

AN ABSTRACT OF THE THESIS OF

BURTON WARREN ADAMS for the MASTER OF SCIENCE
(Name of student) (Degree)

in Ocean Engineering presented on 30 MARCH 1971
(Major) (Date)

Title: SYSTEM DESIGN FOR DUNGENESS CRAB PROCESSING

Abstract approved: _____

Redacted for privacy

(William Engesser)

Redacted for privacy

(Fred Burgess)

Dungeness crab is an important fishery on the Pacific Coast. The processing subsystem of the fishery is hampered by a variety of problems that have acted to impede technological innovations that could improve efficiency and sanitation in seafood plants. This paper provides background for problems encountered by the processors, discusses the existing plant operations, and points out problems inherent with the existing system. System I presents solutions to identified problems, the principle ones being a crab butchering machine to replace the manual-operation; improved work design method for shucking crab meat; and a multi-purpose shaker table to combine the freshening, inspection, de-watering and can-filling operations.

If all equipment and procedure changes recommended in System I are implemented, an estimated capital investment of \$18,350 will yield an annual savings of \$13,600.

System II presents new concepts in crab processing. This

system incorporates, a centrifuge to separate meat from the shell, a forming machine to make meat more consumer acceptable, cryogenic freezing to improve quality and improved packaging to increase sales.

Finally, the following nine specific areas are identified for future studies:

- | | | |
|-------------|---------------------------|-----------------------|
| 1) cooking | 4) crabmeat centrifuge | 7) cryogenic freezing |
| 2) cooling | 5) formed body meat | 8) packaging |
| 3) shucking | 6) crabmeat water content | 9) Tanner crab |

Most of the above topics relate to the further design and refinement of System II, but probably the most important area for development lies in the Tanner crab fishery. Harvesting of this untapped species, in Oregon, will aid employment stabilization and increase effectiveness of people and plant facilities.

System Design for Dungeness Crab Processing

by

Burton Warren Adams

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1971

APPROVED:

Redacted for privacy

Dean of Engineering and Professor of Civil Engineering
in charge of major

Redacted for privacy

Professor of Industrial Engineering
in charge of thesis

Redacted for privacy

Acting Head of Department of Civil Engineering

Redacted for privacy

Dean of Graduate School

Date thesis is presented 30 MARCH 1971

Typed by Ilene Anderton for Burton Warren Adams

ACKNOWLEDGEMENT

This research has been partially supported by
NATIONAL SCIENCE FOUNDATION SEA GRANT GH 97

Appreciation is extended to participating

SEAFOOD INDUSTRIES

THE NATIONAL MARINE FISHERIES SERVICE

OSU'S MARINE ADVISORY STAFF

and other
COOPERATING DEPARTMENTS

TABLE OF CONTENTS

INTRODUCTION	1
Statement of Problem	1
Background	2
DUNGENESS CRAB PROCESSING IN OREGON	8
Unloading Boats	8
Holding Crab Prior to Butchering	10
Butchering	11
Cooking	13
Cooling	14
Distribution	16
Shucking	17
Existing Work Place and Shucking Tools	19
Weighing of Shucked Meat	20
Shell and Tendon Separation by Brining	21
Freshening	22
Draining	22
Final Inspection	23
Canning	25
SYSTEM I	29
Unloading Boats	29
Holding Prior to Butchering	30
Butchering	31
Cooking	33
Cooling	33
Distribution	35
Shucking	35
Improved Work Place and Shucking Tools	37
Weighing of Shucked Meat	39
Shell and Tendon Removal by Brining	39
Combination Freshening, Inspection, De-watering and Can Filling	41
PROCESSING BENEFITS FROM SYSTEM I	44
SYSTEM II	49
Unloading and Holding Crabs	49
Butchering, Cooking and Cooling	50
Separating Meat from Shell	51
Forming Finished Product	53

Freezing	53
Packaging	54
Handling the Packaged Product	54
AREAS FOR FURTHER STUDY	55
Cooking	55
Cooling	55
Shucking	56
Centrifuge for Crabmeat	56
Formed Lump or Body Meat	57
Crabmeat Water Content	58
Cryogenic Freezing of Crabmeat	58
Packaging for the Consumer	59
Tanner Crab Fishery	59
SUMMARY AND CONCLUSIONS	62
Summary	62
Conclusions	64
BIBLIOGRAPHY	66
APPENDIX I	69
Design Considerations for Constructing an Overflow Brine Tank	69
APPENDIX II	71
Possible Considerations for Improved Cooling of Crab Sections and Preliminary Test Results	71
APPENDIX III	74
Standard Labor Time for a Full Body Crab Picking	74

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1. Seasonal landings of Dungeness crab in Oregon	3
2. Crab storage well in fishing vessel	6
3. Standard fish boxes	9
4. Pallet-sized boxes	9
5. Holding crab prior to butchering	10
6. De-backing and eviscerating crab	12
7. De-backing crab with vertical knife	12
8. Continuous cooker	13
9. Batch crab cookers (left) and cooling tank (right)	15
10. Cooling bath at end of continuous cooker	15
11. Basket of crab sections for distribution to pickers	16
12. Pan, anvil and hammer	18
13. Removing body meat	18
14. Cleaning up crab shells during picker's coffee break	20
15. Shrimp processing operations	25
16. Prototype butchering machine removing back of Dungeness crab	32
17. Overflow brine separation tank	41
18. Shaker table for freshening, inspection, de-watering and can-filling	42

List of Figures (cont.)

<u>Figure</u>	<u>Page</u>
19. Schematic of crabmeat centrifuge	52
20. Increasing catch of Tanner crab in Alaska	61
21. Schematic drawing of combination cooker/cooler	73

LIST OF TABLES

<u>Table</u>	<u>Page</u>
I. Summary of problems existing in one or more seafood plants.	27
II. Feasible Process Changes Recommended in System I.	28
III. Potential Cost Benefits of System I.	45
IV. Sanitation and Quality Benefits of System I.	47
V. Temperatures of Crab Meat Versus Time and Cooling Method.	73
VI. Standard Labor Time for a Full Body Crab Picking	74

SYSTEM DESIGN FOR DUNGENESS CRAB PROCESSING

INTRODUCTION

Statement of Problem

Many major problems face the crab processor today. These range from uncertain year-to-year supply of live crabs to incomplete knowledge of total market conditions affecting the sale and distribution of Dungeness crab. Specifically the major problems are: 1) uncertain year-to-year supply of live crabs; 2) difficulty in obtaining and keeping women crab pickers; 3) quality control in processing; 4) rising labor costs; 5) old equipment; and 6) lack of information on factors affecting marketing, e. g. prices and supply available in various cities, packaging and selling selected crab meats.

The total crab system can be broken down into four divisions: 1) conservation, 2) harvesting, 3) processing and 4) distribution. This paper discusses processing and pertinent outside factors which influence this subdivision. Existing processes and procedures, including identification of problems, are described and documented. Following a summary of problems, two improved systems are presented: System I and System II.

The objectives of System I are an immediately feasible processing system that reduces labor costs, improves product quality and

processing efficiency. The major improvements in System I are the development of a butchering machine, work design of a new crab shucking method and using a shaker table to combine the freshening, inspection, de-watering and can-filling operations.

System II is ultimately feasible; it presents significant processing changes that depart from traditional crab processing. Implementation of this system requires the adaptation of existing technology and in-plant testing. The major changes presented are live crab holding tanks, crab meat centrifuge, meat forming machine, cryogenic freezing system and development of the Tanner crab fishery. These improved processing methods and machinery should lead to greater employment stability.^{1/}

Background

The Dungeness crab (*Cancer magister*) is commercially caught in the coastal and estuarine waters of North America, from San Francisco to the Aleutian Islands. Development of the Dungeness crab industry is hindered because the supply available varies greatly from year to year apparently due to natural causes (Figure 1).

^{1/} Robert Walls, Industrial Engineering Graduate Student, is investigating employment stabilization in the seafood processing industry.

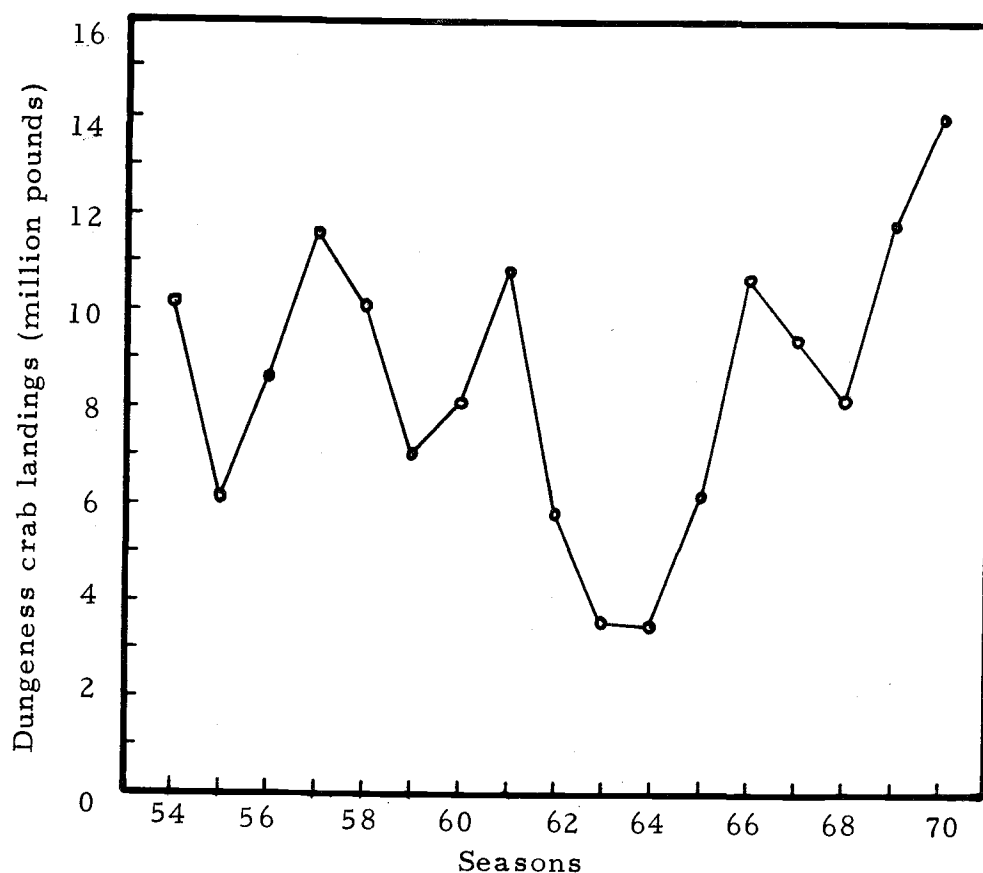


Figure 1. Seasonal landings of Dungeness crab in Oregon.

The Pacific Coast Dungeness crab fishery, in 1970, yielded a record catch for the second consecutive year of 57.2 million pounds. This surpassed the previous record catch of 49.1 million pounds in 1969. The 1970 catch, by states in millions of pounds, was: Alaska, 9.2; Washington, 18.5; Oregon, 14.0; and California 15.5. Oregon's record catch was an increase of 2.2 million pounds from the previous record catch of 11.8 million pounds during 1969 (Figure 1). The record catch in Oregon offset Alaska's catch decrease of 2.4 million

pounds to 9.2 million pounds (N. M. F. S. , 1970).

In spite of the record Dungeness crab catch, which exceeded the King crab catch by 6.5 million pounds, market prices were firm. This stability is accounted for because of wider distribution of whole and live Dungeness crabs and the scarcity of King crab, the prime competitor of Dungeness crab.

The Tanner (Snow) crab fishery has been spurred by the sharp decline in King crab resource since 1967. The 1970 catch was 15.2 million pounds as compared to 118 thousand pounds in 1967. The development of the Tanner crab fishery may be an economic solution to the highly variable year-to-year catches of Dungeness crab.

The Dungeness crab catch adds several million dollars annually to Oregon's economy, as about 90 percent of the crab is sold outside of the state. During the 1970 season, fishermen received an average of 24 cents per pound (N. M. F. S. , 1970) or about \$3.2 million for the 14.0 million pounds of crab landed. The value added by the seafood processors amounted to about \$2.6 million, adding to a wholesale value of about \$5.8 million.

Harvested Dungeness crabs are males having a minimum legal size of six and one-quarter inches across the carapace; while the largest crabs measure about ten inches. The average caught Dungeness crab weighs about two pounds, yielding about one-half pound of picked meat. Traditionally they are caught in baited crab

pots set out on the ocean floor during the regular season running from 1 December to 15 August. The pots, identified by surface buoys, are hauled up after one to eight days "soak", depending upon weather and rate of catch. Legal size male crabs are tossed into a large tank containing circulating seawater, while females, undersized and molting crabs are cast back. The pot is baited again, cast back and the boat moves on to the next pot.

R. Barry Fisher (1970) has developed improved gear and methods for harvesting Dungeness crabs. This new system should significantly reduce cost and handling effort required by fishermen through using lighter gear and long-line pot retrieval compared to individual pot retrieval now practiced. Smaller and lighter gear is particularly significant since the number of pots per fishing vessel now ranges from about 450 to over 800 as compared to an average of about 200 pots six years ago.

After the crabs are caught, it is absolutely essential that they remain alive and healthy until they are butchered^{2/} at the processing plant. If crabs are allowed to become weak or die prior to butchering, irreversible chemical and physical changes occur in the meat. Unfortunately, most processors let the crabs become weak because the de-backing operation is easier and quicker. The meat from weak

^{2/} Butcher: to remove the back (carapace) and eviscerate.

crabs is low quality and the meat from dead crabs friable and difficult to remove from the shell (Dassow, 1963). Therefore, to maintain healthy crabs, fishermen keep them in a large steel tank or in a well that is supplied with circulating seawater (Figure 2). The seawater should be aerated and circulated three times per hour to maintain an acceptable level of dissolved oxygen (50% saturation) (Dewberry, 1970) and the temperature must be kept below 50°F to keep the crabs' respiration rate low (Dassow, 1963).



Figure 2. Crab storage well in fishing vessel.

The typical Oregon seafood processing plant is located on a bay or estuary. In addition to crab, it processes salmon, tuna, shrimp, and possibly bottom fish. Even during high season in January and February, the supply of live crabs is not regular due to weather conditions preventing fishermen from leaving port. At the other extreme, when fishing is good, the processors put the fishermen on limits because the processing system is not flexible enough to handle high

catches. Its 30-40 women crab pickers shuck 100-200 thousand pounds of meat per season. Over the past 20 years there has been little technological progress because of the relatively few days per season crabs are processed at plant capacity. The fruit and vegetable industry has long suffered similar problems which it is now solving by using equipment adaptable to more than one type of product. Recent developments in shrimp processing (Engesser, 1970) make it feasible to utilize some of the same processing equipment for shrimp and crab processing. One specific piece of equipment is the shaker table depicted in System I.

DUNGENESS CRAB PROCESSING IN OREGON

The processing subsystem begins with unloading of fishing vessels and ends with canning and freezing of the shucked crab meat. This chapter describes the major crab processing operations, pointing out variations that exist from plant to plant.

The major operations are titled and numbered to facilitate cross reference with summaries and tables. They are also subdivided into part (A) description of the current operation and (B) description of the problems encountered with the particular operation.

1. Unloading Boats

(A) All plants utilize an electric winch rigged to a boom for unloading fish products. Crabs are unloaded in a variety of containers. Most plants utilize standard small wood fish boxes (Figure 3) or a gondola-hopper; these in turn are dumped into pallet-sized wood boxes which hold about 400 pounds of live crab, although a few plants use the pallet box directly (Figure 4).

(B) The use of the smaller boxes or the gondola required additional handling because these are dumped into large boxes for holding or trucking to the processing plant. The dumping into larger boxes causes additional damage to the crabs and agitated crabs bite each other.



Figure 3. Standard fish boxes.



Figure 4. Pallet-sized boxes.

2. Holding Crab Prior to Butchering

(A) Commonly unloaded in evening, crabs are held in wooden^{3/} boxes (Figure 5) until the following morning when the sorting and butchering operation commences.



Figure 5. Holding crab prior to butchering.

(B) Crabs rapidly become weak when removed from cold aerated seawater; therefore, holding equipment and procedures need to be improved to insure healthy crabs up to the moment of butcher. This freshness is essential if the final product is to have consistent quality. Also, since wood harbors bacterial contamination, wood boxes should be lined with plastic or replaced by complete plastic

^{3/} USDA has banned all wood from meat processing plants because it harbors bacteria. As sanitation regulations become stiffer for seafoods, it can be expected that wood will be prohibited in seafood processing plants.

containers to facilitate cleaning and elimination of potential contamination (Adams and Fisher, 1970).

3. Butchering

(A) Before the butchering operation, the crabs are normally^{4/} sorted into three categories: 1) large prime crabs with undamaged shells are selected for marketing as whole or shell crabs; 2) dead and very weak crabs are normally culled; and 3) remainder (about 50 percent) are shucked for frozen canned meat.

Live crabs destined for shucking are de-backed and eviscerated, prior to cooking, by one of three methods:

1. The back or carapace is manually torn off, lungs manually removed, and some viscera removed by workers shaking the section. The crab section is then broken into halves prior to cooking. Some plants choose to cook the whole section.^{5/}

2. In most plants the crab is grasped by its legs on each side and hit against a stubby spike to remove its back (Figure 6).^{6/}

^{4/} One seafood company does not market whole crabs.

^{5/} Some processors believe yield is increased by reducing meat exposure during cooking.

^{6/} One plant's method is similar to this method except a breaking edge is used instead of a stubby spike with the result that the crab is split into half sections.



Figure 6. De-backing and eviscerating crab.

Then the lungs are removed manually before the section is dropped into the chain conveyor to the cooker.

3. In one plant the crab is grasped by the legs, driven mouth first onto a vertical knife (Figure 7). Then the body section is wedged away from the back and the lungs are manually removed.



Figure 7. De-backing crab with vertical knife.

(B) Manual de-backing of crabs is a slow, difficult and fatiguing operation. It also requires too many men (4 to 5) to supply sufficient de-backed crabs for a normal crew of 30-35 women crab pickers. Manual butchering normally requires a previous sorting operation for "whole crab" and cull.

4. Cooking

(A) The sections or half sections are cooked either in a continuous cooker (Figure 8) or in a batch cooker (Figure 9). In the typical batch cooker, the crab sections are placed in a large wire basket and lowered into steam heated water; about 210°F.

When a continuous cooker is used, eviscerated crab sections are directly conveyed into the cooker providing a continuous product flow.



Figure 8. Continuous cooker.

Cooking times for crab sections normally range from 10-14 minutes; the variations are caused by the physiological condition of the crabs, the type of cooker, the rate at which crabs are added to the cooker and possibly other factors.

(B) Batch cookers have several problems not associated with continuous cookers: 1) require highly dependable labor to control cooking time and temperature; 2) higher labor costs due to more handling; 3) unequal cooking of all sections; and 4) a longer lapse time between butchering and cooking.

Lower capital investment is the prime advantage of batch cookers.

5. Cooling

(A) Cooked sections are cooled by water spray or by submerging in a water bath. The plants that use batch cookers simply transfer the basket of cooked sections into a water bath (Figure 9). Plants using a continuous cooker either extend the chain link conveyor belt through a spray cooling section or allow the crab sections to drop into a cooling bath at the end of the cooker (Figure 10).

(B) Both of the described methods can provide adequate cooling, provided the water temperature is cool enough (less than 50°F). The bath water must be circulated sufficiently to carry away the heat.

In several plants cooling of the cooked sections is inadequate.



Figure 9. Batch crab cookers (left) and cooling tank (right).



Figure 10. Cooling bath at end of continuous cooker.

Insufficient cooling has the following negative effects: 1) increased difficulty of shucking; 2) lower shucking yield; 3) faster bacteria growth; and 4) shucked meat of poorer appearance.

6. Distribution

(A) Cooled sections are distributed to pickers in batches weighing about 30 pounds (Figure 11). A few plants weigh sections for each

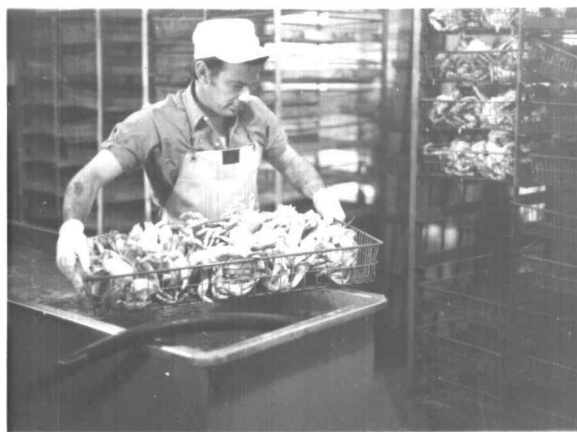


Figure 11. Basket of crab sections for distribution to pickers.

picker to determine individual picker yield. Weighing sections for each picker discourages discarding small legs, tips and joints. Pickers tend to do this because the smaller pieces are slow picking and yield little meat.

(B) Weighing sections for each picker is not the most cost-effective method of controlling picker yield. It requires additional

handling, additional paper work and can add additional contamination.

7. Shucking

(A) At present, no satisfactory machinery has been developed to remove meat from Dungeness crabs. Therefore, skilled women manually remove the meat from the shell. They use a hammer, anvil and two shucking pans, one for leg meat and one for body meat (Figure 12). The meat is shaken out by women hitting the half section on the top edge of the pan (Figure 13) while the hammer is used to crack the legs prior to shaking out leg meat.

As crab sections are shucked, body meat is kept separate from the leg meat. This divisioning is done because of the industry-wide practice of packing choice whole leg pieces on the top layer of No. 10 cans for appearance.

(B) In each processing plant the method utilized for shucking varies to some degree; it even varies between pickers. The accepted method in each plant has resulted from a long trial-and-error history and is usually the one the "floor lady" ^{7/} has found acceptable after years of experience as a picker herself.

^{7/} The "floor lady" is the woman supervisor for the crab pickers.

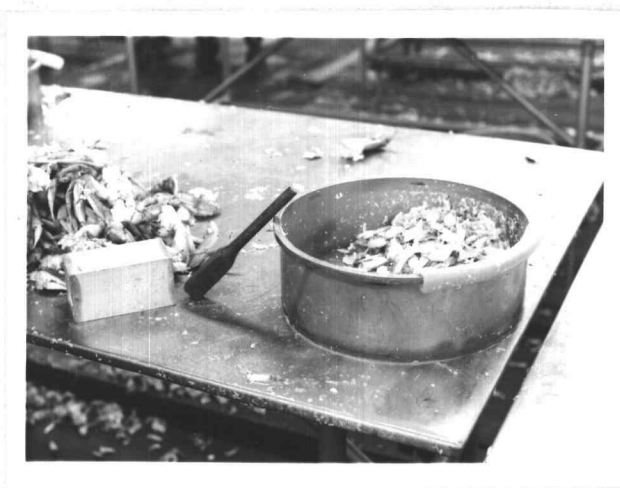


Figure 12. Pan, anvil and hammer.



Figure 13. Removing body meat.

8. Existing Work Place and Shucking Tools

(A) The size of the table top work space varies considerably from plant to plant. Some plants have partitions between individual work areas, some none. The shucking tools, the hammer and anvil, are usually aluminum. The meat pans are stainless steel with a perforated bottom to allow excess moisture to drain.

(B) Some serious problems are light weight meat pans that wobble or bounce when the meat is hit out, shucked shells that litter the floor, and table tops that are not cleaned before delivery of each batch of crab sections. Unstable pans require excessive hits to remove crab meat. In most plants shucked shells are simply deposited on the floor and cleaned up each coffee break (Figure 14). These shells can be an indirect source of microbial contamination although a direct major source is unclean table tops. The slime that accumulates can breed significant bacterial contamination within an hour, depending upon the temperature.^{8/}

^{8/} Personal communication, J.S. Lee, microbiologist, Dept. of Food Science and Technology, Oregon State University.



Figure 14. Cleaning up crab shells during picker's coffee break.

Other lesser problems in the picking area are corrosion products from the reaction between saltwater and the aluminum hammers, wrong size anvils, no stands for adjusting different height pickers to the existing tables and the fatiguing effect of pickers standing on cold, hard concrete. Also lack of adequate picker work space is a source of squabbles between adjacent pickers because some will try to slide small crab legs to other pickers.

9. Weighing of Shucked Meat

(A) Periodically women pickers carry pans of meat to a central scale because they are paid according to the amount of meat they

shuck.

(B) Most plants still use scales calibrated in pounds and ounces. The English measurement system is out of date and its continued use makes calculations slower and more prone to mistakes; hence labor costs for record keeping increase.

10. Shell and Tendon Separation by Brining

(A) After being weighed, the meat is dumped into a concentrated brine solution (90° - 100° salinometer) to permit the slightly heavier shells and tendon to sink while the meat floats. The meat is stirred for a minute or two, scooped out and dumped into a tank of fresh water to remove excess salt.

A few plants use a tank in which the brine circulates via an overflow spout and a return pump. The overflowing brine carries the floating meat into a strainer or onto a conveyor.

(B) Using a regular tank (no overflow) prevents a continuous product flow and usually results in meat being subjected to the brine for varying lengths of time.

Several of the overflow brine tanks are poorly designed because they do not provide sufficient depth of brine flow through the spout. Therefore, the meat floating in the brine tank is caught at the entrance lip of the spout and will not overflow with the brine without assistance from the worker.

Poorly designed brine overflow tanks develop excess foam, which hinders the operation.

Few plants in Oregon refrigerate their brine tanks. Since brine tanks harbor bacteria, refrigeration is an important step towards improving the quality of the meat by reducing bacteria growth.

11. Freshening

(A) Crab meat picks up excessive salt from the brining operation. Therefore, the meat is stirred in a tank of fresh water to remove excess salt.

(B) This operation requires additional handling which can add contamination. It also does not provide the desired continuous product flow.

12. Draining

(A) The meat, now water saturated, must be drained prior to canning. This is usually accomplished by setting the meat out in perforated pans on a rack for several minutes, although a few plants utilize a centrifuge.

(B) Rack draining is a poor practice because of added handling required, and the rarely constant drain time results in canned meat of significantly different water content.

Variations in water content of canned meat is of particular

significance because the processor cannot consistently fill cans to yield the correct drained weight after they have been frozen. The consumer is unhappy if the drained weight is less than that stated on the can and if a large volume of drip pours out upon opening the can.

Presently there is a significant controversy whether or not crab meat should be centrifuged to remove water prior to being canned. The controversy stems from how the water content of canned meat affects drip loss and quality of the defrosted product. Meat water content varies due to processing time variations of brining, freshening and draining. The amount of drip loss from defrosted crab meat is a function of initial water content, freezing rate, length of time frozen and possibly other factors, e. g. storage temperature.

A few plants centrifuge crab meat for an exact time interval to give the canned meat a constant water content. Centrifuging permits filling cans to a known weight to allow for drip loss when defrosted. Other processors claim the water protects the frozen product from dehydration.

The controversy is unresolved and needs further study to determine the optimum meat water content to minimize drip loss and maximize quality.

13. Final Inspection

(A) Prior to canning, the meat is subjected to a final inspection

on a table under ultraviolet (U. V.) light. The U. V. light makes the shells and tendon appear fluorescent, a fact which facilitates location and removal.

(B) The U. V. light is not very effective unless most of the regular light is screened out.

The major objection of the final inspection is its relative position in the sequence of operations. Harrison and Lee (1968) have shown conclusively that the final inspection of shrimp, for antennae and shells, can increase the microbial count twenty-fold, or greater, and that washing after handling can result in a three-fold reduction in microbial count. Their results "demonstrated that most microbial contaminants were on the surface of the shrimp and could be partially removed by washing or brining."

Figure 15 is a schematic diagram of the consecutive operations involved in processing shrimp. Operations that reduced the microbial count are placed to the right and operations that increased the microbial count are placed to the left. The actual microbial counts measured in processing plants X and Y are shown adjacent to each operation. For example, the washing operation for plant Y reduced the total microbial count from 6.6×10^3 to 1.8×10^3 and the gram-positive cocci count from 4.6×10^3 to 1.1×10^2 .

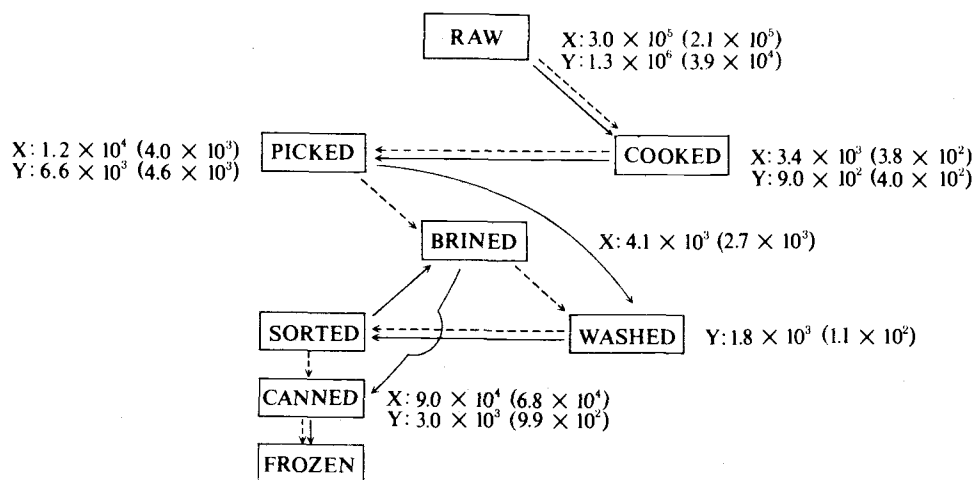


Figure 15. Shrimp processing operations. X and Y denote shrimp processing plants. Processing steps employed at plant X are indicated by broken lines, and at plant Y by solid lines. Total microbial counts at each step and the gram-positive cocci counts (in parentheses) are also shown. (from Harrison and Lee, 1968)

14. Canning

(A) The crab meat is hand packed into No. 10 cans which hold five pounds. First, white body meat is packed, followed by assorted leg meat and topped by choice, whole leg and claw pieces. This particular method of can filling is traditionally done for appearance. Finally, the can is vacuum sealed and frozen.

(B) This slow, manual method of filling crab meat into cans is a potential source of bacterial contamination.

Also, there is the problem of marketing the five-pound cans of crab meat. It is probable that retail demand could be significantly increased if body meat and leg meat were packed separately in

smaller cans. This would enable the supermarket shopper to select a reasonably sized package tailored to her specific desire, e.g. cheaper body meat for crab cakes or fancy leg meat for cocktails.^{9/}

Table I that follows provides a summary of the problems encountered in each of the listed processing areas. Table II provides a summary of the typical current processes and indicates proposed processing changes that are individually discussed in the following chapter. Each operation is numbered for reference to the discussions in chapters II and III.

^{9/} Interviews with two managers of large Safeway stores revealed that the vast majority of chickens are sold by parts.

TABLE I

Summary of Problems Existing in One or More Seafood Plants

Ref.

1. Inefficient and damaging method of unloading crabs from boats.
2. Holding procedures for live crabs detrimental to obtaining consistent quality product.
3. Manual butchering of crabs is difficult and requires too many men.
4. Batch cooking does not cook all crabs equally; it's highly dependent upon a good employee to control cooking time and temperature.
5. Inadequate cooling after cooking has several negative effects.
6. Unsatisfactory and unsanitary baskets for delivering sections to pickers.
7. Trial and error evolved shucking methods and poor control of shucking yield.
8. Table tops, at times, not cleaned between delivery of each batch of crab sections, wobbly shucking pans slow down shucking, accumulation of shells on floor source of indirect contamination.
9. Scales calibrated in pounds and ounces make calculations slow and prone to mistakes.
10. Batch brine tanks don't provide efficient product flow and warm brine breeds bacteria faster than refrigerated.
11. Inspecting crab meat after the freshening operation adds contamination that can be removed by the freshening operation; hence poor sequence of operations.
12. De-watering operation requires too much batch handling.
13. Stationary inspection table requires too much handling of product.
14. The obsolete hand filling of cans is a source of bacterial contamination. Standard five-pound cans may retard marketing of crab meat to consumer.

TABLE II

Feasible Process Changes Recommended in System I

Typical current processing	Proposed processing
Ref. #	Operation
	<u>Unloading Boats</u>
1. Small wood fish boxes or gondola-hoppers.	Large plastic containers or plastic lined wood boxes to prevent dumping.
	<u>Holding Procedures</u>
2. Held out of water overnight before butchering	Hold in circulating seawater or chilled moist air or butcher and hold.
	<u>Butchering</u>
3. Manually butchered.	Machine butchered.
	<u>Cooking</u>
4. Batch cooker	Continuous cooker.
	<u>Cooling</u>
5. Quick dip.	Extended circulating water or spray.
	<u>Distribution</u>
6. Baskets	Sanitized wire baskets each use or use conveyors.
	<u>Shucking</u>
7. Trial and error evolved method.	New picker work design.
	<u>Work Place and Tools</u>
8. Light wobbly shucking pans, shells on floor, inadequate cleaning of picker work place.	Firm hitting bar or heavy gauge flat-bottom pans, flume to remove shells, clean picking stations between each batch of sections delivered.
	<u>Weighing Meat</u>
9. Scales calibrated in pounds and ounces.	Scales calibrated in pounds and tenths of pounds.
	<u>Brining</u>
10. Simple tank.	Overflow tank, refrigerated.
	<u>Freshening</u>
11. Simple dip tank.	Shaker table.
	<u>De-watering</u>
12. Drain rack or spinner.	Shaker table.
	<u>Inspection</u>
13. Stationary table with ultra-violet light.	Shaker table with ultra-violet light.
	<u>Canning</u>
14. Hand filling of cans.	Meat funnelled, at end of shaker table, into cans on revolving table.

←
← same
table
←

SYSTEM I

Efficient processing and a quality product go hand in hand. Almost without exception the most efficient operation will produce the best consistent quality product. Several of the recommended processing improvements are dollar justified in Chapter IV, while others have quality and sanitation benefits.

The quality and sanitation benefits need to be evaluated, by the processors, in light of how much they are willing to pay to obtain a consistent top quality product and more desirable safety and sanitation conditions. An example of the type of questions processors might ask are: "If I produce a consistent top quality product, can I command a premium market price?"^{10/} and "Will profits be greater because of higher quality and greater customer satisfaction?"

1. Unloading Boats

Unloading crabs from vessels can be done faster with less damage to the crabs when large pallet-sized boxes are used. Unloading with small fish boxes or gondola-hoppers requires dumping into large pallet-sized boxes for trucking and holding. Crabs can be brought to the butchering operation in the same pallet-sized container.

^{10/} One seafood company does command a premium price because of its reputation for a consistently quality product.

These pallet-sized wood boxes should be tapered to allow stacking within one another. Stacking boxes together reduces space and shipping costs during empty shipment. Ideally all seafood processors should agree upon a standard plastic container—one that has adequate drain holes. Plastic is easier to clean and does not harbor bacteria.

2. Holding Prior to Butchering

Ideally, crabs should be de-backed and eviscerated as soon as they are unloaded from the boats. Cleaned sections require less space, and overnight cooling may have shucking advantages. If the crabs are not immediately de-backed, they should be held in a tank of seawater that is aerated and cooled below 50°F. If no holding tanks are available, the crabs should be placed in refrigerated moist air (about 32°F.), but not for more than 24 hours (Blackwood, Varga and Dewar, 1968).

Tests on Queen crab showed it was not possible to get a top organoleptic^{11/} quality product from dead or weak crabs (Dewar, Varga and Anderson, 1969). These tests also proved that picking yield decreases as quality decreases and that the shucked product has a poor appearance. Although the Queen crab (similar to Tanner crab) used in these experiments will not have identical decay characteristics

^{11/} Organoleptic: subjective testing for flavor, odour and appearance.

to those of Dungeness crab, the physiological characteristics ^{12/} are similar enough to draw parallel trends for Dungeness crab meat.

3. Butchering

The butchering operation has always been done manually; sometimes it is aided by a rotating nylon brush to remove the lungs.

Adams and Neil Spencer of Winchester Bay Seafoods (1971) have developed a prototype machine that will mechanize this operation. This machine will do the butchering and cleaning faster, using less labor. Since this will be one of the first Dungeness crab operations to be mechanized, it should create an estimated annual savings of \$2400 for an initial capital investment of \$3000.

The butchering machine (prototype, Figure 16) moves the live crab into a wedged knife that removes the back or carapace; rotating nylon brushes remove the gills or lungs; water spray removes the viscera and cleans the remaining crab section before it is carried into a continuous cooker. A conveyor or flume will carry away the offal from the butchering machine. Fifty percent of the live crab is lost to waste in the butchering operation.

^{12/} See Waterman (1960) for description of crab physiology.

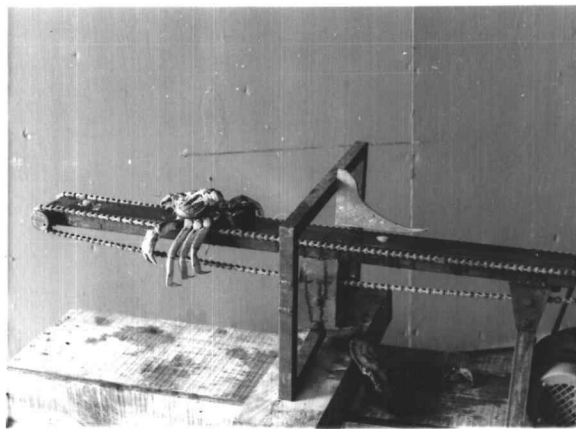
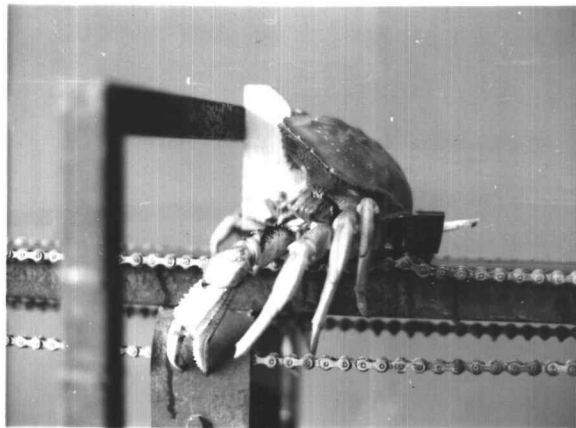
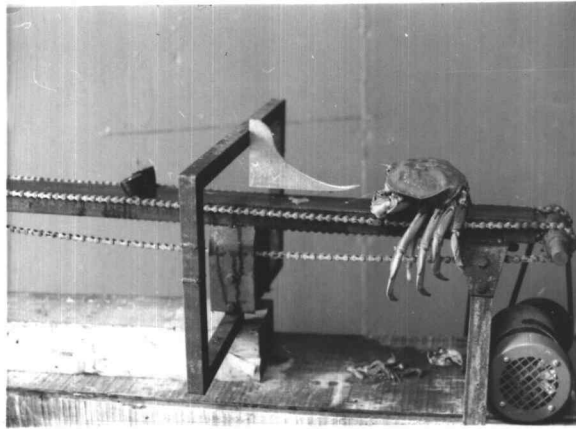


Figure 16. Prototype butchering machine removing back of Dungeness crab.

Utilizing the butchering machine also has the cost-saving advantage of combining the sorting operation with the butchering one.

As the operators pick up the live crabs to feed the butchering machine, they sort out the ones for the whole-crab market and cull the dead.

4. Cooking

A continuous cooker is recommended because labor costs are reduced; furthermore, there is a fast, steady product flow, automatic control of cooking time and temperature, and all crab sections are cooked equally. The cleaned, eviscerated crab sections coming out of the butchering machine are fed directly into the cooker, eliminating handling and possible contamination.

5. Cooling

Spray-cooling of crab sections is recommended because it is more effective ^{13/} and more sanitary than bath cooling. The chain link conveyor belt that carries the crabs through the cooker can be extended to carry the sections through a spray cooling unit (see Figure 21 in Appendix II). The cooling efficiency can be further improved by blowing air through the spray cooling unit. This adds a chill effect by increasing the evaporation rate of cooling water from

^{13/} Preliminary cooling rate tests by Adams showed spray cooling to be more effective than bath cooling; see Appendix II.

the crab sections. Using spray cooling eliminates the possibility of contamination that could occur possibly with a bath cooling system.

Although bath cooling is not as effective as spray cooling, it can be effectively used if the crab sections are allowed to remain in the cooling water for sufficient time and the water is adequately circulated.

If the crab sections are distributed to the pickers in wire baskets (Figure 10) there should be a submerged rack in the cooling tank to hold the baskets. Then sections dropping from the cooker will settle into these baskets. The rack keeps the baskets off the bottom of the tank, allowing better circulation of cooling water. The tank must be long enough to accommodate several baskets, so that as the basket under the cooker fills up it can be slid over to make room for an empty basket and allow the filled baskets to continue cooling. The length of the cooling tank must be determined by the rate the sections come from the cooker and the temperature of the cooling water. Tests by Adams indicate that the sections must remain submerged, in circulating 45° F. water, for longer than four minutes for center body meat to cool below 105° F. (see Appendix II).

Quick, effective cooling shrinks the meat away from the shell which allows easier shucking with a greater yield. The meat

obtained from well-cooled sections is more attractive and more cohesive.^{14/}

6. Distribution

It may be desirable to distribute crab sections with conveyors passing down the center of one or more long work tables. The arrangement could be similar to conveyors used for distributing bottom fish.

If wire baskets are used to distribute crab sections, they should be made of stainless steel. Wire baskets allow for good circulation of cooling water in the cooling tank after cooking, and stainless steel facilitates cleaning and allows less chance of contamination. These baskets should be sanitized in water chlorinated to 25-50 ppm (Doyle, 1969) after each use and after sanitizing rinsed in water containing 5 ppm ^{15/} free chlorine.

7. Shucking

The existing shucking methods have evolved through trial and error, and, until recently, shucking had not been analyzed from an

^{14/} From an experiment conducted at a large commercial crab processing plant in Alaska. Personal communication John Dassow, National Marine Fisheries Laboratory, Seattle.

^{15/} Doyle (1969) recommends that all processing water be chlorinated to 5 ppm free chlorine.

engineering viewpoint, namely design of motion patterns as well as tools. This is surprising because shucking costs are by far the greatest single cost in processing crab meat. The Industrial Engineering Department at Oregon State University has done an extensive work design analysis of current crab shucking methods. This study resulted in an improved picking method by Willis and Cholvanich (1970) that has recently been successfully introduced into one Oregon crab processing plant. At the end of the first month the shucking rate per hour had increased 20 percent without any investment in new tools or equipment.

A color-sound training film, now in production, will demonstrate the new method. It should be available in 1971 to aid in training women in the improved method.

In addition to increasing the picking rate, the processor must control the yield from the crab sections. Some plants weigh sections distributed to each woman picker. This is an effective method to control yield and discourage pickers from discarding small legs, but it required more handling and record keeping. A cheaper method is to establish a relationship between body meat and leg meat. Depending upon their molt condition, crabs will yield a relatively constant relation between body meat and leg meat. Preliminary tests ^{16/}indicate

^{16/} From tests at one processing plant by author.

fully developed ocean crabs will yield 55 percent body meat and 45 percent leg and claw meat. Since women pickers will normally remove most of the body meat (because it is usually easy and quick) the amount of leg meat they shuck relative to the amount of white meat will provide a direct measure of the proficiency of each picker.

As body meat and leg meat are shucked and weighed separately, the weights should be recorded separately and the ratio of body meat to leg meat compared each day to evaluate the pickers. If one or more pickers show low amounts of leg meat compared to body meat, they may require closer supervision. Again scales should be calibrated in pounds and tenths of pounds to facilitate calculations and record keeping.

8. Improved Work Place and Shucking Tools

Pickers should have a stainless steel or plastic topped table that is vibration free. Individual work areas, for interference free shucking, should be a minimum size of two and one-half feet by four feet. ^{17/} Ample work space eliminates interference and should increase production.

A heavy rubber pad should be available for pickers to stand on because concrete is fatiguing and reduces production rate. Stands

^{17/} From tests at one processing plant by author.

should be available for different height pickers to adjust their working height to the optimum, relative to table height.

Pans for shucking crab meat should be of heavy gage stainless steel and have flat bottoms. These characteristics insure that the pan will not bounce or rock when the meat is hit out. A rocking pan results in inefficient, slow shucking, because it requires more hits to remove the same amount of meat. ^{18/} Pans also need adequate drain holes so that pickers are not paid for water.

Plastic hammers and anvils are recommended. The best anvil is a solid block of plastic three inches by three inches by six inches because it is heavy enough to prevent movement, has no inside surfaces to clean or harbor bacteria, and allows no corrosion products such as those formed with aluminum and saltwater. The plastic hammer has the advantage of no corrosion, and it is slightly lighter than existing aluminum ones; therefore there is less tendency to smash legs and claws. Lighter hammers should result in more choice leg pieces and fewer shells. Plastic hammers and anvils are utilized in the Canadian crab processing industry (Dewberry, 1970).

The existing work areas need better sanitizing procedures. Each picker's work place should be rinsed with chlorinated water

^{18/} Motion picture analysis of hitting out crab body meat showed that an average of eight hits were required when wobbly shucking pans were used as compared to three hits when heavy firm pans were employed (Willis and Cholvanich, 1970).

(5 ppm) prior to the delivery of each batch of crab sections. This minimizes bacteria contamination as the new batch of crabs should be relatively sterile as they have not been touched since cooking.

The shucking tables should have a flume trough to carry away the shucked shells. This would eliminate 90 percent of the shells that now end up on the floor, a process which can result in indirect contamination of the meat.

9. Weighing of Shucked Meat

All scales should be calibrated in pounds and tenths! Change over should be relatively easy as most scale manufacturers have interchangeable scale faces. The change should result in fewer mistakes and a 25 percent reduction in bookkeeping.

The pickers should pick up a clean pan from a chlorinated water bath. The pan should be submerged because this will require the picker to immerse her gloves completely. A short hose with a spray nozzle is an effective method for pickers to clean off their aprons prior to getting a clean shucking pan. The nozzle is best operated with a foot peddle.

10. Shell and Tendon Removal by Brining

Brine separation of shells introduces several processing problems, such as too much salt in the meat, dissolving of a small amount

of protein which significantly affects the flavor (Steinberg and Tretsven, 1968), and yield loss. But a better method is not presently known; possibly an air cleaner-blower, as used for shrimp, would work for claws and hams (legs).

Therefore, a carefully constructed brine overflow tank is recommended for shell separation (see Appendix I and Figure 17). Since the brine solution is continually being diluted by water in the crab meat added to the tank, care must be taken to insure that the brine solution does not drop below 90° salinometer. If it does, the loss of meat due to sinking can be very expensive.

Refrigerating the brine in the overflow tank has several benefits:

1) lower temperature means less bacteria growth, 2) there is less dissolving of the protein by the brine solution caused by the lower reaction temperature, and 3) there is less breakage and better appearance of the leg pieces. ^{19/}

^{19/} From an experiment conducted at a large commercial crab processing plant in Alaska. Personal communication John Dassow, National Marine Fisheries Laboratory, Seattle.



Figure 17. Overflow brine separation tank.

11-14. Combination Freshening, Inspection, De-watering and
Can Filling

The brine tank should overflow onto a multi-purpose shaker table. The shaker table combines the freshening, inspection, de-watering and can filling operations (Figure 18). Overflowing brine carries the meat onto the shaker table. The first section of the shaker table is fitted with a punched plate bottom that allows the brine to return to the recirculating pump. The meat is conveyed through the freshening section to remove excess salt picked up during the brining. Under ultraviolet light the meat continues past the inspectors, who pick out any remaining shells and sort choice leg sections

into a parallel channel. The meat passing the inspectors is conveyed on punched plate to allow the table action to remove excess water. At the end of the table the meat is funneled into cans that revolve on a rotating table.

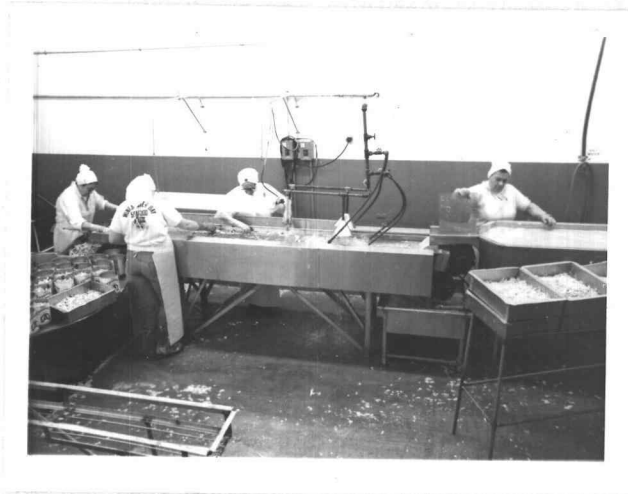


Figure 18. Shaker table for freshening, inspection, de-watering and can filling.

Ideally the inspection operation should precede the freshening operation to minimize bacterial contamination. But providing the inspectors wear gloves, laboratory bacteria analyses have shown that this freshening operation removes virtually all bacteria normally tested for in crab meat. Therefore there is no significant sanitation advantage to locate the inspection operation prior to the freshening for this combined shaker table operation.

Samples of crab meat drawn for bacterial analyses have shown

that crab meat introduced into the overflow brine tank with bacteria counts in the thousands emerge from the end of the shaker table with the following normal results: gram-positive and gram-negative counts ranging 0-100, coliforms count less than 100 and total count per gram less than 500. The ability of this equipment to remove bacteria substantiates the findings of Harrison and Lee (1968) that most bacteria is on the surface of the product and can be washed off.

The combined shaker table processing operation is a significant breakthrough for processing crab meat because of greatly reduced handling, rapid can filling and, most importantly, the lowest bacteria counts consistently achieved by the Dungeness crab processing industry.

The more efficient the process, the better quality of the final product!

PROCESSING BENEFITS FROM SYSTEM I

Benefits that should be realized by System I are summarized in two tables: Table III recommends equipment and procedure changes that may be dollar evaluated. For each equipment and procedure change recommended, initial capital costs and yearly dollar payback are estimated. Also, additional benefits that are difficult to assign a dollar value are listed. If all recommendations listed in Table III are implemented, It is estimated that an initial capital investment of \$18,330 will pay back \$13,580 annually.

Table IV recommends additional changes that are difficult to evaluate on a direct dollar basis but can be qualitatively evaluated because a better quality product should result. The changes are presented along with estimated capital costs and expected benefits.

Recommended changes in the following two tables, are numbered, the same as the pertinent discussions in Chapters II and III, for easy reference.

TABLE III. Potential Cost Benefits of System I.

Equipment and procedure changes		Estimated ^a one-year economic potential	Direct processing benefits
Ref. #		Costs (Initial)	Yearly payback
1.	Utilize pallet-sized boxes to unload crabs to eliminate changing containers.	\$ 50 ^b	\$ 200 Faster unloading, eliminates dumping of crabs so fewer damaged crabs.
3.	Install butchering machine.	\$3000	\$2400 ^c Combines sorting operation, less fatiguing work, greater production with fewer workers.
4.	Continuous cooker with automatic temperature and time control.	\$6000	\$1200 ^d Steady product flow, equal cooking for all crabs, automatic control of time and temperature.
7.	Implement new improved crab shucking method.	\$1000	\$2500 ^e Higher yield, greater production with less facilities and floor space and fewer pickers.
	Implement method to control crab picker yield	\$ 300	\$2000 ^f Compared to weighing crab sections to each picker there is less handling, labor, and contamination.
8.	Heavy gage flat-bottom shucking pans or firm base.	\$ 750 ^g	\$ 400 Faster shucking with less effort.
9.	Scales calibrated in pounds and tenths.	\$ 50	\$ 200 Faster calculations, fewer errors.
10.	Brine overflow tank replacing dip tank.	\$1200	\$ 900 Reduced handling, steady product flow, better control of salt content.

Table III Continued

Ref. #	Costs (Initial)	Yearly payback	
11-14. Shaker table to combine inspection, freshening, de-water- ing and can-filling.	\$6,000	\$3800 ^h	Reduced handling, im- proved sanitation, less floor space, fewer workers, faster can filling.
TOTALS	\$18,350	\$13,600	

Assumptions and restrictions:

- a. Estimates based on model simulation for plant employing 30 women crab pickers and processing 120,000 pounds canned crab meat during 60 full working days.
- b. Modification of existing boxes for electric hoists.
- c. Requires two men to feed crabs to machine and one man part time to deliver crabs.
- d. Requires only one part-time worker.
- e. Increase shucking rate 20 percent reduces shucking costs 8 percent.
- f. Proper management and training.
- g. 50 stainless steel pans at \$15 each.
- h. Additional payback can be gained by using shaker table to process shrimp.

TABLE IV. Sanitation and Quality Benefits of System I.

Ref. #	Equipment and procedure change	Cost ^a	Direct benefits in quality, sanitation and environment
2.	Install tanks to hold live crabs or hold in refrigerated moist air.	\$6000	Stabilize employment, fewer dead crabs, improved quality of final product.
5.	Adequate cooling of cooked sections.	\$ 600	Lower bacteria growth, easier shucking, greater shucking yield, better appearance of shucked meat.
8.	Stainless steel wire baskets, that fit cooling tank, for distributing crab sections.	\$ 400 ^b	Less handling of sections, better cooling, less product contamination.
	Size of individual work stations 4 ft. x 2.5 ft. or greater.	Variable	Efficient shucking, elimination of squabbles between pickers.
	Heavy Rubber pads for pickers to stand on, stands to adjust short picker's height	Variable	Less worker fatigue, greater production from existing facilities.
	Plastic hammers and anvils	\$ 300 ^c	Lighter hammers smash fewer leg and claw pieces, fewer shells in meat, lower tool cost, no corrosion products.
	Squeeze and rinse each work place with chlorinated water before delivery of each batch of crab sections	Variable	No build up of scum that harbors bacteria, no contamination from one batch to next batch of crab.
	Spray nozzle, with foot peddle, to rinse off aprons and hands after weighing each batch of meat.	\$ 150	Improved sanitation.

Table IV Continued

Ref. #	Equipment and procedure change	Cost	Direct benefits in quality, sanitation and environment
8.	(Continued)		
	Flume to carry away shells	\$ 500	Eliminate source of indirect contamination, better working conditions, better plant appearance to buyers.
10.	Refrigerate brine tank.	\$3000	Less bacteria, less protein dissolved which affects flavor, consistent quality product.

a. Estimated initial costs.

b. 50 baskets at \$10 each.

c. 100 plastic hammers at \$1.50 each plus block plastic for
anvils.

SYSTEM II

The ultimate system is technically feasible today but will require greater capital expenditures, the adaptation of existing technology to the seafood industry and in-plant testing. Product quality is maximized by optimizing material handling facilities and machine utilization. Mechanization reduces human contact with the product and reduces the total processing cycle time.

In order to justify increased capital expenditures for this system, Oregon seafood plants would have to increase their facilities use. This could be done by improving marketing and developing the Tanner (Snow) crab fishery. During 1971 and 1972 Russia will harvest considerably more Tanner crab than King crab from the Bering Sea crab fisheries, 35,000 cases of canned Tanner crab as compared to 23,000 cases of King crab. ^{20/}

In the immediate future, this system would better suit the larger crab processing plants in Alaska where labor costs are significantly higher than Oregon, Washington and California.

Unloading and Holding Crabs

Crabs unloaded from boats should be dumped into holding tanks

^{20/} United States and Russia Northeastern Pacific fisheries agreements for 1971 and 1972.

containing cool (below 50°F.) aerated seawater or be butchered immediately. Holding tanks can keep the crabs healthy for several days. Damage to crabs is prevented by dumping into water filled holding tanks.

Holding tanks allow the processor to schedule steady production; one or two days of bad weather would not interrupt the supply of live crab. Therefore production costs are lower due to fewer overtime wages, fewer workers, better facilities use, fewer facilities, and happier workers because they work steadily.

Butchering, Cooking and Cooling

Taken from holding tanks or immediately from boats, healthy crabs are selected for marketing as whole crabs or fed into the butchering machine. The eviscerated crab sections from the butchering machine are fed directly into the continuous cooker/cooler (Figure 21, Appendix II). As the sections exit the cooking water, they continue along on the same chain link conveyor belt into the spray cooling section. Spray cooling is used because it is more effective than the normal dip tank cooler and more sanitary.^{21/} With dip tank coolers there is the possibility of contaminating the bath water; this is not possible with a spray cooling arrangement. The

^{21/} Spray cooling is more efficient because it utilizes the principle "heat of vaporization" (539 calories/gram-°C.).

efficiency of spray cooling can be significantly increased by using a fan to force air through the spray cooling unit. This increases the evaporation rate, thereby providing a chill factor to aid in cooling the sections.

Separating Meat from Shell

There are two possibilities of separating the meat from the shell: (1) feed the whole crab section (chopped into pieces) into a centrifuge or (2) it may be desirable to shuck the body meat and large ham pieces from the legs; placing the small legs, tips and joints into a centrifuge. Table VI in Appendix III shows that under the present method for shucking just body meat a 50 pounds per hour rate is practical. Selection of the second separation method must be based on the assumption that large leg pieces command a significantly higher price than pieces formed by a machine. Also, availability of women pickers must be considered.

A crab meat centrifuge (Figure 19) should remove nearly 100 percent of the shell, and since contact time with the brine solution is very short (about five seconds with the Bird centrifuge) excess salt uptake should not be a problem.

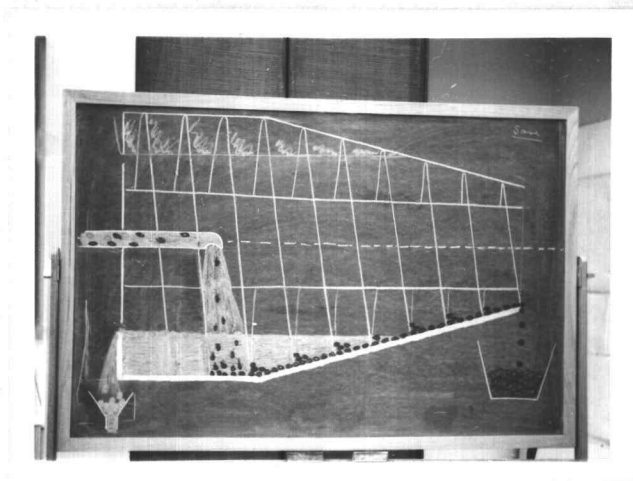


Figure 19. Schematic of crabmeat centrifuge.

Due to different densities, the centrifuge separates the shell from the lighter body meat. The shells as shown, by the dark spots in Figure 19, are thrown against the sides by the rotating auger and emerge from the right side of the tumbler while the meat rises to the top of the brine solution and flows out of the left side.

The National Marine Fisheries Service Laboratory (formerly Bureau of Commercial Fisheries), in Seattle, in cooperation with the Bird Machine Company ran preliminary, successful tests on a crabmeat centrifuge. The Bird Machine Company is presently perfecting a production model designed specifically for crabmeat.

Forming Finished Product

The crab meat from the centrifuge is mixed with a small percent binding material, e. g. comminuted raw fish flesh, and fed into the forming machine. The forming machine can produce whatever shape and sized product is desired, e. g. crab patties, leg sections.

Freezing

After the desired crab meat shape is formed, it is passed through a cryogenic food freezing machine for quick efficient freezing. Since the freezing is quick, there is little time for ice crystals to grow and damage the tissue structure of the meat, as happens during conventional freezing. This cryogenic freezing should virtually eliminate drip loss after defrosting. Also, the surface water on the meat entering the freezing machine forms a protective glaze over the surface of the meat.

Food Machinery Corporation and DuPont Company have been involved with a contract from the National Marine Fisheries Service, Gloucester Laboratory, to research cryogenic freezing of Blue crab meat. DuPont has a 500 pound per hour prototype freezing machine that uses freon 12. ^{22/}

^{22/} From a report on a workshop meeting with members of the Blue crab meat industry on April 21, 1970 at Atlanta, Georgia, sponsored by the National Marine Fisheries Service, Gloucester Laboratory.

Packaging

The frozen crab meat could be packaged into small plastic containers or plastic bags for individual serving portions for the institution and restaurant trade. A recent survey by the National Marine Fisheries Service has indicated that there would be a significant market for this type of package. ^{23/}

Handling the Packaged Product

It is extremely important for one to realize that no matter how effective the processing and freezing operation is, the quality of the product reaching the consumer depends upon packaging and storage conditions. It is necessary to maintain strict quality control right to the point of consumption.

One of the potential problems of changing from the traditional five pound cans is the handling of the product after it leaves the seafood processor. If it is handled poorly and the quality of the product is affected, the processor could gain a reputation for marketing a poor product.

^{23/} Personal communication, Roy Stevens, Marketing manager
National Marine Fisheries Service, Seattle.

AREAS FOR FURTHER STUDY

This chapter presents a short discussion on nine specific areas in crab processing that need further investigation and study. Several of the specific areas recommended for further study are strongly influenced by tradition, inadequate experimentation and myth.

Cooking

The interaction of the factors that influence cooking of crab sections are poorly understood, primarily because little quantitative information is available, e. g. how cooking time affects yield; how cooking temperature affects yield; combination of factors that optimize ease of shucking; how often cooking water needs to be completely changed to prevent contamination. One of the few well-known cooking effects is that when sections are cooked less than ten minutes (not including "come-up" time), there is a high probability that the processed meat will acquire a blue-black tinge. Again the chemistry that causes this is disputed.

Cooling

Presently the quality of meat suffers at some plants, because of inadequate cooling after cooking. Again, as with cooking, there are no quantitative data as to what is the optimum temperature to cool

meat after cooking. Factors such as the following need to be quantitatively evaluated: 1) how cooling affects shucking yield; 2) to what extent cooling to below 60°F. retards bacteria growth compared to some higher temperature; 3) how the rate of cooling affects the shrinkage of the meat away from the shell; and 4) is the greater cohesiveness of cold meat really significant?

Experimentation is also needed to determine how long cooked sections must be spray cooled for the meat temperature to decrease to a specified value.

Shucking

The Willis-Chovanich improved motion pattern design was restricted to current work-place tools and design. Further benefits will be possible by using firm hitting bars in place of pan edges and possibly semi-automated body-meat shell cracking and shaking devices.

Centrifuge for Crabmeat

The Bird Machine Company is in the process of developing a centrifuge specifically for the separation of shells from crab meat. The centrifuge would eliminate the need for women crab pickers, as the crab section would be chopped up and fed into the centrifuge. Production rate would be faster, cheaper and the yield greater than manual shucking. The main problem is that meat from the centrifuge

has little structure. This problem could be eliminated by processing the meat into formed patties or sections.

The successful development of a crab meat centrifuge would spur the development of the Tanner crab fishery by overcoming two major hinderances: poor yield and competition from Japan and Canada by lowering processing costs and increasing yield. The poorly structured meat exiting the centrifuge can be machine formed into desirable shapes to increase consumer acceptance.

Formed Lump or Body Meat

Developments in this area could improve the consumer market for body meat. Also, a market for formed body meat would help develop the Tanner (Snow) crab fishery because the meat obtained from these crabs lacks the consumer appealing appearance of a Dungeness crab (legs and claws).

The National Marine Fisheries Laboratory at Gloucester, Massachusetts has done preliminary research in the production of formed crab meat from flake and lump meat.^{24/} One successful combination was as follows: 87-1/2 percent broken meat, 10 percent comminuted raw fish flesh, and 2-1/2 percent water. The product is

^{24/} From a report on a workshop meeting with members of the Blue crab meat industry on April 21, 1970 at Atlanta, Georgia sponsored by the National Marine Fisheries Service, Gloucester Laboratory.

formed and steamed for two minutes to seal the binder. An unexpected benefit from this formulation of crab meat was a longer shelf life and better quality maintenance as compared to the original broken meat.

Crabmeat Water Content

The problem here is to optimize the quality of frozen crabmeat and to minimize ^{25/} the drip loss that occurs from defrosted crabmeat. Well-drained crabmeat that is frozen and defrosted shortly after freezing, will yield about four ounces of drip from five pounds of packed meat. To solve this problem, investigators should determine how initial water content, freezing rate (hence ice crystal grain growth), stored temperature, length of time frozen, and possibly other factors interact.

Cryogenic Freezing of Crabmeat

Food Machinery Corporation has done some preliminary work with freon freezing of crabmeat for the National Marine Fisheries Service (formerly Bureau of Commercial Fisheries). It is generally

^{25/} Presently some plants pack cans slightly overweight to compensate for the drip loss. But the consumer gets a negative reaction when five or six ounces of water is poured out of a defrosted five pound can of crabmeat.

accepted that cryogenic freezing is a superior freezing method. But before there is a possibility of cryogenic freezing equipment being introduced into the Dungeness crab industry a detailed economic analysis and actual plant demonstrations by equipment manufacturers will be required.

Packaging For the Consumer

Presently most crab meat bought in Oregon supermarkets comes to the market frozen in five pound cans which are defrosted and repacked in smaller marketable packages. Consumer demand could be increased by making crabmeat available in suitable sized container, e.g. one pound tins, eight ounce tins, or serving portions for restaurants and institutions in plastic bags. The present market situation is such that the consumer cannot decide in advance to purchase crabmeat because it is not always readily available at the supermarket. The sale of crabmeat is relegated to a spur of the moment decision on the part of the buyer.

Tanner Crab Fishery

The Tanner crab resource exists on the continental shelf of the North Pacific and in deeper water off the Washington and Oregon coasts. The National Marine Fisheries Service surveys of the upper continental slope south of the Columbia River, have found Tanner

crabs from 175 fathoms to 1050 fathoms with the greatest abundance appearing to be between 175 and 400 fathoms (Pereyra, 1968).

American interest in the Tanner crab fishery really did not begin until 1967 (Figure 20) primarily because of the sharp decline in the King crab resource. In 1962, only 11,000 pounds of Tanner crab were landed in Alaska; in 1967, 118,400 pounds; and in 1970, 15.2 million pounds were landed. The Tanner crab resource in the North Pacific has been estimated at 200-400 million pounds annual sustained yield (Bedard, 1969).

Since 1967 Canada has developed the Queen crab (Tanner) industry in the Gulf of St. Lawrence and off the east coast of Newfoundland. In 1966 the catch was negligible; in 1967 landings of 1-1/2 million pounds; in 1968, 10 million pounds; and in 1970 greater than 16 million pounds. The development of this fishery has been a "success story" primarily because the federal Department of Canadian Fisheries played a leading role, ranging from the design of fishing gear to recommended plant layouts.

The United States Food and Drug Administration has ruled that the Canadians cannot market their crab under the trade-appealing name of Queen crab but rather must label it Snow crab. The name "Snow" will provide advantage for American crab processing because it has a bad reputation as a result of poor quality Snow crab introduced from Japan several years ago. The advantage may be

ephemeral because as the United States develops the Snow (Tanner) crab fishery the name "Snow" may not be as customer appealing as "Queen".

The combination of three factors, the Tanner crab fishery, a centrifuge machine and a meat forming machine, should create an economic boon for fishermen and seafood processors.

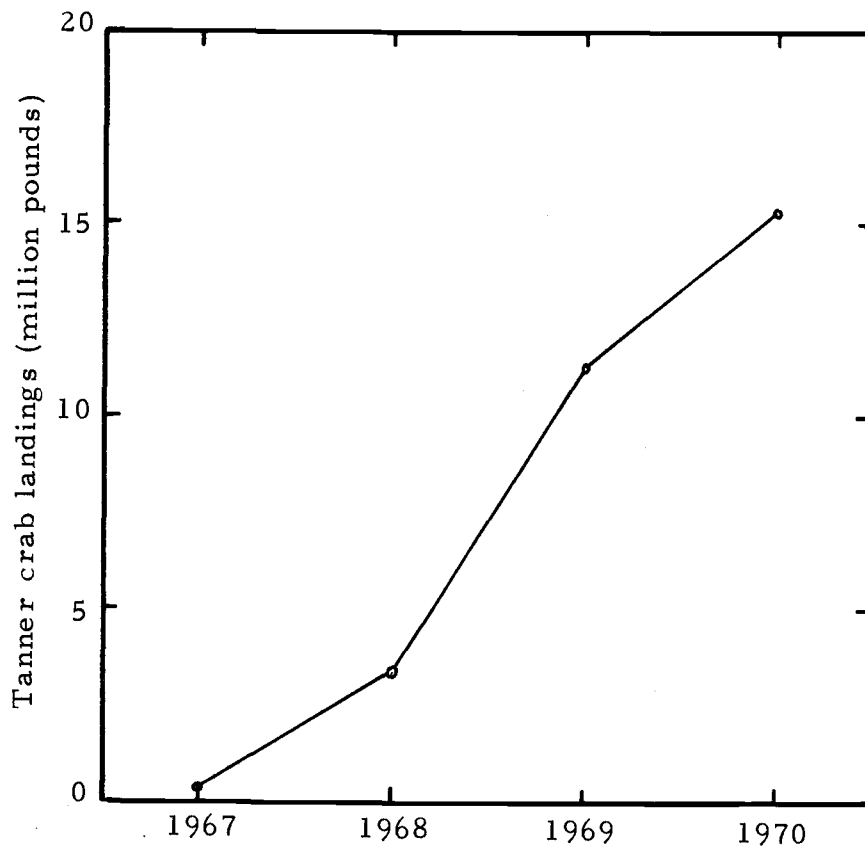


Figure 20. Increasing landings of Tanner crab in Alaska.

SUMMARY AND CONCLUSIONS

Summary

Four main areas have been discussed in this paper: 1) Processing problems facing the seafood industry; 2) An immediately feasible system that can eliminate or minimize the identified problems; 3) An ultimately feasible system that should provide an economic boon to the crab processing industry; and 4) Specific areas needing further testing before System II can be successfully introduced into the seafood industry.

Outside of the seafood plant, the processor's most pressing problem is more effective marketing of crab. Some short range attempts to promote crab have been successful, but a long range plan is desirable. Because of its success, processors should seek an organization similar to the Oregon Grass Seed Association.

The processor encounters a great variety of problems directly related to plant operation. These range from labor problems to machinery problems. A uniform and highly skilled labor force is difficult to maintain. The machinery is generally old and lacks technological innovations.

System I proposes processing changes that should reduce processing costs while increasing the quality of the product, primarily

by improving sanitation. Three major proposals are: 1) a machine to do the butchering operation; 2) the implementation of an improved crab shucking method; and 3) a shaker table that combines the freshening, inspection, de-watering and can filling operations.

An estimated cost pay-back analysis of System I indicates that a capital investment of \$18,350, for equipment and employee training, should create an annual savings of \$13,600.

In addition, there are quality and sanitation benefits that can be obtained by implementing System I. For example, bacterial tests of the crab product, processed with the shaker table, show the lowest bacteria level consistently obtained in the crab processing industry.

System II introduces a new concept in crab processing. The new system is technically feasible, but requires adaptation of existing technology and in-plant testing. The major features of this system are: 1) the use of a centrifuge to separate crab meat from the shell or a combination of traditional shucking for large leg pieces and body meat, while removing meat from small legs with a centrifuge; 2) the use of a meat forming machine to process body meat into a more marketable product; 3) cryogenic freezing of crab meat to improve the consumer product; 4) packaging the quick frozen crab meat in consumer oriented packages; 5) distributing serving-sized portions for restaurants and institutions; and 6) the development of the Tanner crab fishery to stabilize employment and increase processing

plant facilities use.

The development of the Tanner (Snow) crab fishery is particularly important because of the great year-to-year fluctuations in the supply of Dungeness crab and the rapid decline of the King crab resource. In Oregon, the Tanner crab resource is untapped; however, in 1970, 15 million pounds were landed in Alaska compared to an estimated annual sustained yield of 200 million pounds, from the Northeast Pacific.

Areas for further study identified additional work design alternatives for most of the features recommended in System II. In addition, traditional processing areas, such as cooking, cooling and shucking, are discussed in light of specific unknowns.

The appendices present useful information concerning the construction of a brine overflow separation tank and an effective cooker/cooler machine.

Conclusions

The combination of the price squeeze and stiffer sanitary regulations will force a decision upon the processor - to depart from traditional methods and machinery in favor of technological innovation of equipment and greatly increased knowledge of the market or to go bankrupt!

It is apparent that processing costs are increasing faster than

the wholesale price of frozen Dungeness crab meat. This trend in crab processing and most other types of fish products, e.g. bottom fish, shrimp, is forcing the inefficient and unknowledgeable seafood processors out of business. Furthermore, stiffer sanitary regulations, from pending legislation, will create additional financial burden on processors, particularly the inefficient.

BIBLIOGRAPHY

- Adams, Burton W. and R. Barry Fisher. 1970. Plastics as a fish-hold lining material. Corvallis, 13 p. (Oregon. Agricultural Experiment Station. Station Circular 631)
- Adams, Burton W. and Neil Spencer. 1971. Unpublished development work on crab butchering machine. Corvallis, Oregon State University, Dept. of Industrial Engineering. and Winchester Bay, Oregon, Winchester Bay Seafoods.
- Barnett, H., R. Nelson and J. Dassow. 1967. Recent technological studies of Dungeness crab processing. Part 3 Laboratory experiments in the control of drain time. Fishery Industrial Research 3(4): 13-16.
- Bedard, R. W. 1969. Packaging, acceptability, U.S. and European market potential, name of Canadian product, distribution, handling, advertising and promotion. In: Proceedings of Meeting on Atlantic crab fishery development, Canadian Fisheries Reports No. 13. Fredericton, N. B., Canada. Dept. of Fisheries and Forestry, Ottawa. p. 201-207.
- Blackwood, C. M., S. Varga and A. Dewar. 1968. Code of practice for processing Queen crab. Halifax, Dept. of Fisheries of Canada. 18 p.
- Canned fish and shellfish inspection regulations, schedule A, canneries. 1967. Ottawa, Inspection Service Department of Fisheries of Canada, 58 p.
- Dassow, J. A. 1963. The crab and lobster fisheries, In: Industrial fishery technology, ed. by M. E. Standsby and J. A. Dassow, New York, Reinhold. p. 193-208.
- Dassow, J. A. 1968. Characteristics of frozen shellfish: factors affecting quality changes during freezing and storage, part 1 crabs and lobsters. In: The freezing preservation of foods, 4th ed., Vol 2. Westport, Conn., Avi, p. 197-208.
- Dassow, J. A. 1969. Dungeness crab harvesting, processing, and marketing. Industrial engineering seminar, Oregon State University, November 19.

- Dewar, A. B., S. Varga and W. E. Anderson. 1969. Effect of post mortem spoilage on the quality of processed queen crab. In: Proceedings of Meeting on Atlantic crab fishery development, Canadian Fisheries Reports No. 13. Fredericton, N. B., Canada. Dept. of Fisheries and Forestry. Ottawa. p. 163-167.
- Dewberry, Elliott. 1970. Speed is the essence. Food Processing Industry 39(462):50-53.
- Doyle, John P. 1969. Fish plant sanitation and cleaning procedures. Fisheries Extension program, University of Alaska, College, Alaska. 12 p.
- * Engesser, W. F. 1970. Designing a complete shrimp system. Industrial Engineering 2(3):22-26.
- Food Machinery Corporation. 1967. Blue crab mechanization program analysis. Santa Clara, Calif., 87 p.
- Hannigan, K. J. 1965. Plastic can approved for crab meat. Food Engineering 37:88-89. Dec. 1965.
- Harrison, J. M. and J. S. Lee. 1968. Microbiological evaluation of Pacific shrimp processing. Applied Microbiology 18(2):188-192.
- Heerdt, M. 1947. Toughening of frozen crab meat can be retarded. Commercial Fisheries Review 9(2):7-10.
- Heerdt, M. and J. A. Dassow. 1952. Freezing and cold storage of Pacific Northwest fish and shellfish. Part IV, King crab. Commercial Fisheries Review 14(12A):29-35.
- Lee, Charles F., George M. Knobl, Jr. and Emmett F. Deady, 1963. Mechanizing the blue crab industry. Commercial Fisheries Review, 25(7):1-10.
- Montgomery, W. A. 1966. Handling and processing frozen crab meat. Australian Fisheries Newsletter 25(5):23-24, 29-30.
- National Marine Fisheries Service. 1970. Seattle landings, receipts, and value of fishery products. Seattle, p. ii-iii.
- Pacific Marine Fisheries Commission. 1965. Data series, crab and shrimp section. Portland, Oregon.

- Pereyra, W. T. 1967. Tanner crab—an untapped Pacific resource. National Fisherman, July, p. 16A.
- Portland opened to Soviet fish boats. Corvallis Gazette-Times. Oregon. p. 1, col. 3. February 13, 1971.
- Processing of Queen crab. 1969. Fisheries of Canada 21(8):10-13.
- Smith, F. J. 1970. Pricing and marketing Oregon seafoods. Corvallis, 4 p. (Oregon Agricultural Experiment Station. Special report 289)
- Steinberg, Maynard A. and W. Tretsven. 1968. Progress report on the use of CO₂ for processing dungeness crab meat. Talk to Pacific Coast Oyster Growers Assoc., Westport, Oregon 22 August.
- Ulmer, David, Jr. 1964. Preparation of chilled meat from Atlantic Blue crab. Fishery Industrial Research 2(3):21-45.
- Waterman, Talbot H. 1960. The physiology of crustacea, Vol. 1, Metabolism and growth. New York, Academic Press, 219 p.
- Wick, William. (ed.). 1970. Crisis in Oregon estuaries. Corvallis, Oregon State University Marine Advisory Program, 8 p.
- Willis, G. P. and Virivat Chovanich. 1971. Unpublished research on work design of current crab shucking. Corvallis, Oregon State University, Dept. of Industrial Engineering.
- Youde, J. G. and J. R. Wix. 1967. Economics of the Dungeness crab industry. Corvallis, 24 p. (Oregon. Agricultural Experiment Station. Station Circular 627)

APPENDICES

APPENDIX I

Design Considerations for Constructing an Overflow Brine Tank

One of the most important factors for a brine overflow tank to function properly is adequate depth of flow at the spout. This is necessary to allow the meat to overflow with the brine and not be caught at the overflow exit. Normally the depth of overflow must be greater than 5/8 of an inch to insure proper functioning. Therefore the brine pump must have adequate volume relative to the width of the overflow spout. The depth of flow for a given pump discharge and a given spout width can be approximated from the following formula:

$$H = 12(Q/3.1w)^{2/3}$$

where H = overflow depth in inches

Q = pump discharge in cubic feet per second

w = width of overflow spout in feet

note: to convert gallons/minute to cubic feet per second divide by 449

Example calculation:

Given: a) pump discharge is 10 gallons/minute

b) width of overflow spout is 5 inches (0.416 ft.)

$$H = 12 \left[\frac{\frac{10}{449}}{(3.1) (0.416)} \right]^{2/3}$$

$$H = 12 \left[\frac{0.0224}{1.29} \right]^{2/3}$$

$$H = 12 (0.066)$$

$$H = 0.8 \text{ inches}$$

Figure 17 is a suggested shape for an efficient brine overflow tank. The tank can be made of plastic or stainless steel. All pipe and fittings should be plastic because they are cheaper and will give better service in the corrosive brine environment.

Care should be used in selecting a brine pump for dependability and long service life. Stainless steel is not a guarantee of long service as some types of stainless steels give poor service in concentrated saltwater, particularly when the salt brine is not circulating.

Foaming is a common problem with recirculating brine tanks even when a de-foaming agent is added. To minimize foam, a low speed, high-volume pump should be selected.

APPENDIX II

Possible Considerations for Improved Cooling of Crab Sections and Preliminary Test Results

A comparative cooling rate test for cooked crab sections was conducted to determine if spray cooling was more effective than bath cooling.

The test procedure was as follows: First, a reference temperature was measured — that of the meat in a normal-sized crab claw and the meat in the center of the body cavity. The temperatures were measured immediately after the sections exited a continuous cooker where they were cooked for 12 minutes at 210°F.

Upon exiting the cooker, hot crab sections were subjected to spray cooling or circulating bath cooling for 80, 160 and 240 seconds. Temperatures of the meat were taken for the cooling times and the two methods of cooling. The results are summarized in Table V.

TABLE V. Temperatures* of Crab Meat Versus Time and Cooling Method

Time (sec.)	Body cavity		Claw	
	Spray	Bath	Spray	Bath
0	166	166	174	174
80	127	138	100	108
160	90	111	59	82
240	86	-	52	-

*Listed temperatures are mean value of 10 or more samples

The results of Table V show that spray cooling is more effective than a circulating bath at the same temperature as the water spray. After 160 seconds the spray cooled the meat in the body cavity $21^{\circ}\text{F}^{\circ}$ lower than the bath cooling and the claw meat $23^{\circ}\text{F}^{\circ}$ lower than the bath.

Since spray cooling is best, optimum cooking and cooling should be accomplished by a combine cooker/cooler as shown in Figure 21. The crabs sections are carried through the cooking water and then into the spray cooling section on the same chain link conveyor belt. The effectiveness of the cooling can be significantly increased by a heavy curtain at each end of the cooling unit and blowing air through the unit as shown in the schematic.

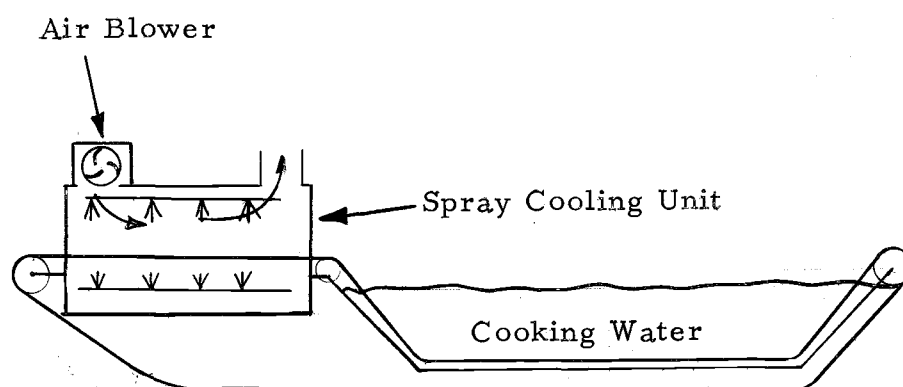


Figure 21. Schematic drawing of combination cooker/cooler.

APPENDIX III

Table VI. Standard Labor Time for a Full Body Crab Picking (seconds)

<u>STANDARD TIME</u>	PRESENT		PROPOSED	
	<u>With Tip Meat (Single Leg)</u>	<u>Without Tip Meat (Multiple Leg)</u>	<u>With Tip Meat (Multiple Leg)</u>	<u>Without Tip Meat (Multiple Leg)</u>
PICK BODY MEAT	19.2 (32.2 & 70.3)*	19.2 (32.2 & 70.3)*	13.0 (47.6 & 103.8)*	13.0 (47.6 & 103.8)*
PICK LEG MEAT	53.6 (9.8 & 20.5)*	22.4 (19.6 & 45.2)*	20.0 (26.4 & 55.1)*	15.2 (28.9 & 66.4)*
PICK CLAW LEG MEAT	20.4 (14.7 & 29.9)*	20.4 (14.7 & 29.9)*	13.8 (21.7 & 44.2)*	13.8 (21.7 & 44.2)*
TOTAL STANDARD TIME IN SECONDS	93.2 (15.5 & 32.8)*	62.0 (23.3 & 49.4)*	46.8 (30.9 & 65.4)*	42.0 (34.4 & 72.4)*

* These values represent the minimum and maximum picking rates in pounds per hour. The picking rate is equal to the standard time multiplied by the meat yield of the whole or component part of a crab. The minimum and maximum yield values were taken from a field test performed by Professor's Langmo and Engesser (OSU) on March 5, 1970. Live whole crab weights were as follows: 21.25 oz minimum and 41.25 oz maximum.

The minimum value used in this study represents the typical size of crab picked. The processor will separate out the larger crabs to be sold as whole crab. Should the larger size crabs be picked, the maximum picking rate could be less than that shown above due to manipulation problems.

Source: Data from analyses of motion pictures by Virivat Chovanich, Industrial Engineering Graduate Student, Oregon State University.