6,347 metric tons of netting and rope worth $10 million.

Tables 16 and 17 provide additional statistics on Korea's exports of fishery products to different countries, for different commodities, during the period 1962-72.

SUMMARY

It is always difficult to project the future direction of a nation's fisheries. However, in the case of the Republic of Korea, it is quite possible that the Koreans may meet or exceed their targets during the coming years. These goals were outlined by the Director General of the ROK Office of Fisheries, Kim Dong Soo, in October 1972:

> "The nation's fisheries production is projected at 2 million metric tons and annual exports of marine products at $350 million by 1976. As a result, the nation is anticipated to rank the fifth in the world in terms of fisheries production and the first in terms of annual exports of marine products."[4]

Whether or not these projections are reached, it is certain that the Republic of Korea will become better able to serve the needs of the nation in fishing and it is also certain that Korean fishermen will be recognized throughout the world as ambitious and skilled fishermen.

[4]Office of Fisheries, *Pictorial Korean Fishery*, Republic of Korea, 1972.

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Abnormal red color can be removed from oysters by heat treatment.

Thermal Bleaching of Red Algal Pigment in Shucked Oysters

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ABSTRACT—A technique for decoloring oysters exhibiting "red liquor" due to ingesting algal pigment is described. The abnormal color was permanently removed by holding the oysters at 55°C for 25 minutes in the aeration tanks. Heat treatment did not noticeably affect the taste or keeping quality of the oyster meat and is feasible using equipment commonly found in most Chesapeake Bay shucking houses.

INTRODUCTION

"Red liquor" in shucked oysters has been a chronic problem for packers (Beaven, 1964; Burrell, 1971; Hunter, 1920; Lear, 1958; Lear and Manning, 1957; and Sieling, 1971). Plant pigments, derived from algae on which the oyster has been feeding, constitute a principal cause of this coloration (Lear, 1958). The color is often not noticeable when the oysters are shucked and packed but may develop several days after packing, when oysters are held at temperatures just above freezing, or immediately after frozen oysters have thawed. The wholesomeness and flavor of such oysters is in no way impaired, but customer rejection often causes serious financial losses to packers (Nelson, 1948).

Oysters feed on the algae causing red color only about two weeks out of each year. Such algae are usually present before oysters cease to feed in the fall and are a problem for only a week or two in shucked oysters. However, during some years the pigment apparently is retained in the intestinal tract of oysters from fall to the following spring (Lear, 1958). Thus, "red" oysters can be a problem to shucking houses for the entire season. Serious outbreaks of red liquor in oysters appear to follow an extended warm fall (Nelson, 1948).

A method of eliminating red pigmentation from shucked oysters would be advantageous to the oyster industry. For a bleaching technique to be of value to the industry, 1) the treated product must have all the attributes of fresh oysters in appearance, taste, and keeping quality, 2) cost of labor and equipment to process oysters must be minimal, and 3) yield after processing should not be greatly reduced.

The purpose of this study was to determine the feasibility of thermal bleaching, employing laboratory and field tests.

LABORATORY TESTS

Objective

Laboratory tests were undertaken to determine the length of time oysters must be held at a specific temperature to decolor red algal pigment. A temperature-time regime least affecting

the appearance, taste, and keeping qualities of oysters was sought.

Methods and Materials

Pint containers of red oysters, obtained from a local shucking house, were held at internal temperatures of 40, 45, 50, 55, and 60°C for 15, 20, and 25 minutes in water baths, for a total of 15 different regimens. Prior to heating, oyster gut contents and free liquor in the can were inspected microscopically to establish that coloration was not due to yeast or bacteria. The pH was used to determine freshness because this criterion is applied by military purchasers, and significant quantities of frozen oysters involved in the red oyster problem go to this market. Novak and Fieger (1957) found that pH was too variable to be used as a test of freshness in commercially stored oysters, but that pH did decrease slowly in stored oysters. The pH was determined by homogenizing oyster meats in a blender and testing with a Beckman Model SS 3 pH meter before and after treatment. In replicate tests, pH was averaged according to Kinney (1973).

Each treatment was applied to ten pints of oysters. One pint from each treatment regimen was frozen and thawed, as this is the surest method of demonstrating red pigment if it is still present in oysters (Table 1). A second group of 45 pints (3 from each regimen) was stored under dry refrigeration of 3-6°C; the third group of 90 (6 pints from each regimen) was held in crushed ice (Tables 2 and 3). The latter two groups were tested every 5 days for appearance, taste, smell, and pH for 15 and 30 days respectively.

Visual observations were made to determine if red color was present and if treated oysters were visibly different from oysters not receiving heat treatment. Two or more raw oysters from each container were eaten at the prescribed intervals to note taste change, if any, with storage time. Smell was also noted at each interval.

Controls of uncolored, fresh oysters (obtained in an area free from problems with red oysters) were stored under similar conditions to compare keeping qualities of treated with untreated oysters.

Table 1.—Treated oysters frozen and thawed after three days.

Temperature °C	Time in Minutes	Appearance	pH Before Treatment	pH After Thawing
40	15	red	6.4	6.4
40	20	red	6.4	6.4
40	25	red	6.4	6.4
45	15	red	6.4	6.4
45	20	red	6.4	6.4
45	25	red	6.4	6.4
50	15	red	6.4	6.4
50	20	clear	6.4	6.5
50	25	clear	6.4	6.4
55	15	clear	6.4	6.4
55	20	clear	6.4	6.4
55	25	clear	6.4	6.5
60	15	clear	6.4	6.4
60	20	clear	6.4	6.4
60	25	clear	6.4	6.5
Control	Control	clear	6.4	6.4

Table 2.—Storage of treated oysters in dry refrigeration at 3-6°C.

		5 days		10 days		15 days	
Temperature °C	Time in Minutes	pH	Appearance	pH	Appearance	pH	Appearance
40	15	6.3	red	6.2	red	5.7	red
40	20	6.4	red	6.2	red	5.6	red
40	25	6.4	red	6.1	red	5.7	red
45	15	6.5	red	6.2	red	5.6	red
45	20	6.4	clear	6.1	red	5.8	red
45	25	6.4	red	6.2	red	5.8	red
50	15	6.4	red	6.3	red	5.8	red
50	20	6.4	clear	6.2	clear	5.6	red
50	25	6.4	clear	6.2	red	5.7	red
55	15	6.3	clear	6.1	clear	5.7	clear
55	20	6.5	clear	6.3	clear	5.8	clear
55	25	6.4	clear	6.3	clear	5.7	clear
60	15	6.4	clear	6.2	clear	5.7	clear
60	20	6.3	clear	6.1	clear	5.8	clear
60	25	6.4	clear	6.2	clear	5.6	clear
Control	—	6.3	clear	6.2	clear	5.7	clear

Table 3.—Oysters held in ice in a cold room at temperatures of 0-2°C after heat treatment.

		5 days		10 days		15 days		20 days		25 days		30 days	
Treatment Temperature °C	Time in Minutes	Appearance	pH	Appearance	pH	Appearance	pH	Appearance	pH	Appearance	pH	Appearance	pH
40	15	red	6.4	red	6.4	red	6.2	red	6.2	red	6.2	red	6.1
40	20	red	6.5	red	6.4	red	6.2	red	6.1	red	6.1	red	6.1
40	25	red	6.5	red	6.4	red	6.2	red	6.1	red	6.2	red	6.1
45	15	red	6.4	red	6.4	red	6.2	red	6.2	red	6.1	red	6.0
45	20	red	6.5	red	6.5	red	6.3	red	6.2	red	6.1	red	6.0
45	25	red	6.4	red	6.4	red	6.1	red	6.1	red	6.1	red	6.1
50	15	red	6.5	red	6.4	red	6.1	red	6.2	red	6.1	red	6.1
50	20	clear	6.4	red	6.4	clear	6.2	clear	6.2	clear	6.2	clear	6.2
50	25	clear	6.4	red	6.4	red	6.3	red	6.2	red	6.2	red	6.1
55	15	clear	6.4	clear	6.4	clear	6.2	clear	6.2	clear	6.2	clear	6.2
55	20	clear	6.4	clear	6.4	clear	6.2	clear	6.2	clear	6.1	clear	6.1
55	25	clear	6.5	clear	6.4	clear	6.2	clear	6.1	clear	6.1	clear	6.1
60	15	clear	6.5	clear	6.4	clear	6.2	clear	6.1	clear	6.1	clear	6.0
60	20	clear	6.4	clear	6.4	clear	6.2	clear	6.2	clear	6.2	clear	6.1
60	25	clear	6.4	clear	6.4	clear	6.2	clear	6.2	clear	6.1	clear	6.0
Control	—	clear	6.4	clear	6.4	clear	6.2	clear	6.2	clear	6.1	clear	6.1

Results of Laboratory Tests

Oysters heated to 40°C remained noticeably red (Tables 1, 2, and 3). One pint of those heated to 45°C initially lost red color, although it returned after freezing and thawing and upon storage (Tables 1, 2, and 3). Red color was lost and did not return after freezing and thawing in oysters heated to 50°C for more than 15 minutes, but the color returned following storage (Tables 1, 2, and 3). All oysters treated at 55°C and 60°C lost red pigmentation and did not regain it after freezing and thawing or during storage of up to 30 days (Tables 1, 2, and 3).

No pH change occurred immediately after heat treatment, but during both storage in ice and dry refrigeration the pH dropped in both controls and treated oysters at the same rate (Tables 2 and 3). There was no visual evidence, such as shrinkage or curled mantle edges, to indicate that oysters had been heated, other than the loss of red color. Flavor of oysters held in ice began to deteriorate and a slight odor developed in both test oysters and controls at 25 days, but neither were spoiled at 30 days. Deterioration of flavor and development of a slight odor occurred at 15 days in oysters held at 3-6°C under dry refrigeration.

Conclusions on Laboratory Tests

Fresh canned oysters heated to 55 and 60°C for 15 minutes lost red coloration caused by algal pigments. Taste, appearance, and smell were not adversely affected by these treatments. This indicated that temperatures in this general range would be best for initial field tests. Time at temperature however might require some further experimentation since, in laboratory tests, time recorded was the period that the center of the oysters in the can were held at desired temperatures. The aeration step in processing is the logical place to treat oysters since heated water may be readily applied. Aeration or "blowing" refers to a procedure where 15 to 20 gallons of fresh shucked oysters are placed in 75- to 150-gallon stainless steel open top vessels, three-fourths filled with water. Compressed air is then piped into these vessels, agitating oysters, so that shell and grit is washed out. Aerators or blowing tanks have tap water, steam, and compressed air supplied from the bottom of the tanks.

Table 4.—Oysters held in a household refrigerator at 3-6°C after heat treatment in an aerator for 25 minutes.

Treatment Temperature °C	0 days		5 days		10 days		15 days		Without heat treatment
	Appearance	pH	Appearance	pH	Appearance	pH	Appearance	pH	frozen and thawed
50	clear	6.4	red	6.3	*				83% red 17% clear
53	clear	6.5	40% red 60% clear	6.3	25% red 75% clear	6.2	*		90% red 10% clear
55	clear	6.4	clear	6.3	clear	6.3	clear	5.8	92% red 8% clear
Control	clear	6.4	clear	6.2	clear	6.2	clear	5.8	100% clear

*No further tests

FIELD TESTS

Objectives

One objective was to determine if it is feasible to heat oysters for a sufficient time in aeration tanks prior to packing in cans in order to decolor algal pigments which cause red coloration. A second objective was to determine shelf life of heat-treated oysters.

Methods and Materials

Oysters used in field tests were selected from batches of oysters known to have red pigment although color might not be apparent. This was determined by inspecting the gut of torn oysters and rapid freezing and thawing of suspected oysters. These oysters came from several areas including upper Chesapeake Bay, Rappahannock River, Potomac River, and Louisiana.

Batches of these oysters, varying in quantity from 10 to 20 gallons of both standards and selects, were placed in aerators three-fourths filled with water which had been heated by steam injection to temperatures of 50, 55, and 60°C. Additional steam was introduced into the tanks until the temperatures reached 50, 53, and 55°C after the oysters had been added. The oysters were aerated for 5 minutes and then allowed to soak for 20 minutes. Temperatures were maintained at 50, 53, and 55°C throughout the aerating and soaking periods. From time to time, the oysters were stirred to maintain a uniform temperature throughout the tank. After oysters had soaked for 20 minutes, cold water was run into the tanks until they overflowed to cool the oysters and wash out grit. In some tests, conducted at 55°C, ice was added to the holding water to lower the temperature of the oysters to packing stage more rapidly. In these instances, soaking was reduced to 18 minutes prior to removal from the aerators.

After treatment, six pint cans of treated oysters from each batch and one can of control oysters were held in a household refrigerator at 3-6°C. Six additional pint cans of treated oysters, one gallon of treated oysters, and one can of control oysters were held in crushed ice in a cold room at 0-2°C. Both of these groups were examined for appearance, taste, smell, and pH at 5-day intervals for a maximum of 30 days. Taste and olfactory observations in this case were the same as in the laboratory tests except that controls and half-pint containers receiving each treatment were distributed at the 5-day intervals to laboratory colleagues for home consumption. Subjects were not told the history of the oysters nor was any stipulation made as to how the oysters were to be prepared. Reports from these people indicated that the oysters were eaten raw, steamed, fried, stewed, and scalloped. (A formal taste panel could not be established for this investigation.)

Controls consisted of oysters from an area not having the "red" problem, shucked simultaneously with "red" oysters. Additionally, six pint cans from the batch of oysters to be treated were frozen and thawed without treatment to determine the likelihood of "red" color showing up in the remaining oysters, had they not been treated. These oysters were inspected microscopically and found to be free of "pink" yeast or bacteria which might cause red color.

Results of Field Tests

Oysters known to contain red pigment in their intestinal tracts that were subjected to 50°C for 25 minutes

Table 5.—Oysters held in crushed ice in a cold room maintained at 0-2°C after heat treatment in an aerator. pH is a mean of all replicates. Replicates at 55°C included pint and gallon cans.

Treatment Temperature °C	0 days		5 days		10 days		15 days		20 days		25 days		30 days		Without heat treatment
	Appearance	pH	Appearance	pH	Appearance	pH	Appearance	pH	Appearance	pH	Appearance	pH	Appearance	pH	frozen and thawed
50	clear	6.4	red	6.3	*				*						83% red 17% clear
53	clear	6.4	25% red 75% clear	6.3	25% red 75% clear	6.3	10% red 90% clear	6.3	10% red 90% clear	6.2	10% red 90% clear	6.1	10% red 90% clear	6.1	90% red 10% clear
55	clear	6.4	clear	6.4	clear	6.3	clear	6.3	clear	6.2	clear	6.0	clear	6.0	92% red 8% clear
Control	clear	6.4	clear	6.3	clear	6.3	clear	6.3	clear	6.3	clear	6.1	clear	6.0	100% clear

*No further tests

showed no obvious color when placed in storage (Tables 4 and 5). All of these oysters developed red color upon storage. Those raised to 53°C for 25 minutes were clear when placed in storage, but 10-66% developed red color, with larger oysters most often showing color. Oysters subjected to 55°C for 25 minutes did not develop red coloration in storage up to 30 days. Oysters from the same batch in each instance above, not having received heat treatment, showed red color when frozen and thawed in 83%, 80% and 92% of the cans, respectively. Keeping quality as measured by depression of pH of treated oysters and controls showed no difference (Tables 4 and 5).

Gallon containers kept as well as pint containers (Table 5). Appearance in all instances was the same in treated as in untreated oysters. Taste tests by the author indicated no difference with time in treated and untreated oysters. The reaction of recipients of test oysters was in every instance favorable with no greater acceptability for control oysters. Again a slight odor developed in both control and treated oysters held in a household refrigerator at 15 days, and at 25 days in those held in ice at 0-2°C. Heat treatment time reduced to 23 minutes at 55°C by adding crushed ice to the aerator for cooling purposes was sufficient to decolorize the red pigment.

CONCLUSION

Oysters may be held at 55°C for 23 to 25 minutes during the aeration process in a shucking house to decolorize red pigments derived from algal food of oysters. A temperature of 53°C during the aeration process is sufficient for small oysters (standards); however, grading by most shuckers is not strict enough to prevent some large (select) oysters from getting into nearly every batch. Therefore, the lower temperature is not reliable.

Advantages of heat treatment of oysters to decolor ingested red plant pigments are:

1) Oysters are no longer subject to customer rejection due to appearance.
2) Treated oysters have the same shelf life as untreated oysters.
3) Neither taste nor appearance (other than loss of red color) is altered.
4) The process may be carried out using existing equipment.

The main disadvantage of this process is the need for strict adherence to time and temperature. This requires close supervision throughout the treatment. Temperatures higher than those prescribed may denature the proteins in the oyster and increase the difficulty in cooling oysters to packing temperature.

Although this treatment has been effective in degrading the red pigment in oysters from many areas during the winters of 1971 and 1972, it may not work for all red algal pigments ingested by oysters and other bivalves.

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