scientific quality evaluation for the post-mortem crabmeat have been described.

METHODS OF QUALITY EVALUATION

It was decided to attempt correlation of organoleptic quality with FFA, TVB, TMA and EPN to devise an objective means of monitoring crabmeat quality.

(a) *Sample preparation:* Live queen crabs from Cape St. Lawrence and Shippegan were held in saltwater aquaria until needed. Control samples were taken from freshly killed crabs. In the experiment, whole dead crabs were stored at +3°C and 23°C. Crabs for post-mortem studies were killed by placing them under vacuum at 45°C for 40 minutes. Before testing crab sections were washed and brushed to remove any traces of viscera. Body meat samples were removed, homogenized in a Cuisinart food processor, and analysed immediately.

(b) *Chemical evaluation:* Free fatty acids were measured according to the direct extraction method of Ke *et al.* (1967); Ke and Woyewoda (1978); TVB by Woyewoda and Ke (1979) (as described for quality assessment of squid); TMA by Dyer (1945) using potassium hydroxide as alkali (Castell *et al.* (19); and extractable protein nitrogen (EPN) by the modified procedure of Dingle (unpublished). The pH of crabmeat solution (1:1 with distilled water) was also measured.

(c) *Organoleptic tests:* For sensory analyses, sections were prepared, boiled for 8 minutes in freshwater in a steam cooker and immediately cooled in cold water. For each panel, one control group of live crabs sacrificed immediately before cooking was used. Panelists assessed body meat samples on the basis of odour, flavour, colour, texture and overall acceptability using the attached grading sheet (Appendix A). Each panelist received one control sample and one or two samples from each experimental group. The assessment of quality was calculated by assigning a score of 5 for the most desirable and a score of 0 for the least favourable assessment. In a following report, a more detailed statistical analyses of the data will be presented using methods described by Woyewoda and Ke (1980).

RESULTS AND DISCUSSION

Quality changes for crab samples held at 3°C and 23°C in terms of FFA, EPN, TVB and pH have been summarized in Figures 1, 2, 3 and 4 respectively. 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 3 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.

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 1. Chemically derived limits are presented for each grade.

Free fatty acid levels of less than 42 µmole/10g meat and EPN of greater than 1.50 mg-N/100gm have been tentatively suggested for good quality crabmeat. Grade B or acceptable quality was set at values of 42-50µmole FFA/10gm for FFA and 1.00-1.50 mg-N/100gm for EPN. Rejection quality was from meat containing FFA values above 50µmole FFA/10gm and EPN values below 1.00mg-N/100gm. It was difficult to set firm limits in Grade B since some scatter 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 measurement are alternative (simpler) methods than EPN for quality assessment.

SUMMARY

We 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 result of the sensory analyses. The recommended procedures have been tested satisfactorily in our laboratory, and can be applied to assess the quality of crabmeat. The described techniques would alleviate the need for time-consuming organoleptic testing which is not always objective. A more extensive study is required to refine and simplify these methods so they can be used on a routine basis in the assessment of crab quality.

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SECTION C

TABLE 1. Comparison of recommended chemical guideline values for assessing the quality of crabmeat and results from organoleptic tests.

Grade	FFA (μmole/10g)	EPN (mg-N/100g)	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

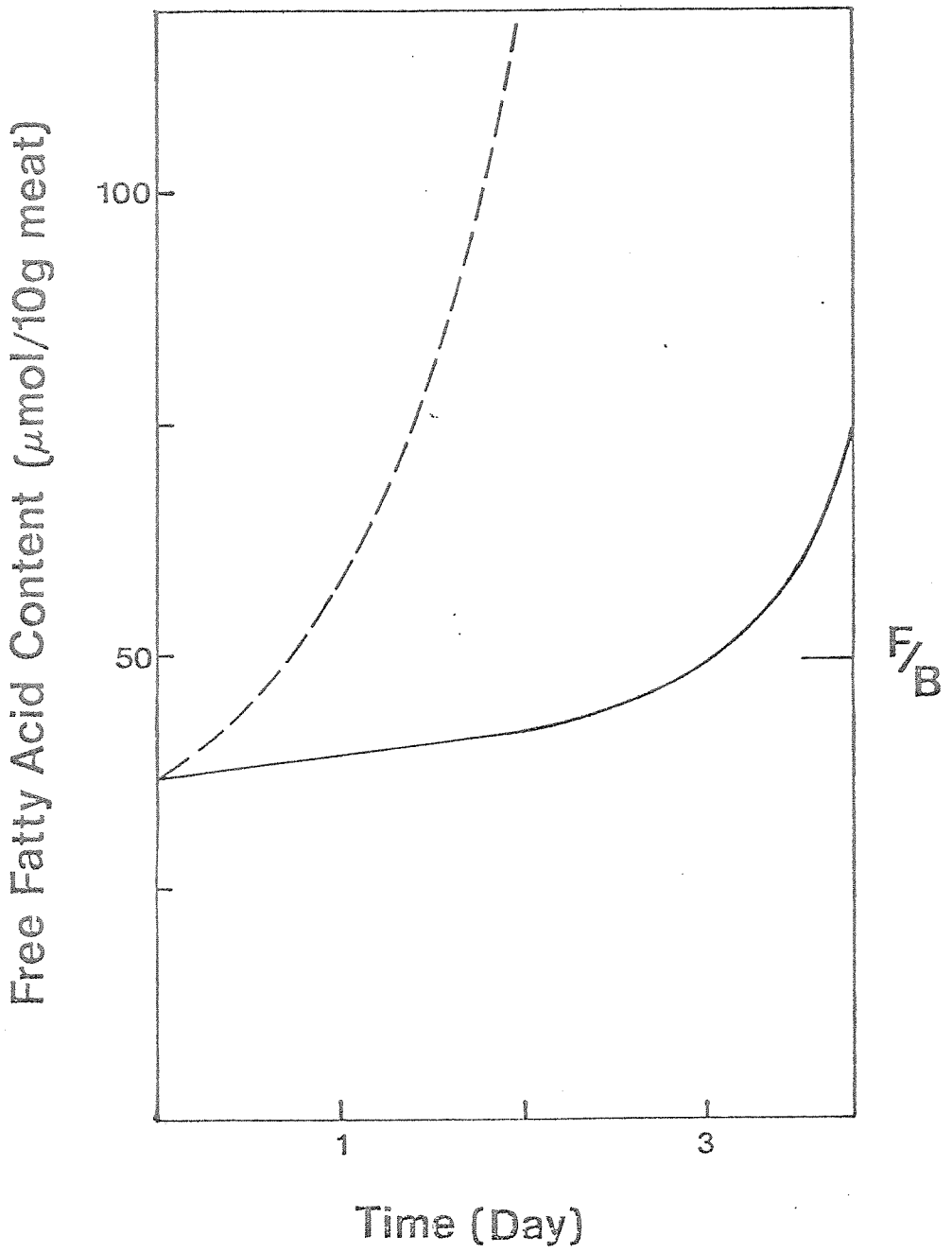
FIGURE 1 - Changes in free fatty acid content over time of body meat from whole Queen crab stored in air at +3°C (——) and +23°C (----).

FIGURE 2 - Changes in extractable protein content over time of body meat from whole crab stored in air at +3°C (——) and +23°C (----).

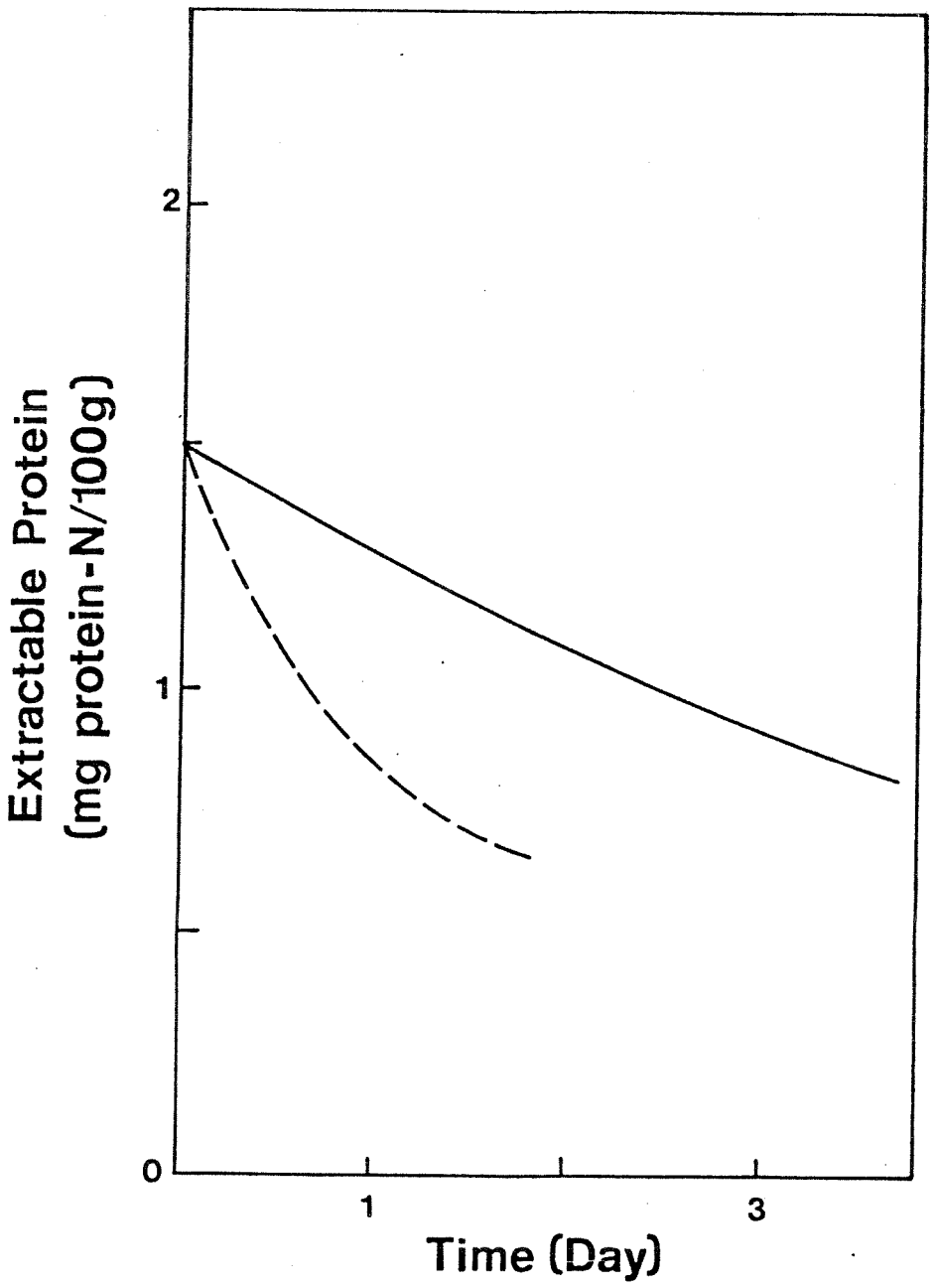
FIGURE 3 - Changes in total volatile bases over time for body meat of whole crab stored at +3°C (——) and +23°C (----).

FIGURE 4 - Changes in pH value over time for body meat of whole Queen crab stored +3°C (——) and +23°C (----).

SECTION C - FIGURE 1



SECTION C - FIGURE 2



SECTION C - FIGURE 3

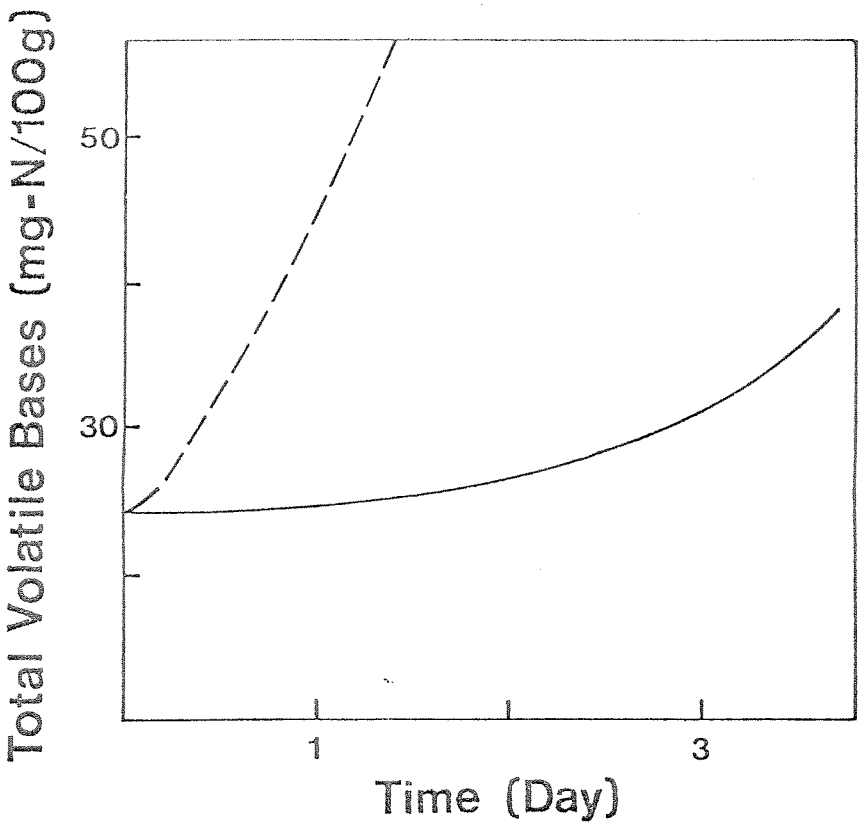
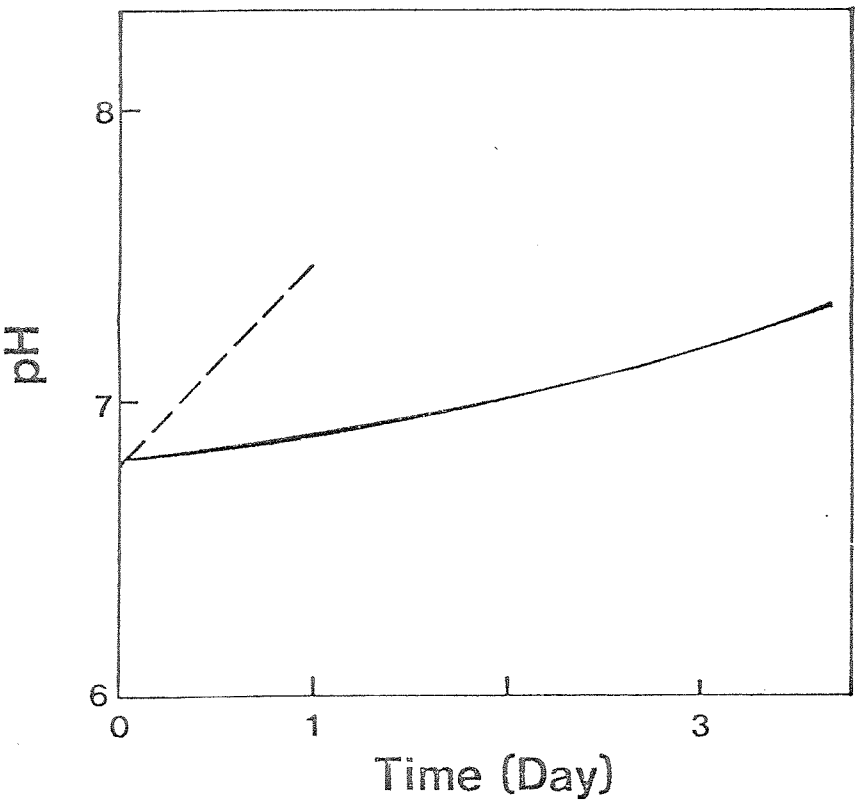


FIGURE 4



APPENDIX A: 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 #	Firm, elastic, moist Long fibres in leg meat	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

* Evaluate the colour of both leg and body meat.

Overall acceptability Sample #	Very Good	Good	Fair	Slightly spoiled	Spoiled	

General Comments:

(D) REVIEW AND SUMMARY OF VARIOUS TECHNICAL INFORMATION CONCERNING ATLANTIC QUEEN CRAB AND RELATED CRAB SPECIES

The production of Queen crab (*Chionoectes opilio*) in Canada has increased greatly since the early 1960's. This species has a worldwide distribution and there is considerable information available on the preservation and processing of queen crab which is also known as snow crab. The main purpose of this report is to compile the recent literature from technical and scientific sources on the quality preservation of Atlantic queen crab, and other crab species native to North America.

Technical publications dealing specifically with aspects of the quality preservation and processing techniques for Atlantic crab fishery have been selected and listed alphabetically in Appendix 1. Appendix 1A includes references dealing with Atlantic Queen Crab and Appendix 1B includes other crab species. References were obtained from Food Science and Technology Abstracts, Biological Abstracts, Chemical Abstracts, government publications from Canada, United States, Japan and Great Britain, as well as proceedings of workshops and technological conferences.

Abstracts and data from literature pertinent to the Atlantic crab industry have been included in Appendix 2-8. The quality improvement of frozen crab meat by using polyphosphate and brine have been summarized in Appendix 3 and 5, respectively. The investigations on various quality assurances for canned crab meat were reviewed and summarized, such as Appendix 2 - Prevention of struvite by hexametaphosphate; Appendix 6 - Shelflife improvements with some pretreatments; Appendix 7 - Effects of various degrees of spoilage on the product quality and Appendix 8 - Effects of using citric acid. The shelflife variation of crab meat by pasteurization has been condensed in Appendix 4. In addition, the results from the original tables and figures from these publications have also been selected and attached with Appendix 2-8.

In the meeting on Quality Improvement in the Crab Industry, April 8-9, 1980 in Fredericton, New Brunswick, A. B. Dewar presented a comprehensive crab report entitled "Effects of Post-Mortem Spoilage on the Quality of Processed Snow (Queen) Crab - A Critical Look at Crabmeat Processing - Some Do's and Don'ts". Since this report has not been published, the complete text of the above article has been included in the Appendix 9.

Appendix 10 and 11 contain two hitherto unpublished reports concerning the effects of season and handling methods on the mortality rates of queen crab in northern New Brunswick. Appendix 10 - Mortality rate of queen crab after landing at dockside and incidence of deadcrabs at the butchering tables in the 1973 season; Appendix 11 - Report on a survey devised to study the mortality rates of queen crab landed in Shippegan, New Brunswick in 1971.

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APPENDIX 2

PREVENTION OF STRUVITE IN CANNED QUEEN CRAB BY HEXAMETAPHOSPHATE.

S. Varga, A. B. Dewar and W. E. Anderson. 1971. Department of Fisheries & Oceans, Regional Inspection & Technology Laboratory, Halifax. Technical Report No. 8: 3 p.

SUMMARY

Struvite crystals ($MgNH_4PO_4 . 6H_2O$) which resemble broken glass become apparent in canned queen crab meat (*Chionoectes opilio*) after 2-3 weeks storage at room temperature and may render the product unmarketable after 7-8 weeks storage. Sodium hexametaphosphate $(NaPO_3)_6$ may prevent struvite formation without having undesirable side effects on the canned queen crab meat. Canned queen crab meat packed with varying concentrations of hexametaphosphate (0.0%, 0.05%, 0.15% and 0.25%) were stored at room temperature and assessed at various intervals for quality, smut and struvite development (Table 2.1). Sodium hexametaphosphate concentrations of 0.15% and 0.25% inhibited struvite formation and retarded smut development without lowering the quality or drained weight of the meat.

TABLE 2.1 Results of Examinations of Canned Queen Crab Meat Packed with Different Concentrations of Sodium Hexametaphosphate

Storage Time in Months	CONCENTRATION OF HEXAMETAPHOSPHATE IN THE MEAT & PICKLE															
	0.0%				0.05%				0.15%				0.25%			
	Struvite	Quality	Smut	*Dr. Wt.	Struvite	Quality	Smut	*Dr. Wt.	Struvite	Quality	Smut	*Dr. Wt.	Struvite	Quality	Smut	*Dr. Wt.
0.0	10	9	8.6	5.53	10	9	9.8	5.69	10	9	9.4	5.72	10	9	9.8	5.67
2	4.6	8	7.6	5.56	9	8	8.2	5.67	10	8.5	9.0	5.80	10	7.8	9.4	5.75
4	3.6	9	7.6	5.64	9.6	8	8.8	5.61	10	8	9.2	5.72	10	7	9.6	5.74
6	6.0	8	7.2	5.55	6.4	8	7.6	5.56	10	7.5	9.4	5.75	10	7	9.4	5.77
8	2.8	7	5.8	5.69	9.0	7	8.2	5.72	10	7	9.2	5.83	10	6	9.4	5.73
12	4.0	6	6.8	5.59	6.6	6	7.8	5.68	10	7	8.4	5.80	10	6	8.8	5.70
TREAT-MENT MEANS	5.17	7.83	7.26	5.60	8.45	7.7	8.4	5.65	10	7.85	9.1	5.78	10	7.14	9.4	5.72

* Drained weight

Department of Fisheries & Oceans, Halifax Inspection & Technology Laboratory Technical Report No. 8, 1971.

APPENDIX 3

EFFECTS OF SODIUM POLYPHOSPHATE ($Na_5P_3O_{10}$) ON THE THAW DRIP AND THE QUALITY OF FROZEN QUEEN CRAB MEAT.

S. Varga, G. G. Sims and W. E. Anderson. 1972. Department of Fisheries & Oceans, Regional Inspection & Technology Laboratory, Halifax. Technical Report No. 11:

SUMMARY

Frozen storage causes a loss in water-holding capacity in crab meat, resulting in a loss of water on thawing or "thaw drip" as it is called. Sodium polyphosphate has been widely used to prevent thaw drip in frozen fishery products. The effect of adding various concentrations of sodium polyphosphate (0.0, 0.25, 0.50, 0.75 and 1.00%) to frozen canned queen crab meat on thaw drip, pH and meat quality after 0, 3 and 6 months storage at -26°C were studied (Table 3.1).

Results showed that polyphosphate concentrations between 0.25 and 0.50% prevented thaw drip and did not adversely affect the quality of the meat, however, concentrations of 0.5% and above caused absorption of the pickle and an increase in weight.

Table:3.1Results of examinations on frozen canned Queen Crab Meat containing different concentrations of Na polyphosphate.

Concentration of added P.P. per Can Contents	STORAGE TIME IN MONTHS																	
	0						3						6					
	Fill in Wt.(oz.)	Drained Wt.(oz.)	% Δ Wt.*	Quality	% P.P.**	pH	Fill in Wt.(oz.)	Drained Wt.(oz.)	% Δ Wt.*	Quality	% P.P.**	pH	Fill in Wt.(oz.)	Drained Wt.(oz.)	% Δ Wt.*	Quality	% P.P.**	pH
0.00%	6	5.83	-2.84	10	0.0	7.43	6	5.72	-4.67	9	0.0	7.44	6	5.81	-3.17	9	0.0	7.38
0.25%	6	5.99	- .16	10	.19	7.63	6	6.12	+2.0	9	.20	7.64	6	6.00	0.0	9	.26	7.58
0.50%	6	6.11	+1.8	10	.45	7.71	6	6.08	+1.33	8	.49	7.78	6	6.07	+1.17	9	.50	7.68
0.75%	6	6.05	+ .8	10	.65	7.91	6	6.04	+ .66	8	.71	7.87	6	6.09	+1.5	9	.73	7.83
1.00%	6	6.24	+4.0	10	.96	7.90	6	6.22	+3.67	8	1.01	7.95	6	6.33	+5.5	8	.98	7.90

* % Δ Wt.: Percentage change in weight.

** % P.P. : Percentage of sodium polyphosphate chemically measured in the meat.

Department of Fisheries & Oceans, Halifax Inspection & Technology Lab., Technical Report No.11 (1972)

APPENDIX 4

PASTEURIZATION AND SHELFLIFE OF PASTEURIZED QUEEN CRAB MEAT. S. Varga, W. E. Anderson, A. B. Dewar and V. Marryatt. 1972. Department of Fisheries & Oceans, Regional Inspection & Technology Laboratory, Halifax. Technical Report No. 14.

SUMMARY

Crab meat can be pasturized to inactivate most of the spoilage microflora, thereby extending its shelflife under refrigeration, but other bacteria may survive the process. Samples of queen crab (*Chionoectes opilio*) were inoculated with *Staphylococcus aureus*, a spore producing bacteria and *Strephyloccus faecalis*, a fairly heat resistant micro-organism before a 1 or 5 minute pasteurization at +76.7°C . Samples were stored at +1°C and periodically examined for organoleptic quality and viability of micro-organisms. Pasteurization at +76.7°C for 1 minute was sufficient to kill all *S. aureus* and *S. faecalis* cells. The maximum storage as determined by organoleptic tests of both pasteurized samples was between 4 and 6 months (Table 4.1).

Table 4.1 Results of Quality Assessment of Pasteurized Queen Crab Meat held at +1°C Storage.

Holding Time in Months	TREATMENTS		
	Process: 1' at 77°C Not Inoculated	Process: 1' at 77°C Inoculated	Process: 5' at 77°C Inoculated
0	10	10	10
1	10	10	10
2	9.0	9.0	9.0
4	9.0	9.0	9.0
6	4.7	4.0	3.7
7	3.0	3.0	-
8	4.0	4.0	-
9	2.0	5.0	-
10	4.0	4.3	-

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APPENDIX 5

CHANGES IN THE QUALITY AND YIELD OF BRINE FROZEN COOKED CRAB SECTIONS DURING COLD STORAGE.

S. Varga, A. B. Dewar and W. E. Anderson. 1972. Department of Fisheries & Oceans, Regional Inspection & Technology Laboratory, Halifax. Technical Report No. 15.

SUMMARY

The crab processing industry is frequently faced with a glut of raw material which cannot be processed before spoilage has occurred. The storage of brine frozen cooked crab sections for subsequent processing has been suggested as a means of ensuring a steady supply of high quality raw material. Samples of queen crab (*Chionoectes opilio*) and red crab (*Geryon quinquedens*) were cooked, brine frozen, packaged to prevent dehydration and stored at -18°C or -26°C . At various times up to 7 months samples were assessed for meat yield and ease of meat extraction before being canned and stored at -34°C or heat processed (110°C for 90 min), and stored at room temperature for 1 week before assessment for organoleptic quality (Table 5.2). This experiment indicated that brine frozen cooked queen and red crab sections can be stored for 3 months at -18°C before further processing without significant losses in meat quality. After 7 months storage the meat is still acceptable, but there are losses in odour, flavour and texture. The decrease in meat

quality is significantly smaller at -26°C than at -18°C. The quality of heat processed crab meat is perceptibly lower than the meat preserved by freezing.

The loss of yield from frozen sections is about 10% after two months storage and 12-15% after seven months (Table 5.1). The decrease in yield can be attributed to the increasingly difficult meat extraction and a loss in the moisture holding capacity of the meat. The red crab has smaller legs than the queen crab making the meat extraction more difficult and the yield lower.

Table 5.1 Meat yield and the relative ease of meat extraction from brine frozen cooked Queen Crab sections stored at different temperatures.

Holding Time of Sections in Months	Storage Temperature			
	18°C		26°C	
	Yield %	Extraction	Yield %	Extraction
0	47.7	5	47.7	5
1	37.9	5	40.7	5
2	38.1	5	39.3	5
3	41.5	5	37.8	5
5	37.1	4	41.4	5
6	35.0	4	38.1	5
7	33.0	4	32.5	5

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Table 5.2 Quality of canned Queen Crab meat derived from brine frozen, cooked sections held at different storage temperatures.

Holding Time of Sections in Months	Quality of Meat			
	Storage Temperature 18°C		Storage Temperature 26°C	
	H	F	H	F
0	10	10	10	10
1	8	9	9	9
2	8	9	9	9
3	8	8	9	9
5	7	7.5	8	8
6	6	7.0	7	8
7	6	7.0	7	8

H = meat preserved by heat process

F = meat preserved by freezing

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Technical Report No. 15, (1972).

APPENDIX 6

THE SHELFLIFE OF CANNED QUEEN CRAB MEAT.

A. B. Dewar, W. E. Anderson and S. Varga. 1972. Department of Fisheries & Oceans, Regional Inspection & Technology Laboratory, Halifax. Technical Report No. 13: 21 p.

SUMMARY

Live crabs (*Chionoecetes opilio*) were caught off Cheticamp, N.S., and were transported in refrigerated, aerated seawater to the Halifax Inspection Laboratory. The crabs were butchered and the sections were subjected to either one of two pre-cooking procedures: (1) a "regular cook" (7 min at 100°C), or (2) a "fractional cook" (10 min at 65°C) followed by shucking and a further cook (3 min at 100°C). The meat was then packed in the absence or presence of citric acid (0.1%) in either tin or aluminum cans which were then sealed (automatic vacuum-sealing), heat-processed (110°C), cooled, packed in cartons, and stored at 21°C for various periods of time (0,4,8, 12, 18, and 24 months). The cans were then opened and examined for pH, drained weight, colour, odour, flavour, texture, blue discoloration, struvite, and smut. The results showed that Queen Crab meat canned from live healthy crabs, and packed in tin or aluminum cans with the addition of citric acid (0.1% of the total can contents), was of good commercial quality up to at least two years in storage at room temperature (Table 6-1). Fractional cooking was successful in preventing blue discoloration, but it had adverse effects on the texture of the crab meat.

TABLE 6.1 Overall quality[1] of heat-processed Queen Crab meat samples subjected to various treatments and stored at room temperature (21°C) for various periods of time.

Storage time (months)	Treatment[2] No.							
	1	2	3	4	5	6	7	8
0	9.0	9.0	8.0	7.5	9.0	8.8	9.0	8.0
4	6.6	8.4	4.8	3.0	6.0	7.0	7.0	5.0
8	4.0	7.8	4.8	4.0	4.2	8.0	6.0	5.0
12	5.0	6.8	1.8	5.0	4.6	7.0	7.0	5.0
18	2.6	6.2	4.0	4.0	2.4	7.0	6.0	4.0
24	3.3	6.5	4.8	6.0	2.5	7.0	7.0	6.0

[1] Five separate taste panel scores were obtained for each characteristic under study (e.g. colour, struvite, smut, etc.). The average was then obtained for these 5 scores. The "overall quality" was judged to be only as good as the lowest score obtained. Thus, it is conceivable that smut could be the limiting factor in one treatment whereas struvite could be the limiting factor in another.

[2] Treatments

No. 1	Cook:	7 min.	Can:	Tin	Citric Acid:	0.0%
No. 2	Cook:	7 min.	Can:	Tin	Citric Acid:	0.1%
No. 3	Cook:	10 min. (150°F)	Can:	Tin	Citric Acid:	0.0%
No. 4	Cook:	10 min. (150°F)	Can:	Tin	Citric Acid:	0.1%
No. 5	Cook:	7 min.	Can:	Al	Citric Acid:	0.0%
No. 6	Cook:	7 min.	Can:	Al	Citric Acid:	0.1%
No. 7	Cook:	10 min. (150°F)	Can:	Al	Citric Acid:	0.0%
No. 8	Cook:	10 min. (150°F)	Can:	Al	Citric Acid:	0.1%

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APPENDIX 7

EFFECT OF POST-MORTEM SPOILAGE ON THE QUALITY OF PROCESSED QUEEN CRAB

A. B. Dewar, S. Varga and W. E. Anderson. 1969. Department of Fisheries & Oceans, Proceedings for Crab Fishery Development Meeting, Can. Fishery Report No. 13, 163-168.

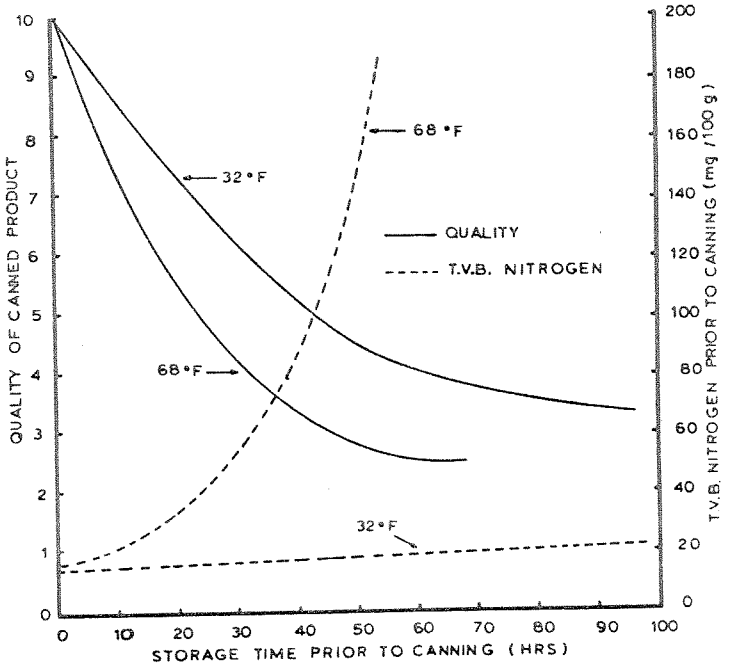
SUMMARY

The quality of crab meat (*Chionoectes opilio*) either heat processed or frozen is dependent on the quality of raw material used for packing. To measure post-mortem spoilage whole dead crabs, cooked and uncooked sections, were stored at room temperature (20°C), or in ice, (0°C). At various intervals total volatile base nitrogen (T.V.B.) was determined and samples were removed for processing as frozen or canned crab meat and additional storage for 3 months before organoleptic assessment (Table 7-1 to 7-4). Dead whole crab produced grade II quality meat after 10 hours at 20 °C or 16 hours at 0°C and grade III quality meat after 24 hours at 20°C or 48 hours at 0°C. Uncooked sections spoiled at a faster rate and cooked sections spoiled at a slower rate than whole dead crabs.

Black discolouration developed on the exposed shoulder meat of all crab sections during storage although it developed at a slower rate on cooked than on uncooked sections. The T.V.B. nitrogen values did not vary significantly at 0°C indicating that it is not a satisfactory indicator of quality for queen

crab meat. The results indicated that it is possible to process an "acceptable" (not excellent) product from dead crab for only a few hours after death has occurred, however, the product will have a limited shelflife.

FIGURE 7.1 QUALITY AND T.V.B. NITROGEN AS A FUNCTION OF STORAGE TIME OF WHOLE CRAB AT 32°F AND 68°F PRIOR TO CANNING.



Department of Fisheries & Oceans, Proceedings for Crab Fishery Development Meeting, Can. Fish. Report 13, 165 (1969).

FIGURE 7.2 QUALITY AND T.V.B. NITROGEN AS A FUNCTION OF STORAGE TIME OF CRAB SECTIONS AT 32°F AND 68°F PRIOR TO CANNING.

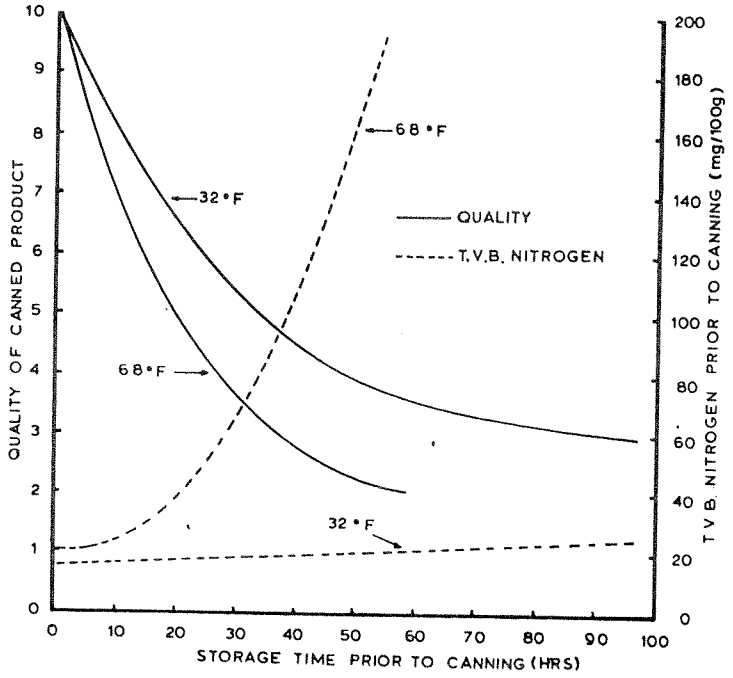
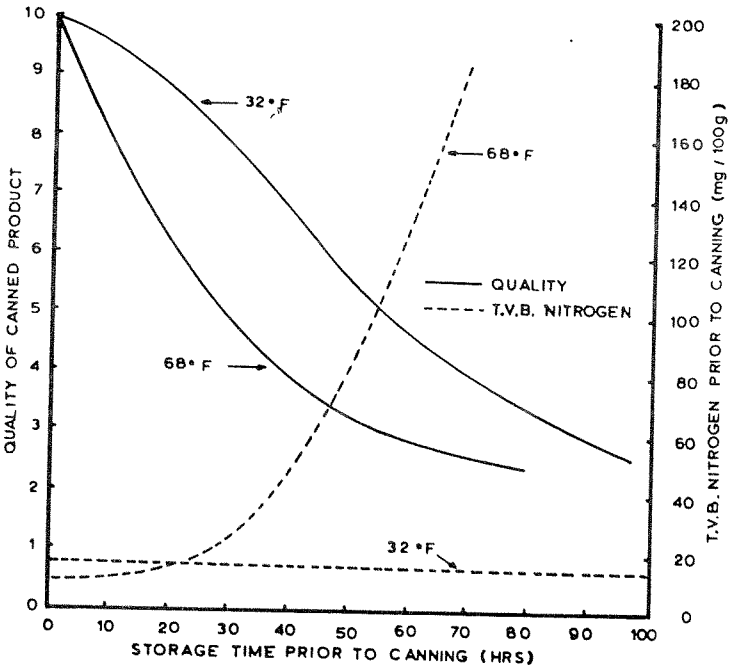


FIGURE 7.3 QUALITY AND T.V.B. NITROGEN AS A FUNCTION OF STORAGE TIME OF COOKED CRAB SECTIONS AT 32°F and 68°F PRIOR TO CANNING.



Department of Fisheries & Oceans, Proceedings for Crab Fishery Development Meeting, Can. Fish. Report 13, 166 (1969).

FIGURE 7.4 THE EFFECT OF HOLDING QUEEN CRAB PRIOR TO CANNING ON THE QUALITY OF THE CANNED PRODUCT.

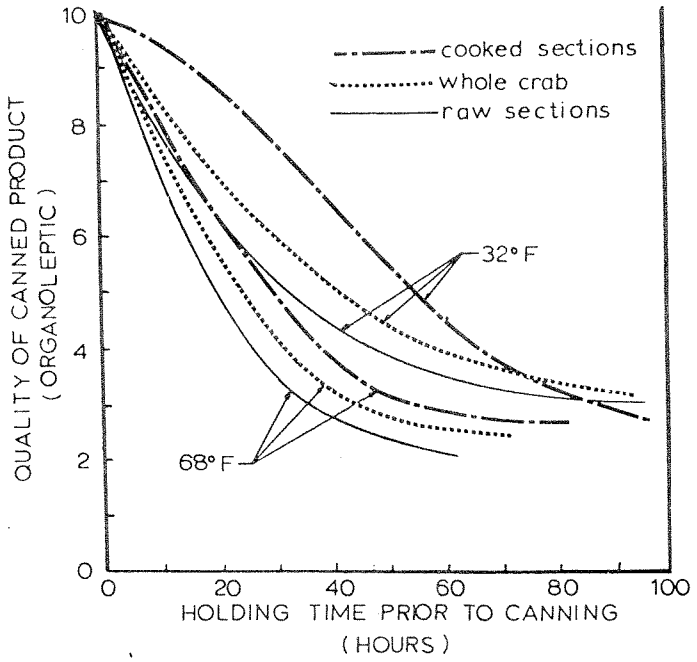
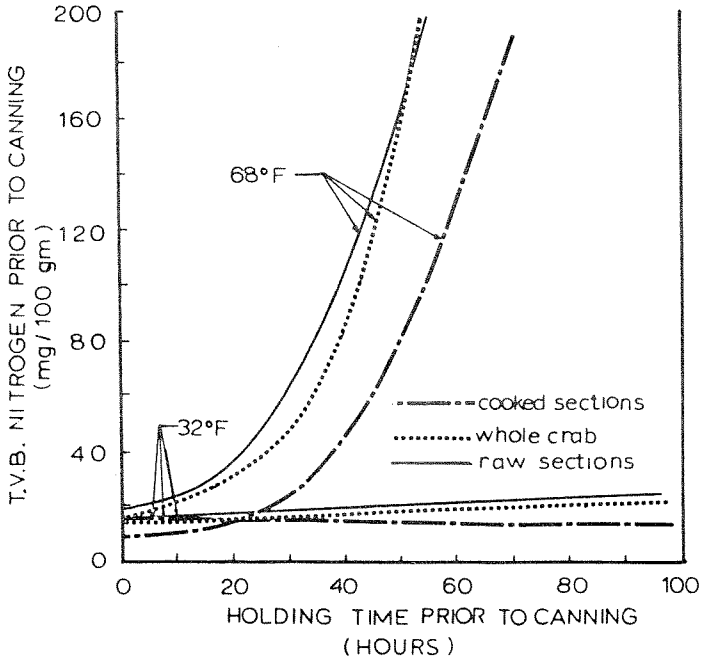


FIGURE 7.5 T.V.B. NITROGEN CHANGES IN QUEEN CRAB PRIOR TO CANNING, (WHOLE CRAB, RAW SECTIONS AND COOKED SECTIONS).



Department of Fisheries and Oceans, Proceedings for Crab Fishery Development Meeting, Can. Fish. Report, 13, 167 (1969).

APPENDIX 8

EFFECT OF CITRIC ACID ON QUALITY OF HEAT PROCESSED CRAB MEAT

S. Varga, A. B. Dewar and W. E. Anderson. 1969. Department of Fisheries & Oceans, Proceedings for Crab Fishery Development meeting, Can. Fish. Report No. 13, 169-174.

SUMMARY

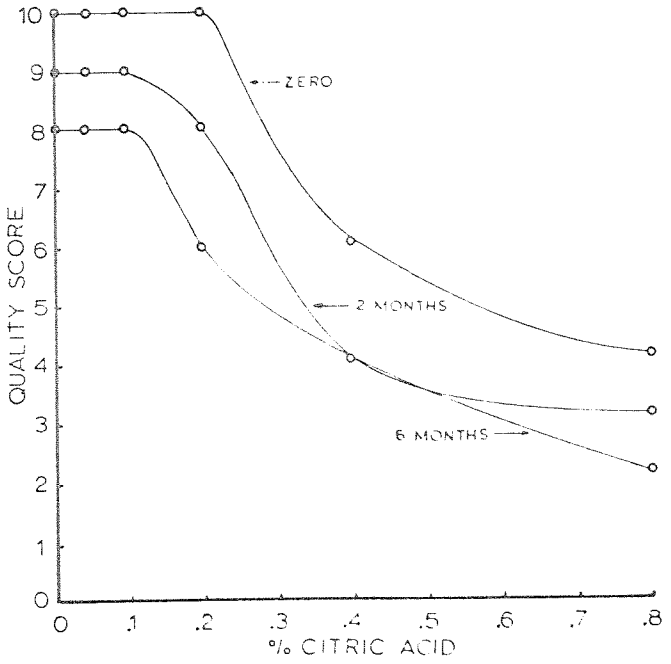
Many workers recommended the acidification of crab meat to prevent blue discolouration and struvite formation. The suggested concentration of acid and the mode of application varies greatly. An investigation was conducted to assess the influence of citric acid treatment on blue discolouration, struvite formation, as well as on meat quality and drained weight in the case of queen crab meat (Table 8-1, Fig. 8-1to8-6). A concentration of citric acid exceeding 0.1% of the can contents stopped the formation of struvite, failed to prevent smut formation, retarded the development of blue discolouration, adversely affected meat quality and the drained weight. Injection of pickle containing the required amount of citric acid was found to be desirable in order to have an accurate control on the citric acid content of the final product.

TABLE 8.1
THE pH OF HEAT PROCESSED CRAB MEAT CONTAINING DIFFERENT CONCENTRATIONS OF CITRIC ACID.

Storage time	% Citric Acid per can content.					
	0.0	0.04	0.1	0.2	0.4	0.8
zero	7.35	7.24	6.98	6.74	6.40	5.83
2 months	7.14	7.00	6.78	6.58	6.28	5.80
6 months	7.23	7.17	6.99	6.81	6.36	6.13

Note: Citric Acid was injected with the brine.

FIGURE 8.1
EFFECT OF CITRIC ACID CONCENTRATION ON THE QUALITY OF CANNED CRAB MEAT.



Department of Fisheries & Oceans, Proceedings for Crab Fishery Development Meeting, Can. Fish. Report No. 13, 172 (1969).

FIGURE 8.2
EFFECT OF CITRIC ACID CONCENTRATION ON THE DEVELOPMENT OF BLUE DISCOLORATION IN CANNED CRAB MEAT.

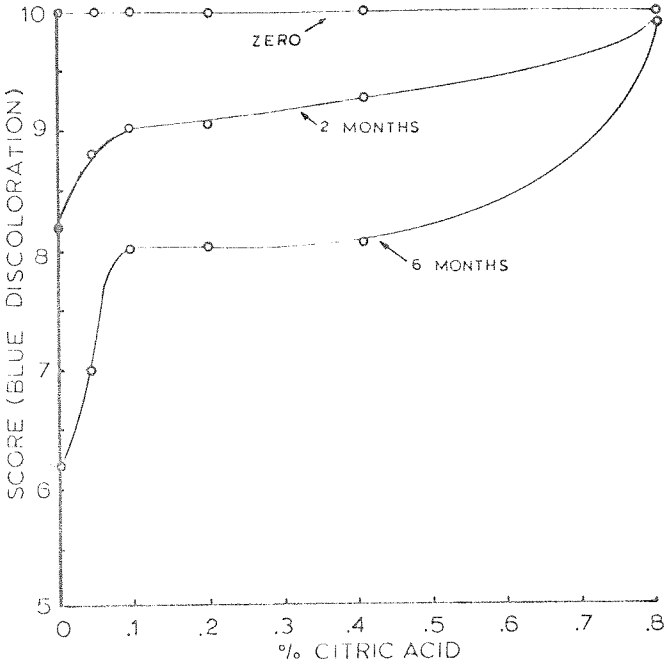


FIGURE 8.3
EFFECT OF CITRIC ACID CONCENTRATION ON THE DEVELOPMENT OF SMUT IN CANNED CRAB MEAT.

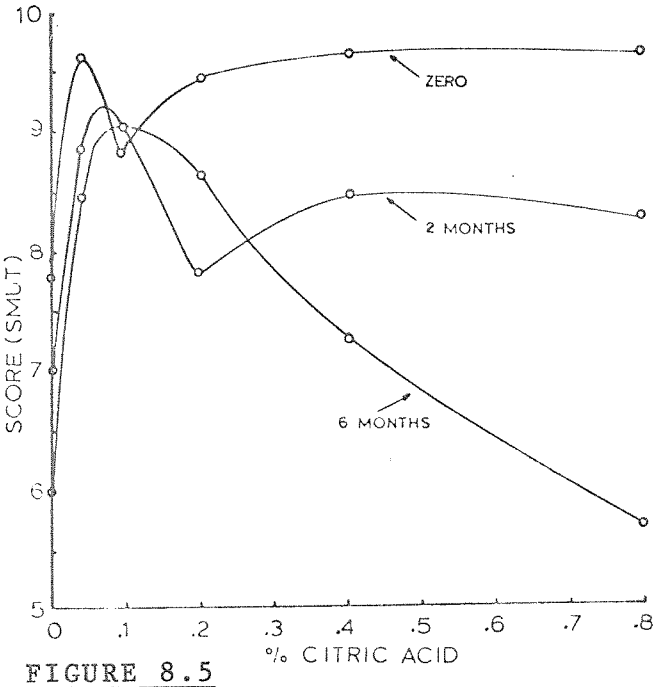


FIGURE 8.4
EFFECT OF CITRIC ACID CONCENTRATION ON THE DEVELOPMENT OF STRUVITE IN CANNED CRAB MEAT.

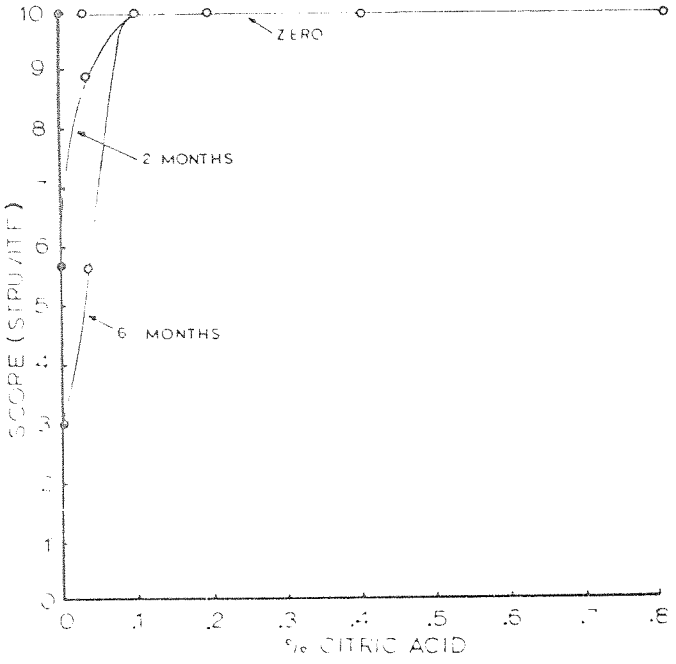
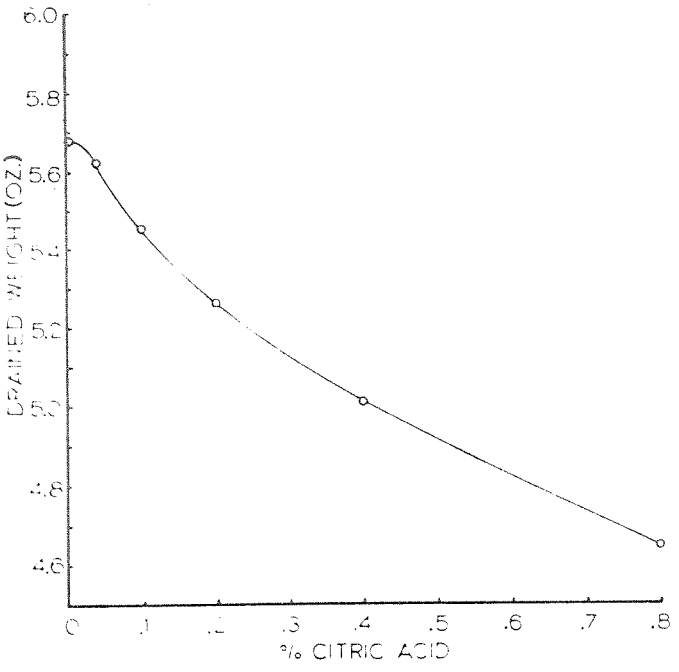
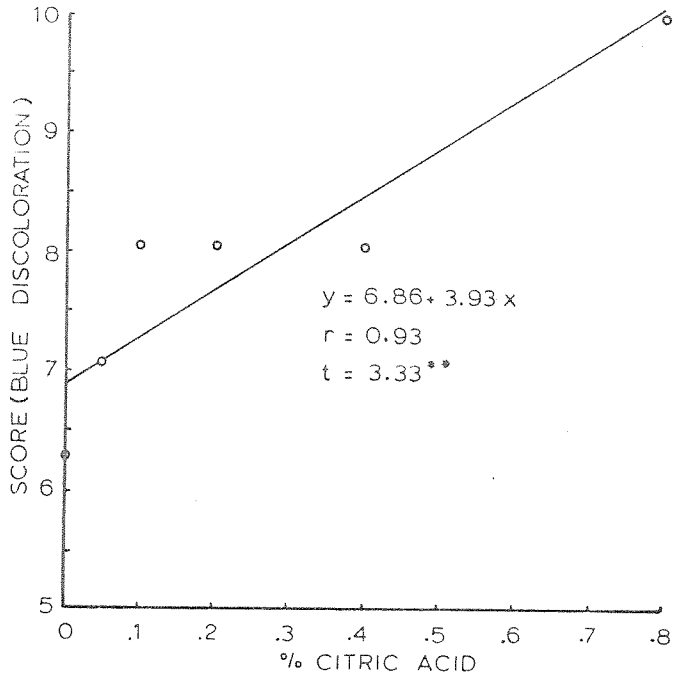


FIGURE 8.5
EFFECT OF INCREASING CONCENTRATIONS OF CITRIC ACID ON THE DRAINED WEIGHT OF HEAT PROCESSED QUEEN CRAB.



Department of Fisheries & Oceans, Proceedings for Crab Fishery Development Meeting, Can. Fish. Report No. 13, 173 (1969).

FIGURE 8.6
CORRELATION BETWEEN CITRIC ACID CONCENTRATION AND THE DEVELOPMENT OF BLUE DISCOLORATION IN CANNED CRAB MEAT.



Department of Fisheries & Oceans, Proceedings for Crab Fishery Development Meeting, Can. Fish Report No. 13, 174 (1969).

APPENDIX 9

EFFECTS OF POST-MORTEM SPOILAGE ON THE QUALITY OF PROCESSED SNOW (QUEEN) CRAB - A CRITICAL LOOK AT CRABMEAT PROCESSING - SOME DO'S AND DON'TS.

A. B. Dewar 1980.

Presented in the meeting of Quality Improvement in the Crab Industry - An Update, April 8-9, 1980 in Fredericton, N.B.

With the time I have at my disposal, I would like to discuss the above noted topic with you in two parts. In the first part of my discussion I wish to refer to a paper entitled "Effect of Post-Mortem Spoilage on the Quality of Processed Queen Crab" by A. B. Dewar, S. Varga and W. E. Anderson, that I presented at a gathering similar to this at Fredericton, New Brunswick, back in 1969. In the second part of my discussion I wish to bring to your attention some of the "DO'S" and "DON'T'S" of canning and packing snow crabmeat.

I am sort of proud of the paper I just referred to because it has stood the test of time and is just as relevant now as it was then. More important, is the fact that the statements we made then from our scientific investigations and observations in the field, at the time, were shown over the years to be factual. I urge you to obtain a copy of this paper and review the information contained in it (a copy is attached for your reference).

The problems associated with packing dead crabs has been recognized since this industry began in the Maritimes. It was recognized that to get a top quality product the animals must be alive and alive at the time of processing, otherwise an inferior or reject product would be obtained. It was also recognized that when dead crabs were packed, a top quality product was not achieved, but often a product that was of borderline acceptability or worse was obtained, depending on the condition of the dead crabs.

Amending the Regulations to permit the packing of dead crabs, (as some have suggested) from a quality improvement point of view, would be going backwards; from an enforcement point of view, it would make a difficult situation impossible to deal with or handle. Not only that, it would appear that we were losing our technical competence.

Familiarity with the mechanism of fish spoilage is a prerequisite to the good handling of the fish. A search of the literature will indicate, without exception, that crustacea must be alive for processing as food. There are good reasons why this is so. The visceral enzymes of crustacea (crabs, lobsters) are so potent that the keeping time of these animals, after death, is extremely short. The rate of enzyme activity is temperature dependent, unlike bacteria, which require time for multiplication, digestive ferments need only an increase in temperature to speed up their operation, which is autolysis or the attacking and breaking down the animal itself, after it is dead. Remember that when the animal is alive these potent enzyme systems have their checks and balances, however, after the animal dies, these checks and balances, that nature has provided, are no longer functioning and so they attack the animal itself.

At a meeting our Department had last fall concerning the problem of packing dead crab, I indicated that during the joint inspections that were carried out by this Department and Health and Welfare Canada, most of the crab observed in the plants, for further processing, were dead and this was in the fall when the ambient temperature is much lower than in the summer months; one can speculate as to the condition of the crab in the hot summer weather. In addition, it was observed that culling carried out at all plants inspected was not satisfactory.

The statement has been made that crabs on the West Coast spoil more rapidly then crabs on the East Coast, after death. I can state that our crabs deteriorate rapidly as well, and I am yet to be convinced there is any difference in the rates of spoilage of the two. However, it appears we have become accustomed to and accept inferior raw material, in many instances, which, of course, results in an inferior product.

Packers that I have discussed the subject with, blame the problem on the "Tread lightly or don't rock the boat approach" of our Department and on one another. It appears that we have to be protected from ourselves. In summary, of this topic, it is my contention that there is a far in excess percentage of dead snow crab, than should be tolerated, accepted for processing in our Maritimes region; and in addition, the culling for obvious blueing and decomposition is not taking place to a satisfactory degree.

I know a lot of you agree with me to one degree or another, or you would not be here today discussing the situation and attempting to find solutions, so that hopefully, working together, we will

reduce the percentage of dead crab processed and as well improve the overall quality of the raw material.

Having said this, our aim should be to process only live crabs or lobsters. This is, of course, easier said than done; however, with education there are a lot of things that can be done to keep the animal (crabs) happy and ensure or prolong their survival for instance:

1. More care should be taken handling the crabs from the time of capture until they are butchered. Rough handling, jarring, dropping, crushing, loss of appendages, etc. all tend to kill or weaken the animal and lessen his survival time. They must be handled with care if they are to survive for any length of time.
2. After capture, more care must be taken to properly protect the crab's new environment to keep him happy so that he will survive longer. This means protection from high temperature, wind, sun, rain or other considerations that will speed his demise. This means careful and speedy icing, if this is the method used, to keep the crabs cool. It also means using the proper amount of ice to do the job; and as well, it means protecting the animal from fresh water, which will kill him quickly by osmosis.
3. More attention must be paid to the length of the fishing trips in relation to the survival of the crabs. Longer trips and larger catches are, of course, more economical, but the survival rate of crabs may be severely curtailed.
4. More attention must be paid to regulating the catch to the processing capacity of the plant to avoid delays and pile ups in the packing of the product.

5. It appears that more attention should be paid to improving the quality of the whole general pack so that there will be less problems with blue discolouration, smut and low or borderline quality.

The points I have raised are general considerations to keep the crabs alive or to ensure that their survival will be at least longer. They may or may not apply to your operation, you can answer that question. However, we must consider them and ask ourselves in which direction are we going.

To be more specific, I should like to discuss small or undersize crab, white or soft shell crab for a few moments.

Small or undersize crab should not be accepted at a plant for two reasons:

- from a conservation point of view;
- they slow up the plant processing operation because shucking them is slow and tedious and the meat yield is also lower (because they require more handling per lb of meat and are more difficult to shuck).

White or soft shell crab should not be accepted at a plant for the following reasons:

- they die very quickly;
- they are very difficult to shuck (when I shuck them I get more meat on my face than in the pan) and the meat yield may be only 50% or less of what would normally be expected;
- the meat tends to turn blue on canning;
- the texture is soft, mushy and watery;
- a lot of blood and precipitated protein will be present on cooking (a lot of fluid is present in the crab sections -

on cooking this fluid becomes a curd or precipitate);

- it is difficult to wash blood and precipitated protein from the broken mushy meat;

To demonstrate a point, I have taken this precipitated blood and protein and canned it. On retorting, it turned blue black,or black.

- since the blood has a pH of 7.8, smut formation may also result in the canned product;
- it is impossible to make a good product out of soft shelled crab, especially when it is in the advanced state.

From what I have just said, it becomes quite obvious that culling of the raw material prior to butchering is very important. In order for a culling operation to be meaningful and successful, it must be carried out as a separate operation - not during butchering. The most that can be hoped for during butchering is that the odd bad crab that escaped the culling will be picked up then.

It is my experience that culling after the product goes on the production line is never successful, and should not be relied on as the only culling the raw material receives. It is inconceivable for instance, that if 25-50% of the raw material going through the line is bad and should be removed, that the workers on the line would discard it - why they would be fired on the spot!! Also, if the meat is shucked it is going to be weighed so that the worker will get the incentive pay that usually is involved. Let's be honest and let's not fool ourselves - I have observed this very situation, too many times, over too many years, in too many plants.

Summarizing the culling operation, it should be:

- a separate operation;
- all dead, blue or otherwise discoloured crab should be removed;

- all cannibalized or severely damaged crab should be removed as they are sometimes in an advanced state of decomposition and should therefore always be suspect;
- all white or soft shell crab should be removed;
- all undersized crab should not be "plucked in the flower of their youth", but rather returned to the sea to grow and develop and be captured another day when they have grown to the proper size.

Butchering Operation

The butchering operation is very important and cannot be over emphasized. Care should be taken to:

- remove all the gill material;
- remove all mandibles and excess cartilage;
- remove all the viscera present (it is difficult to remove the liver and viscera completely from dead crab - it clings to the voids in the shoulder meat;
- muddy or otherwise unclean crabs should be rinsed with clear water before butchering.

Properly butchered sections make the processing task easier later on, for instance - liver and visceral will stain and darken the meat on cooking and is very difficult to remove later on. Excess cartilage will make it more difficult to remove the meat during shucking and it will end up in the meat as well, along with mandibles, parts of mandibles, or gill that is present. If it is there, it is bound to end up in the meat - once in the meat, it is very difficult and expensive to remove in terms of effort and time expended to attempt to remove it. Don't make the work more difficult later on.

Washing

Washing of the sections before cooking is very important:

- it prevents discolouration of the meat by removing the viscera and other extraneous material;
- it removes the blood and other body fluids that will cause blueing and discolouration later on.

Precooking

It is important that the sections be cooked as follows:

- in clean fresh water, not in cooking water that resembles a thin mix of Portland cement!!

If the product is cooked in dirty water, the odour and flavour, especially, and in some cases the colour will be adversely affected by the cooking water.

- adequately cooked so that no sections will be partially raw - remember, raw or partially raw sections discolour very quickly;
- continuous cookers may require a baffle - to sink the sections and prevent them from floating on the top of the water during cooking. Such sections would not be properly cooked;
- sometimes with continuous cookers, it is necessary to add extra steam to the cooking water, where the raw sections enter, to prevent a cold spot.

Fractional Cooking

Fractional cooking in the Maritimes has not become very popular. It is successful in preventing blue discolouration, but the method as carried out in the Maritimes did not give as good a yield of meat. The idea is to cook the meat long enough (10 min at 60 - 66°C) to make the meat firm enough for shucking, while the blood still remains liquid. The blood can then be washed away by rinsing the shucked

meat in flowing water. The shucked meat is then cooked in boiling water for an additional 2-3 minutes to complete the precooking operation.

Cooling and Washing

It is very important that the sections be adequately cooled to approximately 10°C for ease of shucking.

Precipitated blood and protein should be removed from the cooked sections at this point - if it is not removed it will end up in the meat and is very difficult, if not impossible, to remove later on.

Meat Extraction

This operation is very important. Care should be taken to ensure:

- the large leg meats are not shredded and mangled or cut off at both ends, so that one would hardly recognize it as being the large leg that it once was;
- the body meat is removed in as large chunks as possible;
- excess cartilage, gill, tendons, shell, or other extraneous material does not become mixed with the meat at this point.

Removing Extraneous Material From the Meat and Washing

The most successful method of removing extraneous material, shell, gill, gut, mandibles, cartilage, tendons, etc. is with an ultra (U.V.) light (black light) in a darkened area. The product moving on an endless belt under the light is preferable. Don't remove extraneous material by making a snow ball of the meat and then shredding it into another area or container, while picking out the extraneous material at the same time. This method

reduces the chunks of meat to a shredded homogenous mass.

Washing of Meat

I am a firm believer that the meat should be adequately washed after shell and cartilage removal to:

- rinse clean the meat after intensive handling by numerous workers, for bacterialogical and esthetic reasons;
- remove all blood and precipitated protein;
- give the meat a fresh clean appearance.

Wash in:

- clear cool flowing water;
- use a lot of water;
- do not soak the product;
- do not stir the product around like porridge in stagnant water in a container and then make so-called "snow balls".

Draining the Meat

I prefer to see the product drain in shallow pans with adequate holes in them for drainage and the containers sloped at about a 30° angle to facilitate drainage.

This method of removing excess moisture means that the product should not "hang around" so to speak, but that it be drained for approximately 10-15 minutes and then packed into the cans. A higher fill-in weight may be required, but this will not affect the ultimate yield.

Care must be taken to:

- drain uniformly or the drain weights will have a wide range, and weight control will be difficult;

- use a higher pre-determined fill-in weight;
- do not overfill, or low vacuums may result, depending on the method of obtaining vacuum.

Advantages:

- a more nutritious product;
- a better tasting product, providing good raw material is used;
- less head space in the can which should be less conducive to smut formation.

Can Filling

The consumer expects crab meat to be white or red. This means:

- red pigmented legs should be placed pigment side out, in an orderly fashion on the top and bottom of the can to enhance the appearance of the pack;
- fine or white meat should be placed in the centre of the can.

Adding Pickle

Proper acidification of the product with an acid-brine solution to give a citric acid content of 0.1% of the total can contents, is very important.

Remember:

- aim for a pH of 6.85;
- experience has shown that when the pH is over 7.0, especially in the range of 7.3 - 7.6, smut formation and discolouration is quite pronounced, and numerous, serious consumer complaints will result;
- dead raw materials raises the pH and makes pH adjustment very difficult to control;
- too much acid and a low pH ruins the product. It adversely effects the drained weight (makes it lower), the colour, odour, flavour and texture;

- do not use a metal container for storage of the acid-brine solutions as metal ions may go into solution and cause discolouration.
- prepare fresh pickle daily.

* A Word of Caution

The practice of holding cooked sections and/or shucked meat over until the next day, so that all the workers in a shift can start at the same time should not be tolerated. The plant operations should be staggered so that all the butchered and cooked sections, as well as the shucked meat is packed off at the end of the day.

If cooked sections or meat is held over night, it's pH may increase to the point where adding the normal amount of acid will not adjust the pH to the desired level. The temperature at which the sections or meat is held and the holding time are two important factors that will determine the actual rise in the pH, as well as the extent of decomposition.

Can Seaming

Ensure adequate can seaming by proper adjustment of can seaming machine and frequent can seam checks:

- keep adequate can seam records.

Retorting

- add as much pickle as possible as long as enough head space is left to obtain an adequate vacuum;
- aim for a vacuum in the range of 10-14. Do not go below 4 inches of mercury (flippers may result under certain conditions) or above 14 inches of mercury. Vacuums above 14 inches may enhance smut formation. (In frozen crab meat, in cans, the higher the vacuum the better, as it reduces or retards certain chemical reactions, notably oxidation);
- prepare the pickle from a high grade dairy salt;
- do not use a metal container for storage of the acid-brine solutions as metal ions may go into solution and cause discolouration.
- prepare fresh pickle daily.

Can Seaming

Ensure adequate can seaming by proper adjustment of can seaming machine and frequent can seam checks:

- keep adequate can seam records.

Retorting

To obtain a high quality product there must not be any pile-ups any where along the processing line. An even, uninterrupted flow is essential.

- avoid long delays between sealing the cans and retorting (1/2 - 1 hr good);
- ensure retorts are properly equipped;
- use proper venting and come-up procedures;

Avoid unduly long come-up times for a number of reasons e.g., encourages smut formation and may etch or tarnish the outside of the cans due to wet steam with lots of water and oxygen present.

- use an approved process;
- use cook-chex or other thermo indicators as an added safety measure;
- cool quickly and adequately to an average can temperature of 37 to 41 °C;
- use chlorinated can cooling water;
- keep adequate retort records.

Can Handling & Storage

- handle cans gently to avoid denting and especially damage to can seams;
- do not carton until the cans are completely dry;
- store in a dry, cool, clean, storage area.

Much of what I have said can be found in our paper entitled "Code of Practice for Processing Queen Crab". I urge you to obtain a copy and review the material in it. However, there are certain aspects that I feel need more emphasis and this I have attempted to do in the limited time available for such an extensive subject.

In conclusion, it can not be emphasized to strongly, that a high quality product can only be achieved by starting with good quality raw material, using good manufacturing practices and the most up-to-date technology, coupled with a positive attitude towards the whole canning operation in general.

A. B. Dewar
April, 1980.

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APPENDIX 10

MORTALITY RATE OF QUEEN CRAB AFTER LANDING AT DOCKSIDE AND INCIDENCE OF DEAD CRABS AT THE BUTCHERING TABLES IN THE 1973 SEASON.

W.E. Anderson & S. Varga. 1973. Department of Fisheries & Oceans, Regional Inspection and Technology Laboratory, Halifax, N.S. Unpublished: 3 p.

SUMMARY

On the request of Mr. R. J. McNeill, C.I.B. of the Fisheries Service, a monitoring programme was devised to estimate the mortality rates of Queen crab (Chionoecetes opilio) at landing and the incidence of dead crabs at the slaughtering table.

The work was carried out by Mr. W.E. Anderson a member of the Food Science Unit and Inspection Officers from District No. 5 and No. 6. The results are illustrated in Tables No. 10.1 and No. 10.2 respectively.

The crabs were trapped in the Gulf of St. Lawrence and landed in Northern New Brunswick. Onboard the boats they were cooled with fresh water ice in 4-8 feet thick piles. The ice was mixed with the crabs, similarly to groundfish. The maximum holding time on the boats was 48 hours. In District No. 6 the crabs, after landing, were processed with very little delay (1-2 hours). In District No. 5 however, all the crabs processed were trucked in from Northern New Brunswick. The extra transportation affected the crabs adversely

as can be observed in Table No. 10.2.

Procedures:

Diagnosis of death was accomplished by observing the mouth piece movements and the muscle tone of crabs. Absence of movement and muscle tone was taken as evidence of death. In earlier work (Varga et al, 1971) this method of diagnosis was compared to diagnosis based on the observation of heart beat of crab and it was found that about 10% of diagnosis was in error. That is, the mortality rate estimated by the present method is about 10% higher than the actual mortality rate of crabs.

Sampling:

Boat loads were sampled randomly. From each load a sample consisting of about 500 crabs was randomly examined. The observations were categorized as follows:

(1) Lively strong crab: crab with apparent movement.
(2) Weak live crab: detectable movement after physical stimulation.
(3) Dead crab: absence of any movement and muscle tone.

Samplings and examination of samples were carried out separately by the field and the laboratory staff. The results are also reported separately in Table 10.1 and 10.2.

Comments:

The overall mortality rate of queen crabs at the time of landings in District No. 6 was lower in 1973 than in 1971 by about 10%,

in spite of the fact that the crabs were held in direct contact with fresh water ice. This unexpected result might be attributed to the prevailing low temperature in the boat hold resulting in little thawing of fresh water ice and hence lower than anticipated mortality rates.

The mortality rates during the different seasons in District No. 5 and 6 were assessed lower by the field staff than by the Halifax Laboratory personnel. The difference in the data can be attributed to unconscious bias of field staffs as well as to the inherent error of estimates due to variations in the total observations.

The mortality rate of crabs in District No. 5 is exceedingly high. The overall physiological condition of crab at the slaughtering table is poor as can be seen in Table No. 10.2. For the sake of improving the quality of raw crab processed in District No. 5, transportation of live crabs perhaps should be banned. This quality problem could be alleviated by transporting only cooked frozen or chilled sections, rather than live crabs.

The data provided by the staff of District No. 5 is significantly different from the results provided by both District No. 6 and Halifax personnel. It is noted that the field personnel have to enforce a very difficult and contentious regulation concerning the processing of live and dead crab, and their predicament, and the difference in the data observed, is not surprising. The Halifax staff have received at all times, cordial reception and cooperation from both districts for which the authors are most appreciative.

Table 10.1: Incidence of strong, lively, weak and dead crabs at landing in District 6.

SEASON	EXAMINED BY	NO. OF CRABS EXAMINED	% LIVELY AVERAGE (RANGE)	% LIVE-WEAK AVERAGE (RANGE)	% DEAD AVERAGE (RANGE)
Spring May & June	Field Staff	9,097	54.1 (23.1-92.6)	33.9 (3.7-52.2)	12.0 (0.8-29.8)
	Halifax Lab Staff	2,274	40.2 (7.7-68.2)	31.9 (20.8-40.9)	27.9 (10.9-56.4)
Summer July & August	Field Staff	10,531	32.0 (9.0-54.6)	44.4 (32.0-58.3)	23.6 (5.8-42.6)
	Halifax Lab Staff	389	5.2 (-)	48.8 (-)	46.0 (-)
Fall Sept. & October	Field Staff	NIL	-	-	-
	Halifax Lab Staff	1,389	38.7 (31.7-46.0)	50.1 (43.0-54.6)	11.2 (8.9-13.7)
OVERALL RESULTS	Field Staff	19,628	42.3 (9.0-92.6)	39.6 (3.7-58.3)	18.1 (0.8-42.6)
	Halifax Lab Staff	4,052	36.3 (5.2-68.2)	39.8 (20.8-54.6)	23.9 (8.9-56.4

Table 10.2: Incidence of strong, lively, weak and dead crab at butchering stations in District 5.

SEASON	EXAMINED BY	NO. OF CRABS EXAMINED	% LIVELY AVERAGE (RANGE)	% LIVE-WEAK AVERAGE (RANGE)	% DEAD AVERAGE (RANGE)
Spring May & June	Field Staff	1,784	9.3 (0.8-21.0)	82.2 (70.3-96.5)	8.5 (0.3-18.0)
	Halifax Lab Staff	270	1.8 (-)	36.3 (-)	61.9 (-)
Summer July & August	Field Staff	616	0.5 (0.3-0.6)	71.9 (57.8-86.3)	27.6 (13.4-41.6)
	Halifax Lab Staff	NIL	-	-	-
Fall Sept. & October	Field Staff	631	15.1 (6.6-21.5)	77.2 (76.5-77.7)	7.7 (0.8-16.9)
	Halifax Lab Staff	NIL	-	-	-
OVERALL RESULTS	Field Staff	3,031	8.7 (0.3-21.5)	79.0 (57.8-96.5)	12.3 (0.3-41.6)
	Halifax Lab Staff	220	1.8 (-)	36.3 (-)	61.9 (-)

APPENDIX 11

REPORT ON A SURVEY DEVISED TO STUDY THE MORTALITY RATES OF QUEEN CRAB LANDED IN SHIPPEGAN, N. B. IN 1971.

S. Varga, J.B. Myrick, T. Hache and M. Chaisson. 1971. Department of Fisheries & Oceans, Regional Inspection & Technology Laboratory, Halifax, N.S. Unpublished: 4p.

SUMMARY

On the request of Mr. R. J. McNeill, C.I.B. of the Fisheries Service, a study was undertaken to assess the mortality rates of Queen crabs (Chionoecetes opilio) landed at Shippegan, N.B.

The crabs landed in Shippegan were trapped in the Gulf of St. Lawrence from June to November, 1971. After catching, they were thrown into the boathold (8-9 foot drop) and stored in bulk. During this storage the crabs were in a pile which consisted of a layer of ice, a layer of crabs (2 - 2.5 ft. thick) then a plastic sheet and further layers of ice, crabs as high as 7 - 8 feet. The first caught crabs were held for a maximum of 2 days on the boat. After landing, the crabs were processed immediately or occasionally they were held in crates in a chilled holding room overnight. Dead animals were culled at the wharf during the time of landing.

The objectives of this study were as follows:

(1) Determine the percentage of dead crabs among those culled.

(2) Mortality rate of crabs at landing which were held in bulk onboard the ships.

(3) Mortality rate of crabs held in crates, iced around the container (indirect icing) and handled carefully.

(4) Mortality rate of crabs mixed with ice in the crates and handled carefully.

(5) Mortality rates of crabs at various seasons.

(6) Effect of CO_2 concentration in the air on the mortality rates of crabs.

Procedures:

Diagnosis of death was accomplished by observing the mouth pieces movement of the crabs carefully. Absence of any movement was taken as evidence of death. By counting the number of crabs which were dead among those culled, the actual mortality rate among the culled crabs was determined.

Mortality rates of crabs in the various treatments were established by counting the live and culled crabs in the randomly picked crates. The crabs were culled when the legs were limp, and the muscle tone did not appear to exist.

Seasonal mortalities were determined by counting all the culled crabs among the crabs examined during the given period.

Effect of CO_2 accumulation on the mortality rate of crabs was studied when two separate lots of live crabs were stored in barrels at $35^{o}F$ for 48 hours. The ventilation of one barrel was restricted to a 3 inch diameter hole on the top of the lid while the air from the bottom of the other barrel was continuously pumped out. At the end of 48 hours of storage, the mortality rates in the barrels were determined and the rates were compared. The concentration of

CO_2 in the boatholds was measured with a FYRITE CO_2 indicator (Model CND) manufactured by Bacharach Instruments Company, 625 Alpha Drive, Pittsburgh, Pa. 15238, U.S.A.

Results:

The relative frequency of dead animals among the culled crabs was $RF = \frac{1304}{1461} = .8925$.

Thus the probability that the culled crab was dead is about 90%. The mortality rates of crabs handled carefully in crates onboard the boats and refrigerated with ice which was placed around the crates was $\frac{117}{416} \times 100 = 28.2\%$. The mortality rates were $\frac{92 \times 100}{174} = 53\%$ when the crabs were mixed with ice in the crates. The monthly and seasonal mortality rates of crabs which were stored in bulk onboard the boats are illustrated in Table 11.1. The death rate of crabs in the barrel held at $35^{o}F$ for 48 hours without air circulation was $\frac{23 \times 100}{74} = 31\%$ and $\frac{17 \times 100}{75} = 22.7\%$ in the barrel in which the air was circulated to prevent CO_2 buildup. The difference between these two mortality rates is not significant at 95% level of confidence. CO_2 measurement made in the boat holds at the wharf did not show measurable CO_2 content in the air. The sensitivity of measuring instruments, however, was likely too low.

Discussion:

The probability of separating dead crabs from live ones by culling, is about 90%. This efficiency, however can be improved by experience and training.

The mortality rates between the crabs stored in bulk or handled carefully in crates was not significantly different. Direct icing of crabs, however, decidedly increases the mortality rate of crabs.

The mortality rates among the crabs held onboard the boats was highest in the spring, intermediate in the summer and lowest in the fall. It would be difficult to explain these differences. They could either be attributed to dissimilarities in handling or some other factors not recognized to date. The annual loss of 32% is excessively high. To eliminate the mortality or lower it significantly, the crabs would need to be stored in sea water of proper temperature and oxygen content. The loss of about 1/3 of the catch through poor holding is extremely wasteful. The supposition that the accumulating CO_2 in the boat hold could magnify the mortality rate of crabs could not be substantiated. The assumption, however, may have validity deserving some further attention and investigation with more sensitive instruments.

The conclusion of this study can be summarized as follows:

(1) Dead crabs can be recognized readily by the absence of muscle tone in the legs.

(2) Direct icing of queen crabs with fresh water ice should be avoided.

(3) The crating and more careful handling as compared to the present bulk holding of crabs would not result in substantially lower losses of captured queen crab at Northern New Brunswick according to the figures of this investigation.

(4) The seasonal mortality of queen crab amounting to 32.6% of the catch is excessively high. It can be reliably lowered either by abbreviation of the fishing trip or by the storage of crabs in sea water tanks.

Table 11.1: Mortality rates of Queen Crab stored in bulk onboard fishing vessels for 1 - 2 days and subsequently landed at Shippegan, N. B. during 1971 fishing season.

Season	Month	No. examined	No. culled	Mortality rate	Max. range of mortality rates
Spring	June	1303	589	45.1%	13.3 - 65.0%
Summer	July	1535	586	38.2%	4.5 - 65.0%
	August	558	129	23.1%	21.0 - 44.0%
	Summer total	2093	715	34.2%	4.5 - 65.0%
Fall	September	1004	273	27.0%	2.0 - 74.0%
	October	682	79	11.6%	2.5 - 26.0%
	Fall total	1686	352	21.0%	2.0 - 74.0%
Total for 1971		5082	1656	32.6%	2.0 - 76.0%