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DEVELOPMENT OF IMPROVED TECHNIQUES
FOR SHUCKING PACIFIC OYSTERS

May 1971

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INTRODUCTION

A serious constraint in producing fresh, marketable oysters in the Pacific Northwest, and perhaps throughout the world, is that of economically removing the meat from the shells (shucking). The productivity of the oyster industry throughout the United States, including the Pacific Northwest, has steadily dropped since the 1940's. Many factors have contributed to this decline, such as seed shortages, labor shortages, mortalities and pollution; however, the labor shortage probably represents the first crucial problem to be overcome before an expansion of the industry can take place.

The primary market for Pacific oysters in the Pacific Northwest utilizes a fresh raw product and shucking of fresh oysters is currently accomplished entirely by hand. Shucking comprises about 20-25 percent of the production cost of fresh oysters. A skilled oyster shucker can open a maximum of about 25 gallons of Pacific oysters per day; the average production is probably closer to 15 gallons per day, depending on size. Hand shucking requires considerable manual dexterity and a critical shortage of skilled openers currently exists in the Northwest. The production of fresh Pacific oysters in Washington was about 9.1 million pounds in 1960, 8.2 millions pounds in 1963 and 6.7 million pounds in 1966 (Washington State Department of Fisheries statistics). Of this total production approximately 85 percent are hand opened, with the balance being steamed open and subsequently canned. The potential for a greatly expanded fresh oyster market exists, based on past consumption, but it is unlikely that sufficiently skilled personnel could be obtained to meet the demand if the harvest were significantly increased.

Alternative solutions to counteract the labor shortage include: (1) development of an automated shucking process or machine, or (2) identification or development of techniques to simplify hand opening.

Several attempts to develop machines for automated shucking of East Coast and Gulf varieties of oysters have been undertaken in the past and efforts in this direction are still underway. Because of the difference in physical characteristics between Eastern and Pacific species, such as (a) larger size and irregular shape, (b) high incidence of clusters in the Pacific variety, and (c) the deeply scalloped bill of the Pacific

oyster, it is unlikely that any machine or technique successfully developed for shucking the Gulf-Eastern varieties can be adapted to economically shuck Pacific oysters. In fact, it is more likely that a machine capable of shucking Pacific oysters could be adapted to the Gulf-Eastern varieties and therefore efforts on a national scale would have to include adequate provision of Pacific oysters to assure that the Pacific Coast industry would not be further jeopardized.

SUMMARY AND CONCLUSIONS

The objectives of this study were to identify and assess the feasibility of new or improved methods for automated shucking of Pacific oysters. A secondary goal was the identification of techniques to facilitate hand opening to reduce labor requirements.

Exploratory experiments were performed with both single and clustered oysters on potential treatments and treatment combinations including: cryogenic freezing, chemical treatment, ultrasonic energy, explosive decompression, electrical shock, local heating, mechanical shock and vibration, carbon dioxide, microwave heating, vacuum, vacuum with microwave pretreatment, and anesthetic agents.

In all, twelve techniques or combinations of techniques were investigated. The results are summarized on the following table.

SUMMARY - OYSTER TREATMENT METHODS INVESTIGATED

Method	Parameters	Results
Cryogenic freezing followed by peripheral thawing	-320°F 150°F	Bond of both hinge and adductor muscle broken. Oysters easily separated after thawing.
Chemical treatment	Papain(enzyme) EDTA (complexing agent) Aqueous $MgCl_2$	No effect Produced shell gaping
Ultrasonic energy	50-100 watts	No effect
Explosive decompression	20-1500 psig Gas and liquid	No effect
Electrical shock	0-5000 volts 0-0.02 amp	No effect
Local heating	Propane torch Oxyacetylene torch	No effect
Mechanical shock and vibration	Sharp blow 10-30 cps	No effect No effect
Carbon dioxide	Saturated aqueous solution	No effect
Microwave heating	Low energy	Inconclusive - some specimens were cooked.
Vacuum	0-29 in. Hg vacuum	No effect
Vacuum with ultrasonic pre-treatment	29 in. Hg vacuum 400 watts	Inconclusive .25% of specimen shells gaped 1/4 inch
Anesthetic agent	Ether Chloroform Chlorodane MS-222 Quinaldine	Inconclusive

The only method investigated that was found capable of adaptation to fully automated oyster shucking was cryogenic freezing followed by peripheral thawing. Such a process is economically feasible in that the material cost for operation is approximately 98¢ per gallon of shucked oyster meat. Figure 1 shows a flow diagram for a cryogenic oyster shucking process.

Some quality degradation of the processed product was observed during the freezing experiments. After thawing, the outer surfaces of processed oysters appeared to have a series of essentially parallel longitudinal splits or cracks. Bleeding was generally moderately severe. Lower rates of freezing (as in a deep freeze or by suspension above a liquid nitrogen pool) eliminated this effect. However, shell-meat separation did not occur under these conditions.

The occurrence of textural oyster damage during rapid freezing is contrary to the behavior of meat and food products. Structural damage is generally avoided by rapid rates of freezing such that intracellular and extracellular ice crystal growth is prevented or minimized. It is possible that by appropriate oyster pretreatment, selection of optimal cooling rates, or selective cooling through one surface that the degradation effect will be avoided. These possibilities were not investigated.

The most effective method of producing oyster shell gaping was found to be by treatment involving exposure to an aqueous magnesium chloride solution. Further development of this process is warranted to optimize ion concentrations, temperature, residence time, composition and concentration of additives for use in pretreating Pacific oysters for hand shucking.
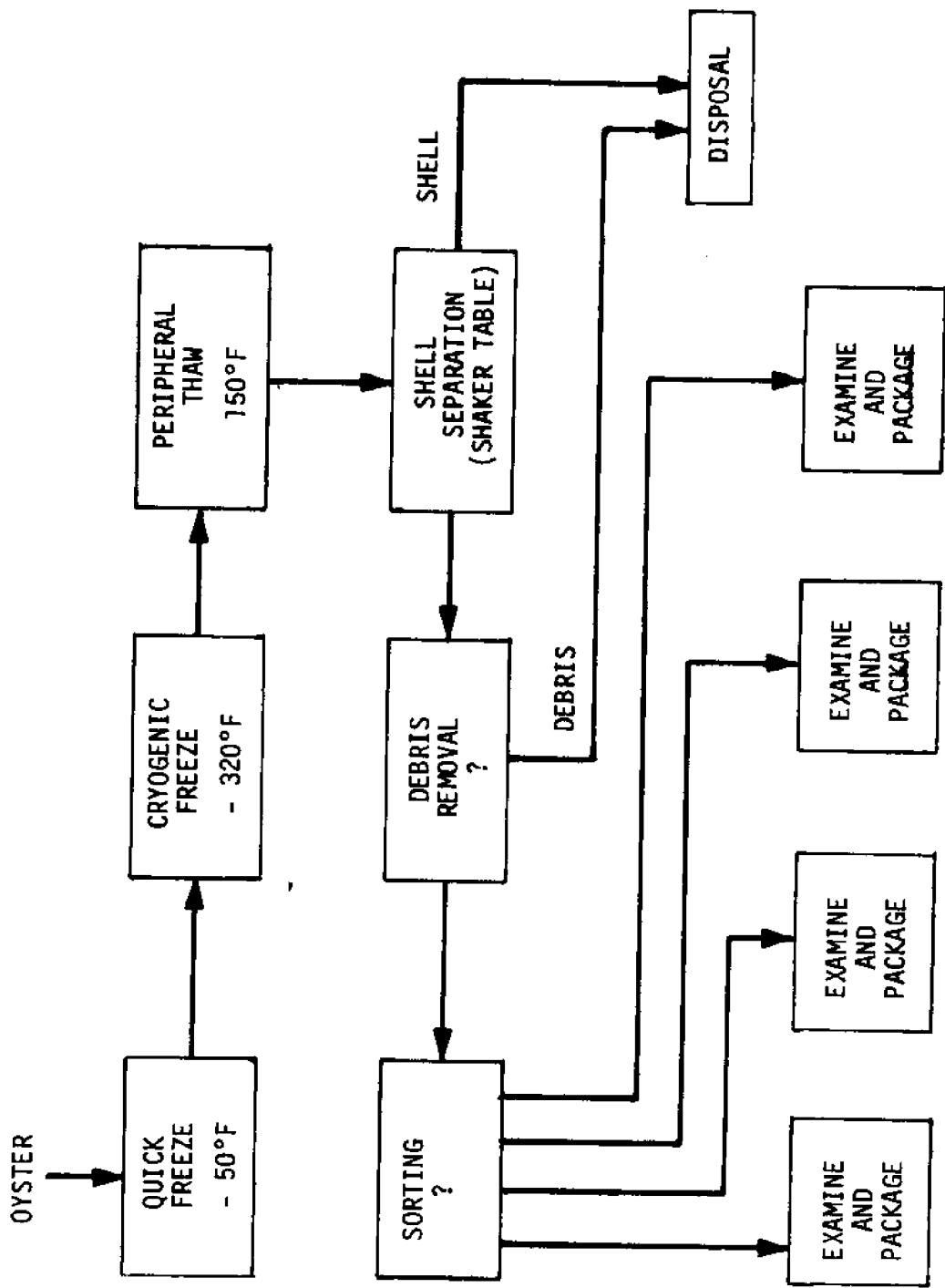
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FIGURE 1

CRYOGENIC OYSTER SHUCKING PROCESS
(FLOW DIAGRAM)

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RECOMMENDATIONS

Exploitation of the cryogenic freezing process for oyster shucking can be by either of two paths:

- Use of the process as presently envisioned for the preparation of convenience foods which would not be adversely affected by textural degradation (stews, breaded oysters, canned cooked oysters, etc.).

- Elimination of the texture damage while retaining the shucking effect followed by development of a system such as is shown on Figure 1. This would require further experimentation and complete absence of freezing damage may not be possible.

It is recommended that the first course of action be pursued and a lesser effort continued on the latter. It is recognized that development in this direction will mean a more limited immediate applicability and may require that processing interests, beyond those of the Pacific oyster industry, be involved.

It is strongly recommended that the technique of inducing oyster shell gaping by exposure to aqueous solutions of metallic ions be developed. This process, although not directed toward a fully automated system, offers significant economic advantage to the industry by reducing the cost and required personnel skill for hand shucking. The following tasks should be performed:

- Review FDA regulatory status of possible treatment agents, in terms of allowable concentrations or other limitations of use.

- Determine optimal solution concentrations exposure times and exposure temperature of those materials acceptable to FDA for compatibility with oyster processing operations, variations in oyster metabolism during the harvest season, and maximum economic advantage.

- Determine quality characteristics of processed oysters in comparison to oysters shucked by conventional methods--flavor, texture, storing qualities, and bacterial contamination.

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- Specify the equipment, methods, materials, layouts, etc., for putting the treatment method into operation.
- Assist the industry in installing and initial operation of the processing system at a typical oyster processing site.

DISCUSSION

An initial state-of-art survey of oyster shucking revealed the development of numerous small machines that crush, grind or break the bill of the oyster to facilitate hand shucking. Most of these are patented (Appendix A). Other processes employing thermal properties for shock have also been developed to aid hand shucking. The "hot dip" or "shock" method[1] of opening oysters was presented by the South Carolina State Board of Health to a shellfish workshop, Washington, D.C. in 1961. This method is used in South Carolina where the oysters are small (500 to 600 per gallon) and generally clustered. It is reported that, under well controlled conditions, this method produces a product with good keeping qualities and low bacterial count.

As a first step toward a better understanding of the forces associated with prying or forcing the shell halves apart, the tensile strength of the adductor muscles of a series of Pacific oysters was measured. It was found, as expected, that the muscle strength was greater for the larger oyster. Figure 2 shows the adductor muscle tension as a function of displacement for a large and a small oyster. It was noted that a lower rate of displacement of the two shell halves yielded lower values of the measured muscle strength than similar sized oysters opened at higher rates. Figure 3 shows a typical plot of muscle tension as a function of shell separation for low opening rate.

After the preliminary base work was completed, an Edisonian series of experiments were performed to investigate a variety of approaches to either sever the adductor muscle and hinge or to cause shell gaping. These are described in the following paragraphs.

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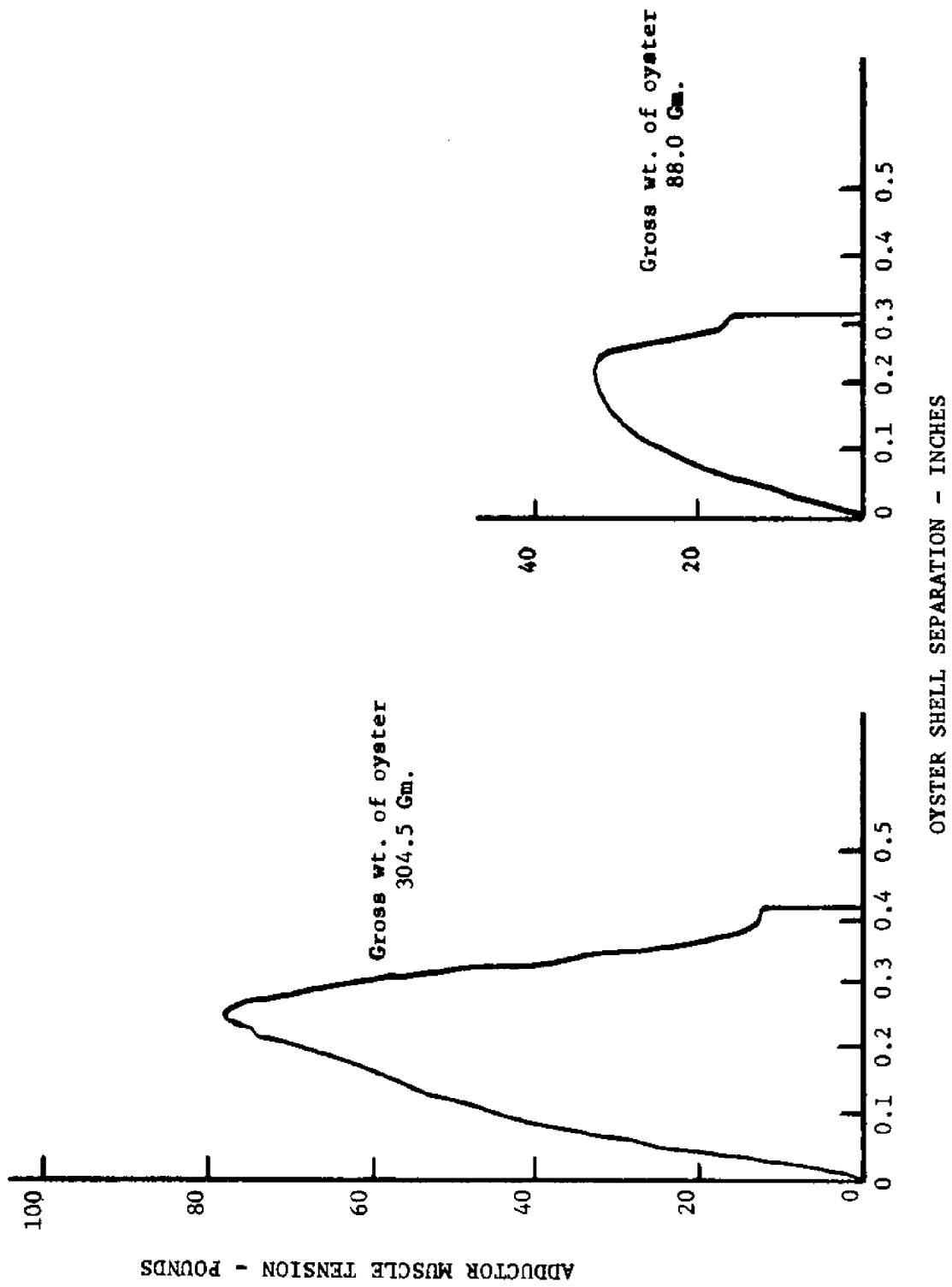
FIGURE 2

ADDUCTOR MUSCLE TENSION WITH A DISPLACEMENT RATE OF 0.2 IN/MIN.

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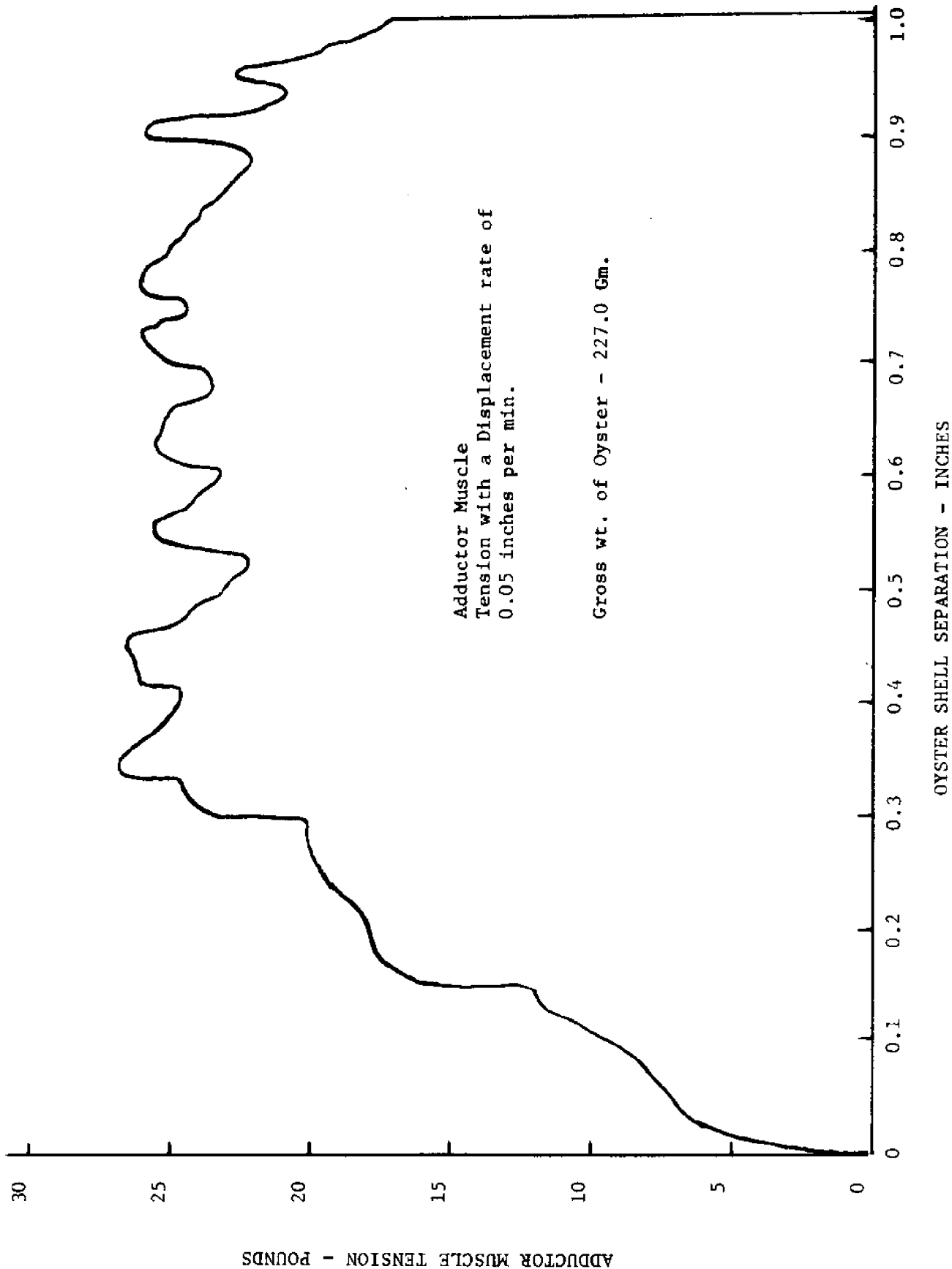
The graph shows ADDUCTOR MUSCLE TENSION – POUNDS (vertical axis, 0 to 30) plotted against OYSTER SHELL SEPARATION – INCHES (horizontal axis, 0 to 1.0).

Adductor Muscle
Tension with a Displacement rate of
0.05 inches per min.

Gross wt. of Oyster – 227.0 Gm.

FIGURE 3

ADDUCTOR MUSCLE TENSION WITH A DISPLACEMENT RATIO OF 0.05 IN/MIN.

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I. Freezing Treatment

A series of experiments employed a cryogenic freezing technique. For these experiments, the oysters were immersed in liquid nitrogen to freeze them and then thawed to remove the oyster from its shell. Ninety-seven percent of the oysters treated in this manner were found to have the bond between the adductor muscle and the shell destroyed. The oysters were allowed to come to thermal equilibrium in the liquid nitrogen (-160°C at atmospheric pressure). Thawing was accomplished in both air and by immersion in warm water. In most cases thawing was limited to the peripheral regions sufficient to allow the oyster meat to fall from its shell. Table I presents the results of these experiments.

TABLE I

EFFECTS OF CRYOGENIC FREEZING
(Liquid Nitrogen)

Oyster Gross Weight grams	Immersion Time seconds	Thawing Method	Remarks
87.0	82	Ambient Air	Hinge broken, oyster detached from shell
142.5	127	"	" "
204.5	103	"	" "
277.0	136	55°C H_2O	" "
112.0	96	"	Hinge broken ~20% of interface area still attached on one end of muscle
165.5	131	"	Hinge broken, oyster detached from shell
183.0	139	"	" "
223.0	135	"	" "
248.5	129	"	" "
158.5	128	"	" "

The results of these experiments were very encouraging and a second series was conducted to investigate the energy propogation through the oyster when exposed to this treatment. Thermocouples were implanted in the test specimens, one in the adductor muscle at the interface

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between the muscle and shell, and another in the center of oyster body. The temperature data for these tests was recorded as a function of time. Figure 4 shows a typical plot of temperature versus time during the cryogenic freezing of an oyster. During these tests, additional data was secured on the weight of both the oyster shell and the shucked meat and the liquid nitrogen consumed during the freezing operation. This data was used to make an approximate economic evaluation of this shucking technique. Data from these experiments is presented on Table II.

TABLE II

EFFECTS OF CRYOGENIC FREEZING

Oyster Gross Weight grams	Shucked Meat Weight grams	Consumed LN$_2$ Weight grams	Data Record number	Remarks
163.5	29.0	260	1	Hinge broken, oyster detached from shell
144.5	28.5	227	2	"
74.0	15.5	120	3	"
203.5	58.0	327	4	"
184.0	37.0	293	5	"
221.0	51.5	354	6	"
157.5	29.5	250	7	"

Again, as in the first series of cryogenic experiments, the oysters were allowed to come to equilibrium temperature with the liquid nitrogen. Reduction of these data shows a fairly uniform ratio by weight, of the liquid nitrogen consumed and the gross weight of the oysters. Figure 5 shows the amount of liquid nitrogen consumed per unit weight of shucked oyster meat as a function of the weight of shucked oyster meat. Figure 6 shows the amount of liquid nitrogen per unit of gross oyster weight as a function of gross oyster weight.

Based on a conservative average of 7.5 grams of liquid nitrogen consumed to process one gram of shucked oyster meat and a cost of liquid nitrogen of $0.04 per liter, the material cost to shuck one pound of oyster meat would be 17.6¢ or approximately $1.56 per gallon. This agrees rather well with a calculated value of 17.3¢ per pound of oyster meat assuming: a ratio of shell weight to oyster meat weight of five to one, an oyster specific heat of 0.85 BTU/lb-°F above 32 degrees fahrenheit, an oyster specific heat of 0.45 BTU/lb-°F below 32 degrees fahrenheit,

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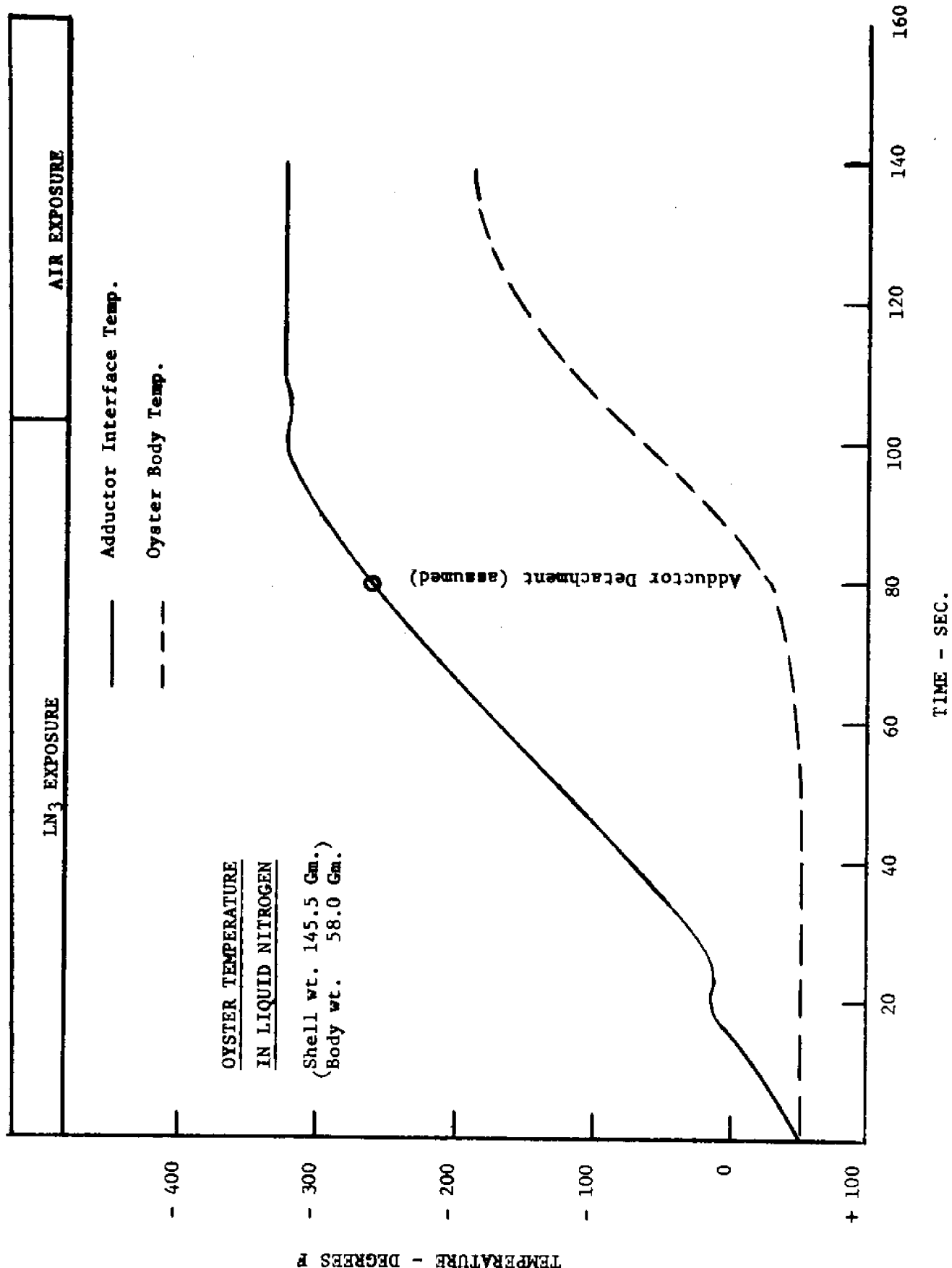
FIGURE 4

OYSTER TEMPERATURE TIME COURSE FOR LIQUID NITROGEN IMMERSION

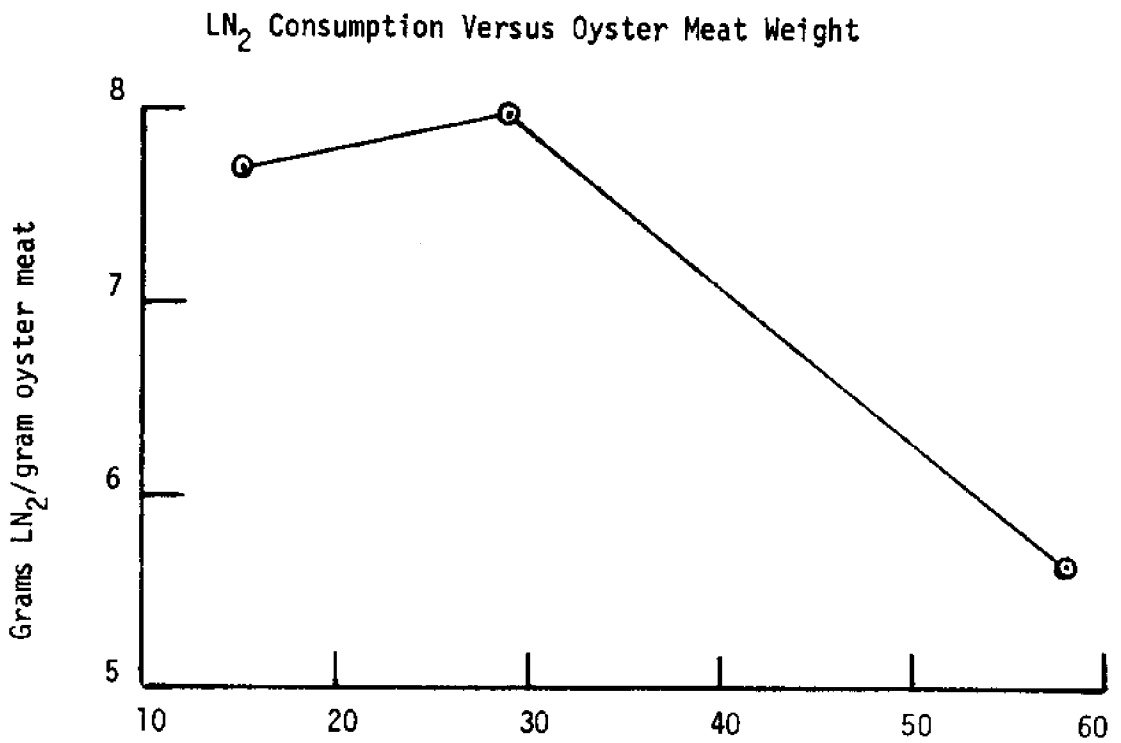## LN$_2$ Consumption Versus Oyster Meat Weight

Grams LN$_2$/gram oyster meat

FIGURE 5

WEIGHT OF SHUCKED OYSTER MEAT

LN$_2$ Consumption Versus Oyster Gross Weight
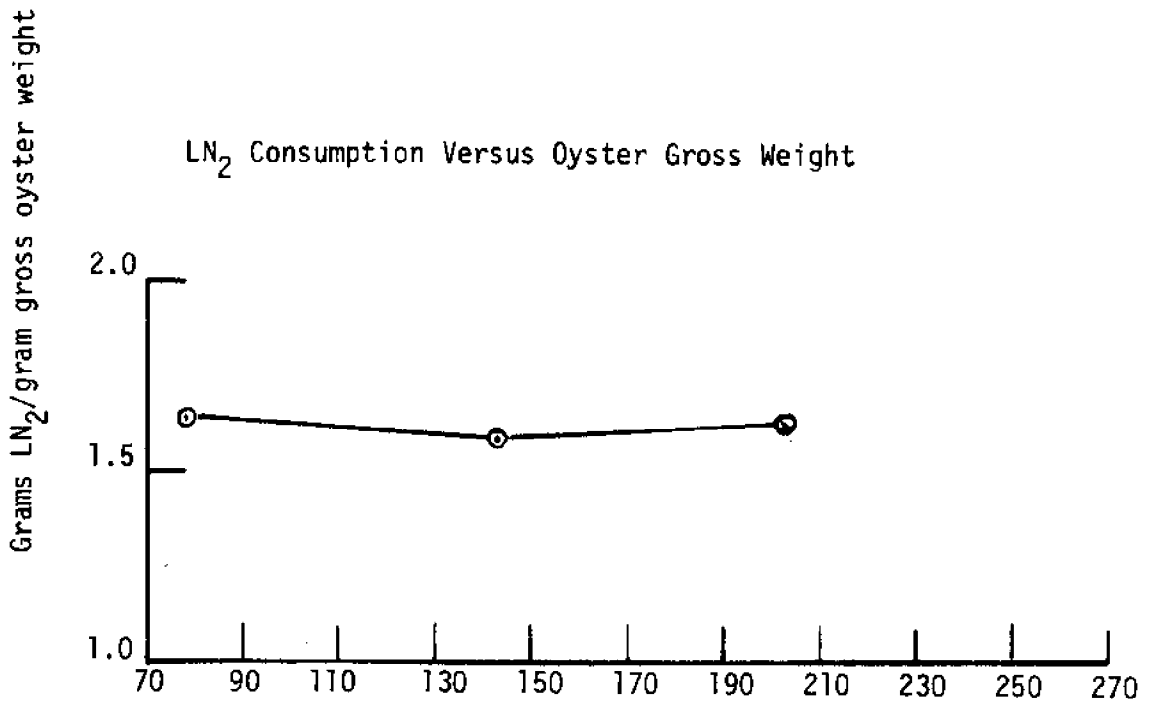

Grams LN$_2$/gram gross oyster weight

FIGURE 6

GROSS OYSTER WEIGHT - GRAMS

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a shell specific heat of 0.20 Btu/lb-°F and a latent heat of fusion for the oyster meat of 120 Btu/lb. The material cost of this process could be reduced by precooling with conventional refrigeration equipment.

Examination of cryogenic shucked oysters after thawing revealed some textural degradation--in the form of splits in the oyster body surface tissue. Considerable bleeding occurred. The degree of textural degradation was variable with all specimens showing some damage. The mechanism for this was considered to be dependent on the freezing rate and another series of experiments were performed in an attempt to remedy this problem. Table III presents the results of these tests.

TABLE III

EFFECTS OF CRYOGENIC FREEZING

Oyster Gross Weight grams	Treatment Sequence Before Thawing	Results
122.0	Vacuum for 30 minutes to remove free water then cryogenic freezing, oyster weight after vacuum 11.0 grams	Small stress fractures on surface
232.0	Vacuum for 60 minutes to remove free water then cryogenic freezing oyster weight after vacuum 197.0 grams	Small stress fractures on surface
382.0	Vacuum for 90 minutes to remove free water then cryogenic freezing, oyster weight after vacuum 337.5 grams	Small stress fractures on surface
499.0	Vacuum for 120 minutes to remove free water then cryogenic freezing, oyster weight after vacuum 472.5 grams	Small stress fractures on surface
	Frozen for 18 hours at 0°C then cryogenic freezing	Lesser amount of stress fractures but adductor muscle still attached
	Two hour immersion in corn syrup solution to lower freezing point and inhibit crystallization then cryogenic freezing	Small stress fractures on oyster surface

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TABLE III (Continued)

EFFECTS OF CRYOGENIC FREEZING

Treatment Sequence Before Thawing	Results
Cryogenically frozen in nitrogen vapor to reduce freezing rate	Very few stress fractures, most adductor muscles still attached
Immersed in cryogen for 20 seconds then held at 0°C for 18 hours	Very few stress fractures, but adductor muscle still attached

It was first believed that a reduced cooling rate would alleviate the problem of stress fracturing. A reduced rate of cooling did indeed eliminate the stress fracturing. However, although the oyster hinge was broken, the bond between the adductor muscle and the shell was still intact. These efforts showed that the mechanism that successfully shucks the oyster requires a high cooling rate. When the rate is sufficiently high to shuck the oyster, it also causes stress fractures in the frozen oyster meat. It is not known at this time whether some finite cooling rate would eliminate the effect. Such a cooling rate would be difficult to achieve considering the variance in oyster size and thermal properties.

The textural degradation phenomenon is a paradox in comparison to meat and other food product damage during freezing. Generally, the slower the freezing rate, the more likely the occurrence of textural degradation. Most authorities attribute this to the growth of intracell and intercell ice crystals at low rates of freezing.

A possible explanation for the oyster damage is suggested by the mechanical effects of cooling a solid, water laden body from the outside. The outer surface is cooled more rapidly and therefore contracts at a higher rate than the average for the entire body. Tensile forces, in excess of the strength of the surface tissue are thereby caused.

B. Chemical Treatment

Three chemical approaches were examined for an immersion process to shuck oysters. One involved the use of an enzyme named papain. A seawater solution containing 0.2 Mg/Ml papain and buffered to 10^{-3} cystine (cysh) was used for this experiment. Immersion in the papain solution for 72 hours produced no noticeable effect. The second chemical investigated was a 0.4 molar solution of EDTA (disodium dihydrogen ethylenediaminetetraacetate) in water. The immersion time for the oysters in this experiment was also 72 hours and here again no noticeable effects were observed.

The literature search revealed a patented chemical process [3] for gaping oysters. The patent, issued in 1961, describes a process whereby oysters are immersed in a solution for a short period of time (one to three minutes) after which the oysters shells gape and the meat may be removed by hand shucking. The solutions were made up with potable water and a source of multivalient metallic ions. Chloride salts of aluminum, copper, zinc, magnesium, manganese and calcium were used. During seasons of the year when the oysters are low in glycogen, the immersion time before opening occurs is said to be extended. Acceleration of the process may be achieved by exposing the oysters to polysaccharides. One of the polysaccharides that gave excellent results was a proprietary product known as cartose (a dextrin base commercially employed as a baby food).

Several experiments were performed to confirm this technique for the Pacific oyster species. A magnesium chloride solution, adjusted to a specific gravity of 1.29 and a pH of 7.2, was used. Cartose was added. Several of the specimens opened in three to four minutes while others required as long as an hour before gaping. Observations of these experiments revealed that once the oyster opened for a normal pumping cycle in this solution, gaping would continue to maximum. An additional 15 to 20 minutes in the solution was sufficient to maintain permanent gaping after the oysters were removed from the solution. The most consistent results were achieved when the solution temperature was adjusted to match the normal bed environment. The results of these experiments are presented in Table IV.

TABLE IV

EFFECTS OF IMMERSION IN METALLIC SALT SOLUTION
$(MgCl_2)$

Oyster Gross Weight grams	Immersion Time minutes	Temperature °C	Remarks
220.5	10	13	4 min. to open, closed 5 min. after removal
270.5	20	13	3 min. to open, remained open after removal
246.0	20	13	5 min. to open, remained open after removal
276.0	35	14	20 min. to open, remained open after removal
214.0	25	11	18 min. to open, closed 7 min. after removal
227.5	65	21	39 min. to open, remained open after removal
219.0	125	25	112 min. to open, remained open after removal
184.0	100	25	85 min. to open, remained open after removal
258.5	95	12	80 min. to open, remained open after removal
301.5	45	12	32 min. to open, remained open after removal
208.0	25	12	11 min. to open, remained open after removal
234.0	40	12	28 min. to open, remained open after removal
283.0	30	12	17 min. to open, remained open after removal
192.5	20	13	6 min. to open, remained open after removal
204.5	20	13	8 min. to open, remained open after removal

The full text of the patent for chemically gaping oysters provides
an interesting insite on the morphology and physiology of the mollusk
and is appended to this report for the reader's enlightenment (Appendix B).

C. Ultrasonic Energy Treatment

A series of experiments was performed to investigate the effects of ultrasonic energy on adductor muscle-shell integrity. Both fresh and seawater were used as the sound coupling medium. Two different vibration transducers were used: a 50 watt unit and a 400 watt unit. No tendency for oysters to open when exposed to this treatment for varying durations was observed. Extended exposure to the ultrasonic vibration was found to noticeably raise the temperature of the test specimens. The results of these experiments are presented in Table V.

TABLE V
EFFECTS OF ULTRASONIC ENERGY ON PACIFIC OYSTERS

Oyster Gross Weight grams	Fluid	Transducer Energy (watts)	Exposure Duration min.	Remarks
219.7	Seawater	50	5	No effect
84.1	"	50	10	No effect
176.0	"	50	15	No effect
197.4	"	50	20	No effect (warm to touch)
230.5	"	50	30	" "
291.3	H_2O	400	5	No effect
244.3	"	400	10	No effect
92.8	"	400	15	No effect (warm to touch)
207.6	"	400	20	" "
301.8	"	400	30	" "

D. Explosive Decompression

Explosive decompression from pressures up to 1500 psig in both liquid and gaseous environments was investigated. The test specimens were sustained at test pressure for fifteen minutes before almost instant decompression. No visible effect was observed on oysters tested during these experiments. Table VI summarizes the results of these experiments.

TABLE VI

EFFECTS OF EXPLOSIVE DECOMPRESSION ON PACIFIC OYSTERS

Oyster Gross Weight grams	Environment	Test Pressure psig	Remarks
315.7	H_2O	200	No effect
284.1	"	500	No effect
94.2	"	1000	No effect
216.7	"	1500	No effect
271.5	Air	200	No effect
192.2	"	500	No effect
228.9	"	1000	No effect
183.6	"	1500	No effect

E. Electrical Shock Treatment

Several experiments employed electrical shock to hopefully induce gaping. The experiments incorporated the use of a power supply with an output up to five kilo-volts. Electrodes were attached to the oysters on opposite sides at the thickest section. Each specimen was first washed with deionized water to eliminate the outer surface of the shell as a conducting path for the current. It is not known whether the current passes through the body of the oyster or through a saline film within the oyster shell. The oysters tested were exposed to increasing one thousand volt increments for a period of one minute per increment. These tests produced no noticeable change in the test specimens. The results of these tests are shown in Table VII.

TABLE VII

EFFECTS OF ELECTRIC SHOCK ON PACIFIC OYSTERS

Oyster Gross Weight grams	Applied Voltage	Approximate Current milli amp	Remarks
94.8	1000	4	No effect
"	2000	8	"
"	3000	12	"
"	4000	16	"
"	5000	20	"
110.7	1000	4	"
"	2000	8	"
"	3000	11	"
"	4000	15	"
"	5000	19	Slight change of color at point of contact of one electrode
115.8	1000	4	No effect
"	2000	7	"
"	3000	11	"
"	4000	15	"
"	5000	19	"

F. Local Heat Treatment

A series of experiments were performed in which heat was applied to the oyster shell at a point where the adductor muscle attachment was expected to be. Both propane and oxy-acetylene flames were used for varying durations of heat application. Subsequent examination of each test specimen revealed varying degrees of cooking or burning. All of the oysters treated in this manner failed to open. Data from these tests are shown on Table VIII.

TABLE VIII

EFFECT OF LOCAL HEAT ON PACIFIC OYSTERS

Flame Type	Application Time Seconds	Oyster Gross Weight grams	Remarks
Propane	15	209.5	Failed to open
"	30	162.4	" "
"	45	301.0	Failed to open, partially cooked
"	60	226.1	" " " "
Acetylene	15	181.7	" " " "
"	30	254.6	Failed to open, muscle burned
"	45	283.3	" " " "
"	60	277.1	" " " "

G. Mechanical Shock Treatment

Mechanical shock experiments were conducted by striking test oysters with a metal bar. Several of the oysters subjected to this treatment were observed to gape very slightly.

A series of mechanical vibration experiments employed the penumatic air hammer. The vibration equipment was securely fastened to the test specimen and the test performed with both the oyster and vibrator submerged in seawater. No effect could be detected as a result of this treatment which included testing at frequencies ranging from 10 to 30 cycles per second for durations up to three hours. Table IX presents the results of this testing.

TABLE IX

EFFECTS OF MECHANICAL VIBRATION ON PACIFIC OYSTERS

Oyster Gross Weight grams	Vibration Frequency cycle/second	Duration of Exposure minute	Remarks
330.2	10	30	Failed to open
307.4	"	60	"
295.4	"	120	"
342.0	"	180	"
300.9	20	30	"
268.1	"	60	"
319.1	"	120	"
304.0	"	180	"
318.9	30	30	"
272.5	"	60	"
215.6	"	120	"
311.3	"	180	"

Each test specimen exposed to this treatment was hand shucked and the adductor muscle attachment examined. There was no evidence to indicate that the attachment had been disturbed in any of the oysters subjected to vibration.

H. Carbon Dioxide Treatment

Three oysters of gross weights 96.2 grams, 102.7 grams and 11.4 grams were simultaneously submerged in a seawater solution into which finely dispersed bubbles of CO_2 were generated through a porous ceramic disc. It was hopefully expected to produce an anesthetic effect which would relax the adductor muscle. The oysters were observed periodically for a period of 64 hours. The test specimens were found to have opened approximately 3/16 inch some time between the sixtieth and sixty-fourth hour of exposure.

I. Microwave Treatment

Several oysters were exposed to microwave energy in a 2450 MHz microwave oven. The results of these tests were considered inconclusive because of poor repeatability. In one test twenty second exposure caused the oyster to explode, while another would cause only rapid

cooking of the oyster. Shorter exposure times also produced inconsistent results. Some of the oysters were gaped, while others exposed for the same duration were unaffected. All trials failed to significantly loosen the adductor muscle and the meat of those immediately hand shucked was very warm. This method[2] to facilitate shucking appears to have some merit but would require an investigation much more refined than was performed in this study to confirm or develop it. Table X presents the results of the microwave heating experiment.

TABLE X

EFFECTS OF MICROWAVE HEATING ON PACIFIC OYSTERS

Oyster Gross Weight grams	Exposure Time seconds	Remarks
160.2	15	Failed to open
124.8	15	"
221.6	20	"
182.1	20	Exploded
204.4	30	Failed to open
211.7	30	"
196.2	45	Slightly gaped
185.1	45	Failed to open
250.1	60	Slightly gaped, meat very hot
223.3	60	" "

J. Vacuum Treatment

A series of experiments was conducted to determine the effect of a vacuum environment on Pacific oysters. The oysters were subjected to vacuums ranging to 29.0 inches of mercury for durations up to two hours. None of the combinations of vacuum and exposure time employed caused the oysters to open. The results of these experiments are shown on Table XI.

TABLE XI

EFFECTS OF VACUUM ON PACIFIC OYSTERS

Oyster Gross Weight grams	Exposure Time minutes	Vacuum inches Hg	Remarks
92.7	30	10	Failed to open
176.1	60	10	"
139.0	120	10	"
215.0	30	20	"
191.8	60	20	"
221.9	120	20	"
284.6	30	29	"
244.0	60	29	"
204.3	120	29	"

A second series of vacuum experiments was performed which incorporated a 400 watt ultrasonic bath pretreatment. The results of these tests are considered inconclusive in that only two of the seven oysters were gaped while those tested in repeated experiments were unaffected. The data from these tests is shown in Table XII.

TABLE XII

EFFECTS OF VACUUM WITH ULTRASONIC PRETREATMENT ON PACIFIC OYSTERS

Oyster Gross Weight grams	Ultrasonic Exposure minutes	Vacuum Exposure minutes	Vacuum in Hg	Remarks
116.2	10	15	29	Opened 3/16 inch after 5 minutes on vacuum
128.3	10	30	29	Opened 3/16 inch after 8 minutes in vacuum
167.5	10	60	29	Failed to open
132.7	10	120	29	"
111.5	20	30	29	"
177.4	20	60	29	"
168.2	20	120	29	"

K. Anesthetic Agent Treatment

Two vapor phase anesthetic agents were investigated for gaping oysters. The first, ether, had no effect on the oysters. The second anesthetic used was chloroform. The results of these experiments varied from no effect to a well gaped oyster for a variety of exposure durations.

Three aqueous solutions containing anesthetic agents were investigated for gaping oysters. The agents were; quinaldine, chlorodane, and MS-222, a commonly used fish anesthetic. All of these materials tested failed to produce gaping in the test specimens.

REFERENCES

1. The South Carolina Report on the "Hot Dip" or "Shock" Method of Opening Oysters, 1961 Shellfish Workshop, Washington, D.C.

2. Opening Oysters and Other By-Valves Using Microwave Energy, 1969 Mendelsohn, J. M., Ronsivalli, L. J., King, F. J., Carver, J. H., Learson, R. J., Spracklin, B. W., and Kenyon, E. M.

3. Process for Chemically Opening By-Valves,United States Patents Office- Patent No. 3,013,883, December 1961.

4. Handbook of Food Additives, Thomas E. Furia, Editor, published by the Chemical Rubber Co., 1968.

5. The Freezing Preservation of Foods, Vol. 2, D. K. Tressler, W. B. van Arsdel and M. J. Copley, 1968.

ACKNOWLEDGMENTS

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APPENDIX A

PATENTS

Blake, Philos, "Improved Oyster Knife," U. S. Patent 10,798 (1854).
Fixed parallel members combined with a knife for breaking off the shell-nose.

Towers, W. H., "Oyster Opener," U. S. Patent 10,810 (1854). A foot
treadle clasp and a lever actuated knife guided by Vse-members engaging
edges of shell.

Holtzman, George, "Improvement in Oyster Shuckers," U. S. Patent 115,474
(1871). A lever actuated edge-crusher, a second lever to force wedge
in crushed edge, and a knife swinging on a universal joint to severe
muscle.

Starin, John H., Jr., "Improvement in Oyster-Openers," U. S. Patent 133,267
(1872). A knife combined with pinching jaws for lip breaking.

Wells, Richard, "Oyster Shucking Machine," U. S. Patent 211,449 (1879).
A notching die actuated by a foot treadle or powered to chip shell-edge.

Ward, A., "Oyster Opener," U. S. Patent 247,445 (1881). A lever operated
wedge-knife.

Drake, Cunningham, "Oyster Clamp," U. S. Patent 299,756 (1884). Hinged
members to clamp oyster with lip projecting.

Daismarre, O. B., "Oyster Knife," U. S. Patent 390,759 (1888). Knife,
spring retracted in a guard-block.

Wood, James S., "Oyster Knife," U. S. Patent 469,312 (1892). Knife com-
bined with pincher type shell notcher.

Johnson, B. S., "Oyster Trimming Machine," U. S. Patent 699,182 (1902).
A circular saw with conveyor feed of oysters for cutting opening.

Elagdan, Silliman, "Oyster Opening Tool," U. S. Patent 708,014 (1902).
Pincher-type hinge and wedge insertion, combined with knife attached to
one handle.

Torsch, H. L. and Parker, J. H., "Process of Shucking Oysters," U. S.
Patent 848,608 (1907). Articulated clamps conveying oysters past milling
cutters to open hinge and, hook-open and insert knife.

Torsch, E. L. and Parker, J. H., "Machine for Shucking Oysters," U. S.
Patent 848,784 (1907). Same as U. S. Patent 848,608.

Klinge, William, "Oyster Shucking Apparatus," U. S. Patent 880,222 (1908).
Lever operated clamp, wedge--opening of hinge end and knife insertion.

Lekam, Philip, "Oyster Opener," U. S. Patent 930,771 (1909). Crank
operated milling-cutter opener and wedge insertion.

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Hall, A. F., "Oyster Opener," U. S. Patent 997,996 (1910). Lever operated wedge insertion.

Tiffany, E. D., "Clam Opener," U. S. Patent 1,041,198 (1912). Lever operated clamp.

Savieo, Leo, "Oyster Shucking Machine," U. S. Patent 1,060,502 (1913). Treadle operated wedging knives.

Dandridge, K. P., "Oyster Shucking Machine," U. S. Patent 1,117,984 (1914). Screw-clamp, lever shell-break.

Buras, Morbert, "Hammer," U. S. Patent 1,314,465 (1919). Hammer with shield for flying particles.

Mandvill, Arthur P., "Oyster Opening Machine," U. S. Patent 1,439,181 (1922). Conveyor with clamping fingers to yieldingly deliver oyster to wedge-knife opener where arm with clamping fingers picks up oyster on half shell and delivers it to second knife.

Egli, Huldreich, "Oyster Shucking Machine," U. S. Patent 1,445,672 (1923). Horizontal rotating table with clamps to hold oysters hinge up aligned with wedges and knives operating during rotation.

Beysrle, O. W., "Automatic Oyster Shucker," U. S. Patent 1,499,965 (1924). Clamping conveyor with wedge and knife insertion.

Richens, John M., "Oyster Opening Device," U. S. Patent 1,597,622 (1926). Lever shear with attached knife.

Vannce, W. P., "Oyster and Clam Opener," U. S. Patent 1,737,626 (1929). Crank or foot treadle actuated screw forcing lips of oyster over turning pointed knife.

DeLende, Emile, "Oyster Opener," U. S. Patent 1,741,015 (1929). Combination wedge and knife on lever piveting on universal joint to open oyster resting against a backstop.

Robinson, Henry, "Oyster Opener," U. S. Patent 1,857,872 (1932). Lever actuated pinion and rack forcing wedging knife into oyster resting against backstop.

Boudreaux, Hamilton J., "Oyster Opening Apparatus," U. S. Patent 1,974,766 (1934). Rack and pinion drive of wedge and knife separately into hinge end of oyster.

Briasco, A., "Safety Oyster Opener," U. S. Patent 1,950,424 (1935). A guarded short knife and retracting long knife.

Prytherch, Herbert P. and Koehring, Vera, "Method of Opening Bivalves," U. S. Patent 2,041,727 (1936). A process of tumbling and immersion in non-injurious muscular relaxation chemical.

Frazier, "Clam Opener," U. S. Patent 2,136,816 (1938). Straight lever actuated shearing knife.

Dickerson, Leary, "Oyster Punching Machine," U. S. Patent 2,299,311 (1942). Treadle actuated, spring loading trip hammer to shear notch in shell-lips.

Dickerson, "Oyster Punching Machine," U. S. Patent 2,444,636 (1948). Powered version of U. S. Patent 2,299,311.

Plock, John, "Oyster Opening Method," U. S. Patent 2,473,608 (1949). Lever actuated wedge insertion near hinge.

Plock, John, "Oyster Opening Apparatus," U. S. Patent 2,473,609 (1949). Lever actuated pointed members to slide shells and twist off hinge joint.

Doiron, P. A., "Scallop Shucking Machine," U. S. Patent 2,476,962 (1949). Hinge-opening, knife insertion.

Wesik, "Adjustable Clam Opener," U. S. Patent 2,520,790 (1950). Cleaver with pivot adjustable vertically.

Labat, L. H., "Oyster Check," U. S. Patent 2,612,653 (1952). A ribbed check for holding the oyster while prying, cutting, etc.

Gonyear, "Clam Opener," U. S. Patent 2,691,794 (1954). Suction-cup and horizontal cleaver.

Gaetti, R. B. and Pittman, W. D., "Oyster Opening Apparatus," U. S. Patent 2,738,546 (1956). Lever engaging half-shell to slide with respect to other half nesting in rubber pocket.

Thompson, "Clam Opener," U. S. Patent 2,747,220 (1956). Crescent shaped cleaver on fixed pivot.

Palmere, "Oyster and Clam Opener," U. S. Patent 2,808,613 (1957). Half-round cleaver associated with shell-spreaders and juice catching.

Skrmetta, "Oyster Shucking Machine," U. S. Patent 2,818,598 (1958). Tumble-separator for steamed oysters.

Hedlin, "Detachable Pivoted Knife," U. S. Patent 2,822,845 (1958). Cleaver and crusher on detachable pivot to operate against wooden block for cutting or crushing various foods.

Seal, R. D., and Harris, S. O., "Apparatus for Recovering Meats of Bivalves," U. S. Patent 2,823,414 (1958). Tumble and spray separator for steamed bivalves.

Colangelo, "Shell Fish Opener," U. S. Patent 2,854,638 (1958). Combination of short point and arcuate knife for manual prying and cutting of shell fish.

APPENDIX B

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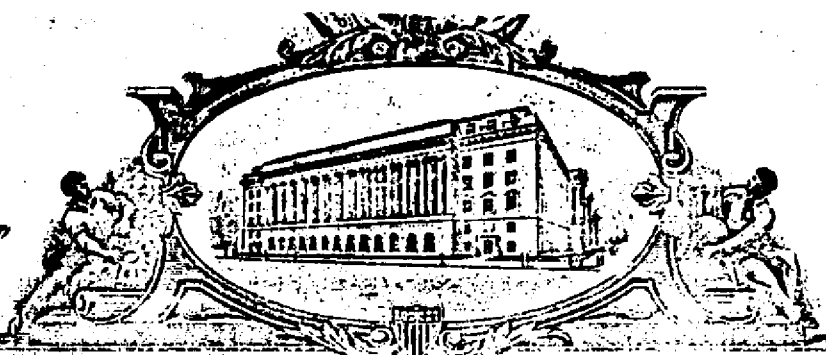
3,013,883

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

Whereas Clyde J. Welcker and Roland L. Welcker,

of

New Orleans, Louisiana,

PRESENTED TO THE **Commissioner of Patents** A PETITION PRAYING FOR THE GRANT OF LETTERS PATENT FOR AN ALLEGED NEW AND USEFUL INVENTION THE TITLE AND A DESCRIPTION OF WHICH ARE CONTAINED IN THE SPECIFICATION OF WHICH A COPY IS HEREUNTO ANNEXED AND MADE A PART HEREOF, AND COMPLIED WITH THE VARIOUS REQUIREMENTS OF LAW IN SUCH CASES MADE AND PROVIDED, AND

Whereas UPON DUE EXAMINATION MADE THE SAID CLAIMANT S are ADJUDGED TO BE JUSTLY ENTITLED TO A PATENT UNDER THE LAW.
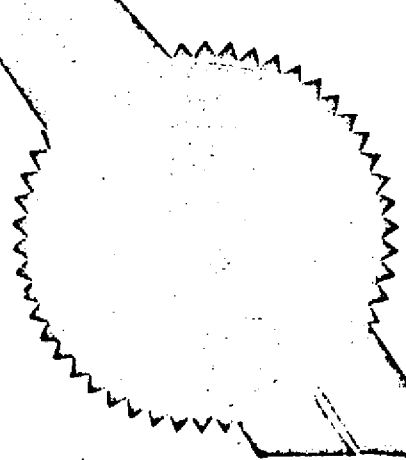
NOW THEREFORE THESE **Letters Patent** ARE TO GRANT UNTO THE SAID

Clyde J. Welcker and Roland L. Welcker, their heirs
OR ASSIGNS

OR THE TERM OF SEVENTEEN YEARS FROM THE DATE OF THIS GRANT

RIGHT TO EXCLUDE OTHERS FROM MAKING, USING OR SELLING THE SAID INVEN-
THROUGHOUT THE UNITED STATES.

In testimony whereof, I have hereunto set my hand and caused the seal of the Patent Office to be affixed, at the City of Washington this nineteenth day of December, in the year of our Lord one thousand nine hundred and sixty-one, and of the Independence of the United States of America the one hundred and eighty-sixth.

Attest:

Attesting Officer.

Commissioner of Patents.

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The present invention relates to the process and solutions employed for chemically opening oysters and other mollusks for removal of the edible meats therefrom and is a continuation-in-part of our similarly entitled application Serial No. 5,110, filed January 28, 1960 (now abandoned).

Commercially, oysters are opened by hand, using a knife, mallet, chisel, block or combination of all these tools or knife alone depending upon the technique of the oyster shucker. In the commercial oyster house, the shucker in achieving speed sacrifices quality of workmanship. These oysters may be cut in other places besides in the eye. The oysters which are completely processed by hand are washed and then packed in containers which are refrigerated or frozen. The oysters obtained in this manner are fresh, whole and have lost no weight. The quality of the oysters can approach that of the oysters in restaurants but usually is lower.

Another commercial method is to steam the oysters. The oysters are steamed at temperatures of 240° F. plus, at pressures of 12 p.si.g. plus. The oysters under this form of process are essentially cooked. There is a 60–70% shrinkage in the oysters with an accompanying weight loss. What is really achieved in the steam process is that the adductor muscle elongates through the process of heating. The heat cleaves the protein links and the oysters open. The adductor muscle is still fixed to the shell. The steamed oysters have to go to human shuckers where they are cut from the shells. The shucking operation is very fast for the oysters are already open. By this process very small oysters can be marketed which would be really difficult to completely open by hand. These steamed open oysters are washed and further cooked in the canning process.

The process of the present invention eliminates the manual work that has to be done upon a tightly closed oyster shell when the hand shucking process is employed. It also avoids the shrinkage in the oyster meats which is attendant with the steam process.

Basically, we provide solutions into which the closed oysters may be dumped and within a very short space of time, one to three minutes, the oysters will open their shells and the meat may then be removed therefrom without the method of steaming or manually beating and prying upon the oyster shells. The chemicals in the bath must be acceptable to the oysters so that they will crack their shells open and the oysters will not immediately close and stay closed. The oysters may be made to want to open and to pump water. The chemical changes must be fast acting, non-poisonous and must not alter the physical appearance of the oysters or their taste.

We therefore have developed solutions of varying concentrations of water soluble carbohydrates, non-poisonous and edible for human consumption. We have found that the oysters can be fattened and we have enlarged the oyster body to such an extent that it almost bulges out of the shell. This fattening step takes place with the addition to the solution of polysaccharides which when

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the salinity of the water is controlled and the water temperature controlled, will result in a quickly fattened oyster.

As the result of our research program with oyster cultivation involving the morphology as well as the physiology of the mollusk, it became evident that oysters can be chemically opened. This chemical method proved to be highly effective, non-toxic and economically feasible. This chemical process for opening oysters resulted through an awareness of the needs and requirements of the oyster and its relationship to its environment. It became obvious that the defenses of the oyster are formidable. Forceful means are met with great resistance by the oyster.

The very conditions that exist to make oysters thrive would have to be a route of attack. Any chemical agent that could be used and result in a marketable oyster meat would have to be consumed by the oyster through the living process. Therefore, the initial response of the oyster to the agent must be favorable and conditions of environment such as to affect body functioning at their highest level. The oyster has to consume the agent and build a concentration of it in the body sufficient to make shell closure (muscle contraction and/or nerve repsonse) difficult or impossible.

In our disclosure, all phraseology and verbs most certainly denote the oyster is alive prior to and during our opening process. Whether the oyster is alive or dead upon removal from shell will be determined by extent to which the process is allowed to continue, concentrations and specific metal ion used. This final status is optional and at the discretion of the operator of the process.

All steps before application of opening process must be in the direction of the preservation of life. The manner in handling should parallel the care and judgment used in transplanting and/or seeding beds to insure greatest yield.

Severe exposure to temperatures above 50° C. must be avoided. Temperatures of a range of the order of 5° C. to 49° C. are operative whereas temperatures of 50° C. or above are lethal to the oyster. Long exposures at 50° C. will result in a 100% kill. Oysters freeze approximately at −2° C. with a cessation of body action. From 5–10° C. body functions and pumping rate is at a minimum. With rising temperatures above 10° C., biological action and pumping increase until approximately 30° C., falling off sharply above this temperature.

Another factor which may injure or even kill an oyster is rough or abusive physical handling. Sudden jarring or tumbling must be avoided to insure rapid and unimpaired reaction of oyster to the opening process. Unnecessary or severe shoveling in freezing weather will kill oysters. Severe tumbling will damage oysters and slow their revival to a normal activity.

Should the jarring be severe enough to kill the oyster, those with the shells in a closed position will stay closed and open only upon decomposition.

In order to best understood the development, it is advantageous to clearly picture the oyster (formerly Ostrea now re-named Grassostrea).

The oyster is a member of the phylum of animals, shellfish, bivalves of the mollusk group, subgroup known as Grassostrea.

The oyster consists of valves (half shells) jointed at the pointed, narrow end by a hinge with a body encased by the valves. Part of the body called the adductor

muscle (eye) forms a connective tissue between the two valves.

A portion of the adductor muscle serves as a latch mechanism pulling the two valves together, thus closing the valves. The edges of the valves mate perfectly.

The adductor muscle, when in the contracted state, closes the two valves offsetting the hinge action of keeping them apart due to the ligament orientation and material construction.

The two valves of the oyster are not the same size or shape. The left valve is more deeply concave-convex. It is this left side which is attached to some rock or other material when the oyster first sets. The right valve is more flat and forms a lid or operculum to the stony case formed by the lower valve. The soft parts of the body are lodged in the deep cavity of the lower valve and are covered by the flat operculum.

If an oyster is held sideways with the hinge away from the observer and the flat operculum towards the right hand side, the upper is the dorsal side and the lower the ventral; the posterior end lies toward the observer and the anterior end away from him. Therefore the two valves really represent the right and left sides of the mollusk and consequently the flat operculum is spoken of as the right valve and the large fixed valve as the left valve.

At the narrow or pointed end is a hinge ligament of resilient material, formed like the shells, as an excretion from the living tissues of the oyster. The function of the ligament is to exert force in the direction to affect the opening of the shells. This end of the oyster is referred to as anterior.

The edge of the two valves mate in such a way that the shells are perfectly engaged around the periphery except in the very close proximity of the hinge ligament. The hinge ligament is situated in a void or cavity between the two valves. The position of departure of the line of perfect mating of the two shells to form the ligament cavity serves as a fulcrum or pivotal point for the opening and closing of the shells.

The hinge ligament serves as a spring pulling the two valves together on its side of the pivotal point and the adductor muscle in the contracted state with its greater leverage (greater distance on the posterior side from the pivot) closes the shell.

The action of the hinge ligament is constant in the direction of affecting an opening of the shells. To the best of knowledge, this ligament is at no time under the control of the nervous system and is in tension due to its resilient structural material.

However, the adductor muscle is very much a part of the body of the oyster. It is living tissue considered as part of the anatomy of the body of the oyster receiving a blood supply through a system of arteries and under control of the nervous system.

A closer look at the adductor muscle reveals that it is composed of two masses. In the greater posterior position is the smaller mass referred to as the voluntary muscle, latch muscle, smooth muscle, tetanic or nacreous part. This portion of the adductor muscle keeps the shell closed. It is fast acting and is either in the contracted state or relaxed. Its action is to release the shells for the hinge ligament to open them or to contract and completely offset the action of the ligament.

The voluntary action of the nacreous portion of the adductor muscle is stimulated into fast action (contraction) by the visceral ganglia of the nervous system. Control of the nacreous adductor is through the visceral ganglia.

The larger mass of the adductor muscle immediately adjacent to the smaller portion and anterior to it is the vitreous muscle, slow acting muscle or the involuntary muscle. This portion of the adductor is under the initial stimuli or direction of the cerebral ganglia receiving impulses from nerve cells on the esophageal area, gills, flaps

and tentacles sensing for favorable conditions immediately external to the oyster.

The nerve impulses from the cerebral ganglia are directed through the visceral ganglia to control the action of the vitreous muscle to regulate the amount of gape of the oyster.

It has been found that when the positioning of the valves are under the influence of the vitreous adductor muscle there are three distinct shell positions: 1st stage—slightly apart for sensing of condition by cerebral ganglia; 2nd stage—valves midway apart for reduced amount of pumping; and 3rd stage—where shells are greatest apart for maximum pumping of the oyster.

It has been found that when an oyster has its shells closed, its heart does not beat. Biochemical action occurs, energy is consumed and any circulation is through a process of osmo regulation.

In the closed position cell activity continues until it reaches some critical minimum level whence a stimulus is sent to the visceral ganglia releasing or placing the nacreous adductor muscle in a state of relaxation. The shells part or gape.

Emphasis could be placed on the fact that energy is being expanded to keep the adductor muscle in a state of contraction and relaxation must occur for the living oyster to once again build up its food supply so necessary for body function and growth. The shells part upon relaxation. The oyster then pumps water through itself to extract food.

The shell parts and the cerebral ganglia sense the condition of the water for such factors as food content, concentration and dangerous materials or unfavorable conditions. This sensing is done in stage 1 with the valves slightly parted.

Depending upon the biochemical activity level of the oyster, and water conditions, the cerebral ganglia can control whether the shells are farthest apart for maximum pumping or at an intermediate condition.

Any unfavorable external condition sensed by the cerebral ganglia is fed into the visceral ganglia and thence to the nacreous adductor muscle for immediate contraction and valve closure.

Stimuli for valve closure may commence from any part of the body served by the nervous system which would feed into the visceral ganglia not involving the cerebral ganglia. This would be as in the case when the oyster has fed sufficiently.

Since the oyster is sedentary, food must be in the water in close proximity so that by motion of the cilia of the oyster, water is pumped to extract oxygen, minerals and food matter.

Low oxygen and food concentration calls for large quantities of water to be pumped. Conversely, large concentrations call for smaller quantities of water.

Dangerous materials or water conditions result in the oyster closing and staying closed until death and decomposition. The oyster just can't move itself to more favorable water bottoms.

We have found that oysters thrive best in water whose mineral or salinity content is within definite limits, sufficient food to sustain life, well aerated, non-polluted and where water temperatures are sustained long enough in their spawning limits. Water temperatures too great stunt growth and if too high will actually kill oysters.

Each species of oyster has an optimum temperature range for pumping activity which is also indicative of other biological functions such as heart beat rate. We found with the oyster—*Grassostrea virginica*—this activity temperature range was 15–30° C.

The *Grassostrea virginica* will have a specific favorable temperature depending upon the geographical latitude and location they abound in and for the season of the year. The different varieties of Grassostrea will also have a temperature range associated with the specific sub-group for the geographical and seasonal conditions.

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It became evident with numerous experiments at different times of the year, different concentrations and temperatures that a certain pattern or underlying requirement gave best results.

What is most desired is for the oyster to open and pump the solution. The conditions should be most favorable to the sensing facilities of the oyster.

We received optimum results when temperatures were within 25–30° C. for *Grassostrea virginica*. The heart beats faster, more water is pumped which resulted in a faster build-up of our desired reagent in the oyster.

The overall salinity of the test solution was held within the optimum salinities for the oyster growing area—1.012 to 1.020 specific gravity hydrometer readings. Any drastic change in the salinity was avoided. The process of the present invention is operative through a salinity range of 1.004 to 1.036 (hydrometer).

We are using the term salinity to refer to total salt content of the water.

In formulating our solutions, we kept in mind the practicalness of using the fresh potable water that may be available in the locale of the operation. For all intents and purposes, municipal water supplies will be considered as fresh water and any dissolved matter negligible. If this should not be the case and the dissolved materials are excessive, then they should be taken into account.

Test solutions in New Orleans, Louisiana were made with city water which is mildly alkaline in pH. Sufficient desired salt was added to give the specific gravity desired. It was found that the use of a specific gravity float or hydrometer gave good correlation with chemical concentration on such basis as normality and ppt.

MgCl₂ salt possesses excellent properties in as much as the salt alone need be added to bring the gravity reading into the desired range provided the pH is of the correct value. The addition of a suitable acid or base such as HCl or NaOH respective will modify the pH. MgCl₂ additions to New Orleans water did not require any pH correction.

As an example, for a specific gravity reading of 1.020— MgCl₂ was slowly dissolved in New Orleans city water to bring it to the proper value by hydrometer reading. The pH remained on the alkaline side and no pH correction was needed.

No greater difficulty was involved with manganese, zinc and calcium chloride.

Where the salt will impart acidic conditions to the solution through hydrolysis depressing the pH below 6.5, slight base (NaOH) is added and aeration controlled to prevent precipitation from solution. For such salts, the limit of solubility will be controlled by pH, degree of aeration and buffering action of the solution.

Acid solution conditions are easily detected in the taste, physical appearance and feel of the oyster. If the [H⁺] ion concentration is sufficient in itself to exert hydrolytic action on muscle constituents, the resulting oyster meat is not marketable.

Since it is the aim of our press to achieve the desired results through the action of a multivalent metal ion, it is considered incompatible and non-desirable that the action of [H⁺] concentrations be at pH's below a pH of 6.5. It has proved advantageous to have neutral to alkaline solutions in the broad range of 6.5 through 9.5.

For the more active metallic ion (cations) such as aluminum, copper and zinc, their multivalent cation concentration is much smaller than for manganese, magnesium and calcium. Their individual concentrations impart only a fraction of the overall salinity for a favorable condition affecting the oyster. For these salts, the specific gravity has been adjusted by the addition of the monovalent ions from the salt sodium chloride.

The specific gravity of 1.012 to 1.020 represents an optimum range for oysters grown in the Gulf Coast region.

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This value will change with geographic location and variety of oyster.

Oysters at different times of the year and in different phases of development, will possess a greater or lesser tolerance for salt concentrations. At certain times in the summer and winter the specific gravity of tests reached 1.036.

In practical operations, preliminary tests should be conducted for the specific variety of oyster, state of development and corresponding condition of geographical locale as to give salinity values for optimum time to opening of oysters.

Separate oyster tests with varying salinities established an optimum salinity for the oyster handled.

Excessive concentrations of NaCl or KCl by themselves serve to cause shell closure and death of oyster with accompanying decomposition before shell opening.

To insure a supply of oxygen, the test solutions were aerated using equipment normally found in aquarium systems.

To serve as food, soluble carbohydrates were used. Polysaccharides were most easily obtainable and the following were used. All tested were found acceptable: glucose, dextrin, maltose, dextrose, sucrose (separately and in combination).

Initial tests were conducted with the above mentioned polysaccharides and it finally developed that a proprietary product known as Cartose (a dextrin base commercially employed as a baby food) gave excellent results, was easy to use and gave a solution that looked and smelled like the natural meso-polyhaline waters.

Oysters were kept in solutions of known temperatures, salinity and polysaccharide concentrations to observe their behavior. This was conducted with oysters at different times of the year.

The oysters were placed in separate solutions containing the chloride salts of aluminum, copper, zinc, magnesium, manganese and calcium.

While we have used the term "salt," it will be understood that the word "salt" includes not only the chloride or chlorate of the elements above identified but also includes the sulphate, phosphate, acetate, nitrate, floride and bromide.

This word "salt" is a collective term but it must be soluble in solution. It also must be loosely coordinated.

The element or metal of the salt employed must be soluble and its ions loosely coordinated and capable of stabilizing the pyrophosphate structure of the adductor muscle.

All of the above salts affected opening of the valves and eventually permanent opening of the valves.

For equal concentration, the fastest reactions were with aluminium; then secondly, copper; with zinc very close to it; thirdly, magnesium and manganese. It is our finding that magnesium and manganese reaction rates are very similar. Calcium reacted very slowly and the time for permanent valve opening was many times slower than those for the other reagents.

Upon evaluation of the findings using various salts, tests were conducted to fill in additional data using magnesium chloride (MgCl₂) as the active reagent affecting valve opening.

Various concentrations were used to determine magnesium chloride exposure time and the overall effect on the oyster. Beyond a definite concentration, in a pH range of the order of 7.0 to 9.5, the effect is irreversible and the valves stay open and the oysters are killed.

It is noticed that the opening and closing of the oyster becomes very sluggish at low concentrations. The next effect of increased concentration is a prolonged shell opening with very little reflex action remaining in the sensing mechanism of the oyster. If the oyster is taken out of the solution and submerged in a normal solution for oyster cultivation and the shells forced to open and close

by pressing of the shells with one's fingers, eventually the adductor muscle revives and the oyster can once again be brought to a normal condition. These concentrations are within the equilibrium life cycle of the oyster.

With the use of magnesium chloride and the polysaccharide, there are no harmful effects to the oyster. It is edible, there are no toxic effects and the oysters were successfully refrigerated. There is no apparent discoloration.

The fastest acting agent aluminum chloride ($AlCl_3$) in sufficient concentrations can literally tear the oyster to pieces. Too strong a concentration of aluminum, zinc, copper and manganese can cause deterioration of oyster body and bloating of gills. If such a concentration exists for magnesium, it was never reached in our tests.

At the time of the year when oysters are very high in glycogen, the polysaccharide could be omitted and the reagent worked alone. At the time of lowest glycogen content, for the same reaction time the polysaccharide proves most useful.

At both times, for equal concentrations, the presence of polysaccharides increases the reaction rate as a time reaction accelerator or opening accelerator and decreases the time required for valve opening.

In the normal state of oyster muscle action, we find in the muscle at the side of myosin a triggering mechanism in which actin plays a prominent role. According to experiences, the resting muscle contains no actomyosin, but contains actin and myosin side by side, kept apart by the subtle balance of attractive and repulsive forces with a slight predominance of repulsion. These repulsive forces are electric and the ATP (linked to myosin) plays with its four negative charges, a leading role. This balance of forces is destroyed, for an instant by excitation whereupon actin and myosin form actomyosin. In the actomyosin thus formed the terminal phosphate bond P—O—P of ATP becomes split and its energy put into action. Relaxation involves the rephosphorlation of the ADP into ATP which, with its four charges restored, pushes actin and myosin apart whereupon the free myosin particles rebuild their water structures and stretch out into filaments again, thus becoming ready for a new contraction.

ATP is adenosine triphosphate. ADP is adenosine diphosphate.

The ATP molecule

(E')
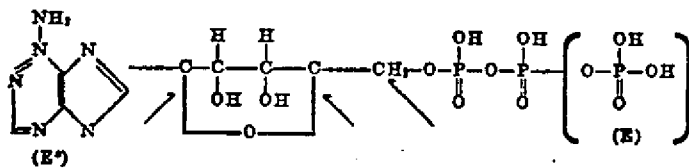
Electron pairs Π electron of conjugated double bond are source of E*

E=chemical bond energy

At points where arrows are shown, molecule has ability to change its shape and curl up.

N^1 of the NH_2 group at position 6 and N at position 7 come into close position to the O^1 of the two OH^1 units when molecule curls up. This curling up occurs in contraction of muscle.

Myosin is a protein whose molecule is a thin filament. The myosin molecule is proposed to be further divided into meromyosin L and H; L and H standing for light and heavy respectively. The H meromyosin is plumper and upon precipitation, settles faster. It is further proposed that the myosin molecule consists of one H meromyosin and two L meromyosins in a chain.

Actin is a typical globular protein capable of being polymerized from the G (globular) to the F (fiber) actin. Actin, as a proteinous material, is charged more negative than myosin.

The release of the energy of the chemical bond of the P—O—P link (12,000 cal.) is effected through the formation of a magnesium complex with ATP. Magnesium is available from an enzyme substrate. The reactions in a normal muscle are equilibrium reactions. This magnesium complex can be picture as follows:
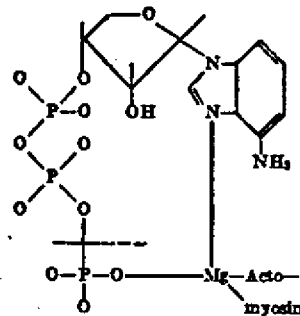
The dotted line indicates the breaking of the P—O—P link.

Rest: Actin+Myosin—ATP!

⇅

Excitation: Actomyosir--ATR!r

Contraction: Actomyosin—ATP.

⇅

Relaxation: Actomyosin—ATP ⇌ Actomyosin ADP+Phosphate

Actomyosin—ADP+CP ⇌ Actomyosin—ATP!+C

⇅

Actin+Myosin—ATP

The energy released during this process is used by the muscle to contract. This breaking of the energy rich phosphate is enzymatically promoted by the magnesium ion which is known to form a stable complex.

When the terminal P—O link is broken and the bond energy released, actomyosin—ADP is formed. The magnesium complexes with the enzyme substrate. In normal muscle action the ADP attached to the contracted actomyosin will attempt to reform ATP by reacting with another molecule of ADP or with a molecule of CP. Only upon the reformation of ATP does the original complex reform, re-establishing the system of actin, myosin—ATP magnesium complex.

When foreign metal ions or additional magnesium ions are introduced in excess over the normal magnesium concentration, this ionic increase will produce an interference with the decomposition of the original actin, myosin ATP complexes. Three phosphate groups containing a total negative charge of four are present in the ATP molecule attached to the enzyme. These negative charges are neutralized by one magnesium ion in the enzyme complex leaving an additional two negative charges which will permit the addition of another magnesium ion.

The additional magnesium ion stabilized the

O—P—O—P—O

link through the formation of a pyrophosphate which is known to be a very stable link as shown in the analytical determination as magnesium pyrophosphate. This effectively prevents the breaking of the terminal P—O—P bond and the release of its bond energy under normal conditions. Since this bond is not broken and no energy is released, muscle contraction will not occur. The muscle will remain in its relaxed state.

Pyrophosphate form complexes of the type $M^{II}(P_2O_7)$= with divalent ions such as magnesium and complexes of

the type $M^{III}(P_2O_7)^-$ and $M^{III}(P_3O_7)_2^{-4}$ with such metals as aluminum. These groupings can be represented as:
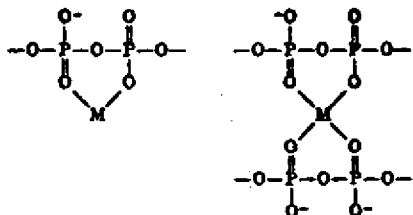

The formation of a chelate ring of six atoms adds to the stability of the grouping.

Magnesium in water solution is present as the hydrated magnesium ion and its structure and environment is completely different from that of the ATP which contains a sugar group. The presence of this dissimilar medium makes it difficult for the magnesium ion to enter into that part of the cell where the enzyme mechanism occurs. However, if magnesium is in a slight alkaline medium where its positive charge has been slightly decreased due to the presence of complexed hydroxyl groups, it is now possible to complex this magnesium hydroxy complex with sugar or sugar-like molecules such as polysaccharides.

In the presence of these complexing agents, the entrance of the complexed magnesium into the enzymatic process becomes vastly accelerated. The Mg ATP complex becomes destroyed by further complexing with the magnesium polysaccharide complexes.

However, in the enzymatic cycle magnesium can also be introduced without adding polysaccharides because in certain seasons of the year, the oyster itself is known to be high in glycogen, a polysaccharide which can form similar complexes with magnesium hydroxy complexes. Because the complex ion formation has to occur in the oyster itself, the entrance in the enzymatic cycle becomes much slower. Thus muscle relaxation will occur much slower also.

The magnesium ion can also affect the enzyme cycle (an equilibrium process) in that increases of the concentration on the product side will increase the stability of the reactants, shifting the equilibrium to the left.

$$ATP + Enzym \rightleftharpoons Enzym\text{-}Photphat + ADP$$
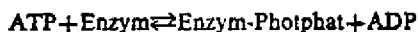
This would then stabilize the ATP complex and prevent the formation of ADP and thus decrease the release of energy needed for muscle contracture.

The magnesium ion can interact with myosin in the resting muscle by increasing the positive charge of the myosin and thereby decreasing the tendency for the actomyosin to form. Magnesium hydroxy polysaccharide complexes with the myosin giving a slight increase in the repulsive forces stabilizing the myosin and actin as separate entities and thereby preventing the formation of the actomyosin Mg ATP complexes.

The effect of metal ions in interfering with the enzyme actions of the ATP—ADP processes is a function of the size and charge of the metal ion. This size and charge is well known to be a major factor in the complexing ability of most metal ions. Group 1–A elements have little or no effect on the enzyme process and are not specific for any of the processes which were described above. Polyvalent ions with a size larger than magnesium in group 2–A seem to belong in the same group as the group 1–A elements. Metal ions other than these two groups, however, would all interfere with all of the processes mentioned, but the rate and extent of interference would differ markedly from metal ion to metal ion, depending first upon its size and second upon its charge. For magnesium, relatively large amounts which can very easily and very correctly be analytically determined are needed to bring about the relaxation of the muscle. All

other metal ions which produce similar effects need much smaller amounts introducing a larger uncertainty in the exact determination of the desired concentration.

Since relatively large amounts are necessary in the case of magnesium to bring about a relaxation phenomenon under equilibrium conditions, it is thus easily possible to eliminate the interference of the magnesium ion with the enzyme process equilibrium. The normal process of relaxation and contracture due to ATP—ADP decomposition and the subsequent release of the high energy phosphate is then re-established.

If the equilibrium is pushed by adding extra amounts of metal ion, the formation of the actomyosin ATP Mg complex is primarily interfered with and the oyster will die. The amount of metal ion necessary to bring about this death will vary from metal ion to metal ion for the reasons expressed above and very small highly charged metal ions such as Al (111) and Be (11) will do this in exceedingly small concentrations.

This method of opening oysters has proven 100% effective, on all sizes and shapes. The inherent property of the utilization of glycogen enables this process to be used to process the oyster most economically and justifiably at the time of the year the oysters are the largest and have the greatest food value.

With the shells thus opened, the oysters are easily removed by knife without danger of cutting the body and incurring weight loss due to bleeding. Such an overall operation of chemically opening and hand shucking the opened oysters is very rapid. This is considering that a manual operation is to follow the chemical operation.

As previously stated, the oyster is in no manner physically altered by treatment with magnesium chloride singly or with polysaccharide. The same cannot be stated for the present mass production of steaming where there is terrific shrinkage and weight losses as high as 70%.

When the chemical method is compared to the mechanical shock method, there is a 100% efficiency of opening for the chemical with no mutilation as compared to uncertain efficiencies of opening and possible shredding of oyster with the shock method. It must be stated that in the shock method, oysters that have died with their adductor muscle fully contracted begin to gape only when the muscle disintegrates.

Although we have disclosed herein the best forms of the invention known to us at this time, we reserve the right to all such modifications and changes as may come within the scope of the following claims.

What we claim is:

1. The process of chemically opening bivalve mollusks comprising placing the mollusks in an aqueous solution of a salt of the metal of the group of aluminum, copper, calcium, magnesium, manganese and zinc having a solution specific gravity of the range of 1.004 to 1.036 having available metallic ions of the elements set forth above loosely complexed for entering into cell reaction in the mollusks, maintaining the temperature of the solution within the range of 5° C. to 49° C., and maintaining the pH of the solution within a range of the order of 6.5 to 9.5 to open the mollusks.

2. The process of claim 1 further comprising the additional step of adding water soluble polysaccharides to the solution as a time reaction accelerator.

3. The process of claim 1 further comprising the additional step of adding a polysaccharide of the group of glucose, dextrin, maltose, dextrose and sucrose as a time opening accelerator.

4. The process of opening bivalve oysters of the species *Grassostrea virginica* comprising placing the oysters in an aqueous solution of a salt of the metal of magnesium having a solution specific gravity of the range of 1.012 to 1.020 having available metallic ions of magnesium loosely complexed for entering into cell reaction in the oysters, maintaining the temperature of the solution within the range of 15° C. to 30° C., and maintaining the pH of

the solution within a range of the order of 7.0 to 9.5 to open the oyster.

5. The process of claim 4 further comprising the step of adding water soluble polysaccharides to the solution as a time reaction accelerator.

6. The process of opening oysters of the species *Grassostrea virginica* comprising placing the oysters in an aqueous solution of a salt of the metal of aluminum having a solution specific gravity of the range of 1.012 to 1.020 having available metallic ions of aluminum loosely complexed for entering into cell reaction in the oysters, maintaining the temperature of the solution within the range of 15° C. to 30° C., and maintaining the pH of the solution within a range of the order of 7.0 to 9.5 to open the oysters.

7. The process of claim 6 further comprising the additional step of adding water soluble polysaccharides to the solution as a time reaction accelerator.

8. The process of opening oysters of the species *Grassostrea virginica* comprising placing the oysters in an aqueous solution of a salt of the metal of copper having a solution specific gravity of the range of 1.012 to 1.020 having available metallic ions of copper loosely complexed for entering into cell reaction in the oysters, maintaining the temperature of the solution within the range of 15° C. to 30° C., and maintaining the pH of the solution within a range of the order of 7.0 to 9.5 to open the oysters.

9. The process of claim 8 further comprising the additional step of adding water soluble polysaccharides to the solution as a time reaction accelerator.

10. The process of opening oysters of the species *Grassostrea virginica* consisting of placing the oyster in an aqueous solution of a salt of the metal of calcium having a solution specific gravity of the range of 1.012 to 1.020 having available metallic ions of calcium loosely complexed for entering into cell reaction in the oysters, maintaining the temperature of the solution within the range of 15° C. to 30° C., and maintaining the pH of the solution within a range of the order of 7.0 to 9.5 to open the oysters.

11. The process of claim 10 further comprising the additional step of adding water soluble polysaccharides to the solution as a time reaction accelerator.

12. The process of opening oysters of the species *Grassostrea virginica* comprising placing the oysters in an aqueous solution of a salt of the metal of manganese having a solution specific gravity of the range of 1.012 to 1.020 having available metallic ions of manganese loosely complexed for entering into cell reaction in the oysters, maintaining the temperature of the solution within the range of 15° C. to 30° C., and maintaining the pH of the solution within a range of the order of 7.0 to 9.5 to open the oysters.

13. The process of claim 12 further comprising the additional step of adding water soluble polysaccharides to the solution as a time reaction accelerator.

14. The process of opening oysters of the species *Grassostrea virginica* comprising placing the oysters in an aqueous solution of a salt of the metal of zinc having a solution specific gravity of the range of 1.012 to 1.020 having available metallic ions of zinc loosely complexed for entering into cell reaction in the oysters, maintaining the temperature of the solution within the range of 15° C. to 30° C., and maintaining the pH of the solution within a range of the order of 7.0 to 9.5 to open the oysters.

15. The process of claim 14 further comprising the additional step of adding water soluble polysaccharides to the solution as a time reaction accelerator.

16. The process of chemically opening bivalve Grassostrea comprising placing the Grassostrea in an aqueous solution of a salt of the metal of the group of aluminum, copper, calcium, magnesium, manganese and zinc having a solution specific gravity of the range of 1.004 to 1.036 having available metallic ions of the elements set forth above loosely complexed for entering into cell reaction in the Grassostrea, maintaining the temperature of the solution within the range of 5° C. to 49° C., and maintaining the pH of the solution within a range of the order of 6.5 to 9.5 to open the Grassostrea.

17. The process of claim 16 further comprising the additional step of adding water soluble polysaccharides to the solution as a time reaction accelerator.

References Cited in the file of this patent

UNITED STATES PATENTS

| 2,041,727 | Prytherch et al. | May 26, 1936 |
| 2,824,005 | Strasburger | Feb. 18, 1958 |