Freezing Gulf of Mexico Shrimp At Sea

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

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 to many fishermen with larger boats and investment money to spare. Trials in the last few years have indicated considerable promise for holding fresh shrimp in refrigerated sea water aboard the vessel. (Idyll, Higman and Siebenaler, 1952.) Another approach is the possibility of freezing the shrimp in low temperature brine at sea followed by thawing, packaging and refreezing ashore.

Freezing the packaged shrimp aboard the vessel solves the problem of long trips since even a four to six 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 units may be easily designed for small space requirements. 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 advantages, as well as the problems, of brine freezing fish at sea have been demonstrated by the Fish and Wildlife Service's 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 Gulf of Mexico area, using the facilities of the FWS vessel *Oregon*, which was engaged in exploratory shrimp fishing at the time. Among the factors considered were the handling conditions of the shrimp prior to freezing, freezing of whole and headless shrimp, effect of extended immersion periods in brine, importance of brine circulation, problems of glazing brine frozen shrimp for bulk storage, amount of salt (sodium chloride) absorption in the flesh, effects of thawing and refreezing brine frozen shrimp, and comparison of keeping quality with air frozen shrimp.

Experimental

All freezing trials at sea were conducted aboard the Fish and Wildlife Service vessel *Oregon* during March and April, 1952. Both the white shrimp (*Penaeus setiferus*) and brown shrimp (*P. aztecus*) were brine and air frozen

during exploratory trips off the Mississippi, Louisiana and Texas coasts. In addition, fresh iced white shrimp obtained from the commercial fishery were frozen for comparison. A sample of commercially packaged and frozen brown headless shrimp was obtained for comparative storage tests with the experimental samples. All samples of frozen shrimp were shipped under refrigeration at the conclusion of the work in May, 1952, to the Fishery Products Laboratory, Ketchikan, Alaska, where storage tests and examinations were conducted until February, 1953, when the tests were concluded.

Shrimp processed at sea were brine or air frozen within two hours after catching, with the exception of one lot of whole shrimp which was iced for three days prior to heading and freezing. Both whole and headless shrimp were frozen by the two methods. All shrimp were rinsed thoroughly with clean sea water before freezing. Air frozen shrimp were prepared as the control sample and were packaged in five 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 frozen shrimp were prepared by immersing five to 10 pound lots of shrimp for about 15 minutes in circulating 85° salometer brine chilled to 5° F. Using small lots, the brine temperature increased not more than 5° F. during the freezing period. After removing the shrimp from the brine they were drained briefly, rinsed in fresh water chilled to 34° F., drained, packaged in one or five-pound waxed cartons, and stored in air at 0° F. The effect of chilling the shrimp in fresh cold water (34° F.) prior to immersion in the brine was determined. The freezing rate of the shrimp was determined by observation of 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. Samples of shrimp for salt penetration tests were taken by allowing particular lots of the shrimp to remain in the brine up to 48 hours and removing small samples (approximately one pound) at intervals from 15 minutes to 48 hours. 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 volume of shrimp to volume of brine.

The experimental brine freezer was constructed of equipment readily available at low cost in view of the limited time and funds available for this study. A 55-gallon open-top drum was wrapped with two-inch rock wool batts and used for the brine tank. Approximately 60 feet of one-half inch copper tubing was coiled in the bottom of the drum and along the inside, and connected to a one-half horsepower Freon-12 air-cooled refrigeration compressor. A one-quarter horsepower centrifugal pump with neoprene impeller and two-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° salometer 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.

Whole shrimp which had been brine frozen at sea and stored in air at 0° F. for several weeks were used for thawing and refreezing tests ashore. Preliminary trials indicated that the shrimp could be thawed sufficiently for heading by immersing them 10 to 15 minutes in running fresh water at 60° F. The shrimp were still cold and slightly stiff. After heading, the shrimp were rinsed well with fresh water, packaged in one-pound 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 which were headed before brine freezing were not thawed and refrozen but were stored for comparison.

Table 1 summarizes the main variables in the samples of shrimp frozen at sea and ashore for storage tests at 0° F.

Table 1. *Shrimp Samples Frozen for Storage Tests*

AF (air frozen)	
1. Control	Headed, packaged, frozen immediately at sea.
2. Iced	Iced at sea three days, headed, packaged, frozen.
BF (brine frozen)	
3. Refrozen	Brine frozen at sea, thawed, headed, packaged, and refrozen in air ashore.
4. Not refrozen	Headed, brine frozen, packaged at sea.

In addition to the above samples, two small lots of commercially caught white shrimp were obtained from 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 determination of salt (sodium chloride) content, two or more subsamples of six or more shrimp were drawn from each sample lot of shrimp, thawed, and peeled. Each sub-sample of shrimp meat was analyzed for total sodium chloride content by the official procedure of the Association of Official Agricultural Chemists (AOAC, 1950).

Organoleptic examination of the frozen, thawed, and cooked shrimp samples was made after five, eight, 15, 26, and 40 weeks of storage at 0° F. The frozen shrimp were thawed quickly in fresh water and cooked seven minutes in boiling water. 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 white shrimp were tested separately in case there were quality differences due to species.

Results

Observations of shrimp handling methods prior to freezing at sea and at shore processing plants indicated that warm temperature, air, and sunshine are the most important factors which cause rapid loss in quality to the shrimp caught in southern waters. Softening and moderate discoloration of the whole shrimp were observed after icing as little as three days. Both at sea and ashore samples of shrimp left in the shade but exposed to warm air for periods of six to eight hours showed similar significant loss of quality. The results of later examinations of the frozen samples reminded us 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 limited time and facilities did not permit preparation of the samples under strictly uniform conditions.

After several freezing tests at sea it was apparent that the most effective handling procedure for shrimp prior to freezing was the use of an ice water tank in which the whole or headed shrimp could be chilled immediately after separation from the catch. With the limited capacity of the experimental brine freezer, this preliminary chilling not only minimized the quality loss during delays but also improved the efficiency of the freezing process. Shrimp chilled thoroughly in ice water before immersion 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 immersion in the brine. This glaze was noticeable on the surface of such shrimp after removal from the brine.

Observations of shrimp immersed in circulating brine at 5° F. indicated that shrimp averaging 20 to the pound headless would freeze in 10 minutes. Larger shrimp required five minutes longer, or a total of 15 minutes until solidly frozen. Smaller shrimp averaging 35 headless shrimp per pound were frozen in four minutes to an internal temperature of 15 to 23° F. A maximum of eight 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 one-pound package of headed shrimp required four 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. 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 brine circulation was also found important in maintaining 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 brine was also necessary to keep the brine from freezing on the refrigerated coils and obstructing the flow between the coils.

Brine frozen shrimp did not take a good glaze if dipped into cold water immediately after removing 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. Brine frozen shrimp were glazed more effectively if cold water was sprayed over them in the box after the shrimp were stored for a few days at 0° F.

Brine frozen whole shrimp were found to be quite bulky, and a five-pound waxed carton held only three 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.

The analyses of salt content of air and brine frozen shrimp (Table 2) showed a salt content of 0.14 to 0.46 per cent by weight in the air frozen

shrimp. The two samples of iced shrimp had a somewhat lower content than the shrimp frozen immediately at sea. The lower salt content was probably caused by the leaching effect of the melting ice. The salt content of shrimp frozen and held in brine for periods up to four hours was about 1.5 per cent. Surprisingly enough the 15-minute samples were as high in salt content as the two and four-hour samples. A significant increase was found for the 24-hour (2.1 per cent) and the 48-hour (2.4 per cent) samples. The low value of 0.16 per cent for the refrozen shrimp is interesting since it indicates that the absorbed salt was leached quite rapidly during the washing prior to refreezing. The value of 0.7 per cent for the headless shrimp frozen in brine for 15 minutes is only slightly higher than that of the whole shrimp. Commercially iced shrimp absorbed the salt more rapidly and showed an excessive salt content of 2.6 per cent after 1.5 hours in brine and 7.0 per cent after 21 hours. These shrimp were quite soft before freezing which might account for the increased absorption. Taste tests indicated that a salt content of 1.5 per cent was not excessive. If the shrimp were boiled, it was necessary to add the usual amount of salt to the water for flavoring.

Table 2. *Salt Content of Frozen Gulf Shrimp*

Sample	Description	Length of Time in brine[1] Hours	Salt Content % by weight meat[2]
AF (air frozen)			
1. Control	Brown shrimp, frozen immediately at sea	0	0.46
2. Iced			
a. Brown shrimp	Iced 3 days before freezing	0	0.27
b. White shrimp	Commercial lot, iced from Cameron, La.	0	0.14
BF (brine frozen)			
3. Refrozen	Frozen at sea, thawed, headed, refrozen ashore	0.25	0.16
4. Not refrozen			
a. Whole brown shrimp	Frozen immediately at sea	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
b. Whole white shrimp	Commercial sample of iced shrimp (Bayou la La.	0.5	2.0
		1.0	2.5
		1.5	2.6
		24.0	2.6
		48.0	3.7
c. Headless brown shrimp	Frozen immediately at sea	0.25	1.7
d. Headless white shrimp	Commercial sample of iced shrimp (Cameron, La.	0.5	1.9
		1.0	2.2
		1.5	2.6
		21.0	7.0

1. 85° salometer sodium chloride brine at 5° F. plus or minus 5°.
2. Average of two or more sub-samples.

Preliminary organoleptic examinations aboard vessel of brine frozen shrimp indicated that the 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 flesh. Flavor and texture of the cooked shrimp were normal, and very little salt appeared to have been absorbed by the flesh during brine freezing.

The process of thawing, heading and refreezing the brine-frozen shrimp ashore seemed to offer no problem. After thawing 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.

Examinations after five and eight 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 slight dehydration due to 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 the 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 apparent in the difficulty of peeling the shrimp and a slightly strong off flavor. These shrimp were still in good condition but 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 due to dehydration and the strong off flavor. The fact that the refrozen shrimp compared favorably at this time with the air frozen samples indicated that it was not brine freezing in itself which was the problem but rather the method of packaging which allowed dehydration. Loss of glaze was also found in the re-frozen and air-frozen shrimp which were packaged before freezing. Shrimp at the corners and edges of these packages were slightly dehydrated and the flavor and texture suffered accordingly. In brine-frozen shrimp the adverse changes accompanying dehydration were noticeably greater than with the air-frozen, possibly due to the catalytic effect of salt absorbed in the surface flesh during brine freezing. When completely protected from dehydration (e.g. shrimp from the interior of the package), samples of both brine- and air-frozen shrimp had good color, flavor and texture after the 26 weeks of storage.

After 40 weeks of storage, the dehydration of shrimp at the corners and edges of all packages of glazed shrimp was much more pronounced and made a fair comparison of the variables difficult. The further observation of these samples showed without question that brine-frozen shrimp must be even more carefully protected from such dehydration if quality is to be preserved for periods of six or nine months. The loss in quality of the air-frozen shrimp

under conditions of moderate dehydration was even so of greatest significance and was the factor limiting the storage life of these samples to nine 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 catching. It was present to a moderate degree in those iced three days, and to a greater degree in the commercially iced samples which 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.

Discussion

If brine freezing of shrimp were used commercially, the re-freezing process appears to be the most satisfactory. Aboard the fishing vessel, the 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 draining briefly, set in the refrigerated brine tank for freezing. After freezing, the baskets could be removed and stored in the refrigerated hold at 0° F., or the shrimp could be dumped into boxes for stacking in the hold. In either case a water spray could be used to glaze the shrimp and protect them from dehydration for the duration of 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 are protected from dehydration. Such frozen shrimp might be used by the smaller plants for equalizing production during periods of peak fishing.

There was no evidence from these tests that brine freezing, or thawing and refreezing such shrimp caused any change from the normal color, flavor, or texture of air frozen shrimp from the same lot. Comparison of shrimp frozen at sea using absolutely fresh shrimp with iced shrimp indicated that the fresh flavor was better preserved by immediate freezing. 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 adequately protect packaged glazed shrimp 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 if the shrimp were packed efficiently with an absolute minimum of air space within the carton.

For commercial application of brine freezing of shrimp, it is recommended that the following procedure be used: (1) Only fresh firm whole or headed shrimp should be frozen; (2) shrimp should be chilled in fresh ice water just prior to brine freezing; (3) shrimp should be removed from the brine within four hours after freezing, rinsed in cold fresh water (34°F.), stored at 0° F., and protected from dehydration; (4) the temperature of the brine should be maintained at 10° F. or lower to minimize salt absorption; and (5) brine

frozen shrimp should be thawed in fresh running water at 60° F. for 10 to 15 minutes, headed immediately, washed in fresh water, packed in waxed cartons with a minimum of air space, overwrapped with moisture vapor-proof film, and stored at 0° F. or lower.

Literature Cited

IDYLL, CLARENCE P.; HIGMAN, JAMES B., and SIEBENALER, J. B., 1952. *Experiments on the holding of fresh shrimp in refrigerated seawater.* Florida State Board of Conservation, The Marine Laboratory, University of Miami, Coral Gables, Florida. Mimeographed. 23 pp.