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FREEZING GULF-OF-MEXICO SHRIMP AT SEA

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ABSTRACT

Freezing (in air) shrimp at sea aboard the vessel immediately after they are caught produced a high-quality product more nearly approaching the absolutely fresh state than the iced shrimp normally found on the market. Brine-freezing shrimp at sea for later thawing and refreezing ashore resulted in a product whose color, flavor, and texture were comparable to shrimp air-frozen at sea. Both of these products were superior to shrimp iced at sea. Particularly significant was the fact that shrimp frozen at sea aboard vessel showed no development of "black spot" discoloration. A recommended procedure for commercial application of brine-freezing shrimp is given.

INTRODUCTION

The development of the shrimp fishery in the Gulf of Mexico and other southern waters has brought new technological problems to the shrimp industry. Expanding shrimp markets have brought more and larger vessels with larger payloads. As boats range hundreds of miles from port, icing the shrimp for more than 10 to 12 days creates a quality problem. Softening, black-spot discoloration, loss of flavor, and spoilage of shrimp held too long in ice have meant a loss of dollars to the fishermen and a loss of product quality to the consumer.

Recognition of these problems has encouraged the adoption of better handling practices aboard vessel, improved icing procedures, and hold refrigeration for preservation of ice on the outbound trip. Packaging and freezing the raw headless shrimp aboard vessel appears to be a satisfactory solution of the quality problem for many fishermen with larger boats and the required capital for the freezer installation. Another promising solution is the holding of fresh shrimp in refrigerated sea water (Idyll, Higman, and Siebenaler 1952) aboard vessel. Still another solution is to freeze the shrimp in low-temperature brine at sea and then thaw, package, and refreeze them ashore.

Freezing packaged shrimp aboard the vessel solves the quality problem encountered on long trips, since even a 4- to 6-week trip may be accomplished with no appreciable loss in quality to shrimp properly frozen and stored. The freezing of shrimp in brine aboard vessel appears to offer several excellent advantages compared to other systems. Brine freezers are adaptable to small boats, since packaged refrigeration units may easily be designed for small space. Brine-freezing of small and irregular-shaped products such as shrimp is efficient and fast. Complete protection against dehydration (freezer burn) is insured during the freezing cycle as contrasted with air-blast freezing. A large volume of cold brine is an excellent reserve of refrigeration during peak periods of fishing. Many of the practical ad-

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vantages, as well as the problems, of brine-freezing fish at sea have been demonstrated by the U. S. Fish and Wildlife Service studies aboard the trawler Delaware off the New England coast.

The present study was intended as a small-scale trial of brine-freezing shrimp at sea in the coastal area of the Gulf of Mexico. The facilities used were those of the Fish and Wildlife Service vessel Oregon, which was engaged in exploratory shrimp fishing at the time. Among the factors considered were: (1) quality of the fresh shrimp, (2) effect of chilling the shrimp before freezing, (3) freezing rate, (4) importance of brine circulation, (5) glazing, (6) storage of brine-frozen shrimp, (7) thawing and refreezing brine-frozen shrimp, (8) salt content of frozen shrimp, and (9) a comparison of keeping quality of brine-frozen shrimp with that of air-frozen shrimp.

Fig. 1 - U. S. Fish and Wildlife Service exploratory fishing vessel Oregon at dock, Pascagoula, Mississippi.

EXPERIMENTAL

All freezing trials at sea were conducted aboard the Fish and Wildlife Service vessel Oregon during March and April 1952. Both the white (Penaeus setiferus) and brown-grooved (P. aztecus) shrimp were brine-frozen and air-frozen during exploratory trips off the Mississippi, Louisiana, and Texas coasts. In addition, iced fresh white shrimp obtained from the commercial fishery were frozen for comparison. A sample of commercially packaged and frozen brown-grooved headless shrimp was obtained for comparative storage tests with the experimental samples. At the conclusion of the work aboard the exploratory vessel Oregon in May 1952, all samples of frozen shrimp were shipped under refrigeration to the Fishery Products Laboratory, Ketchikan, Alaska, where storage tests were conducted until February 1953, when the tests were concluded.

Shrimp processed at sea were frozen either in refrigerated brine at 5° F. or in still air at -20° F. within two hours after being caught, with the exception of one lot of whole shrimp that was iced for three days prior to being headed and frozen. Both whole and headless shrimp were frozen by the two methods. All shrimp were rinsed thoroughly with clean sea water before being frozen. Air-frozen shrimp were prepared as the control sample and were packaged in 5-pound waxed cartons, placed in the sharp freezer at -20° F. for 24 hours, glazed with cold fresh water, and stored at 0° F.

BRINE FREEZING: Brine-frozen shrimp were prepared by immersing 5- to 10-pound lots of shrimp for about 15 minutes in circulating 85-degree salimeter brine (22.4 percent salt) chilled to 5° F. With small lots the brine temperature increased not more than 5° during the freezing period. After the shrimp had been removed from the brine, they were drained briefly, rinsed in fresh water (chilled to 34° F.), drained, packaged in 1- or 5-pound waxed cartons, and stored in air at 0° F. The effect of chilling the shrimp in fresh cold water (34° F.) prior to their immersion in the brine was determined. The freezing rate of the shrimp was determined by observation of the amount of area actually frozen as indicated on the cut sections of shrimp removed at intervals from the brine, and also by use of a metal-stem thermometer thrust into the middle portion of individual shrimp. In salt-penetration tests, shrimp were kept in the brine for 48 hours. Small samples (approximately 1 pound) were removed at intervals during this time. Observations

were made on the importance of brine circulation and methods of keeping the chilled brine in contact with the shrimp. Because of the limited capacity of the experimental brine freezer, no observations were possible on the optimum ratio of the volume of shrimp to the volume of brine.

Fig. 2 - Setting the shrimp trawl aboard the Oregon off the Mississippi coast in April 1952. Equipment for brine-freezing tests was placed in the starboard brine well, accessible through the hatch shown alongside the deckhouse.

In view of the limited time and funds available for this study, the experimental brine freezer was constructed of equipment readily available at low cost. A 55-gallon open-top drum was wrapped with 2-inch rock-wool batts and used for the brine tank. Approximately 60 feet of $\frac{1}{2}$-inch copper tubing was coiled in the bottom of the drum and along the inside and connected to a $\frac{1}{2}$-horsepower Freon-12 air-cooled refrigeration compressor. A $\frac{1}{4}$-horsepower centrifugal pump with neoprene impeller and 2-inch heavy-duty rubber hose were used to pump the brine from the bottom of the tank to the top, where it was discharged directly over the shrimp. Approximately 40 gallons of 85-degree salimeter brine (made up with C-grade mined salt) were added to the tank. A cover was necessary during periods of rough weather to keep the brine from sloshing out. The cover was slotted to allow access for the refrigeration coils and the brine hose. Covered galvanized wire-mesh baskets and open-mesh cotton bags were used to hold the shrimp during freezing tests. A dial-type metal-stem thermometer was used to indicate brine temperature. The brine-freezing equipment, with an extra drum for a glazing tank, was placed amidships in a large refrigerated well maintained at 34° to 38° F. With no freezing load, the minimum temperature of the brine at the bottom of the tank was -2° F. and that at the top +2° F.

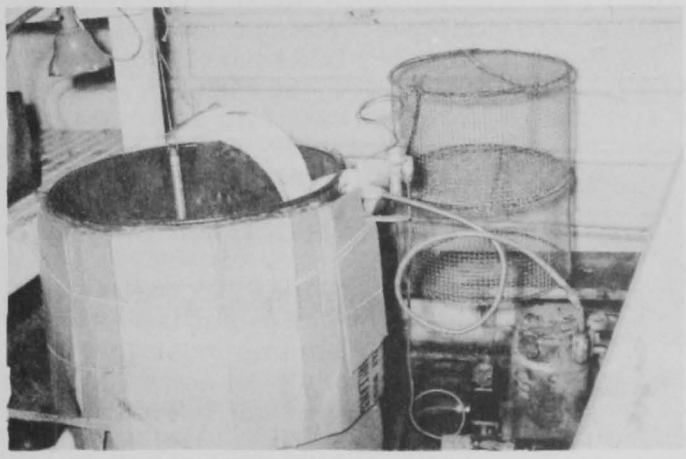

Fig. 3 - Improvised brine freezer aboard the Oregon, showing hose connections over the top of the tank and copper coil connected to compressor on the right.

Whole shrimp that had been brine-frozen at sea and stored in air at 0° F. for several weeks were used for thawing and refreezing tests ashore. In order to thaw the shrimp rapidly prior to being headed, they were immersed for 10 to 15 minutes in running fresh water at 60° F. The shrimp were then still cold and slightly stiff. After being headed, the shrimp were rinsed well with fresh water, packaged in 1-lb. waxed cartons, and frozen in air at -20° F. The following day, the shrimp were glazed in the package with fresh cold water (34° F.) and stored at 0° F. Shrimp that were headed before being brine-frozen were not thawed and refrozen but were stored for comparison.

SAMPLES: The main variables in the samples of shrimp frozen at sea and on shore for storage tests at 0° F. are summarized in table 1.

Table 1--Shrimp Samples Frozen for Storage Tests

Type of freezing used	Sample designation	Treatment of sample
Air	Control	Headed, packaged, and frozen immediately at sea
	Iced	Iced at sea, then headed, packaged, and frozen at sea, if done experimentally; or on shore, if done commercially
Brine	Refrozen	Brine-frozen at sea, then thawed, headed, packaged, and refrozen in air on shore
	Not refrozen	Left whole, brine frozen, and packaged at sea
		Headed, brine-frozen, and packaged at sea

In addition to the above samples, two small lots of iced white shrimp were obtained from commercial boats at Bayou La Batre, Alabama, and Cameron, Louisiana, and frozen in air and in brine ashore. These samples of frozen white shrimp were prepared primarily for salt-penetration studies and comparison with the shrimp frozen at sea. For the determination of salt (sodium chloride) content, 2 or more subsamples of 6 or more shrimp were drawn from each sample lot of shrimp, thawed, and peeled. Each subsample of shrimp meat was analyzed for total sodium chloride content by the procedure of the Association of Official Agricultural Chemists (1950).

EXAMINATION: Organoleptic examination of the frozen, thawed, and cooked shrimp samples was made after 5, 8, 15, 26, and 40 weeks of storage at 0° F. The frozen shrimp were thawed quickly in fresh water and then cooked 7 minutes in boiling water. The appearance and odor of the thawed shrimp were noted. The cooked shrimp were coded and graded by laboratory taste panels for appearance, flavor, and texture. The brown and the white shrimp were tested separately in case there were quality differences due to species.

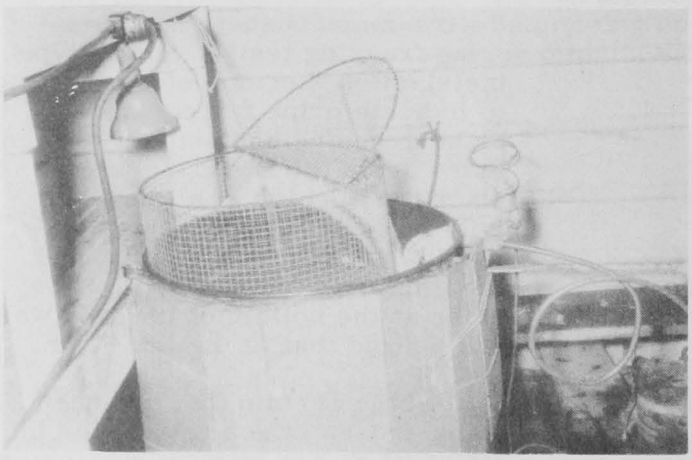

Fig. 4 - Basket for holding shrimp, showing hinged top. Two baskets could be placed in the brine tank for freezing tests.

RESULTS

FACTORS AFFECTING QUALITY: Observations of the methods of handling shrimp prior to their being frozen at sea and at processing plants on shore indicated that warm temperature, air, and sunshine are the most important factors that cause rapid loss of quality in shrimp caught in southern waters. Softening and moderate discoloration of the whole shrimp were observed after they had been held in ice for as short a time as three days. Both at sea and on shore samples of shrimp left in the shade but exposed to warm air for periods of 6 to 8 hours showed similar significant loss of quality. The results of later examinations of the frozen samples served as a graphic reminder of the well-known rule that the best any method of freezing can accomplish is to fix the quality of the product at the time it is frozen. Quality comparison of the frozen samples was difficult in some cases because the limited time and facilities did not permit preparation of the samples under strictly uniform conditions.

CHILLING: After several freezing tests had been run at sea, it was apparent that the most effective procedure for handling shrimp prior to their being frozen was to use an ice-water tank in which the whole or headed shrimp could be chilled im-

mediately after they had been separated from the catch. This preliminary chilling not only minimized the quality loss during delays before the shrimp were frozen but also improved the efficiency of the brine-freezing process. Shrimp chilled thoroughly in ice water before being immersed in cold brine appeared to freeze faster and had a better appearance. The cold water on the outside of the shrimp tended to freeze as a thin glaze immediately after the shrimp had been immersed in the brine. This glaze was noticeable on the surface of such shrimp after their removal from the brine.

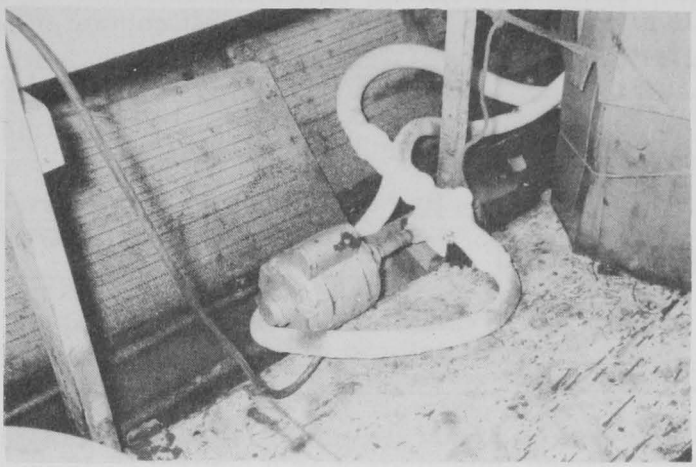

Fig. 5 - Pump used for circulation of refrigerated brine in tank.

FREEZING RATE: Observations of shrimp immersed in circulating brine at 5° F. indicated that headless shrimp averaging 20 to the pound would freeze in 10 minutes. Larger shrimp required 5 minutes longer or a total of 15 minutes until solidly frozen. Smaller shrimp averaging 35 headless shrimp per pound were frozen in 4 minutes to an internal temperature of 15° to 23° F. A maximum of 8 minutes was required to lower the temperature to about +5° F. Thus a maximum immersion time of 15 minutes appeared necessary for freezing Gulf shrimp in circulating brine at +5° F. In contrast, a 1-pound package of headed shrimp required 4 hours to freeze in still air at -20° F. Tests with immersion in still brine indicated that the time required to freeze would be about twice as long with single shrimp and several times as long with quantities of several pounds. This was due to the tendency of the shrimp to float together at the top of the brine.

IMPORTANCE OF BRINE CIRCULATION: The rapid circulation of the brine over the top of the tank appeared important in keeping the shrimp separated and allowing optimum contact of the chilled brine with each shrimp. With the experimental brine freezer the rapid circulation of the brine was also found important in maintaining the uniform temperature of the brine throughout the tank. Still brine or even slowly-circulating brine tended to layer, a warm layer of brine appearing over the top of the cold dense brine at the bottom. The rapid circulation of the brine was also necessary to keep the brine from freezing on the refrigerated coils and obstructing the flow of brine between the coils.

GLAZING: Brine-frozen shrimp did not take a good glaze if dipped into cold water immediately after being removed from the brine. The glaze was fragile and tended to chip off readily, affording little protection from dehydration if such shrimp were stored in bulk in large boxes or cartons. Brine-frozen shrimp were glazed more effectively if cold water was sprayed over them after they had been stored for a few days at 0° F.

STORAGE OF BRINE-FROZEN SHRIMP: Brine-frozen whole shrimp were found to be quite bulky. For example, a 5-pound waxed carton held only 3 pounds. The brine-frozen tails were slightly less bulky, but still did not permit efficient packaging because of the unavoidable air space left in the carton. Even with reglazing, such shrimp showed excessive dehydration because of the rapid moisture transfer within the carton.

THAWING AND REFREEZING: The process of thawing, heading, and refreezing the brine-frozen shrimp ashore seemed to offer no problem. After being thawed, the shrimp were slightly softer than the fresh shrimp as taken from the water, but

were definitely firmer and easier to head than much of the iced shrimp handled during the tests. The shrimp could be headed while partially frozen; however, packaging was easier if the shrimp were completely thawed.

SALT CONTENT: The salt content of the various samples of air-frozen shrimp is given in table 2. The lower salt content of the shrimp that were iced prior to being frozen (0.27 percent and 0.14 percent) as compared with that of the shrimp that were frozen immediately as a control (0.46 percent) was probably due more to leaching by the melting ice than to sample variation.

Table 2--Salt Content of Meat of Air-Frozen Shrimp

Sample designation	Kind of shrimp used	Treatment of sample	Salt content of meat 1/
			Percent
Control	Brown	Frozen immediately at sea	0.46
Iced	Brown	Held in ice 3 days before being frozen at sea	0.27
Iced	White	Commercial sample (Cameron, La.) held in ice at sea before being frozen on shore	0.14

1/Average of 2 or more subsamples.

The salt content of the various samples of the brine-frozen shrimp is given in table 3. The low value of 0.16 percent for the refrozen shrimp is interesting, since it indicates that the absorbed salt was leached quite rapidly while the shrimp were being thawed in running water. The data on the whole brown shrimp were irregular, owing probably to sample variation. The trends are sufficiently clear, however, to indicate that the absorption of salt from the brine was very rapid during the first

Table 3--Salt Content of Meat of Brine-Frozen Shrimp

Sample designation	Kind of shrimp used	Treatment of sample	Time in brine 1/	Salt content of meat 2/
			Hours	Percent
Refrozen	Whole brown shrimp	Brine-frozen at sea, then thawed in running water, headed, packaged, and refrozen in air on shore	0.25	0.16
Not refrozen	Whole brown shrimp	Frozen at sea immediately after being caught	0.25	1.5
			0.5	1.2
			1.0	1.2
			2.0	1.4
			4.0	1.5
			24.0	2.1
			48.0	2.4
	Headless brown shrimp	Frozen at sea immediately after being caught	0.25	1.7
	Whole white shrimp	Commercial sample (Bayou La Batre, Alabama) held in ice before being frozen	0.5	2.0
			1.0	2.5
			1.5	2.1
			24.0	2.6
			48.0	3.7
	Headless white shrimp	Commercial sample (Cameron, La.) held in ice before being frozen	0.5	1.9
			1.0	2.2
			1.5	2.6
			21.0	7.0

1/85-degree salimeter sodium-chloride brine at 5° (+5°) F.
2/Average of 2 or more subsamples.

quarter hour and that the absorption apparently continued, at a much slower rate, for at least as long as 48 hours. The value of 1.7 percent for the headless brown shrimp frozen for a quarter of an hour is slightly higher than that of the whole brown shrimp frozen for the same length of time (1.5 percent), but the difference between the two is within the range of sample variation. The data on the whole white shrimp iced before being brine-frozen indicate a slightly higher salt content than whole brown shrimp frozen immediately at sea. Otherwise the data follow the same trend. The data for the headless white shrimp iced before being brine frozen are similar, except that the amount of salt absorbed in 21 hours was very high. These shrimp were quite soft before being frozen, which may account for the high absorption.

Taste tests indicated that a salt content of 1.5 percent was not excessive. If the shrimp were boiled, it was necessary to add the usual amount of salt to the water for flavoring.

KEEPING QUALITY: Examinations aboard vessel indicated that brine-frozen shrimp compared very favorably with air-frozen whole and headless shrimp prepared from the same lots. Headless shrimp frozen in brine showed no discoloration on the shell or the exposed meat. Flavor and texture of the cooked shrimp were normal, and very little salt appeared to have been absorbed by the meat while the shrimp were being brine-frozen.

Examinations after 5 and 8 weeks of storage (computed from the time the shrimp were first frozen) indicated that the brine-frozen shrimp were equal in quality to the air-frozen shrimp. No undesirable discoloration, toughening, or excessive absorption of salt were noted in the brine-frozen shrimp. Since the brine-frozen headless shrimp were rather loosely packed in the waxed cartons, there was a slight amount of dehydration caused by moisture transfer within the carton, but the quality of the shrimp as a whole did not appear to be impaired. The refrozen shrimp appeared indistinguishable from the air-frozen shrimp, and the taste panel was unable to find any differences in flavor and texture.

After 15 weeks of storage there were no substantial changes in the quality ratings, with the exception of the brine-frozen headless shrimp. The increasing dehydration of these shrimp in the loosely-packed cartons was noticeable and was especially apparent in the difficulty of peeling the shrimp. Accompanying the dehydration was the development of a slightly strong off-flavor. Although these shrimp were still in fairly good condition, they were definitely inferior to the refrozen and the air-frozen samples.

After 26 weeks of storage all samples of shrimp were still in good condition except the brine-frozen headless shrimp, which were rated on the borderline of marketability owing to dehydration and the development of a strong off-flavor. The fact that the refrozen shrimp compared favorably at this time with the air-frozen shrimp indicated that it was not brine-freezing that was the cause of the problem but rather that it was the method of packaging which allowed the shrimp to dehydrate. Loss of glaze also was found in the refrozen and air-frozen shrimp packaged before being frozen. Shrimp at the corners and edges of these packages were slightly dehydrated, and correspondingly the flavor and texture were adversely affected. In brine-frozen shrimp, the adverse changes accompanying dehydration were noticeably greater than in the air-frozen shrimp, possibly because of the catalytic effect of salt (or impurities in it) absorbed in the surface meat during brine-freezing. When completely protected from dehydration (e.g., shrimp from the interior of the package), samples of both brine-frozen and air-frozen shrimp had good color, flavor, and texture after the 26 weeks of storage.

After the samples had been stored for 40 weeks at 0° F., it was found that the glazed shrimp showed surface dehydration of those shrimp at the corners and edges of all packages. This development made difficult a fair comparison of the other var-

iables being considered. Further observation of these samples showed without question that brine-frozen shrimp must be very carefully protected from dehydration if quality is to be preserved for periods of 6 to 9 months. The loss in quality of the air-frozen shrimp under conditions of moderate dehydration was also of greatest significance and was the factor limiting the storage life of these samples to 9 months.

Quality comparisons of the various lots of air-frozen shrimp during the storage tests were interesting. Black-spot discoloration was completely absent in shrimp frozen immediately after being caught. It was present to a moderate degree in those shrimp that were iced 3 days and to a greater degree in the commercially-iced shrimp that were frozen. Flavor differences were apparent to members of the taste panels but preferences varied. Some seemed to find the iced shrimp more flavorsome, whereas others thought iced shrimp were too strong in flavor by comparison and preferred the fresher flavor of the shrimp frozen immediately at sea.

DISCUSSION

If brine-freezing of shrimp were used commercially, the refreezing process appears to be the most satisfactory. Aboard the fishing vessel, the whole shrimp could be sorted rapidly into baskets in the ice-water chill tank on deck. The baskets of chilled shrimp could then be removed and, after being drained briefly, set in the refrigerated brine tank and frozen. After the shrimp were frozen, the baskets could be removed and stored in the refrigerated hold at 0° F., or the shrimp could be dumped into boxes and stacked in the hold. In either case a water spray could be used to glaze the shrimp and protect them from dehydration during the trip. Once ashore the shrimp could be thawed, headed, and packaged for refreezing as desired. Alternately, they might be thawed and processed for frozen-breaded-shrimp or precooked-shrimp products. The tests have shown that several weeks' storage of the brine-frozen whole shrimp is quite practical and could be extended if shrimp were protected from dehydration. Such frozen shrimp might be used by the smaller plants for maintaining production.

From the tests conducted it was indicated that brine-freezing shrimp at sea or thawing and refreezing such shrimp ashore resulted in a product of color, flavor, and texture comparable to air-frozen shrimp prepared from the same lot. Freezing shrimp at sea in air or in brine immediately after they were caught produced a high-quality product more nearly approaching the absolutely fresh state than the iced shrimp now normally found on the market. The appearance of such shrimp frozen at sea was far superior to iced shrimp because of the complete absence of black-spot discoloration. It should be emphasized that for refreezing, only the use of absolutely fresh shrimp and prompt handling during freezing, thawing, and refreezing will give the best results.

Regardless of the method for freezing shrimp, there is no doubt from these tests that to protect packaged glazed shrimp adequately from dehydration, the waxed carton should be wrapped with moisture-vapor-proof film. Experience with similar frozen products has shown that use of such film would eliminate the necessity of glazing the shrimp if they were packed properly with an absolute minimum of air space within the carton.

The following procedure is recommended for commercial brine-freezing and processing of shrimp:

Freezing Aboard Vessel:

(1) Use only fresh firm whole or headed shrimp.

(2) Chill shrimp in fresh ice water.

(3) Freeze shrimp in a strong (sodium chloride) brine (85-degree salimeter or 22.4 percent salt) at 0° to 5° F. Circulate brine continuously during the freezing process.

(4) Remove shrimp from the refrigerated brine immediately after they are frozen, but in no case allow them to remain in the refrigerated brine longer than 4 hours. Rinse briefly in cold fresh water.

(5) Store the brine-frozen shrimp at temperatures no higher than +5° F., preferably lower. Protect from dehydration during storage.

Processing Ashore:

(6) Thaw brine-frozen shrimp in running cold water at 60° F. (about 10 to 15 minutes).

(7) Remove shrimp from thawing tank. Remove heads from whole shrimp. Rinse and cull unsound shrimp.

(8) Pack uniformly in waxed cardboard cartons with a minimum of head space. Overwrap with a moisture-vapor-proof film.

(9) Refreeze shrimp at -10° F. or below and store at 0° F. or below.

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NEW CANADIAN ICELESS REFRIGERATED FISH CONTAINER

A test model of a new iceless refrigerated fish container was demonstrated recently in Montreal by the Canadian National Railways. The container features aluminum double-wall construction throughout, the space between the walls being filled with block insulation. Refrigeration is maintained by a mixture of sodium sulphate and water contained in sealed rubber tubes mounted in removable aluminum plaques which screen the load from outside heat. A series of tests has demonstrated that fresh fish prechilled to -1.6° C. (29° F.) can be transported for periods of over three days with less than 0.6° C. (1° F.) variation in temperature. Standard containers will have a capacity of 160 pounds. It is expected that the development of this container will help to extend markets for fish to points not directly served by railroads.

--World Refrigeration, July 1953.