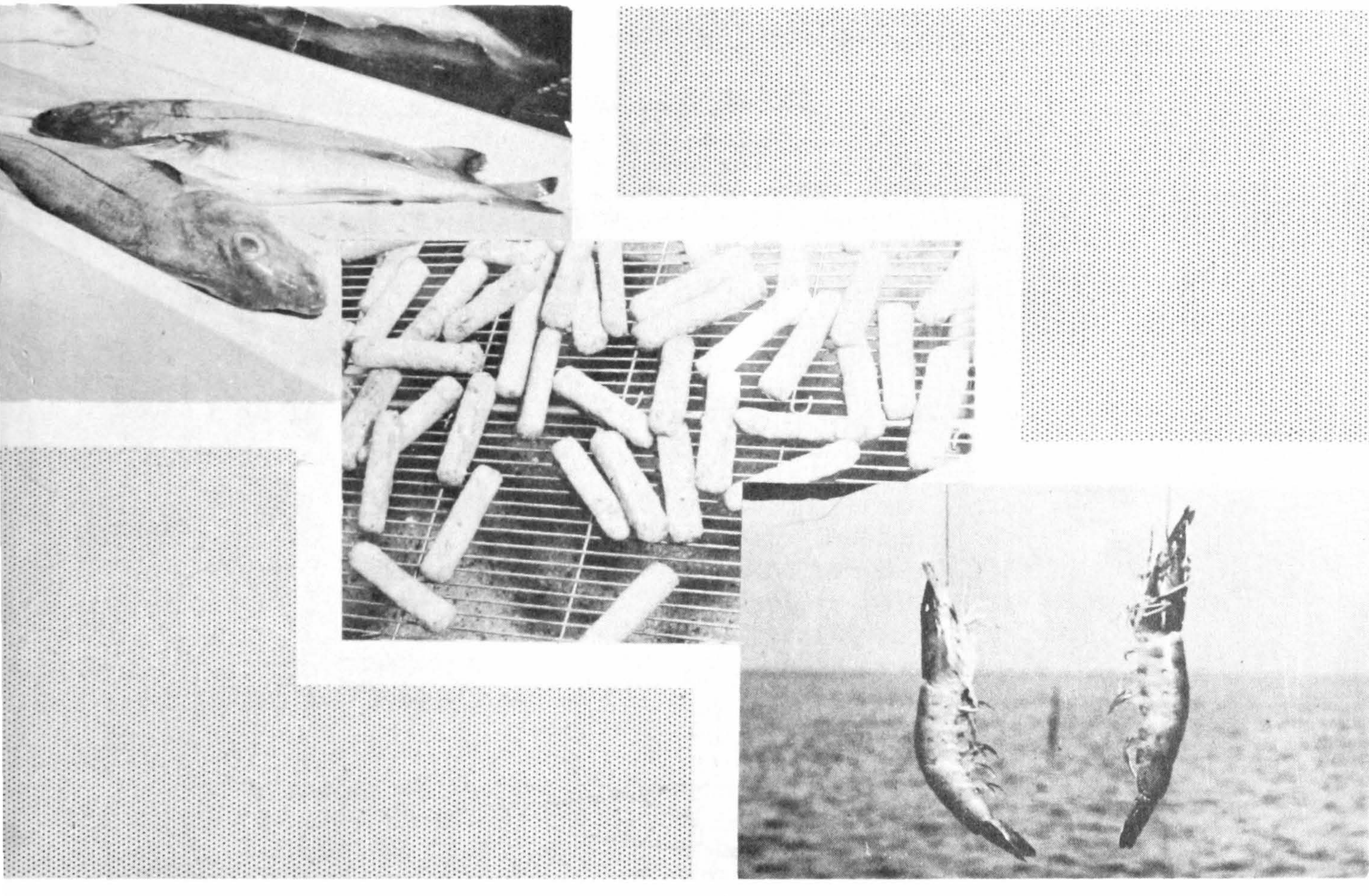
EFRIGERATION OF FISH - PART 4

PREPARATION, FREEZING, AND COLD STORAGE OF FISH, SHELLFISH, AND PRECOOKED FISHERY PRODUCTS



UNITED STATES DEPARTMENT OF THE INTERIOR

Douglas McKay, Secretary

FISH AND WILDLIFE SERVICE

John L. Farley, Director

Fishery Leaflet 430

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REFRIGERATION OF FISH: PART FOUR

PREPARATION, FREEZING, AND COLD STORAGE OF FISH, SHELLFISH, AND PRECOOKED FISHERY PRODUCTS

By

John A. Dassow[1/] (Section 1), S. R. Pottinger[2/] (Section 2), and John Holston[3/] (Section 3)

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This leaflet is part four in a series of five on "Refrigeration of Fish." Titles of the other four leaflets are:

*Part 1 (Fishery Leaflet 427) -- Cold-Storage Design and Refrigeration Equipment
*Part 2 (Fishery Leaflet 428) -- Handling Fresh Fish
Part 3 (Fishery Leaflet 429) -- Factors to be Considered in the Freezing and Cold Storage of Fishery Products
*Part 5 (Fishery Leaflet 431) -- Distribution and Marketing of Frozen Fishery Products

This series of leaflets is prepared under the general supervision of Charles Butler, Chief, Technological Section, Branch of Commercial Fisheries, Washington, D. C., and edited by Joseph W. Slavin, Refrigeration Engineer, Fishery Technological Laboratory, East Boston, Massachusetts, and F. Bruce Sanford, Chemist, Fishery Technological Laboratory, Seattle, Washington.

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*These leaflets have not yet been published.

SECTION 1

FISH

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INTRODUCTION

Freezing as a form of preservation undoubtedly dates back thousands of years to the time when man first occupied the northern and Arctic regions of the world. As the art of fishing developed, these early day fishermen found that their fish taken through the ice of northern waters in the winter became firm and hard when exposed to the cold winter air. In contrast to the rapid spoilage of whole fish taken during the summer, these winter-caught fish could be stacked like cord wood near the fisherman's dwelling and could be kept frozen during the cold weather until thawed and eaten. The early Eskimo even found that a hole in the frozen ground could be used to store his fish through the warmer months. This primitive and natural cold storage was probably the first use of low temperatures to maintain fish in a fresh condition for long periods. It was only with the introduction of artificial refrigeration during the latter part of the nineteenth century that freezing as a form of preservation was possible at any time of the year and in any area.

Natural freezing is presently employed for winter commercial fisheries on many of the large lakes and rivers in northern areas. Fish are usually taken by means of gill nets set through holes in the ice or by means of traps or pound nets. The whole fish are allowed to freeze naturally in the frigid air and are then taken by truck, sled, or plane to a central area for glazing and boxing. Such fish are usually frozen

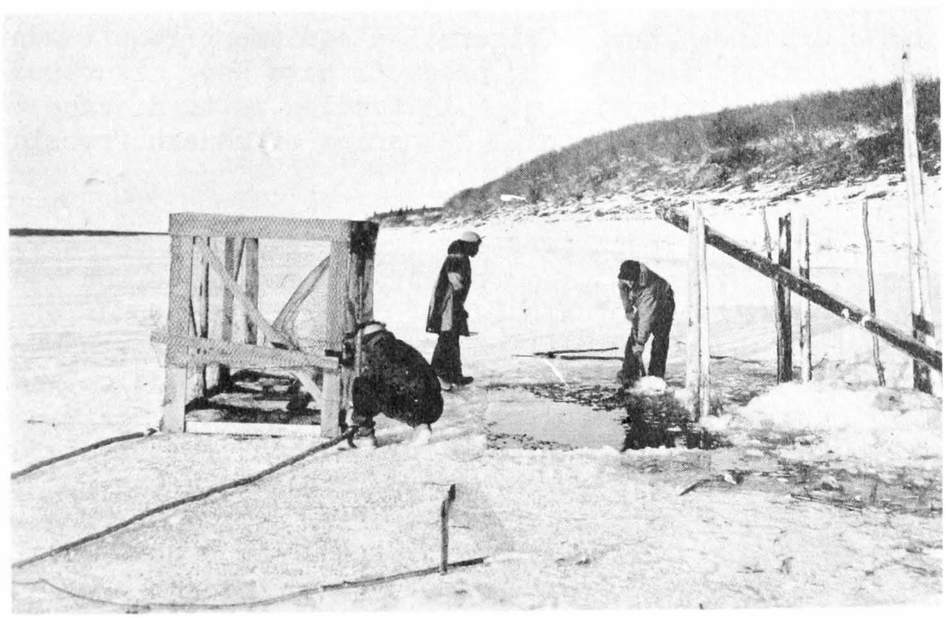

Figure 1.—Placing fish trap for whitefish through ice on Yukon River below Marshall, Alaska during early winter.

before rigor mortis has set in; hence the fish are of excellent quality and, on thawing, can be dressed or filleted for fresh-fish markets in the distribution centers. Whitefish are commonly taken and handled in this manner in the winter lake fisheries of Canada.

The quantity of fish preserved by natural freezing is relatively small compared to that preserved by mechanical refrigeration. The latter development has provided the consumer with high quality frozen fish in many forms at all seasons of the year. Differences among the many species of fresh and of salt-water fish have resulted in the use of specialized processing and freezing methods for fish with similar characteristics. Most species are iced on the fishing vessel and are then prepared and frozen at shore plants. A considerable volume of a few species such as tuna and salmon are frozen at sea aboard vessel. In the following discussion,the first part deals with the processing methods for major species of fish frozen at shore plants, and the second part with those frozen at sea.

FREEZING FISH AT SHORE PLANTS

A most important factor in planning the production of frozen fish is the nature and diversity of products to be frozen. This factor controls the production flow of fresh fish to the fish preparation room, to the freezer, and finally to the storage rooms. In a modern processing operation for frozen fish, the cold storage facilities and the refrigeration equipment are designed for the most efficient production, considering the individual product volume and the economics of freezer installation and operation. The refrigeration equipment requirements and the basic freezing methods for fishery products have been discussed in Fishery Leaflet 427. The objective of this section is to discuss the application to the important commercial fisheries of modern freezing methods in shore plants.

Fish are frozen in the round (whole), drawn (eviscerated only), dressed (eviscerated and trimmed), and packaged form. Anderson and Peterson (1954) reported that, of a total of 325 million pounds of fishery products frozen during 1951, 150 million pounds of fish fillets and steaks were frozen in the packaged form. This total production was reported by over 250 domestic freezing plants handling fish. Salt-water fish accounted for 76 percent of the total production, shellfish for 22 percent, and fresh-water fish for 2 percent. In table 1, the relative importance of the main producing areas and species of fish frozen is indicated. In the New England area, the three most important species--ocean perch, whiting, and haddock--accounted for 44 percent of the total production of frozen fishery products during 1951. The three most important species of the Pacific Coast States and Alaska--halibut, salmon, and sablefish--accounted for 14 percent of the total. The 14 species or categories shown in table 1 comprised 90 percent of the production.

Most species of fish fall in a representative group that is closely

Table 1.--United States production of frozen fishery products in 1951 1/

A. Main production areas	Production Millions of pounds	Percent of total
All areas	325	100
New England	177	54
South Central	54	17
Alaska	34	10
Pacific coast	30	9
Middle Atlantic	12	4
South Atlantic	12	4
North Central	6	2
B. Main species		
Ocean perch	71	22
Shrimp	56	18
Whiting	52	16
Halibut	26	8
Haddock	21	6
Salmon (all species)	13	4
Bait and animal food (from salt-water fish)	12	4
Fresh-water fish	7	2
Flounder	7	2
Sablefish	5	2
Cod	5	2
Scallops	5	2
Pollock	4	1
Squid	4	1

Note: The sections indicated include the following states:

New England--Maine, Massachusetts, Rhode Island, and Connecticut.

Middle Atlantic--New York, New Jersey, and Pennsylvania.

South Atlantic--Maryland, District of Columbia, Virginia, South Carolina, Georgia, and Florida.

North Central--Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, Nebraska, and Kansas.

South Central--Kentucky, Tennessee, Alabama, Mississippi, Louisiana, Texas, and Arkansas.

Pacific--Washington, Oregon, California, Arizona, Colorado, Utah, and Montana.

Production of fish frozen on United States fishing or transporting craft is not included in this table.

1/ Anderson and Peterson (1954).

allied in biological characteristics, habitat, or methods of catching and freezing. In the following discussion, the groups are classified as groundfishes, salmon, tuna and mackerels, herrings, fresh-water fish, and fish used in whole or part for bait or for animal food.

Groundfishes

The term groundfish is applied to many species of fish that live on or near the bottom. The principal groundfishes are ocean perch, whiting, haddock, halibut, flounder, cod, pollock, and sablefish. With the exception of halibut and sablefish, these groundfish are produced in greatest quantity by the New England fishery and are fished throughout the year. Halibut and sablefish are produced in the Alaska and Pacific coast areas during seasons set by regulations. In addition, smaller quantities of Pacific ocean perch, flounder, and cod are landed at Pacific ports throughout the year. As was pointed out previously, production figures for frozen fish during 1951 (table 1) demonstrate that 5 of the 6 most important species frozen are groundfishes. During 1951, approximately two-thirds of the total production of frozen fishery products was contributed by the groundfishery.

These fish are caught mostly with otter trawls--large bag-shaped nets that are dragged along the ocean bottom. Two wire cables from either the side or the stern of the fishing vessel are used to drag the net. These cables are fastened to two, large, iron-weighted frames, called otter boards or doors, which are dragged on the bottom and keep the mouth of the net open by the pressure of the sea against the doors as the boat moves slowly forward. The net or fish bag is hauled to the surface at intervals, and the fish are dumped on the deck. The fish are washed, sorted, and iced in the hold (Fishery Leaflet 428). A small part of the groundfish catch is obtained with line trawls and sink gill nets. The line trawl consists of a line laid along the ocean bottom with baited hooks attached to short lines fastened in turn to the ground line at frequent intervals. The sink gill net is weighted to hold it close to the bottom in the path of the fish, which are entrapped in the meshes by their gills.

In considering the freezing methods for the groundfishes, one may conveniently subdivide the group into the codfish and related fishes, the flatfishes, and the ocean perch and related rockfishes. These are all lean fish--generally small fish less than 5 to 10 pounds in individual weight--and are handled and frozen in a comparable manner. Halibut and sablefish are best treated separately because the size, catch methods, and processing differ in many respects to other members of the groundfishes.

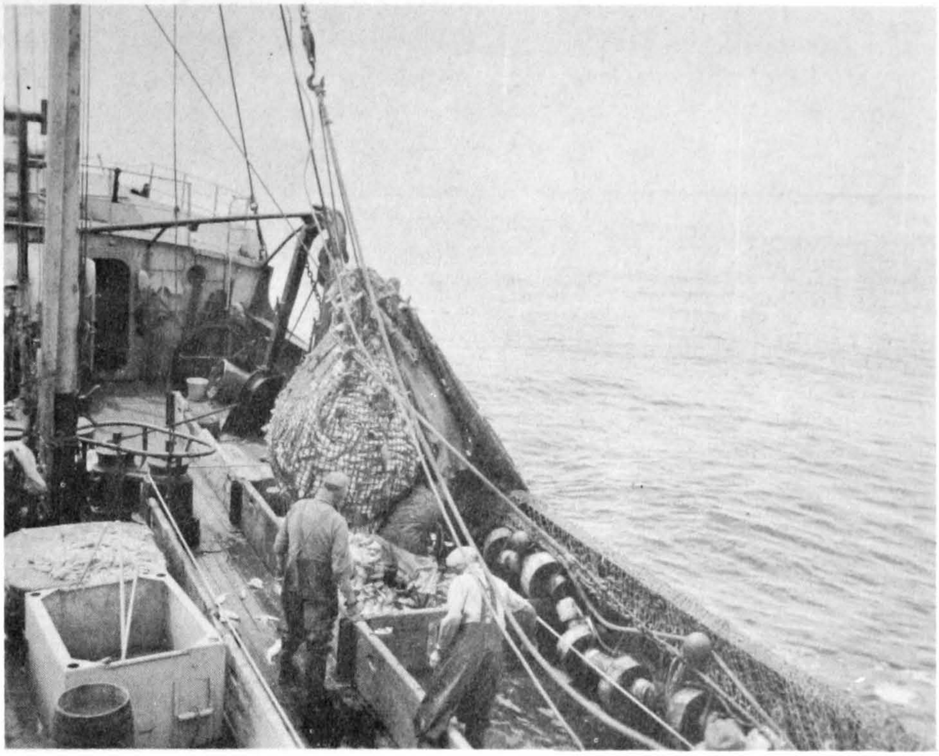

Figure 2.--Dumping a trawl catch of bottom fish caught off the New England coast.

Figure 3.--A catch of bottom fish caught off the New England coast by the Service's research trawler Delaware.

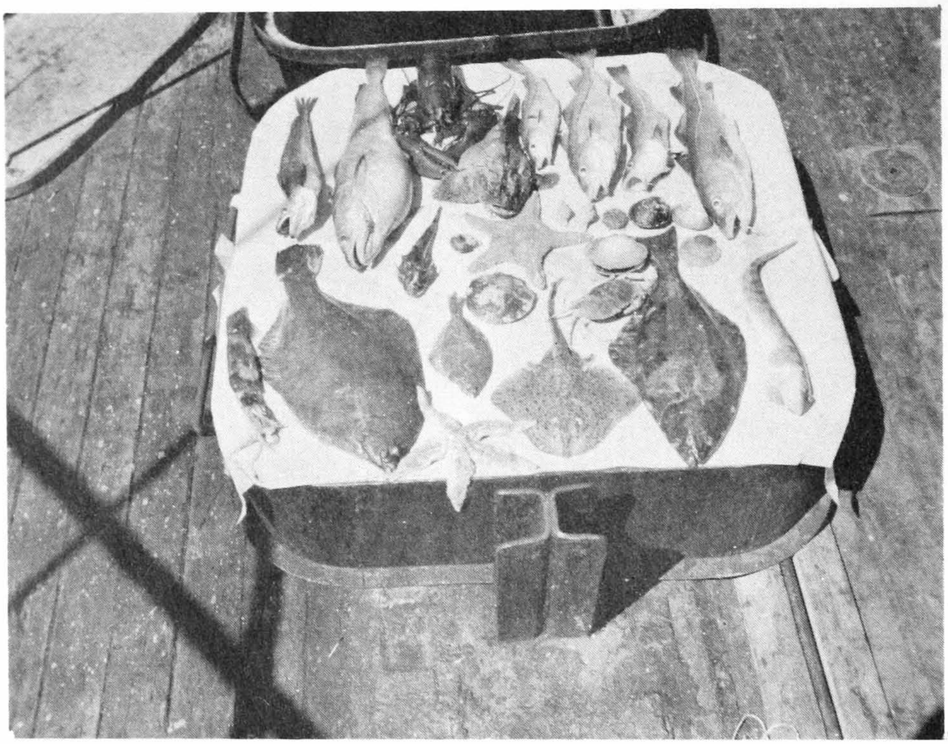

Figure 4.--Various species of fish and bottom life caught by trawl off the New England coast. From left to right--top--whiting, hake, lobster, puffer, scrod haddock, haddock, scrod cod, and cod--middle--sculpin, hermit crab, starfish, periwinkles, quahog clams, crab, and scallops--bottom--squid, lemon sole, dab, starfish, skate, halibut, and ocean pout.

Codfishes

This group includes Atlantic cod (Gadus morhua), Pacific cod (Gadus macrocephalus), whiting (Merluccius bilinearis), haddock (Melanogrammus aeglefinus), pollock (Pollachius virens), hake (Urophycis sp.) and related fish. The greater portion of the amount frozen is in the filleted and packaged form; however, over 45 million pounds of whiting were frozen in the headed and gutted form during 1951 (Anderson and Peterson 1954). Pacific cod is the only member of the group frozen in sizeable quantity on the Pacific coast, the major production of these species being in New England, with a much smaller production in the Middle Atlantic States 1/. Atlantic cod and haddock fillets, frozen in blocks, are being widely used for the preparation of fish sticks.

Flatfishes

The flatfishes include over 30 species of flounder and related fishes of which about half occur in the North Atlantic and half in the North

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1/ Middle Atlantic States--New York, New Jersey, and Pennsylvania.

Pacific. About 10 species are important commercially. The species from the two coasts are similar in general appearance and range in size from 1 to 5 pounds each, for most members of the group. They form a unique family in that every flatfish starts out life with eyes on both sides of the head and swims erect, as do other fishes. As the young fish develop, one eye migrates around the head close to the other eye, the fish begins to swim on its side, and the blind side remains white while the upper side becomes pigmented. The introduction of the otter trawl and the development of the filleting industry stimulated the growth of the flounder fishery. Most of the flounder catch is filleted for use. In some species, the fillet from the blind or white side is not skinned; however, the fillet from the pigmented side is always skinned. Flounder fillets are often sold as "sole," although, technically, the true sole does not occur off American shores. Common names for various flounder produced on the Atlantic coast are gray sole (Glyptocephalus cynoglossus), lemon sole (Pseudopleuronectes dignabilis), yellowtail (Limanda ferruginea), and blackback (Pseudopleuronectes americanus). The term "sole" is also used for a number of flounder produced on the Pacific coast—such as rex, petrale, sand, dover, and English sole all Pleuronectidae. The halibut is a member of the flatfishes but will be discussed separately, as was previously explained.

Ocean perch and the rockfishes

Although the ocean perch or rosefish (Sebastes marinus) is a member of the rockfish family, it deserves special mention because of its preeminence in frozen-fish production. During 1951, over 71 million pounds of ocean perch fillets were frozen in the New England area, an amount equal to 22 percent of the total frozen fish and shellfish production. The growth of the ocean perch fishery was spectacular in the decade from 1930 to 1940, when it was found profitable to catch and fillet this small fish, which averages only 1/2 to $1\frac{1}{4}$ pounds in individual weight. Practically the entire catch is taken by means of the otter trawl, which is fished for ocean perch throughout the year. Ocean perch, in common with other rockfishes, suggest a bass or perch in appearance but are not related to either. The fish are washed and scaled before being filleted.

The Pacific rockfish species utilized commercially in the United States are similar in characteristics to the Atlantic ocean perch but average somewhat larger in size, usually from 2 to 5 pounds. About 35 species of rockfish are found on the Pacific coast of which 8 or 10 species are commonly used commercially. Of these, Pacific ocean perch (Sebastodes alutus), red rockfish (S. ruberrimus), bocaccio (S. paucispinis), chilipepper (S. goodei), and channel rockfish (S. alascanus) are preferred species for freezing because of their better keeping quality in cold storage. As with Atlantic ocean perch, these rockfish are filleted and packaged, for the most part; however, a small quantity is frozen in the dressed, headless form for some markets.

Fillets

On the east coast, groundfish are usually eviscerated or gutted at sea before being iced; on the Pacific coast, groundfish are usually iced in the round. In either case, the fish are washed thoroughly after being unloaded and go directly to the filleting room. In both hand and machine filleting, the boneless strip of flesh is cut from both sides of the backbone, and the fillets are skinned. The fillets are then washed or rinsed free of slime, blood, or debris, after which they are inspected. The fillets are commonly dipped in dilute sodium chloride brine at this point. After being drained, the fillets either are wrapped in a moisture-vapor-proof material and placed in the carton or are placed directly in the carton, which is overwrapped afterward with a moisture-vapor-proof paper or film (common carton sizes contain 1, 2½, 5, or 10 pounds of fillets). The packages are then ready for the freezer. For some markets

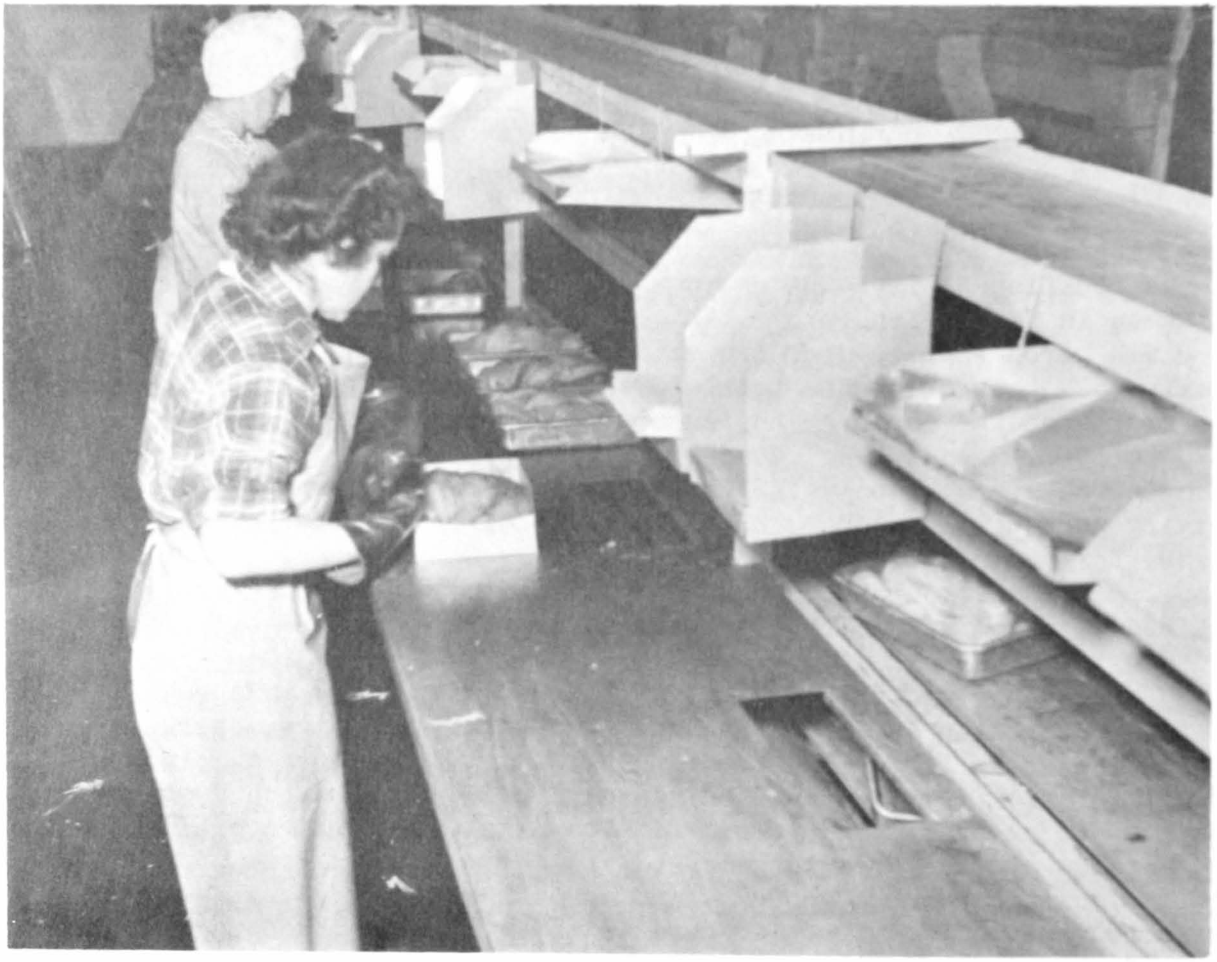

Figure 5.--Packing fillets in a 5-pound waxed carton for freezing. The fish are weighed in the metal pans prior to packing.

and where later processing into fish sticks or squares is intended, the fillets may be placed in metal trays holding 5 or 10 pounds of the fillets. The resulting block of fish, after being frozen, is given an ice glaze (preferably) and is placed in a waxed carton for storage. For use in fish stick production, it is important that the blocks be prepared to close size tolerances (Fishery Leaflet 430, section 3). Additional information on these preliminary operations may be found in Fishery Leaflet 428.

Dressed Fish

Certain species of fish such as whiting, hake, and pollock are commonly stored in the round aboard the fishing vessel and are then headed and gutted at the shore plant and marketed as frozen dressed fish. Careful washing of the dressed headless fish is necessary to remove slime, blood, and debris. For most species in this group, the fish are small and are frozen in pans. The pans hold from 25 to 40 pounds of fish, have sloping sides to facilitate removal of the frozen fish, and are usually constructed of galvanized iron sheet, 20 to 22 gauge. A common size is 16 inches in width, 26 inches in length, and 3 inches in depth. Fish frozen in this manner are usually for institution or retail fish trade in which the dressed fish is desired for use. In many cases, the retail fish market thaws and fillets the dressed fish for sale.

Freezing methods

Freezing Packaged Fish

In the following, the methods and problems in handling groundfishes during the freezing process will be principally discussed. Details of equipment, construction, and operation will be found in Fishery Leaflet 427. Many of the factors considered here will apply also to freezing other groups of fish to be discussed later.

The packaged fish may be frozen in any one of three common types of freezers: the sharp or circulating-air freezer, the multiplate freezer, and the blast freezer.

Freezing packaged fish in the sharp freezer.—As is discussed in Fishery Leaflet 427, section 3, the use of a sharp freezer for packaged fish is limited by the slow freezing-rate and the considerable handling of products required. For these reasons, only the 5- and 10-pound cartons are usually frozen in the sharp freezer and then only when a plate or blast freezer is not available. Even in large plants, however, sharp freezers may be used during periods of heavy production of packaged fish, when all freezing facilities must be utilized to handle the peak loads. The packages are taken in to the freezer on hand trucks or carts and are placed on the freezer shelves. In some cases, trays may be placed directly on the refrigerated shelf coils. In others, the packages may be placed on heavy galvanized iron sheets laid on top of the coils. In both cases, contact with the shelf coils is poor, and the packaged fish is frozen slowly. The heat transfer between the refrigerated coil and the metal tray is limited not only by the small area of contact but also by the heavy layer of frost that builds up on the coils. The use of heavy iron plates laid on the clean coils or—better yet—bolted to them minimizes the problem of poor contact caused by the build-up of frost.

Normally while the sharp freezer is being loaded, the refrigeration is cut off, and the room temperature comes up to 0° F. or even 10° F., depending on the quantity of warmer air entering the freezer when the doors are opened. After the freezer has been loaded, the refrigerant is allowed to flow through the coils, and the temperature is gradually lowered during the next 12 to 18 hours to -20° to -30° F. One or two large fans are often used to equalize the temperature throughout the room to prevent warmer air from accumulating near the ceiling, especially in sharp freezers with a high ceiling. This circulation of the air does not greatly increase the freezing rate of the packages as compared to still air at the same temperature, since air moving at a much faster rate is required for this purpose. Generally, because of the slow freezing rate and the economics of loading and unloading, the packages will be left in the sharp freezer from 12 to 24 hours.

Tests at the Technological Laboratory of the Fish and Wildlife Service at Seattle showed that a 2½-inch-thick, 5-pound carton of fillets out of contact with the shelf coil required 8.7 hours to freeze in circulating air at -20° F., and 9.5 hours in circulating air at -8° F. When the same size package was placed on a full refrigerated plate at -27° F. with still air at -20° F. over the package, the freezing time was 3.5 hours in one test and 4.2 hours in a second test. In the common-type sharp freezer, however, the poor heat transfer between the package and the shelf coil precludes such a reduction in freezing time. Figure 1 of section 3 of Fishery Leaflet 427 shows that approximately 10 hours was required to sharp freeze a 2½-inch-thick package of fillets in a test conducted at the Service laboratory in East Boston. In most sharp freezers from 12 to 16 hours are required for freezing 5- or 10-pound cartons of fish fillets, allowing 3 hours for cooling the product to the freezing point (approximately 30° F.), 8 to 10 hours for freezing, and an additional 2 or 3 hours for cooling the product to 0° F.

Freezing packaged fish in the multiplate freezer.—For freezing packaged fish in the multiplate freezer, the packages are usually placed on narrow trays that can be slid conveniently onto each shelf. Wooden spacers or trays of the same height as the cartons must be used to prevent crushing of the packages. Cartons loaded on a given shelf must all be of the same height. Most plate freezers are of the batch type;

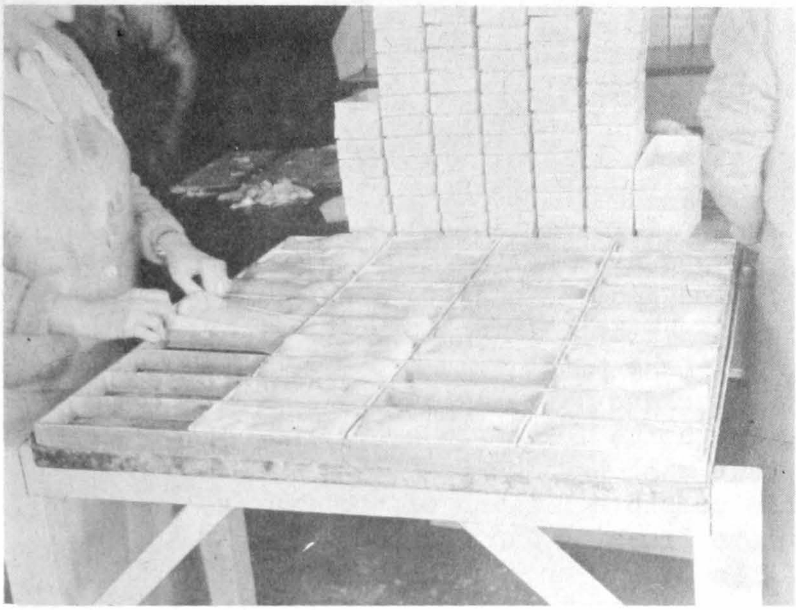

Figure 6.—Filling the tray for a plate freezer with 1-pound packages of fillets. The fillets are overwrapped after being frozen.

the packages will therefore be exposed to room temperature on an average of from 1 to 3 hours while each load is being accumulated and placed in the freezer.

It is desirable to keep this time interval to a minimum, since fillets tend to lose "drip" during this time. In some cases, the drip thus formed may wet or stain the carton. In others, a pocket of free liquid is formed within the package, which looks unsightly when the frozen product is unwrapped.

Another problem in cases of long delay after packaging and prior to freezing is that of bacterial growth within the package. Depending on the degree of contamination (which, in turn, depends on the quality of the fish and the handling methods) and the temperature of the fillets during the delay, this factor may be of no significance—or great significance. Many large buyers and some producers of frozen fillets are now specifying the maximum permissible total bacterial count, number of coliforms, or other bacteria indicative of contamination.

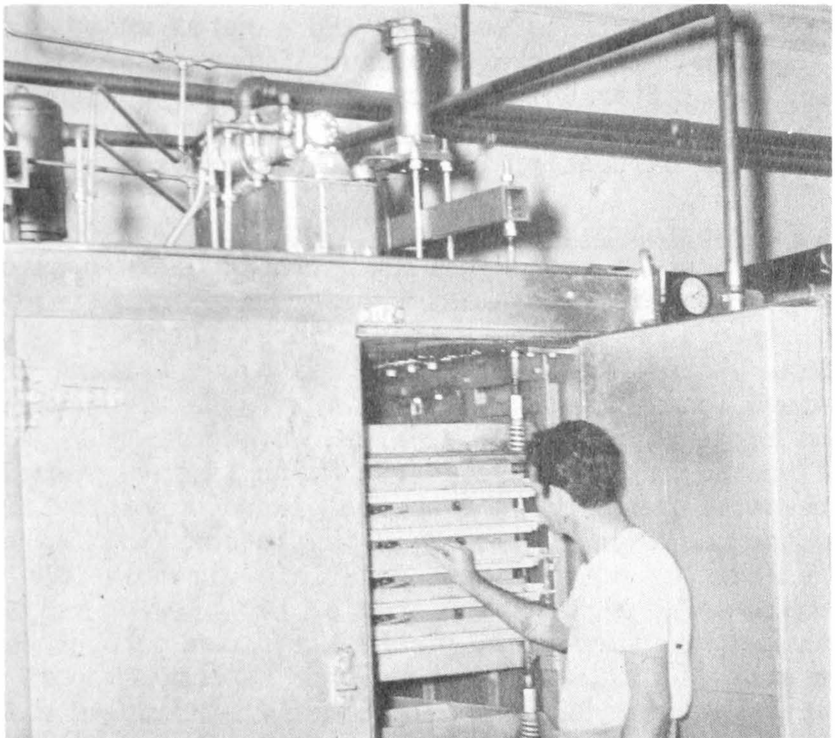

Figure 7.—Packaged fish being frozen in a multiplate freezer. (Photo courtesy of the Southern Fisherman)

The increasing interest in quality control by the public health and other governmental agencies concerned with food products indicates that the producer must not overlook any point in the processing line at which the product might be affected by bacterial contamination or growth.

After the plate freezer has been loaded, the doors are closed, pressure is applied by a hydraulic ram on the bottom plate, and all plates are brought into smooth and firm contact with the cartons as a pressure from 1 to 10 pounds per square inch is applied on the packages. If the cartons are properly filled and the spacers are properly adjusted, the expansion of the fish (approximately 7 percent by volume) during the freezing process will take place <u>within</u> the package. As a result, small voids within the package are eliminated, and the fish is brought into intimate contact with the moisture-vapor-proof material enclosing it. The final package will then be uniform on all sides and have a minimum of voids. This complete filling of the package is a very important advantage of plate freezing, and it adds greatly to the appearance and cold-storage life of the product. Total freezing time in a compression plate freezer is determined by the thickness of the packages, if proper plate temperatures are maintained during the cycle. As is shown in figures 4, 5, and 6 of section 3 of Fishery Leaflet 427, a 1-inch-thick package holding 1 pound of fillets required 60 minutes total freezing time from 36° to 0° F.; a 2-inch-thick package holding 5 pounds of fillets required 180 minutes under similar conditions; and a $2\frac{1}{2}$-inch-thick package holding 10 pounds of fillets required 260 minutes. After being frozen, the small packages, if not previously labeled, are overwrapped and labeled by automatic machines, assembled in master cartons of 24 to 48 packages, and stored at 0° F., or lower.

<u>Freezing packaged fish in the blast freezer</u>.—Although blast freezers are not as economical in operation for freezing packaged fish as are plate freezers, the blast freezers are installed in many fish plants and cold storages because of their versatility. Fish in the round, dressed fish, panned fish, or packaged fish may be frozen simply by using different loading methods or various types of buggies. Packaged fish in the larger cartons are usually loaded directly on the trays or shelves of the buggy or wheeled cart, which is then pushed into the blast freezer. Small cartons may be placed on narrow flat trays at the end of the packing line and slid on the shelves. In some plants, the packages are placed on large trays laid directly on a pallet board. Hollow, double-sided racks are placed on top of each tray or layer as they are stacked, so the blast of cold air flows between each two layers. Trays or spacers of proper size must be used to support the weight of the layers above. Some installations are arranged with fixed shelves in the blast freezer for air flow between adjacent shelves. In others, the shelves may be moved up or down, and a simple jack or hydraulic ram is used to raise the shelves in close contact with both top and bottom of the trays or packages. It can be seen that, in this way, a blast-freezing operation can have the important advantage of the plate freezer

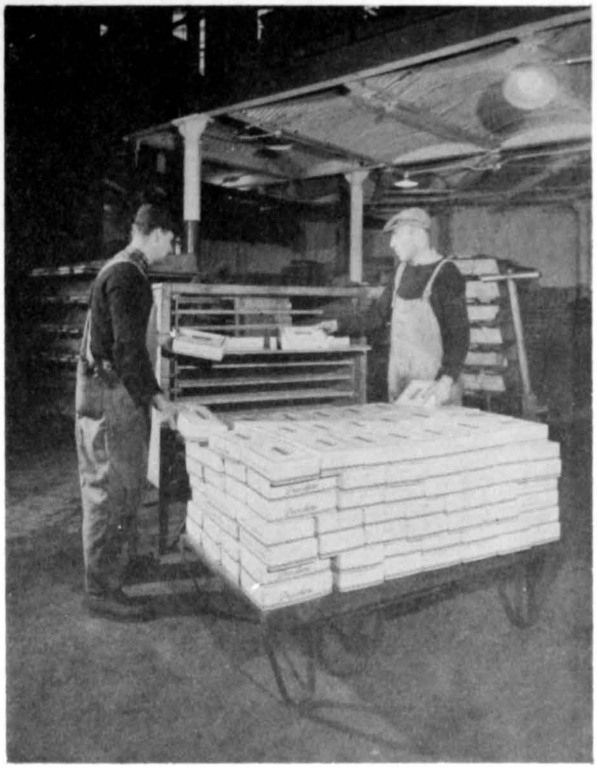

Figure 8.--Loading 5-pound packages of fish on a blast freezer rack. (Photo courtesy of Quincy Market Cold Storage and Warehouse Company)

with respect to the confinement of the packages between two refrigerated plates.

The total freezing times for blast freezing packaged fish are considerably longer than for multiplate freezing. For example, figure 10 in section 3 of Fishery Leaflet 427 indicates a total freezing time (from initial temperature of package to 0° F.) of $2\frac{1}{2}$ hours for 1-inch-thick packages, of 5 hours for 2-inch-thick packages, and of $7\frac{1}{2}$ hours for $2\frac{1}{2}$-inch-thick packages.

The blast freezer lends itself very well to the freezing, in metal pans, of fish fillets, usually prepared for institution packs in the 5- or 10-pound size. A metal cover is used to protect the surface of the fish during freezing. After freezing, the pans are dipped briefly in water to release the block of frozen fillets, which are then glazed and placed in a waxed carton of comparable

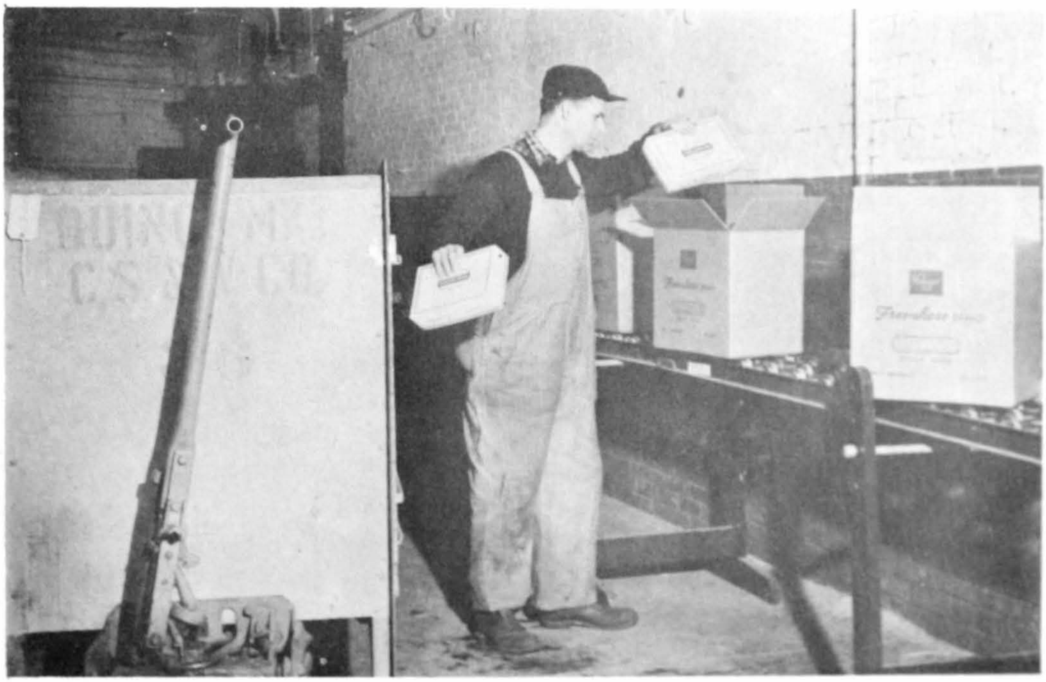

Figure 9.—Placing 5-pound packages of frozen fish in master cartons for storage. The packages were frozen in the blast freezer on the rack shown at the left. (Photo courtesy of Quincy Market Cold Storage and Warehouse Company)

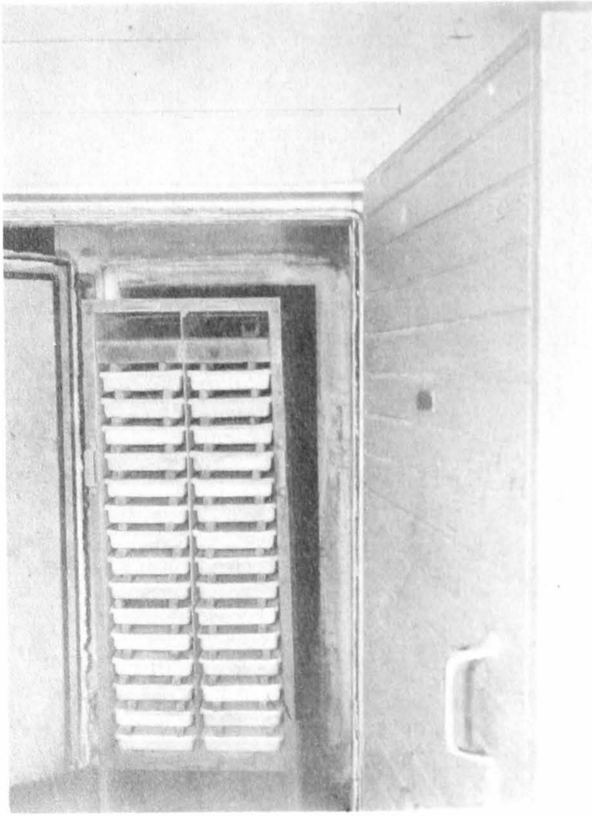

Figure 10.--Loading a blast freezer. The fish fillets are frozen in the aluminum pans with lids.

size. Occasionally, for production of fish blocks to be used for later preparation of fish sticks or fish squares, the glazed blocks are placed into a master carton with a protective waxed or treated paper between each layer and on the top and bottom. Long cold storage of this type of container inevitably results in dehydration of the exposed edges of the fish blocks. For greater protection against drying during storage, the pre-cut frozen fish squares may be wrapped in moisture-vapor-proof film and packaged several units to a master carton.

Freezing Panned Fish

The dressed fish in large pans may be frozen in either the sharp freezer or the blast freezer. In either case, freezing requires 12 to 24 hours. Since the fish are not covered or protected on top, some drying of the skin surfaces takes place during freezing. This drying

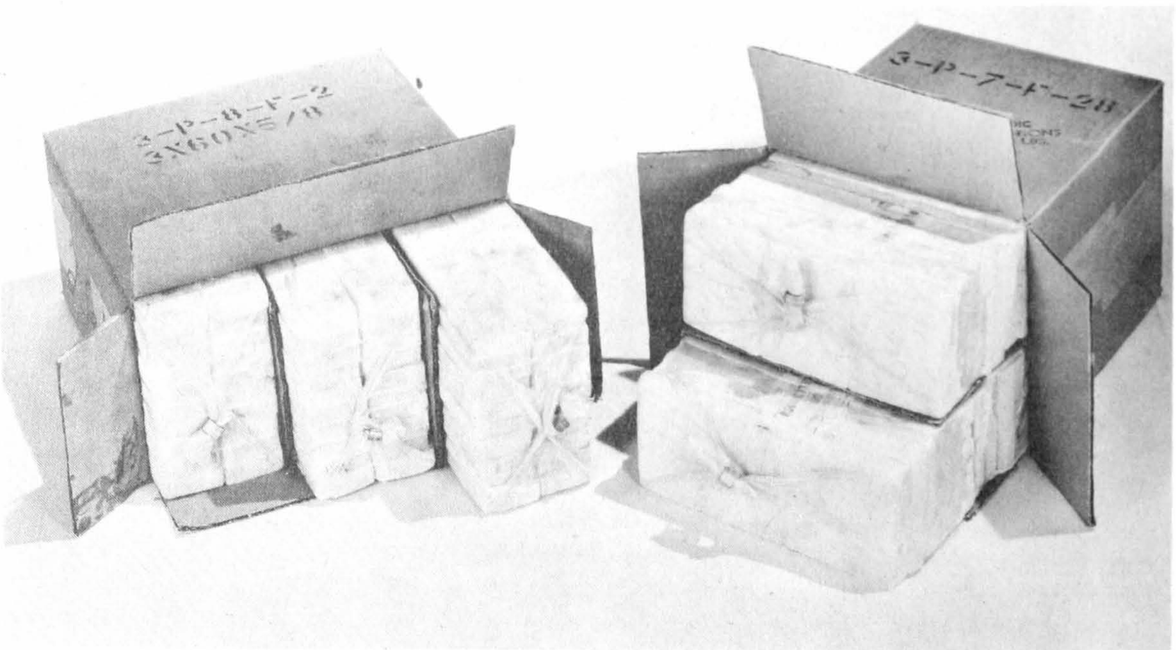

Figure 11.--Frozen pre-cut fish squares packaged in moisture-vapor-proof film and master cartons for institution use. (Photo courtesy Atlantic Coast Fisheries Company)

is especially noticeable in those blast freezers where the differential between the air temperature and the coil temperature (that is, for the coils in the blast cooler) is considerable. A maximum of 10° F. for this temperature difference is usually specified in blast-freezer installations. Immediately after completion of freezing, the fish are removed from the pans and are given a heavy ice glaze before being placed in storage. The blocks of dressed fish are placed in large cartons or wooden boxes for shipment.

Occasionally, individually frozen fish are prepared by freezing only one layer of fish to a tray. These fish are glazed and are placed in boxes lined with paper for storage and shipment.

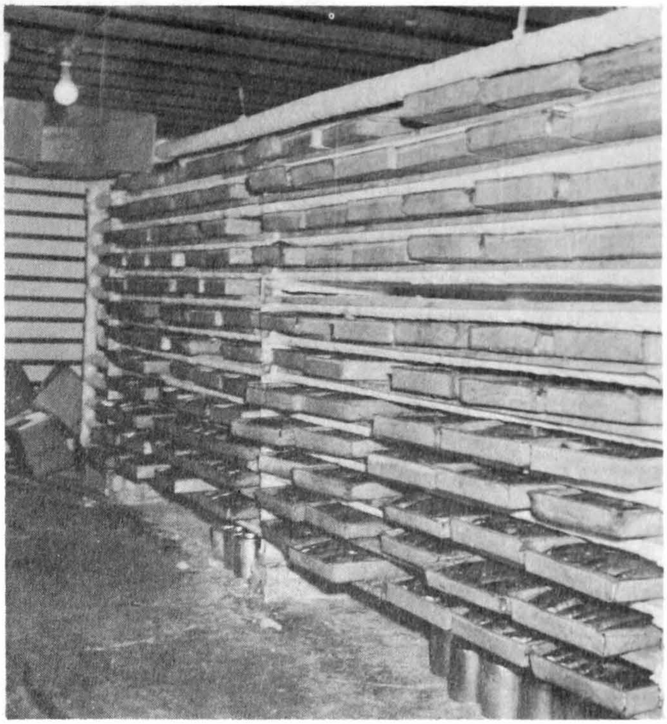

Figure 12.—Freezing panned fish in a sharp freezer. (Photo courtesy of Southern Fisherman)

Halibut

Halibut have been produced almost entirely on the Pacific coast and in Alaska since the decline of the Atlantic halibut fishery many years ago. Pacific halibut (Hippoglossus stenolepis) is a much larger fish than are other members of the flatfishes, and it ranges in size, as a commercial fish, from 5 to over 80 pounds. The fishery is centered primarily on the banks off the Pacific coast and Alaska. The season, gear, and area catch-limits are strictly regulated by the International Pacific Halibut Commission. The fishery, in recent years, has generally been from May to September. Halibut are a bottom fish, but by regulation, they may be caught only by line trawls except for a small amount allowed incidentally in the salmon troll fishery--and this only during the regular halibut season. Halibut are commonly caught in areas that are 5 to 8 days' run from port. They are gutted soon after being caught and are iced in pens partitioned in the hold of the boat. The fish, after being landed, are headed, inspected, graded for size, and washed prior to freezing. In 1951, approximately 26 million pounds of halibut were frozen, the greater part being frozen in the dressed, headless form in sharp freezers.

Figure 13.--Bringing a halibut over the rail in the Pacific fishery. The fish are placed in the checker in the foreground and are eviscerated before being iced. (Photo courtesy of International Pacific Halibut Commission)

Frozen Dressed Halibut

The washed halibut are sorted in wheeled carts according to the following size categories: chicken, from 5 to 10 pounds; medium, from 10 to 60 pounds; large, from 60 to 80 pounds; and whale, over 80 pounds.

The fish are placed on large galvanized iron sheets laid over the coils in the sharp freezer. Large fish are usually loaded on the bottom coils, and the smaller fish are loaded towards the top. This procedure is followed partly as a matter of ease in loading. In addition, the temperature at the top coils tends to be somewhat warmer than at the bottom coils; therefore the larger fish are frozen in the colder location. With large fish such as halibut, it is important that the fish are placed straight on the shelves and not overlapping.

Figure 14.--A sharp freezer loaded with halibut.

A full sharp-freezer requires 36 to 48 hours for freezing the fish. By that time, the temperature of the room should be down to at least -10°F. If there is no need to reload the freezer immediately, the fish will be left longer, and the freezer temperature will drop to -25° to -30° F. When a need for freezer space is great, the cold-storage operators may unload or "strip" the freezer as soon as the fish are solidly frozen. This unloading does not occur, however, until the temperature of the fish has fallen to about 10° F. In practice, the operator determines the condition of the fish by examination--sometimes knocking them to see if they have the proper ring, thus signifying the extent to which they have become frozen.

In many cold storages, the frozen halibut are removed by hand, stacked in carts, and taken to the storage rooms for later ice glazing. In some installations and especially in those in which a conveyor belt is used to speed freezer loading and unloading, the fish are glazed immediately after being removed from the freezer. A chemical compound is usually added to the glazing water to minimize cracking of the glaze (see Fishery Leaflet 429, section 3).

Frozen Packaged Halibut

A small amount of halibut is cut into steaks or fillets and is then packaged and frozen in plate or blast freezers. Much of the packaged halibut for both the consumer and institutional market is prepared by sawing the frozen halibut into steaks, which are then glazed and wrapped. Small halibut and the tail sections of the larger halibut are often filleted. Uncooked halibut sticks and squares prepared from frozen blocks of fillets have been marketed recently. The blocks are prepared in a similar manner to other fillet blocks, by freezing the fillets in a covered metal pan or tray in a plate or blast freezer.

Sablefish

Sablefish (*Anoplopoma fimbria*), sometimes called black cod, are produced in the North Pacific, mainly during the summer and fall months. The fish are caught both with otter trawls and with long lines and run, in length, up to 3 feet and, in weight, up to 40 pounds. Many are caught along with halibut on long lines. Sablefish are unusual in that they are the only commercial bottom fish that has a high fat content, commonly about 12 to 14 percent. The flesh is firm, white, and flaky, with full rich flavor. For this reason, it is considered an excellent fish for smoking, and much of the frozen dressed sablefish, after being thawed, is used for this purpose. Over 5 million pounds of frozen sablefish were produced during 1951.

Most of the catch is frozen in the dressed, headless form and is handled very similarly to halibut. A small quantity is cut into steaks, packaged in 1-pound cartons, and frozen in plate or blast freezers.

Salmon

There are five species of Pacific salmon. Three of these--king or chinook (*Oncorhynchus tshawytscha*), silver or coho (*O. kisutch*), and fall or chum (*O. keta*)--are the main species frozen in shore plants.

A much smaller quantity of pink salmon (O. gorbuscha) are frozen and then later thawed for canning or smoking. The red salmon (O. nerka) are commonly frozen at sea for later thawing and canning and are discussed in a later section of this leaflet. During 1951, over 13 million pounds of salmon were frozen, which included about 4 million pounds of kings, 6 million pounds of cohos, and 3 million pounds of chums. A small quantity of ocean-caught steelhead trout (Salmo gairdnerii) are also caught and frozen along with the salmon.

King salmon are the largest of the salmon and, in the commercial fishery, run from 6 to over 50 pounds. They are highest in fat content when caught in prime condition. Coho salmon average much smaller—from 6 to 15 pounds--and are lower in fat content than are the king salmon. These two species are primarily caught by ocean trolling, with either artificial lures or herring. A smaller quantity are taken by the gill-net fisheries in and around major rivers and by the seine fisheries during closely regulated seasons. Chum salmon average about 7 to 9 pounds in weight, are the leanest of the salmon, and are produced mostly by the seine fishery. Depending on the species and area, salmon are caught in greatest abundance during the seasonal runs from May to November.

Frozen dressed salmon

Salmon are frozen primarily as the dressed headless fish, in sharp freezers. Grading, inspection, washing, and freezing practices are similar to those for halibut. Few of the larger king salmon are frozen, since most of them are used for mild-curing and later smoking. Most frozen salmon range from 6 to 15 pounds in weight. Prompt removal from the freezer and thorough glazing are desirable to minimize dehydration and accompanying yellowing and development of rancidity in the surface flesh of this prime species.

Frozen packaged salmon

For packaging, either the fresh or frozen salmon is cut into steaks about 3/4 inch in thickness. Steaks cut from fresh or thawed fish are wrapped and packaged in the 1- and 5-pound cartons. Frozen fish are often cut (or sawed) into steaks by use of a bandsaw similar to that used with halibut. These frozen steaks are glazed and either wrapped for a consumer package or placed in a large carton for retail dealers or institutional use. The large cartons are either lined with protective paper or overwrapped. Packaged fresh salmon steaks in the 1- and 5-pound cartons are most commonly frozen in multiplate freezers.

Tuna and Mackerels

Tuna

Nearly all tuna are frozen at sea for delivery to the canneries;

however, a relatively small quantity (about 600,000 pounds during 1951) is frozen at shore plants for later canning. Freezing tuna at sea is discussed in a later section. The two main species delivered fresh for freezing ashore are bluefin tuna (*Thunnus thynnus*) and albacore (*Germo alalunga*). Bluefin is the important species produced in the New England area; both bluefin and albacore are produced in the southern California fishery.

The tuna are frozen in the round in sharp freezers and stored for later canning. A small amount is used for markets in a few areas where the whole fish is thawed for sale. Tuna are normally canned, and to date, there has been little or no demand for a frozen packaged product.

Mackerels

The mackerels are close relatives to the tunas, are oily fish, and run about 1 to 3 pounds in weight. The common species are the Atlantic mackerel (*Scomber scombrus*) and the Pacific mackerel (*Pneumatophorus diego*). In California, the mackerel catch is taken with seine or round haul nets, hook and line, and gill nets. The main season is from September through December. On the Atlantic coast, most mackerel fishing is off the New England and Middle Atlantic States and is primarily done from purse-seine vessels. Heaviest landings on the Atlantic coast occur in midsummer. Approximately 2 million pounds of mackerel were frozen during 1951, most of which was in the New England area.

Mackerel are frozen mostly as panned round or eviscerated fish. These products are prepared and frozen similar to the pan freezing of small groundfish previously discussed and are glazed and boxed for shipment to wholesale fish markets and to the institutional trade throughout the country. Skinned mackerel fillets are prepared and frozen both in the 1-pound consumer package and the large institutional size. The consumer packages are frozen in either plate or blast freezers.

Herrings

This group includes the herring and smelts of both the Atlantic and Pacific coasts. All species are small and have a rich oily flesh. The fish are caught in various types of nets: seines, wiers, gill nets, and scoop nets. The fishery is usually conducted close to the fishing port; consequently, ice is not ordinarily needed for preservation.

Over 2 million pounds of herring and smelt were frozen during 1951. For wholesale and institution use, the fish are commonly frozen in pans in the round and are then removed, glazed, and boxed for shipment. For consumer use, the fish are scaled, headed, eviscerated, washed, and then packed in 1-pound cartons. These packaged fish are usually plate frozen and overwrapped.

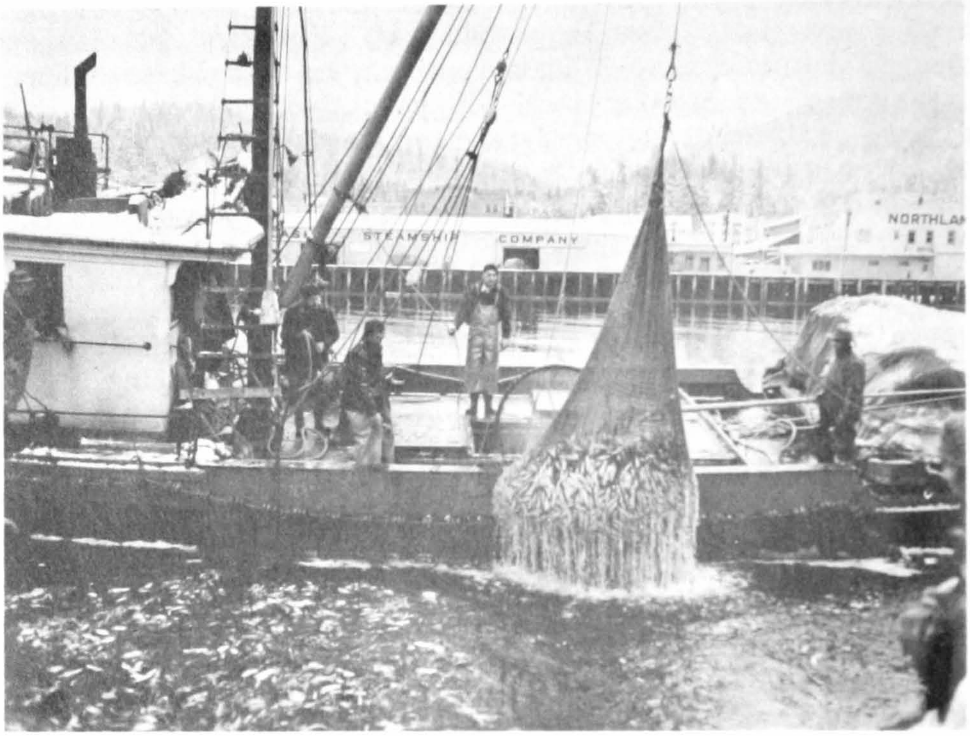

Figure 15.—Brailing a catch of seine-caught herring at Ketchikan, Alaska. These herring are frozen for commercial and sport fish bait.

Fresh-water Fish

About 15 species of fish are produced in considerable volume from the lake and river fisheries. During 1951 over 7 million pounds of fresh-water fish, approximately 5 percent of the total production, were frozen (Anderson and Peterson 1954), mostly in the dressed headless form. All the smaller fish are frozen in pans for convenience in handling. A few species--such as blue pike, lake herring, yellow perch, yellow pike, and whitefish—are filleted for production of the 1-pound consumer package. A considerable volume of the fillets is also packed and frozen in large cartons for the institution and retail fish market.

The greatest part of this production is in the Great Lakes area. Chub (Leucichthys sp.) and lake herring (L. artedi) are the most important, in volume, of the lake fisheries. Both of these are small fish, weighing less than 1 pound, and are frozen in pans or large cartons. The frozen chub are used widely for the production of smoked fish. Whitefish (Coregonus clupeaformis), weighing up to 6 pounds, are produced both as frozen dressed fish and as 1-pound packaged fillets. Catfish (Ameiurus sp.), which are caught in both lakes and rivers, are commonly dressed and skinned before being frozen. Lake trout (Salvelinus namaycush) run 2 to 10 pounds in weight and are frozen, in the

1-pound fillet package, for consumer use, and as the dressed fish, for institution and restaurant use. Most of the catch of fresh-water fish is taken with gill nets; however, trap nets, pound nets, seines, fyke nets, and set lines are also important types of gear used. Much of the catch is obtained by setting nets through a hole in the ice in the winter time.

Figure 16.—Catching lake smelt in a pound net set through the ice, Lake Michigan.

Bait and Animal Food

The freezing of scrap fish and trimmings for bait and animal food has become an important part of the frozen-fish industry in recent years. During 1951, about 14 million pounds were frozen for this purpose, of which more than 12 million pounds were produced from salt-water fish and the balance from fresh-water fish. The marine species used in greatest quantity for bait and animal food include the herrings and scrap bottom fish. These are frozen whole. In areas where large quantities of fish are filleted or canned, the waste portions of species such as cod, ocean perch, and salmon are often recovered and frozen for animal food. The fresh-water species used include lake herring in considerable volume and many of the other less marketable fish from the rivers and lakes of the Midwest.

The commonest method of freezing employs large pans holding 25 to 50 pounds of fish. These pans are placed in sharp freezers. The resulting blocks may or may not be glazed, depending on the market requirements. Another method of freezing employs lined cartons, which eliminates the handling of pans. In a third method, the fish are placed in multilayer moisture-resistant paper bags holding 50 pounds and are then frozen in sharp freezers.

The freezing of herring on the Pacific coast is a good example of an important fish-bait industry. Over 3 million pounds were frozen in 1951 for use in the commercial halibut and salmon fisheries. Large quantities of fish scrap and waste are frozen on both coasts and in the Great Lakes area for use as mink food on commercial fur farms. Another important outlet is the freezing of fish waste for feed in the trout and salmon hatcheries throughout many states.

Miscellaneous Fish

Many species of fish of importance for freezing have not been mentioned. For the most part, the freezing methods are similar to those discussed in this section. In table 2, pertinent information is summarized on commercial handling and freezing methods for representative fish of the United States, including those from both fresh and salt water.

FREEZING FISH AT SEA

Tuna

For many years, the tuna fishery employed crushed ice as a refrigerant on the boats. When the tuna bait boats or clippers 1/ extended their trips for greater distances into subtropical waters, it was impossible to carry sufficient crushed ice to return with fish in first-class condition. During the middle 1930's, satisfactory brine chilling and freezing systems were developed for tuna vessels, and at present, all large tuna clippers use a brine-freezing system. Large tuna seiners fish closer to port and often have a modified refrigeration system with a central refrigerated dry hold, and with brine wells on both sides. This is a dual-purpose system, which enables the tuna seiners to fish sardines. The sardines are caught close to port and are stored in the hold with no ice or refrigeration, for the short run to the cannery. Usually, the refrigerated coils are removed from the large hold during the sardine season. During tuna seining operations, the fish may be held in crushed ice in the large hold or frozen in the brine wells and transferred to the refrigerated dry hold, which is cooled below freezing.

Brine chilling and freezing of tuna aboard the tuna clippers is accomplished by means of steel cargo wells or brine tanks in the hull, located on both sides of the narrow passage above the propeller shaft. Typical large clippers have 12 or 14 brine wells, with a total fish capacity from 240 to 450 tons (Hendrickson 1955). The fish are loaded into the wells by means of deck hatches or manholes. The wells are insulated, and ammonia coils are located along the inner sides, bottom, and under the top. Each well or manifold connecting several wells is equipped with a motor-driven circulating pump and an outlet and intake to the sea.

According to accepted practice, the wells are filled with sea water, the water is cooled to 30° F., and the warm tuna are loaded into the well. It requires from 24 to 72 hours to bring the temperature of the tuna down to 30° F. After the tuna are precooled, salt is added gradually and mixed by means of the brine circulation pumps.

1/ As used in the tuna fishery, the term clipper refers to the large vessels fishing tuna many days from port. At present, all clippers catch tuna by the hook and line method, using live bait to attract the tuna.

Table 2.—Commercial freezing methods for representative fish of the United States

Species	Common size range	Main producing area	Season	Preparation for freezing	Usual freezing method	Preparation for storage	Market form
	Pounds						
Bluefish (*Pomatomus saltatrix*)	1 to 7	Middle Atlantic	All year	Whole, drawn	Sharp freezer	Glazed	Whole, drawn
Blue pike (*Stizostedion vitreum glaucum*)	1/2 to 2	Great Lakes	Sept.-Nov.	Whole, filleted, packaged	Blast freezer	Cartons	Whole, fillets
Butterfish (*Poronotus triacanthus*)	1/4 to 1¼	Middle Atlantic	June-Oct.	Whole, drawn	Pan, sharp freezer	Glazed, boxed	Whole, drawn
Catfish (*Ameiurus* sp.)	1 to 40	Rivers, lakes	All year	Whole, dressed	Sharp freezer	Glazed	Whole, dressed
Chub (*Leucichthys* sp.)	1/10 to 1/3	Great Lakes	All year	Dressed	Pan, sharp freezer	Glazed, boxed	Dressed, smoked
Cod (Atlantic) (*Gadus morhua*)	1½ to 10	New England	All year	Filleted,packaged	Plate or blast freezer	Cartons	Packaged fillets, fish sticks
Cod (Pacific) (*Gadus macrocephalus*)	1½ to 10	Pacific coast	All year	Filleted,packaged	Plate or blast freezer	Cartons	Packaged fillets
Croaker (Atlantic) (*Micropogon undulatus*)	1/2 to 2	South Atlantic	June-Oct.	Whole, drawn	Pan, sharp freezer	Glazed, boxed	Whole, fillets
Eels, common (*Anguilla rostrata*)	1 to 5	Atlantic coast	All year	Whole, dressed	Pan, sharp freezer	Glazed, boxed	Whole, dressed, smoked
Flounder (including sole)	3/4 to 12	New England, Pacific coast	All year	Filleted, packaged	Plate or blast freezer	Cartons	Packaged fillets, fish squares
Haddock (*Melanogrammus aeglefinus*)	1½ to 7	New England	All year	Filleted, packaged	Plate freezer	Cartons	Packaged fillets, fish sticks
Hake (*Urophycis* sp.)	2 to 5	New England	All year	Filleted, packaged	Plate freezer	Cartons	Packaged fillets
Halibut (*Hippoglossus* sp.)	5 to 75	Alaska, Pacific coast	Apr.-Oct.	Dressed, steaked, packaged	Sharp or plate freezer	Glazed, boxed, cartons	Steaks, chunks, packaged steaks, or fish squares
Herring, sea (*Clupea* sp.)	1/8 to 1/4	New England, Pacific coast, Alaska	Nov.-Feb.	Whole	Pan or large carton, sharp freezer	Glazed	Whole, bait and animal food
Lake herring (*Leucichthys artedi*)	1/3 to 1	Great Lakes	Oct.-Dec.	Whole, dressed	Pan or large carton, sharp freezer	Glazed	Whole, dressed, smoked, animal food

Table 2.--Commercial freezing methods for representative fish of the United States (Continued)

Species	Common size range	Main producing area	Season	Preparation for freezing	Usual freezing method	Preparation for storage	Market form
	Pounds						
Lake trout (*Salvelinus namaycush*)	1½ to 10	Great Lakes	May-Nov.	Dressed, filleted	Sharp freezer	Glazed, boxed	Dressed, packaged fillets, smoked
Mackerel (*Scomber scombrus*)	1/2 to 2½	New England, Middle Atlantic	Apr.-Oct.	Whole, filleted	Pan, sharp or plate freezer	Glazed, cartons	Whole, dressed, packaged fillets
Lingcod (*Ophiodon elongatus*)	5 to 20	Pacific coast, Alaska	All year	Dressed, filleted	Sharp or plate freezer	Glazed, cartons	Dressed, packaged fillets
Mullet (*Mugil* sp.)	1/2 to 3	South Atlantic, Gulf	Sept.-Dec.	Whole, dressed	Pan, sharp freezer	Boxed	Whole, dressed, fillets
Ocean perch (*Sebastes marinus*)	1/2 to 1¼	New England	All year	Filleted, packaged	Plate freezer	Cartons	Packaged fillets
Pollock (*Pollachius virens*)	1½ to 12	New England	All year	Filleted, packaged	Plate freezer	Cartons	Packaged fillets
Rockfish (*Sebastodes* sp.)	2 to 5	Pacific coast	All year	Filleted, packaged	Plate or blast freezer	Cartons	Packaged fillets
Sablefish (*Anoplopoma fimbria*)	5 to 15	Pacific coast, Alaska	Apr.-Nov.	Dressed	Sharp freezer	Glazed, boxed	Dressed, steaks, smoked
Salmon, chum (*Oncorhynchus keta*)	5 to 11	Pacific coast, Alaska	Aug.-Nov.	Whole, dressed, steaked, packaged	Brine (canning only), sharp, plate, or blast freezer	Glazed, cartons	Canned, dressed, steaks, packaged steaks
Salmon, king (*Oncorhynchus tshawytscha*)	5 to 30	Pacific coast, Alaska	Apr.-Nov.	Dressed, steaked, packaged	Sharp, plate, or blast freezer	Glazed, boxed, cartons	Dressed, steaks, smoked, packaged steaks
Salmon, pink (*Oncorhynchus gorbuscha*)	3 to 6	Pacific coast, Alaska	July-Sept.	Whole, dressed	Sharp freezer	Glazed, boxed	Canned, smoked
Salmon, red (*Oncorhynchus nerka*)	5 to 10	Alaska, Pacific coast	June-Aug.	Whole	Sharp or brine freezer	Glazed	Canned
Salmon, silver (*Oncorhynchus kisutch*)	5 to 12	Pacific coast, Alaska	July-Oct.	Dressed, steaked, packaged	Sharp, plate, or blast freezer	Glazed, boxed, cartons	Dressed, steaks, packaged steaks
Sauger (*Stizostedion canadense*)	1 to 1½	Great Lakes	Apr.-Oct.	Whole, filleted	Sharp freezer	Boxed	Whole, fillets
Scup (*Stenotomus* sp.)	1/2 to 1½	Atlantic coast	Mar.-June Sept.-Dec.	Dressed	Pan, sharp freezer	Boxed	Dressed
Sea trout (spotted) (*Cynoscion nebulosus*)	1 to 4	South Atlantic, Gulf	Sept.-Dec.	Whole, dressed	Pan, sharp freezer	Boxed	Whole, dressed

Table 2.--Commercial freezing methods for representative fish of the United States (Continued)

Species	Common size range	Main producing area	Season	Preparation for freezing	Usual freezing method	Preparation for storage	Market form
	Pounds						
Shad (*Alosa sapidissima*)	$1\frac{1}{2}$ to 5	Atlantic coast, Pacific coast	May-June	Whole, drawn	Pan, sharp freezer	Boxed	Whole, drawn
Smelt (*Osmerus mordax*) (*Thaleichthys pacificus*) (*Hypomesus pretiosus*)	1/16 to 1/8	New England, Pacific coast, Great Lakes	Feb.-June	Whole, packaged	Sharp, plate, or blast freezer	Cartons	Whole, packaged dressed fish
Swordfish (*Xipias gladius*)	50 to 200	New England	June-Sept.	Chunks	Sharp freezer	Glazed, boxed	Steaks
Tuna, albacore (*Germo alalunga*)	12 to 25	Pacific coast	June-Nov.	Whole	Sharp freezer	Glazed	Whole
Whiting (*Merluccius bilinearis*)	4 to 18	New England	May-Nov.	Whole, dressed, filleted, packaged	Sharp or plate freezer	Glazed, boxed, cartons	Dressed, packaged fillets
Yellow perch (*Perca flavescens*)	1/2 to 3/4	Great Lakes	All year	Whole, filleted	Pans, sharp freezer	Boxed	Whole, fillets
Yellow pike (*Stizostedion vitreum vitreum*)	$1\frac{1}{2}$ to 4	Great Lakes	All year	Whole, dressed, filleted	Pans, sharp freezer	Boxed	Whole, dressed, fillets
Whitefish (*Coregonus clupeaformis*)	$1\frac{1}{2}$ to 6	Great Lakes	All year	Whole, dressed	Pans, sharp freezer	Boxed	Whole, dressed, fillets

During this process, the coils are refrigerated to a lower temperature in order to cool the well below the freezing point. The brine and tuna are cooled to about 15° F. at which temperature the chilled brine is pumped to another well or overboard. The tuna are then held at from 10° to 20° F. in the dry refrigerated well. The fish may be unloaded frozen, and thawed at the cannery; or if they are to be processed promptly at the cannery, the refrigeration in the well will be cut off and the fish thawed by means of circulating sea water during the last few days of the trip. Salt must be added to the sea water during initial thawing to avoid freezing a solid mass of tuna and ice in the middle of the well.

If the refrigeration system is of sufficient capacity and the tuna are frozen in the proper manner, good quality fish are delivered after long trips at sea—commonly 2 to 3 months. During very slow brine freezing, excessive salt is absorbed by the tuna flesh, making it difficult or impractical to control the salt content of the final product. This is especially true with the smaller tuna like skipjack. For this reason alone, the proper application of brine freezing to tuna is most important.

Some of the problems encountered in the application of brine freezing of tuna at sea are:

(1) Assuring adequate refrigeration capacity and use of prechilled sea water and brine for peak fishing periods.

(2) Minimizing excessive salt penetration in smaller fish.

(3) Minimizing the chafing and bruising of the fish in handling, chilling, and storing.

(4) Eliminating quality losses due to incipient spoilage of fish frozen too slowly in overcrowded wells; loading the wells to allow proper brine circulation through the large quantity of fish and to all parts of the well.

(5) Using lower temperatures for freezing and storing to minimize quality losses, especially those due to oxidative rancidity in surface flesh of the frozen tuna.

(6) Using thawing practices which minimize additional salt penetration and which eliminate quality losses in fish thawed earlier than desirable or over too long a period.

These problems can be solved under present conditions and with present vessel equipment; however, a complication often arises because of the higher production cost for the fishermen. For example, during peak fishing periods in warm waters, it may be necessary to limit the day's catch simply because the fish cannot be properly handled and refrigerated before quality losses occur. When the objective is a full load of tuna, the decision to stop fishing while fish are still available is obviously a difficult one to make. Refrigeration equipment with high capacity for handling peak loads, such as supplementary brine coolers, would be a partial solution; however, the additional cost is a deterrent. Extra care should be taken in handling, chilling, and freezing the small fish, in order to minimize the absorption of salt during brine freezing. This means careful loading of the wells, allowing space for proper brine circulation.

Excessive chafing of the fish can only be corrected by more careful handling of the fish during catching, in loading the wells, and during unloading operations. This is easier to correct in the bait boats, since all fish are brought in individually on hook and line. The number of fish taken can be controlled. Through use of a conveyor belt or sluiceway, fish can be carried from the after deck to the wells before too many fish pile up. On the other hand, when good fishing occurs in tuna seining, the net may be overloaded, and the heavy loads cannot be handled without chafing and bruising of the fish. Sometimes fish may die and undergo quality loss while in the seine net, simply because of the time factor in pursing and brailing a large seine.

Controlled loading of wells during chilling and freezing requires that each well be loaded with fish in accordance with the cooling capacity of the well and the size of the fish. Chilling should be accomplished in sea water continuously held at 30° to 32° F. The chilling capacity of the well can be increased through the transfer of chilled sea water from another well or through the addition of crushed ice to the tuna as they are loaded. For example, in the use of ice in chilling, each pound added would provide sufficient refrigeration, on melting, to cool about three pounds of tuna from 80° F. to 32° F. Following chilling of the tuna, the best practice is the use of prechilled brine (5° to 10° F.) for brine freezing. If brine temperatures not higher than 10° to 15° F. are held during the entire freezing cycle and adequate circulation around the tuna is maintained, there is little opportunity for excessive salt absorption or for quality losses due to spoilage. A temperature of not over 10° F. during the storage of tuna in dry wells minimizes oxidative changes. If fish are to be thawed before being unloaded, the refrigerated coils and brine pumps may be used to maintain a uniform brine or sea-water temperature of not over 32° F. in all parts of the well. This use of refrigerated coils and brine pumps avoids the quality losses in small fish or in the outside portions of larger fish, which otherwise tend to thaw more rapidly and thus might be exposed to higher temperatures than are desirable.

Salmon

Most of the production of frozen salmon is prepared at shore plants;

however, a sizeable percentage of the total catch of Pacific salmon (Oncorhynchus sp.) obtained for canning is frozen at sea for later thawing and canning ashore. This practice became of great importance during the later part of the 1940's when companies not having cannery facilities near the Alaskan salmon fishing areas outfitted freezer vessels to bring the salmon from northern areas to the canneries. Occasionally, canneries have also frozen salmon during periods of seasonal glut or peak fishing in order that the surplus might be thawed and canned after the rush period had passed.

As was pointed out by Stansby and Dassow (1951), salmon frozen for later canning should be handled, frozen, and stored with even greater care than that practiced with tuna, because salmon are canned by a different process. Whereas tuna are precooked and only the light meat is canned in the solid or chunk packs, salmon are canned with no precook and normally with the skin and bone intact. There is no opportunity in the canning of salmon for any excess salt to be lost during preliminary cooking. Oxidative rancidity in the surface fatty flesh may occur in both frozen salmon or tuna; however, during the packing of tuna, the skin and dark flesh are scraped off and not packed with the light meat. For these reasons, it is especially important that the salmon be frozen and stored with an absolute minimum of quality change in the fish if a good-quality canned product is to be produced. This minimization of quality change requires greater care in the freezing process, use of ice glaze to eliminate drying during storage, use of low temperatures (0° F. or lower) for storage, and short storage periods--not longer than 2 or 3 months.

At sea, salmon are frozen in circulating air or sharp freezers, blast freezers, or immersion brine wells similar to those used with tuna. Some vessels have been specially built for freezing salmon; others are refrigerated tuna vessels. The salmon are usually obtained directly from the fishermen on the grounds. In Bristol Bay, Alaska, some of the freezer ships carry the fishermen, gear, and smaller boats for gill-net fishing. In other parts of Alaska, most salmon for freezing are obtained from the seine fishery. In either case, the whole salmon is brought aboard and frozen in the round. It has been found unsatisfactory to freeze the drawn or dressed salmon because of the increased oxidative changes in the exposed flesh and the abdominal cavity during storage, especially if brine freezing is used.

In brine freezing salmon, the prechilling operation is not as important as it is in brine freezing tuna, since air temperatures are normally cool and the surface sea-water temperature in the North Pacific and adjacent waters is usually below 50° F. The brine is precooled to 0° to 10° F. and the salmon are loaded directly into the brine well. If brine temperatures of 10° F. or less are maintained, the smaller salmon (4 to 10 pounds) are frozen in 6 hours or less and may be removed to a dry-storage hold maintained at 0° F. Alternately, the brine may be pumped to another well and the salmon stored in the refrigerated well if the refrigerated coil capacity is sufficient to maintain a suitable storage temperature. For storage of only a few weeks, glazing is not necessary, but it is desirable for longer storage periods. The frozen fish may be glazed by the usual process of dipping in cold fresh water (34° to 36° F.) or by means of a cold water spray applied directly to the frozen stacked fish in the storage room. As discussed previously under brine freezing, fish frozen in brine do not take a glaze well because of the salt absorbed in the skin and surface flesh. This salt lowers the freezing point of the glaze adjacent to the skin, the thin layer melts, adhesion of the glaze is lost, and as a result, the glaze does not hold and chips off readily. This problem of glazing brine-frozen salmon has been discussed by Miyauchi (1953).

Of the five species of salmon, sockeye or red salmon (Oncorhynchus nerka) is most commonly frozen at sea for later canning. A substantial volume of pink (Oncorhynchus gorbuscha) and chum (Oncorhynchus keta) is also frozen for later canning and, in some instances, for preparation of kippered salmon. In fish canned after freezing and thawing, there is a tendency toward excessive curd formation and a decrease in the amount of free oil in the canned product. Red salmon should be frozen and stored with considerable care because the premium value of this species for canning lies in its rich red color and high oil content. Undesirable changes may be minimized by proper care in the freezing and storage of the salmon.

Trawl Fish

No substantial volume of trawl or bottom fish is frozen at sea in the present United States fishery. However, the developments in other countries and successful experimental work recently concluded by the Fish and Wildlife Service in the New England area indicate that, in the future, more trawl fish may be frozen. The need for freezing trawl fish at sea has arisen because the larger trawlers of the United States and other countries can no longer operate profitably on the inshore fishing banks. Voyages to fishing banks, 1,000 to 1,500 miles distant, are becoming common for the large ocean-going trawl fleet. It can readily be seen that from the time needed to travel the distances involved and to catch the amount of fish required to operate large fishing boats profitably, crushed ice is not a satisfactory preservative if high-quality fish are to be landed. Lemon and Carlson (1948) described one of the first large-scale fishing operations involving freezing of fish at sea, by a French company, which until 1940 operated a fleet of trawlers equipped for freezing. These vessels used a system of brine freezing in which the whole fish were frozen in a drum revolving in a refrigerated brine tank.

The engineering and economic problems involved in devising and operating satisfactory freezing equipment and frozen-storage facilities for large trawlers are very complex. Considerable changes in design and operation of trawlers as well as in the methods of processing the fish ashore are required in order to make the freezing at sea of trawl-caught fish a success. In recent years, many of these problems have been thoroughly investigated and successfully solved in an extensive series of experiments ashore and aboard the large trawler Delaware, operated by the Fishery Technological Laboratory, Fish and Wildlife Service, Boston, Massachusetts. The comprehensive reports (Freezing Fish at Sea—New England, 1952, 1953, 1954, and 1955) of these studies have included descriptions of the development of pilot-plant and commercial-scale equipment; the application of brine freezing at sea for major species of North Atlantic bottom fish; the problems in handling, storing, thawing, and processing the frozen fish ashore; and recommendations for commercial application.

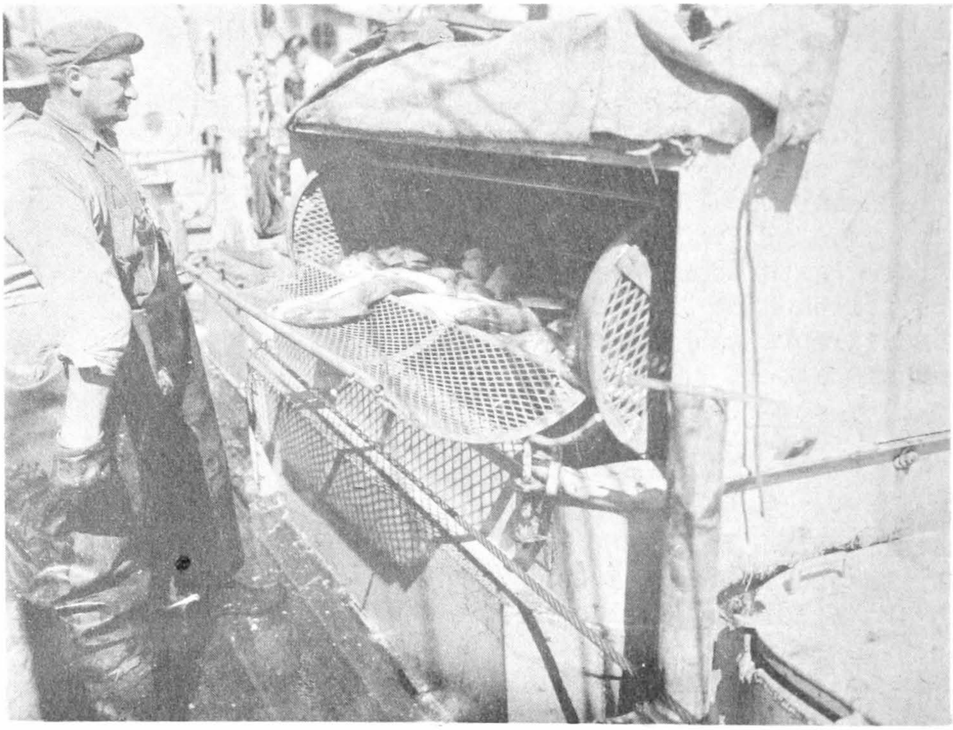

Figure 17.—Loading the baskets of the continuous brine freezer aboard the Service's research trawler Delaware.

Although the use of circulating air or sharp freezers will yield satisfactory results, the use of brine-immersion freezers offers the most promise for conversion of large trawlers for freezing at sea. The brine-freezing recommendations discussed earlier are also important in the freezing at sea of trawl fish. Tests on a semicommercial scale have shown that the trawl fish can be brine frozen aboard the vessel within a few hours after they have been caught, thus assuring retention of the initial high quality of the fish. These fish upon being landed at port, can immediately be thawed and filleted, and the fillets can be packaged and refrozen. Alternatively, the frozen fish can be held in frozen storage ashore for later processing.

Other studies have shown that smaller trawlers, such as those found on the Pacific coast, can also be converted for freezing at sea. A report (Anonymous 1951) indicates that a 57-foot steel-hulled trawler was successfully outfitted for freezing at sea and operated on the Pacific coast.

Factory-Ship Processing

The principle of equipping a vessel for processing completely packaged frozen fish at sea is not new. Large factory ships for freezing, canning, and salting of fish were employed by the Japanese previous to World War II. During recent years, there have been many developments in this type of vessel adapted for filleting, packaging, and freezing of fish at sea.

Smaller factory freezer ships have been designed that not only catch the fish but also process it. On the Pacific coast, the Deep Sea, a trawler of 350 gross tons, was constructed in 1947 for filleting and freezing fish and for processing and freezing crab. This vessel was designed for the capture of both fish and king crab in Alaskan waters and has storage space for 150 tons of frozen product. In recent years, the vessel has been used mainly for the production of frozen packaged king crab meat. A blast freezer is used to freeze the crab meat in large metal trays. Fish may be packaged or glazed and boxed for storage at 0° F. in the refrigerated hold.

Smaller trawlers (60 to 80 feet in length) have been outfitted for filleting and freezing fish or processing and freezing king crab in North Pacific waters. These have not proven successful, however, because of the comparatively high investment and limited economic return and of the problems of operating such small vessels in the open waters of the North Pacific. These vessels have usually been fitted with completely refrigerated holds and an adjacent shelf-type sharp freezer. On these smaller vessels, another problem is the limited freezer capacity, which may prove inadequate during periods of good fishing. Filleting, packaging, and freezing of fish has not been successful in these vessels because space limitations do not permit adequate facilities for catching, processing, packaging, and freezing a pay load in a reasonable time.

The larger factory freezer ship, as developed in recent years, has met with a good degree of success, and a number of firms all over the world have introduced such ships in the international fisheries. The F. V. Fairfree, a converted minesweeper, was (Anonymous 1947) the first British trawler in which fish could be filleted, quick frozen, and packaged at sea within a few hours after being caught. The fillets are washed in wire baskets, packed into trays, and quick frozen in an insulated shelf-type freezer with cold air blast circulation. The blocks of fillets are removed from the trays after being frozen and are then packaged and stored at 5° F.

The largest factory ship constructed and operated in the United States fishery during the past decade was the Pacific Explorer, a converted 410-foot freighter of 8,800 gross tons. This vessel was used in a semi-experimental operation to test, on a commercial scale, the feasibility of utilizing fishery resources distant from present ports. The ship was completely outfitted for freezing whole and packaged fish, canning and freezing king crab, and reducing fish waste to meal and oil. In addition, it was the mothership to a fleet of fishing boats, and carried all supplies for the fishing operation. The vessel was used for freezing tuna, in the South Pacific, and for processing king crab and bottom fish, in the Bering Sea. Fish were frozen in both blast and still-air freezers. The operation of the Pacific Explorer was not commercially successful for many reasons relating to the equipment design and operation and to the problem of producing the products at a profit under the then existing market and labor conditions. Many of these problems are discussed and recommendations for future practice are made in a report of those operations in the North Pacific Ocean and Bering Sea (Wigutoff and Carlson 1950). Existing factory-ship design and operating principles have been developed and modified in part from the results of the large-scale operation of the Pacific Explorer.

The first commercial trawler converted to factory-ship operation on the Atlantic coast was reported (Anonymous 1950) to be the 150-foot vessel Oceanlife. Fish are filleted, packaged in 5-pound cartons, and then frozen in a plate freezer.

The problems of freezing are much more involved aboard factory ships than at a shore plant, with regard to the equipment and its successful operation. Since space aboard ship is always at a premium and since operating costs are high, only equipment of the highest efficiency and durability is desired. The experience gained in the development of techniques and equipment during the past two decades may now be applied to factory-ship operations for supplying frozen packaged fish of the highest quality from the most distant fishing banks.

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SECTION 2

SHELLFISH

By S. R. Pottinger, Chief
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OYSTERS

The origin of the oyster industry is lost in antiquity, for these shellfish were used as food by primitive peoples. It is known, however, that many centuries ago the Romans consumed large quantities of oysters. It is known, also, that the oyster was highly regarded as food by the North American Indians; mounds of oyster shells left by them may be found along our east coast. Large heaps in Maine have been estimated to contain about 7,000,000 bushels of shells. The early American colonists were quick to utilize, as an important source of food, the vast quantities of oysters then available. During the gold rush days in California, there was an active oyster industry centered in the State of Washington, and fancy prices were paid for the small, native oysters when they were shipped to the California market.

Species

Three species of oysters are of commercial value in this country. The eastern oyster (*Crassostrea virginica*) is of primary importance because of its wide distribution and great abundance. It thrives in our coastal waters and bays from Massachusetts to Texas. Single specimens still can be found in Maine,but the oyster beds that existed there years ago have disappeared. On the Pacific coast, two species of oysters are utilized commercially: the Olympia or native oyster (*Ostrea lurida*), and the Pacific oyster (*Crassostrea gigas*). The Olympia is a very small oyster, averaging 2,000 or more to a gallon; its habitat extends from British Columbia to California. Its use is confined to the fresh-oyster trade. On the other hand, the Pacific oyster, introduced from Japan, is a very large species, the average size exceeding that of the largest eastern oysters. This oyster is the more important commercial species on the west coast.

Methods of Harvesting

Oysters are harvested by dredging, tonging, or picking. The particular method employed varies considerably with the geographical location of the oyster beds.

Dredging

On the east coast and in the Gulf of Mexico, most of the oysters are harvested by dredges. These are dragged over the bottom at the end of a tow line from a boat, and the oysters are collected in a mesh bag made of chain or heavy rope attached to the rear of the dredge. When the dredge is filled, it is lifted aboard the boat by a winch, and the oysters are dumped on deck. However, on public beds particularly in Alabama, Florida, and in Chesapeake Bay, hand tonging of oysters is still widely practiced, dredges being prohibited by state laws in some areas.

Tonging

Tonging is done in relatively shallow waters, usually where the oysters are more scattered or are in small beds. Tongs are long scissor-shaped tools, up to 20 feet or more in length, with toothed iron baskets fitting together at one end. The fisherman, working from a small boat, grapples the bottom umtil a number of oysters have been gathered into the basket. The tongs are then lifted, and the oysters are dumped into the boat.

Picking

On the Pacific coast, tonging is practically obsolete. Oysters are now harvested by dredging and by picking. In picking, the workers walk over the surface of the beds, when the tide is out, and pick up the oysters, placing them in wire baskets.

Preparation for Freezing

The shell oysters, after reaching the plant, are sometimes washed under a strong water spray or are often taken into the plant without being washed. They are stored in cool rooms prior to being prepared for marketing. A relatively small quantity of oysters is marketed in the shell for eating "on the half shell." The largest volume of the oyster production, however, is accounted for through distribution as opened or shucked oysters. Freezing oysters in the shell has not proven satisfactory because of the rapid, adverse changes in flavor that occur during frozen storage. For this reason. only the shucked oysters (meats) are frozen.

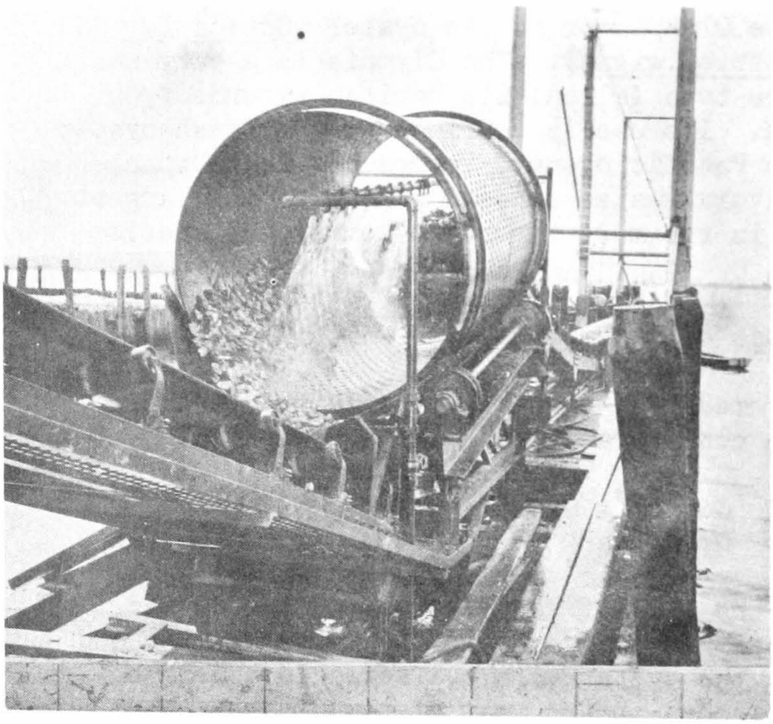

Figure 1.--Washing oyster shellstock before it goes into the shucking house. (Photo courtesy of Southern Fisherman)

Oyster shucking methods

The methods used for shucking oysters vary in the different areas (Pottinger 1944; McKee 1955). The shells are opened by hand and the meats are collected in metal containers; in some areas, these containers are partly filled with water prior to putting the oysters in them. Perforated containers are used in other areas. The oysters are generally sorted into size categories by the shuckers at the time of shucking but this sorting is sometimes done later by machinery. The filled containers are then drained on a washing or skimming table having a perforated top, and the oysters are given a light wash with fresh water from a spray nozzle. This step permits the operator to cull out pieces of shell and mutilated and badly discolored oysters. The oysters may then be placed in a large tank of water and washed by stirring with a paddle or dipper. It is common practice in some areas, following this washing, to "blow" the oysters by forcing air through openings in a pipe at the bottom of the tank, which violently agitates the mass of oysters and water. This agitation removes sand, small pieces of shell, and other foreign matter. The practice of blowing, however, may produce an inferior product, owing to excessive absorption of water, unless properly done.

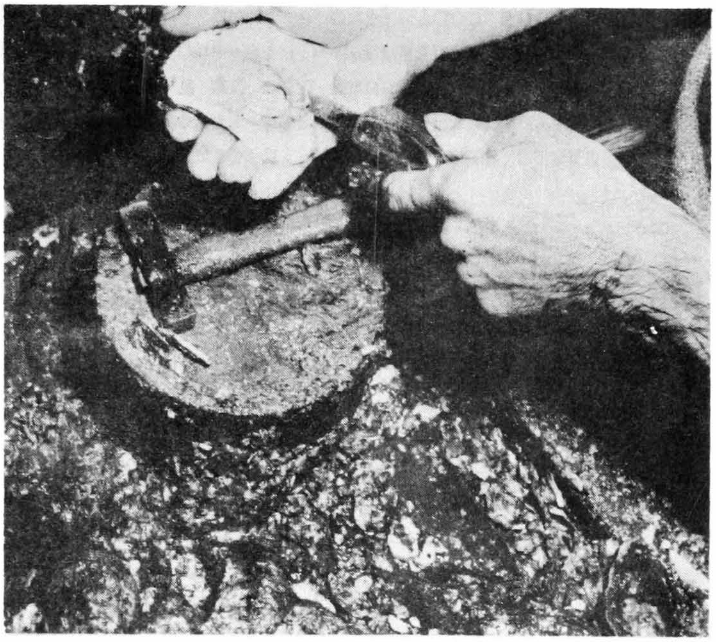

Figure 2.--A knife is used to detach the oyster meats from the opened shell. (Photo courtesy of Southern Fisherman)

Figure 3.--After the oyster meats are removed from the shell, they are washed by being "blown" in large tanks of water. (Photo courtesy of Southern Fisherman)

The U. S. Food and Drug Administration standard of identity specifies that the total time that the oysters are in contact with water or salt water after leaving the shucker--including the time of washing, rinsing, and other contact with water or salt water--is not more than 30 minutes.

After being blown, the oysters are transferred to the skimming table to drain before being packed for distribution. To preserve quality, raw shucked oysters should be cooled to a temperature of 50° F. or less within 2 hours after being shucked. This cooling may be done by placing the packaged oysters in crushed ice in a clean, well-drained bin, chest, or ice box or in a refrigerator free from excessive odors. The packaged oysters are shipped in crushed ice in barrels or boxes.

Grading and sizing of oysters

Raw shucked oysters are packed by grades and sizes, according to definitions and standards of identity established by the U. S. Food and Drug Administration.

Eastern oysters are graded into the following size categories:

(1) Extra large, or counts--one gallon contains not more than 160 oysters.

(2) Large, or extra selects--one gallon contains more than 160 oysters, but not more than 210 oysters.

(3) Medium, or selects--one gallon contains more than 210 oysters, but not more than 300 oysters.

(4) Small, or standards--one gallon contains more than 300 oysters, but not more than 500 oysters.

(5) Very small-one gallon contains more than 500 oysters.

Pacific coast oysters are graded as follows:

A. Olympia oysters: These oysters have no particular size designations; they are uniformly small oysters.

B. Pacific oysters:

(1) Large Pacific oysters--one gallon contains not more than 64 oysters.

(2) Medium Pacific oysters--one gallon contains 65 to 96 oysters.

(3) Small Pacific oysters--one gallon contains 97 to 144 oysters.

(4) Extra small Pacific oysters—one gallon contains more than 144 oysters.

Within each size category, the largest Pacific oysters in the container must not be more than twice the weight of the smallest oyster therein.

Factors to be Considered in the Preparation of Shucked Oysters for Freezing

The freezing of oysters offers wide opportunities for increasing the market for these shellfish. Although oysters are highly perishable and are generally produced in quantity only during the colder months of the year, the proportion of the total production that is frozen is relatively small. Even though marked improvements have been made in refrigerated transportation of foods, there are still definite limitations to the areas over which fresh or unfrozen oysters can readily be distributed. On the other hand, retail outlets for frozen foods are being constantly expanded, and there has been a tremendous increase in the use of home freezers and frozen-food lockers. This expansion in storage facilities offers opportunities for frozen oysters to reach not only the more distant areas but also to become part of the stock of frozen foods maintained in the home freezer and the locker plant.

Certain factors, discussed in the following sections, should be considered in the preparation of shucked oysters for freezing.

Freshness

As is true with all frozen foods, the quality and freshness of oysters that are to be frozen are of primary concern. If the quality is poor at the time of freezing, it will be worse after the product has been stored for some time. Tests made at a Fish and Wildlife Service laboratory showed that oysters, the same as with any other food, must be strictly fresh at the time of freezing if a reasonable storage life is to be expected (Pottinger 1951). Oysters that were considered to be edible and salable, although near the lower limit of freshness at the time of freezing, were found after only 1 month in frozen storage to have a very stale odor, when thawed, and were considered to be inedible. In contrast, strictly fresh oysters frozen at the same time were still quite satisfactory and remained so for several months. These results demonstrate the necessity of using only strictly fresh oysters for freezing.

pH of oysters

The pH of shucked oysters is often used as a reliable indication of the relative freshness of this product. The pH is a measure of the acidity or alkalinity of a substance; a pH value below 7 indicates an acid reaction, whereas a value above 7 indicates an alkaline one. State health departments, the Armed Services, and other agencies concerned with the inspection and distribution of shucked oysters are placing more and more dependence upon pH determinations in judging freshness. The pH forms a basis for expressing quality objectively, rather than as a personal observation or opinion.

The pH of strictly fresh Chesapeake Bay oysters, for example, has been reported to be between 6.5 and 6.8 (Pottinger 1951A). During storage of the oysters in crushed ice, the pH drops gradually until, at a pH of about 5.8, an off-odor generally becomes noticeable, and the oysters are considered to be stale. Similarly, fresh Pacific oysters have been reported to have a pH of about 6.4, dropping during storage to a pH of about 5.9 when stale (Piskur 1947). Although the determination of pH should not be used as the only criterion of freshness, it is a useful quality index in conjunction with other tests. Federal specifications for all fresh raw oysters require a pH of not less than 6.0 at the time of delivery to destination. The pH determination is made on the oyster liquor.

From tests made on frozen oysters, it is not clear whether pH measurements are of value in indicating the state of freshness of oysters that have been held in a frozen condition or of their quality initially. It would appear, however, that the values do not change enough during an extended frozen-storage period to be of much use as an index of freshness for frozen oysters.

Free liquor

Tests conducted by the Fish and Wildlife Service, with eastern oysters, have shown that the method used to clean freshly shucked eastern oysters influences the amount of free liquor released from them after subsequent freezing and thawing. All oysters lose some liquid after they are shucked; the amount lost is dependent, in part, on the method used in washing the shucked oysters. Frozen eastern oysters, upon being thawed, frequently lost more than 20 percent of free liquor, in laboratory tests, with losses of 10 to 15 percent being quite common.

Upon thawing, oysters that were blown in fresh water for 15 to 20 minutes lost more liquor than did those blown for only 3 minutes (Lanham, Kerr, and Pottinger 1948). Those blown for 3, 15, or 30 minutes in water containing 0.75 percent salt and those not blown at all released about equal quantities of free liquor upon thawing, which in each instance was considerably less than the quantity obtained from oysters blown in fresh water for only 3 minutes. In contrast, commercially shucked oysters released much more free liquor upon being thawed than did any of the other lots. These results indicate that the method used in washing the shucked oysters prior to freezing affects the quantity of free liquor formed after the oysters are thawed.

Pink yeast

In some freezing tests carried out at another Fish and Wildlife Service laboratory, several packages of oysters stored at 0° F. for about 1 month showed, upon thawing, a decidedly pink-colored liquor and pink-to-red spots on the oysters. There had been no signs of discoloration of the fresh oysters or liquor prior to their being frozen.

"Pink yeast," which sometimes causes a pink discoloration in fresh oysters, was suspected as being the cause of the off-color, but there seemed little likelihood that it would multiply at as low a temperature as 0° F. Subsequent tests with a culture of the "yeast" isolated from the oysters indicated, however, that it would grow at temperatures of 0° F. or even lower (McCormack 1950). This finding again indicates that the need for following strict sanitary practices in the preparation of oysters for freezing is just as necessary as in the handling of fresh oysters.

Packaging

In planning for the commercial production of frozen oysters, the producer should give careful consideration to the selection of the package. Only too often, a poorly designed or makeshift container is expected to do a job that it is entirely incapable of performing. Shucked oysters are a comparatively "wet" product containing a certain amount of liquid, which fact must be considered in the selection of a package. The package must be watertight to prevent an unsightly discoloration of the package as the result of the leakage of the contents. In addition, the package should be of a type to permit easy filling and handling, and it must provide protection against loss of moisture (dehydration) during frozen storage.

The requirements of the individual producer, and the amount of manual handling prior to freezing, particularly in the smaller plants, will determine to a large extent the type of package selected. If the packaging is done largely by hand, a completely watertight container, such as a sealed moisture-vapor-proof bag within a waxed carton, is desirable. A package of this type may be turned at any angle before freezing without having the contents spill. The bag should be completely expanded at the base before being filled, and after being filled, all air should be squeezed out before the top of the bag is heat sealed. An overwrap will enhance the appearance of the package and further protect the product.

Cartons of the type that do not contain bags but that rely on a moisture-vapor-proof liner or coating to retain the moisture should be overwrapped. When an overwrap is used for a product such as oysters, automatic machine wrapping is to be preferred, as difficulty due to spilling of the contents would undoubtedly be encountered in applying an overwrap by hand. During freezing, oyster meats expand about 7 percent; space must therefore be allowed when filling the package to permit the increase in volume of the contents without leaving voids.

An overwrap for most types of cartons provides added protection against leakage and against normal wear and tear during distribution. It also serves as an excellent medium for the attractive labelling and eye-catching color combinations being used so extensively on frozen-food packages today.

Hermetically sealed cans are increasing in use for packaging frozen oysters, particularly on the Pacific coast, where frozen oysters are commonly packed in the No. 1 standard or eastern oyster can (211 x 400) with C enamel lining (seafood formula). Some producers of frozen eastern oysters are also beginning to use this type of container.

Although no definitions and standards of identity have been established for frozen shucked oysters by the U. S. Food and Drug Administration, producers of frozen oysters generally follow the nomenclature for size designations used for raw shucked oysters (unfrozen).

Freezing (and Cold Storage) of Oysters

Freezing of the packaged oysters may be done by any of the accepted methods of rapid freezing, such as those using blast or multiplate units. The frozen oysters should be stored at a temperature not exceeding 0° F., preferably lower.

The following suggestions are offered in the freezing of oysters:

1. Freeze only strictly fresh, high-quality oysters.

2. Subject oysters to a minimum of washing and blowing in fresh water during the cleaning process. (Water containing 0.75 percent salt, by weight, is preferable.) Drain oysters thoroughly prior to packaging.

3. Use a watertight, moisture-vapor-proof, attractively designed package.

4. When filling and closing the package, leave only enough head space to allow for expansion of the oysters during freezing. Seal tightly to prevent leakage of contents and loss of moisture.

5. Freeze immediately at a low temperature, about -20° F., or lower, if possible.

6. Store at 0° F. or lower.

7. Maintain thorough cleanliness and strict sanitation in all phases of the plant operation, for the production of a quality product.

SHRIMP

Shrimp are among the most popular fishery food products and are in constant demand throughout the year. They may be found in all the coastal waters of the United States and Alaska, but the largest catch is taken in the South Atlantic and Gulf areas.

Of the numerous species of shrimp that are found, five are of commercial importance in the South Atlantic and Gulf areas: the common or white shrimp(*Penaeus setiferus*); three varieties of grooved shrimp (*Penaeus aztecus*, *Penaeus duoarum*, and *Penaeus brasiliensis*); and the sea-bob (*Xyphopenaeus kroyeri*). The fishermen do not distinguish between the three varieties of grooved shrimp. Though formerly the common shrimp was by far the most important commercial species taken in the Gulf area, grooved shrimp now account for the largest landings. The sea-bob is used almost exclusively for drying purposes.

There are also five species of shrimp of major importance in the commercial shrimp fishery in Alaska: pink (*Pandalus borealis*); side-stripe (*Pandalopsis dispar*); humpy (*Pandalus goniurus*); spot or prawn (*Pandalus platycerus*); and coon-stripe (*Pandalus hypsinotus*). The first three varieties make up over 85 percent of the commercial catch of Alaskan shrimp.

In recent years, a small commercial fishery for the pink shrimp has also developed off the coast of northern California. Many American shrimp fishermen also fish offshore in international waters.

A species of shrimp (*Penaeus stylirostris*) closely related to those taken in the fishery of the Gulf of Mexico occurs in the Pacific shrimp fishery of the Gulf of California and accounts for 90 percent (in 1951) of the large production of frozen shrimp imported from Mexico.

Method of Catching

Practically all shrimp are taken by means of a trawl net or otter trawl, consisting of a long bag in which the shrimp are caught and held. In use, it is lowered to the bottom and towed slowly behind the vessel. As the net scrapes over the bottom, shrimp and other marine life are funneled into it. At intervals, the net is hauled up, and the shrimp dumped on deck. Fish, seaweed, and other debris are then sorted out, and worthless material is discarded.

In Alaska, the shrimp are stored whole on deck in wooden boxes holding from 150 to 200 pounds each. No ice is used, since the air temperature is cool and the shrimp are landed daily. In the South Atlantic and Gulf areas, the shrimp are stored with alternating layers of ice in bins in the hold of the vessel. During the first few days of the trip, the usual practice is to remove the heads of the shrimp. During the latter part of the trip, the shrimp are sometimes stored in ice without removing the heads. The boats may remain at sea for a period of 10 days up to 6 weeks. If the vessel stays out more than about 2 weeks, the catch of shrimp is transferred to other vessels, at intervals, for shipment back to port.

Figure 4.--Unloading shrimp from the boat. (Photo courtesy of Southern Fisherman)

Preparation for Freezing

Methods of preparing the shrimp for freezing vary in the different areas. Most of the Alaskan shrimp are marketed in the frozen cooked form, whereas in the South Atlantic and Gulf areas, only a small proportion of the shrimp are cooked prior to being marketed.

Cooked shrimp

As with other ready-to-serve frozen foods, shrimp that have been cooked and frozen appeal strongly to many homemakers because of the ease of preparation.

Methods of Preparation in Alaska

In Alaska (Wigutoff 1953), the whole shrimp, immediately after being landed, are precooked in a tank of unsalted boiling water. Since the purpose of this precook is to facilitate picking, the cooking time is held to a minimum, and as soon as the shrimp rise to the surface, they are removed and placed in trays for cooling. The meats are then picked from the shells, placed in trays, washed under a spray of cold fresh water, and permitted to drain for a few minutes.

Two different methods are used for the further processing of the meats. The method most commonly used is to cook the meats in a salt solution (20° to 30° salometer) for 1 to 3 minutes. The other method is to dip the picked meats in a saturated salt solution for about 3 minutes, followed by draining. The meats are then placed in a steam retort and cooked without pressure for 3 to 4 minutes. Following this brining and cooking process, the meats are allowed to cool, and fragments of shell and antennae are removed. Approximately 35 pounds of cooked meats are obtained from 100 pounds of raw whole shrimp.

Packaging.--Until about 1940, the meats were packed 5 pounds to a 1-gallon can and shipped in ice. With the improvements in refrigerated transportation in recent years, the Alaskan shrimp are almost completely marketed in the dry frozen state and are packed in No. 10 double-seamed cans, 5 pounds of meats to the can. Owing to the increased demand for frozen products in the home, 1-pound and even smaller containers are used. A consumer-size can (307 x 113) holding 4 ounces of meats sealed under vacuum has been marketed. Vacuum packing increases the frozen-storage life of the product and minimizes toughening over long periods of frozen storage.

Besides being marketed as cooked picked meats, some Alaskan shrimp are prepared in other ways. Spot shrimp are cooked whole and frozen in waxed cartons, 20 pounds to the box; frozen raw picked meats of large side-stripe shrimp are packed 6 pounds to a No. 10 can and hermetically sealed. Alaskan shrimp are usually marketed within 6 months after being packed.

Freezing and cold storage.--The freezers are mostly of the shelf type; the temperature of freezing may be between 0° and -20° F. A storage temperature of approximately 0° F. is commonly used; however, lower temperatures of -10° or -20° F. are recommended for storage over periods longer than a few months in order to minimize the development of toughening, discoloration (yellowing), and off-flavors.

Methods of Preparation in South Atlantic and Gulf Areas

The method of preparing frozen cooked shrimp in the Gulf area is different from that used in Alaska. Instead of being cooked in fresh water, the shrimp are boiled in a brine solution, the strength of which varies considerably in the different plants; generally, the salt content of the brine varies between 5 and 15 percent by weight. A large variation in cooking time may also be found in the different plants, possibly being as long as 20 minutes.

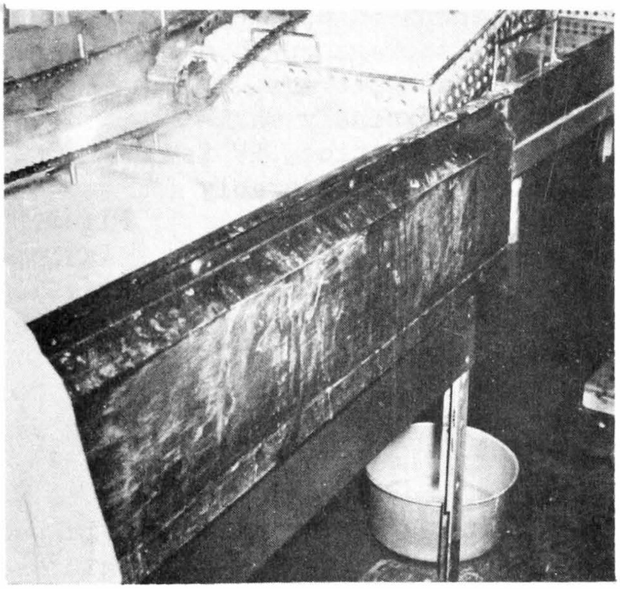

Figure 5.--Cooking peeled and deveined shrimp. (Photo courtesy of Southern Fisherman)

In tests carried out on the cooking of shrimp (Lewis 1947), it was found that a cooking period of 15 minutes or more for peeled shrimp was considered to be too long, since the shrimp were not as desirable as those cooked for shorter periods. Boiling for 5 to 10 minutes produced a better product. Unpeeled shrimp required a somewhat longer period of cooking, varying between 10 and 20 minutes. The most desirable salt concentration of the brine for cooking peeled shrimp was judged to be from $2\frac{1}{2}$ to 5 percent; for unpeeled shrimp, a salt concentration of 10 percent in the brine was found best.

Packaging.--The cooked shrimp, after being cooled, should be packaged immediately. Waxed cartons are widely used, with overwraps having good moisture-vapor-proof qualities; No. 10 cans and cans holding only 5 ounces and 7 ounces are also used and are usually hermetically sealed. The packaged shrimp should be stored at a temperature not exceeding 0° F. The cooked shrimp have a very short frozen-storage life and soon become tough, with a loss of flavor. Peeled boiled shrimp should not be stored longer than 3 months, whereas unpeeled boiled shrimp have been found in tests to be acceptable after storage up to 6 months. These storage periods are probably maximum, and in practice, it is believed that considerably shorter storage periods should be used. Production should therefore be planned so that a rapid turnover in stock will occur.

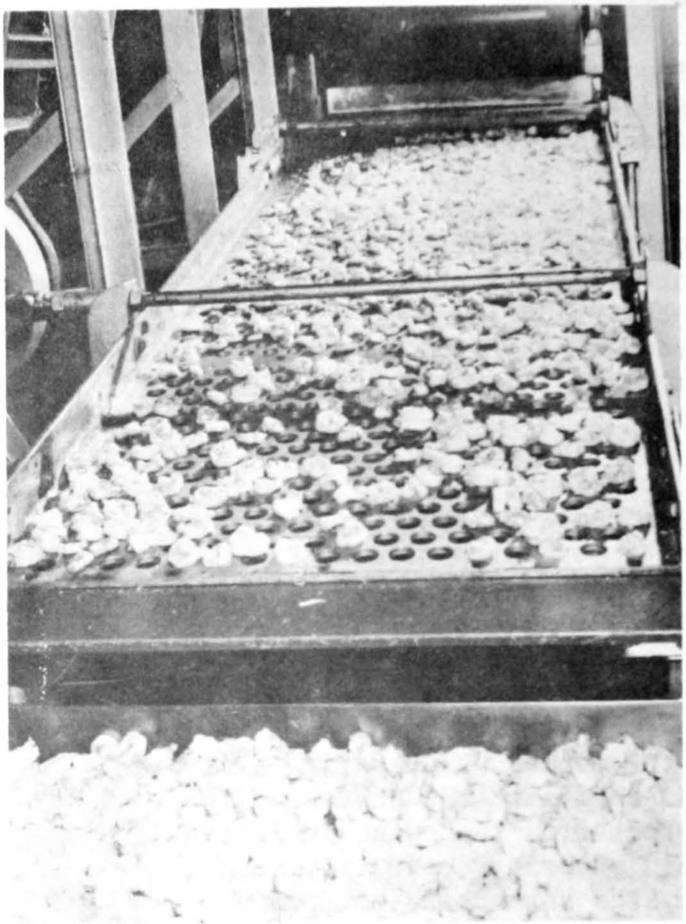

Figure 6.--Cooked and peeled shrimp on automatic grader prior to being packaged. (Photo courtesy of Southern Fisherman)

The need for proper packaging cannot be stressed too strongly (see Fishery Leaflet 429, section 3). For better keeping quality, frozen shrimp must be packaged properly to minimize desiccation and oxidation during storage. Poor packaging is poor economy. Good packaging combined with lower storage temperatures (below 0° F.) will help greatly in prolonging the keeping quality of frozen shrimp and other frozen fishery products.

Freezing and cold storage.--The accepted methods of rapid freezing are suitable for freezing cooked shrimp. To preserve quality, storage temperatures well below 0° F. are desirable.

Raw shrimp

Since only relatively small quantities of shrimp are produced in the cooked form in the South Atlantic and Gulf areas, the methods of handling the shrimp in the plants in these areas are quite different from the methods used in Alaska.

Figure 7.--Upon coming into the plant, the shrimp are inspected and defective ones removed. (Photo courtesy of Southern Fisherman)

Figure 8.--Peeling and deveining raw shrimp. (Photo courtesy of Southern Fisherman)

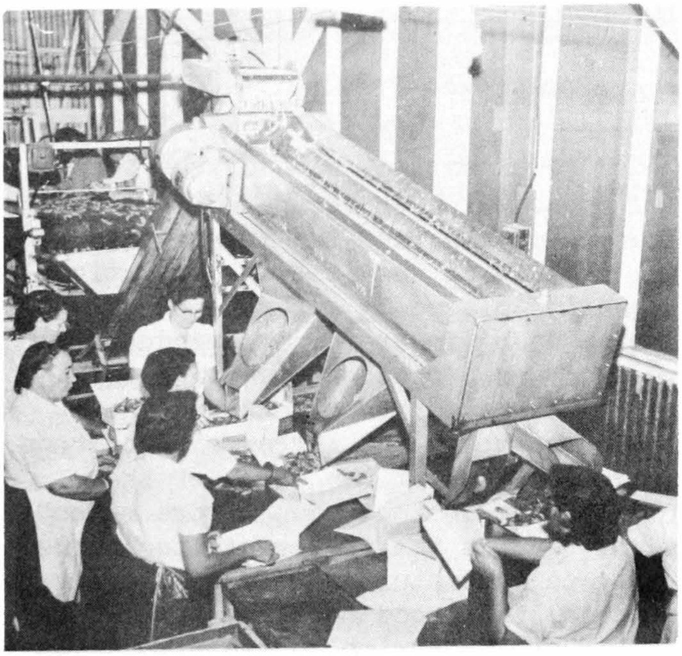

Figure 9.--Grading and packaging of raw shrimp. The grading is done by machinery such as this in some of the plants. (Photo courtesy of Southern Fisherman)

When the shrimp are landed, they are taken to the plant where the heads are removed from any remaining whole shrimp. After being washed, the headless shrimp are inspected to remove defective ones, graded according to size, and either iced for distribution as fresh shrimp or packed for freezing. In addition to shrimp with shells on, peeled and deveined shrimp are frozen also. These operations are done by machinery in many of the plants. Size-grading machines are used extensively, and peeling and deveining operations, formerly done largely by hand, may now be done much more rapidly by machine.

Size Classification of Shrimp

Federal Specification PP-S-316a, "Shrimp, Raw and Cooked; Chilled and Frozen," specifies the following sizes for raw and for cooked shrimp:

Type and condition of shrimp	Count-number of headless shrimp per pound			
	Not-peeled		Peeled	
	Regular	Deveined	Regular	Deveined
Type I, raw, chilled or frozen	15 and less	16 and less	18 and less	19 and less
	16-20	17-21	19-24	20-25
	21-25	22-26	25-30	26-31
	26-30	27-31	31-36	32-38
	31-35	32-36	37-42	39-44
	36-42	37-43	43-50	45-53
	43-50	44-51	51-60	54-63
	51-60	52-61	61-72	64-75
	61 and over	62 and over	73 and over	76 and over
Type II, cooked, chilled or frozen			36 and less	40 and less
	...	...	37-46	41-50
	...	...	47-55	51-60
	...	...	56-83	61-80
	...	...	84-108	81-100
			109 and more	101 and more

Packaging Frozen Shrimp

Cartons of several sizes are used for frozen shrimp, such as the small 8-, 10-, and 12-ounce consumer-type waxed carton with overwrap and 1-pound tray-type cardboard carton with transparent overwrap, and the larger sizes having a capacity of $2\frac{1}{2}$, 5, or 10 pounds. Following the freezing operation, the larger cartons may be opened and the shrimp glazed by spraying cold water on the surface of the frozen block of shrimp or by immersing the product in cold water. About 8 ounces of water are used per 5-pound carton of shrimp. After the shrimp are sprayed, covers are attached to the carton, and the cartons are turned upside down. Glazing of shrimp in the larger-size cartons is inadequate, however, because the glaze evaporates at the edges of the block during frozen storage and the shrimp become desiccated. A more recent method that is being used rather widely and that is the preferable technique, is to omit the glazing entirely and to rely on a moisture-vapor-proof overwrap to prevent dehydration of the shrimp. The use of a good moisture-vapor-proof overwrap on the carton, with careful packing of the shrimp to minimize voids within the carton, will go far in preventing desiccation during prolonged frozen storage.

Freezing and Cold Storage

A temperature of -25° to -40° F. is recommended for freezing shrimp (Divers 1952). This temperature, obtainable in multiplate freezers and in blast freezers, is low enough to freeze the shrimp so rapidly that the cellular breakdown is kept at a minimum. The temperature of storage of the frozen shrimp should be maintained at 0° F., and preferably lower, at all times. At the lower storage temperatures, the development of a rancid flavor in the shrimp is minimized.

Figure 10.--Placing 5-pound packages of frozen shrimp into shipping container for storage or shipment. (Photo courtesy of Southern Fisherman)

Some Factors Affecting the Quality of Frozen Shrimp

Black spot

The development of black spots and blackened areas on fresh shrimp that are held in crushed ice has been a problem for many years. The shrimp thus affected will have one or more black spots or bands at the base of the shell segments or across the back where the shell segments overlap. In severe cases, much of the exterior of the shrimp becomes black, and the interior becomes a black mushy mass. Since in even less severe cases these black spots are associated in the mind of the purchaser with spoilage, shrimp having this discoloration will, of course, have little market value. Although it was at first believed that microorganisms or a mold were the cause, the results of an extensive investigation along these lines failed to support this explanation. Further tests have shown that the discoloration is caused by enzymes that are found within the shrimp (Alford and Fieger 1952). Since the chemical substance that becomes black and the enzymes that cause the blackening are present naturally in the shrimp, some means must be found to prevent the change from taking place. Limiting the amount of air in contact with the shrimp has been found to prevent black-spot development. In laboratory experiments, dipping shrimp in a solution of sodium bisulfite or sodium sulfite has been effective. Commercial application of these methods has not as yet been worked out, nor is it certain that such a treatment would even be permitted under existing regulations. It is quite possible that some other more effective means of preventing black spot in shrimp will be developed.

Black-spot development can be minimized by using proper handling practices for the shrimp. Results of tests conducted by Fieger (1950) indicate that headed shrimp keep longer than whole shrimp. Thorough washing of either the headed or the whole shrimp before icing on the trawler is highly desirable. Improvements should be made in the method of icing and storing the shrimp, such as (1) preventing the water from the melting ice percolating and carrying bacteria through more than 2 or 3 layers of shrimp, and (2) decreasing the crushing of the shrimp in the bins by relieving the weight of the upper layers of ice and shrimp on the bottom layers. This crushing is said to hasten spoilage of the shrimp. Improvements are also desirable in the unloading operation to minimize bruising of the shrimp. In the shore plant, the shrimp should be kept thoroughly iced at all times, and bruised and crushed shrimp should be promptly removed.

Proper icing

Studies have shown that the highest quality in shrimp may be obtained if the shrimp are frozen quite soon after being taken from the water (Fieger and DuBois 1946). Under present conditions of handling, however, this promptness in freezing is difficult to achieve. Means of freezing the shrimp aboard the boats are generally lacking, and freezing facilities ashore are often quite limited. Ice remains the principal means for refrigerating shrimp aboard the vessels at present. Few of the holds of the trawlers are insulated, however, and the ice thus melts more rapidly than it should, often leaving the shrimp inadequately refrigerated.

Coverings for frozen shrimp

The problem of proper packaging of shrimp to maintain quality during frozen storage has not been entirely solved. Large losses in moisture can occur through the use of packages and overwraps that have low resistance to the passage of moisture vapor. Improper glazing or failure to reglaze when necessary will cause the shrimp to lose moisture and become poor in quality in a short time. If shrimp are stored over a long period of time, it is essential that they be inspected periodically and reglazed before all of the glaze has disappeared. When the shrimp are packaged, they should be layered neatly so as to avoid excessive air space. This practice minimizes the dehydration of the frozen shrimp from moisture transfer within the carton, which is an important factor in maintaining product quality during long storage.

Drip losses

Tests have shown that the quantity of drip that is formed upon thawing headless shrimp is dependent on the length of time the product is held in ice storage prior to being frozen (Fieger and Frilox 1953). After an initial period of 4 to 6 days, when the drip values for the frozen product are relatively constant, the amount of drip increases in general with length of storage and may be as high as 5 ounces per 5 pounds of shrimp. It has also been shown that shrimp of high quality produce less drip than do those of lower quality; cull shrimp that were soft, crushed, or spoiled or that had a physical appearance below commercial packing standards produced more drip (about 5.7 ounces per 5 pounds of shrimp) than did a good commercial pack (about 3 ounces of drip per 5 pounds of shrimp).

Brine-Freezing of Shrimp Aboard Vessels

To meet the increasing demand for shrimp, vessels are going greater distances from port than they did formerly. Consequently, the shrimp are held on the boats for such long periods of time as to create a quality problem. Softening, loss of flavor, black-spot formation, and spoilage occur in shrimp held too long in ice, resulting not only in a loss of shrimp but very often in poor quality of the shrimp that is distributed. Although better handling and icing procedures aboard the boats will give a partial answer to the problem, freezing the shrimp immediately after being caught appears to be a more desirable means of preserving quality. The practical advantages of brine-freezing fish at sea have been shown in studies conducted by the U. S. Fish and Wildlife Service in New England. Likewise, the freezing of shrimp in brine aboard vessels would appear to offer certain advantages. Brine freezers are adaptable to small boats and this method of freezing is especially well-suited for freezing small and irregularly shaped products such as shrimp.

Experimental tests

A small-scale trial of brine-freezing shrimp at sea was carried out aboard a vessel in the Gulf area (Dassow 1954). The shrimp were frozen by immersing 5- to 10-pound lots of shrimp for about 15 minutes in circulating 85° salometer brine (22.4 percent salt) at a temperature of 5° F. After the frozen shrimp had been removed from the brine, drained, and rinsed in chilled water, they were packaged in waxed cartons and stored at 0° F. Following several weeks of storage, the shrimp were thawed by being immersed for 10 to 15 minutes in circulating fresh water at 60° F. The shrimp were then headed, washed in fresh water, packaged in waxed cartons, and frozen at -20° F. Shrimp that were headed prior to being brine frozen were not thawed.

It was concluded that freezing shrimp at sea, either in air or in brine, immediately after they were caught produced a high-quality product more nearly approaching the fresh state than iced shrimp normally found on the market. There was a complete absence of black spot on the shrimp.

After several freezing tests had been made, it was found that preliminary chilling of whole or headed shrimp in cold water not only minimized quality losses during the holding of the shrimp before freezing but also improved the efficiency of the brine process.

Recommendations

Based on the above study, the following procedure is recommended for commercial brine freezing and processing of shrimp:

Processing aboard ship:

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° salometer or 22.4 percent salt) at 0° to 5° F. Circulate the 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:

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

2. Remove shrimp from thawing tank. Separate heads from whole shrimp. Rinse, and cull unsound shrimp.

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

4. Refreeze shrimp at -10° F. or below, and store at 0° F. or below.

A commercial application of this brine-freezing process aboard shrimp trawlers in the Gulf area utilizes a freezing solution containing a mixture of salt and a form of sugar (presumably glucose), instead of the straight salt solution. Some advantages claimed in the use of this freezing solution are (1) the shrimp do not stick together; (2) lower freezing temperatures are possible; and (3) a glaze is formed on the shells, which reduces dehydration of the shrimp during frozen storage. Freezing of 5-pound packages of shrimp in a blast freezer aboard the trawlers is also being done. (See Fishery Leaflet 427, section 3 for further details of the freezing of shrimp on commercial fishing vessels.)

The true lobster (Homarus americanus) is caught principally in waters near the shore along the New England and Canadian coasts. Although these lobsters are much more plentiful from Cape Cod north, they are taken to some extent in waters south of this area and are occasionally found as far south as North Carolina.

The spiny or rock lobster is easily distinguished from the true lobster by the absence of the large crushing claws and by the flexible rather than stiff tail fan. There are two species found in the United States: Panulirus argus, in the South Atlantic and Gulf areas; and Panulirus interruptus, on the Pacific coast. Considerable quantities (mostly tails only) are imported into this country from South Africa and Australia.

True Lobster

Method of catching

The true lobster is taken in traps, more commonly called pots, which consist essentially of an oblong box made of ordinary wood laths.

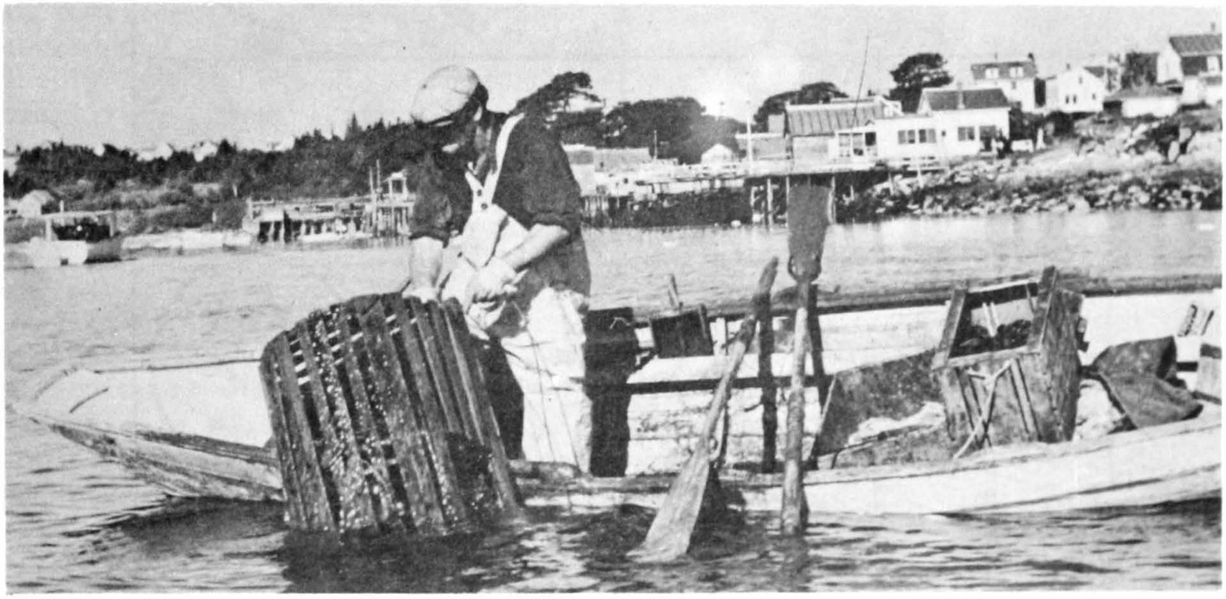

Figure 11.--Fisherman hauling lobster trap aboard boat. (Photo courtesy of Fishing Gazette)

Ends of the pot are made of cotton netting arranged in a funnel shape. In the center of each funnel-end is the opening through which the lobsters, in search for the bait, enter the pot. Fresh, salted, or stale fish is generally used for bait. For fishing, the pots (weighted with stones or other heavy objects) are lowered to the bottom. They are attached by a rope to a buoy that is painted a distinctive color to enable the fisherman to locate his own traps. The traps are hauled about once a day, and any lobsters present in them are removed through a door in the trap.

Effect of freezing

The true lobster is usually marketed alive, boiled whole, or as

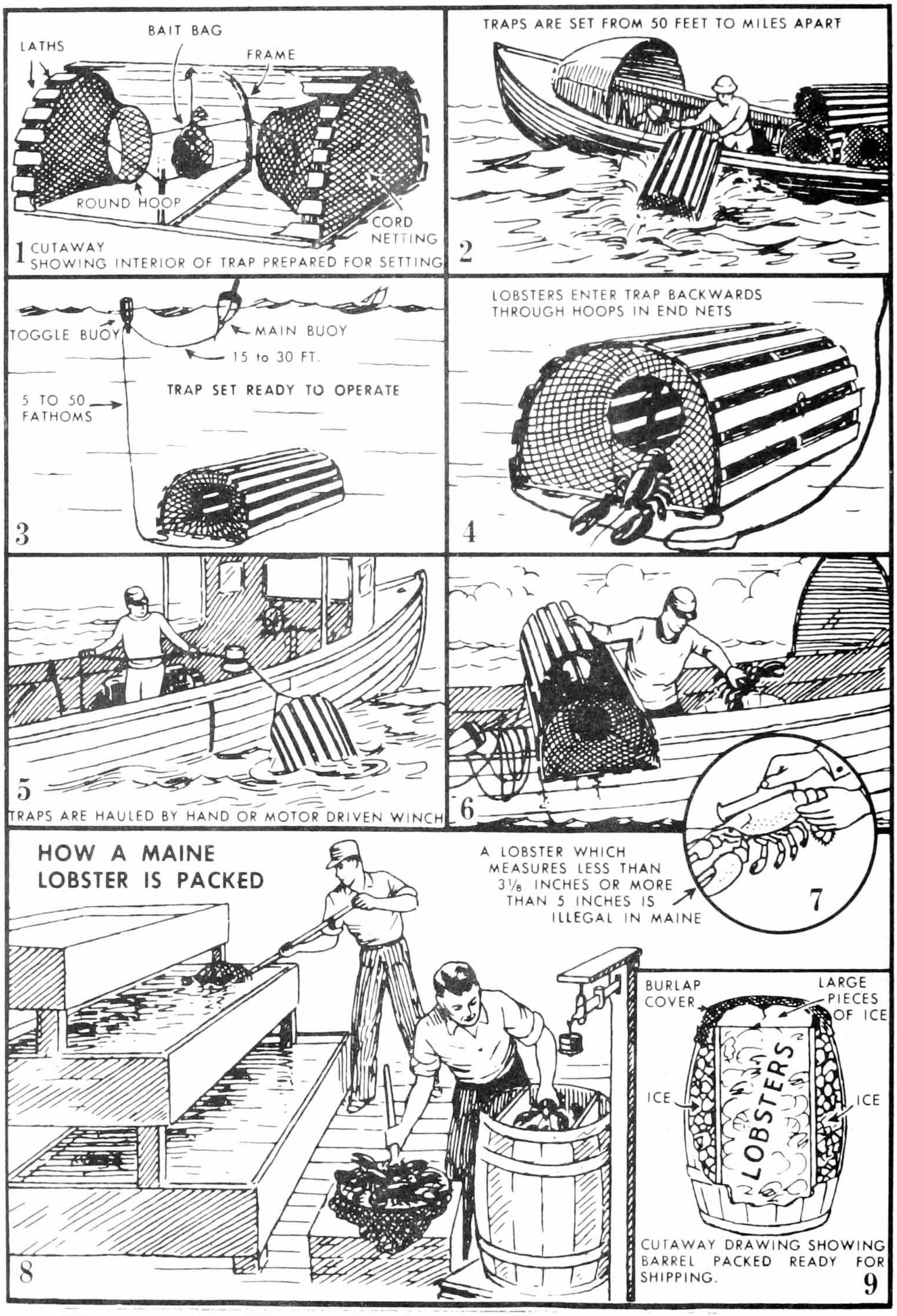

Figure 12.--Views showing how lobsters are caught and packed for shipment. (Photo courtesy of Maine Development Commission)

canned meat; only a very small quantity is frozen. Of the latter, both raw and boiled lobsters are frozen; small quantities of lobster meat are also frozen. Very little information is available regarding the freezing characteristics of lobsters and lobster meat. A few tests were conducted at a Fish and Wildlife Service laboratory (Pottinger 1950) in which whole live lobsters and whole cooked lobsters were frozen in circulating brine at a temperature of approximately 0° F., followed by storage in a room at the same temperature. The lobsters were given an ice glaze to retard desiccation, then packaged individually in heavy aluminum foil wrappers. For testing, the lobsters were thawed, and the uncooked ones were cooked by being boiled in salted water.

The frozen cooked lobsters, in general, were not satisfactory. The meat was often spongy and watery, and was not at all like that of fresh-cooked lobsters. These lobsters were hardly considered satisfactory even at the end of 1 month of storage. The frozen uncooked lobsters were judged to be quite satisfactory after being stored up to 6 months (the end of the tests) insofar as palatability was concerned. One undesirable factor must be considered, however. After the lobsters had been cooked, the meat was found to stick very tightly to the shell. The meat was therefore difficult to remove without tearing it loose and breaking it into small pieces. (United States patent No. 2,501,655, which deals with the freezing of lobsters, states that the difficulties encountered in removing the meat from the shell of lobsters frozen raw and then cooked may be overcome by a brief heat treatment prior to freezing. The theory is that the flesh immediately beneath the shell is cooked sufficiently to loosen it from the shell.)

Frozen cooked lobster meat, stored in hermetically sealed cans at a temperature of 0° F., was considered to be of poor quality even after only 1 month of storage.

Tests conducted in Australia with cooked frozen lobsters (Reay 1951) indicated that in order to retain good quality in these lobsters for a period up to 6 months, storage temperatures approaching approximately -22° F. are required. At -5° F., the limit of satisfactory storage is about 3 months, and at 15° F., deterioration is very rapid. Frozen cooked lobster meat did not store as well as whole lobsters. The probable storage life at -20° F. appeared to be about 3½ months.

Spiny or Rock Lobster

The trade in spiny lobsters in the United States is based mainly on imports, since the domestic production of this species--being confined to the South Atlantic, Gulf, and Pacific coast areas--has been relatively small. Considerable quantities are shipped into this country alive from the islands of the Caribbean and from Mexico, or as tails removed from the body and packed in ice. Large quantities of frozen tails are imported from South Africa.

Method of catching

Spiny lobsters are caught by traps, bag nets, and screen nets. A widely used type of gear is a small circular net tied to a metal hoop at the end of a long pole. The fishing boats are usually operated by 4 or 5 men.

Preparation for freezing

In the preparation of the lobsters for freezing, the general procedure is to remove the tails; the intestine is then taken out by being pulled through a small cut made in the tail. The tails are washed, graded to size, wrapped individually in moisture-vapor-proof cellophane to prevent desiccation during frozen storage, and packed in boxes for freezing.

In a procedure used in South Africa (Empey 1952), the lobsters are brought to the factory alive, washed with sea water, and the tails are removed. The tails are then placed in running sea water for a short time, and drained. Women pickers remove the intestinal tracts from the tails. The prepared tails are then graded and wrapped individually in cellophane with a paper descriptive-label inserted. Twenty-one pounds of tails are packed into 20-pound wooden boxes to allow for a 5-percent loss of weight during freezing and storage.

Freezing is done on shelf coils spaced about 9 inches apart in a room held at about -20° F. The boxes are removed after 36 hours to a storage room held at about -12° F.

The packing of these lobster tails is strictly supervised and must conform to the rules and regulations of the Director of Fisheries, Union of South Africa. The lobsters must be packed for freezing and placed in the freezer within 3 hours after being landed. If the temperature of the cold-storage room exceeds plus 5° F., the product is automatically barred from export.

A 5-pound institutional and home-freezer pack of South African rock lobster tails has been introduced on the market. The new package is made of heavy sulfate board, and contains about a dozen individual tails. The bottom of the pack has instructions for preparation. It is said that the rock lobster tails can be kept frozen for 6 months without deterioration.

Australian rock lobster tails intended for export are also subject to very rigid government inspection (Anonymous 1951). One requirement is that the catch be placed under refrigeration within 2 hours after being caught. The tails are graded into 5 sizes: (1) jumbo, 16 ounces and over; (2) large, 12 to 16 ounces; (3) medium, 9 to 12 ounces; (4) small, 6 to 9 ounces; and (5) midgets, 6 ounces and under.

Frozen cooked rock lobster tails are said to retain their flavor reasonably well in storage (v.d. Merwe and leRoux 1952), but the flesh becomes rather tough and stringy. No sticking of flesh to the shell was found to occur. Some frozen meat is packed in 1/4-pound cans with a transparent top.

CRABS

There are several species of crabs used commercially in this country, of which the blue crab (Callinectes sapidus) is by far the most important. Its range is from Massachusetts to Texas, and it is particularly abundant in Chesapeake Bay and certain parts of the Gulf coast. The next most important crab is the dungeness (Cancer magister), which is found along the west coast. The Alaska king crab (Paralithodes camtschatica, P. platypus, and P. brevipes) is found in the Bering Sea and in the coastal waters and many bays along the Alaska peninsula and the Gulf of Alaska. These are very large crabs, and they often measure several feet from tip to tip of the legs. The rock crab (Cancer irroratus) is the common crab of the New England coast; it is not utilized commercially to a very great extent. There are a number of other species of crabs available in this country, but they are of only very minor importance.

Blue Crab

The blue crab is caught by pots, trotlines, scrapes, and dredges. The crab pot functions very much as does the lobster pot, though constructed of wire mesh instead of laths. Trotlines are made of a long rope to which are attached, at intervals of about 18 inches, snoods which hold the bait. A boat, moving along the line, lifts it, and the crabs cling to the bait until they are free of the water; they then drop into a dip-net. Scrapes and dredges are towed along the bottom by boats; they are hauled in at intervals, and the crabs are dumped on deck. After the catch is culled, the crabs are shoveled into barrels and then brought to the crab-meat plants.

Blue crabs are marketed as live (hard shell) crabs, as meat picked from the cooked crabs, and as soft-shell crabs.

Hard-shell crabs

Only relatively small quantities of whole hard-shell crabs are marketed. Almost the entire production of hard-shell crabs is used for the preparation of crab meat. In the preparation of the meat of the blue crab, the crab is first cooked by steam or boiling water, and the meat is then picked from the shell by hand. The claw meat, which is darker in color, is kept separate from the light-colored body meat. During picking, the body meat is further separated into grades such as white flake, backfin lump, mixed, and other designations, which signify, to a degree, the size of the pieces of meat within a particular grade. The various grades of meat are generally packed in 1-pound cans. Practically the entire output of this meat is distributed in the fresh (unfrozen) state; the cans are packed in barrels with crushed ice for shipping.

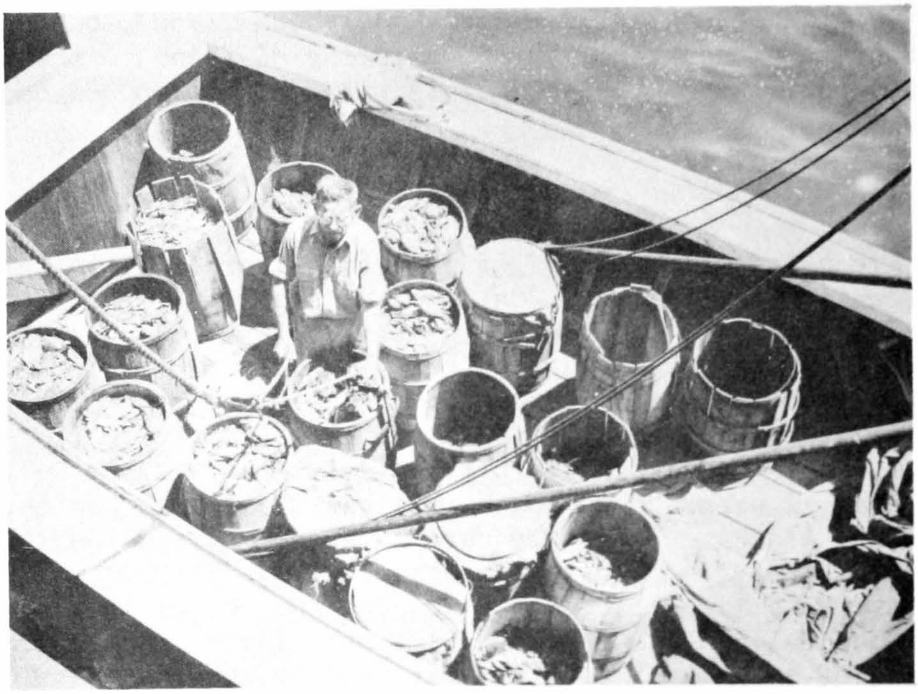

Figure 13.--Unloading barrels of live crabs from boat at crab-meat packing plant. (Photo courtesy of Southern Fisherman)

Figure 14.--Cooked crabs are dumped onto a platform to cool prior to having the meat removed. (Photo courtesy of Southern Fisherman)

Figure 15.--The meat is picked from the cooked crabs by hand. (Photo courtesy of Southern Fisherman)

The frozen product is not considered to be too satisfactory from the standpoint of quality, as it very rapidly becomes spongy and fibrous in texture and loses the delicate characteristic flavor of the fresh product. The frozen-storage life is generally considered to be not over 1 month. Sharp or blast freezers are commonly used for freezing this product; the storage temperature should not exceed 0° F.

Soft-shell crabs

During the hotter months of the year, the crabs shed their hard shells or moult in the normal process of growing. Immediately after moulting, when the new shell is still soft, they are a highly prized article of food and are shipped out alive, packed in moist seaweed. Since they moult only during the warm months of the year, they are available in the live state at that time only.

These so-called soft-shell crabs can be frozen successfully, however, and a relatively large quantity are used for this purpose. In the preparation of them for freezing, they are wrapped individually in sheets of cellophane or parchment and placed in waxed cartons holding a dozen crabs. The crabs are sometimes eviscerated before being packed. They may be frozen by the accepted methods of quick freezing and should be stored at a temperature of 0° F. or below. After extended frozen storage, they tend to become somewhat "watery" upon thawing.

Dungeness Crab

The method used for catching the dungeness crab is similar to that used in the North Atlantic lobster fishery. The meat of the dungeness crab is prepared similarly to that of the blue crab, except that the meat from all parts of the crab is generally combined into one grade. The body meat and leg meat are sometimes separated in layers in the same can. This meat is packed in waxed fiberboard cartons and metal cans of 1/2-, 1-, and 5-pound capacity. The 5-pound or No. 10 can is the most important commercially.

Small quantities of dungeness crab meat are frozen, but adverse changes in texture and flavor limit the frozen storage life of this product to a relatively short period. The meat packed in hermetically sealed cans and stored at 0° F. will keep in marketable condition for at least 3 months. Tests conducted in a Fish and Wildlife Service laboratory have indicated that the quality of this meat can be maintained for longer periods in frozen storage by packing the meat in vacuumized, hermetically sealed cans and by storage at temperatures lower than 0° F. The absence of air in the can apparently helps to retain the flavor of the meat and to retard texture changes.

Dungeness crabs are also cooked and frozen whole. The crabs are placed in large baskets and immersed in brine at a temperature of about 5° F. The crabs freeze in 45 minutes but are usually left in the brine somewhat longer than this. To prevent the brine from flooding the air spaces within the shell of the crab, resulting in excessive salt absorption when the crabs are thawed, the crabs are chilled to about 38° F. just prior to freezing, then immersed in cold water to eliminate the air. After the crabs are frozen, they are rinsed in fresh water and placed in storage at 0° F. for a day or two. They are then reglazed and stored. The frozen crabs are normally marketed within 90 days, but they have been held as long as 6 months with good results. The freezing of raw dungeness crabs yields an unsatisfactory product and is not recommended.

Alaska King Crab

It is only in the last few years that an American fishery for these giant crabs has shown signs of permanent development. Frozen king crab meat may be produced with moderate expenditure for equipment and labor. This permits a refrigerated trawling vessel to utilize the resource to advantage. The techniques used in the preparation and handling of king crab are of primary importance in maintaining the quality of the frozen product (Dassow 1950). King crab meat should be processed with utmost care to insure the maximum retention of color, flavor, and texture. The bright red color on the surface of the claw and leg meat adds greatly to the eye-appeal of this product.

Method of catching

In the Japanese fishery, king crabs are caught in tangle nets that measure about 150 feet in length and 10 or more feet in depth. The net is anchored at each end, and owing to glass buoys and lead sinkers attached to it, hangs loosely near the bottom. The crabs become entangled in the mesh, the net is lifted at intervals, and the crabs are removed by hand. The main American fishery uses the otter trawl. Large pots are used for king crab fishing in some of the inshore waters in Alaska.

Preparation of meat

The live crabs should be sorted immediately after being caught; dead, crushed, and underweight crabs should be discarded. The live crabs should be butchered and processed the same day they are caught. In butchering, the carapace is removed and the crab is split into two portions. The viscera is then trimmed away and the legs are washed thoroughly. Care must be taken in this step to avoid contamination of the meat with visceral material, which will cause discoloration and off-flavors in the finished product. The butchered crabs are cooked in boiling water for about 15 to 18 minutes. After being cooked, the crabs should be cooled quickly by dipping in cold water. In the removal of the meat from the crab legs, the leg segments are separated by hand or are sawed off on both sides of each joint and then shaken to remove the meat. The meat is washed either by spraying with water under pressure or by immersion in water or weak brine, with rapid agitation to remove adhering material. After being washed, the meat should be thoroughly drained.

Freezing and cold storage

King crab meat is much more suitable for freezing than is the meat of other species of crab. Two important factors that lower the quality of the frozen crab meat are changes in color and in texture. Careless cleaning of the meat and packaging the meat too loosely so as to leave air spaces in the package will cause discoloration of the meat. To minimize both toughening and discoloration, the crab meat should be packaged tightly in a moisture-vapor-proof container. For storage up to 1 year, a temperature of 0° F. or lower should be maintained. Storage at temperatures of 10° to 15° F. will cause adverse texture changes and excessive "drip" on thawing.

Cooked king crab meat may be frozen in the shell. Experimental samples cooked before freezing have been stored at 0° F. for periods up to 6 months without marked changes in flavor and texture. After freezing, the cooked crab legs should be glazed for storage to prevent desiccation and flavor changes. The freezing and storage of raw crab legs is not recommended, because of undesirable changes in color, flavor, and texture of the meat.

SCALLOPS

The scallop industry is located principally in Massachusetts, but Maine, Rhode Island, New York, and New Jersey also produce relatively large quantities. The South Atlantic and the Pacific States produce small amounts. Two species are of commercial importance: the bay scallop (*Pecten irradians*), and the giant or sea scallop (*Pecten magellanicus*). The bay scallop industry has declined, and at this time, relatively few are taken. The sea scallop, which is found at many places in the Atlantic Ocean from Cape Hatteras to Labrador, is now one of the major fishery resources of New England, and during the past two decades, there has been about a tenfold rise in production.

Method of Catching and Preparation

Scallops, in general, are caught at about the same locations where considerable amounts of groundfish are taken. They are caught mainly in dredges dragged along the bottom, two sets of gear being towed simultaneously, one on each side of the fishing vessel. After the dredges are dumped on deck, the catch is washed down and the trash is thrown overboard. The fishermen generally open the scallops on board the fishing vessel by inserting a knife between the two shells. The large adductor muscle or "eye" that controls the shell movement is removed. This is the only part marketed, being what in the trade is known as scallop meat. This edible part is washed carefully with running sea water, put into bags that usually contain 20 to 40 pounds of meats, and placed in ice in the fish hold. About 1½ bushels of scallops are generally required to furnish a gallon of meats weighing about 10 pounds. Less than 10 percent of the whole scallop is the "meat" that is used commercially and finally eaten. Some of the remainder is used in various ways, such as for fish bait, but most of it is discarded at sea.

From the wholesaler, scallop meats are usually shipped in 5-gallon tin cans; all fresh shipments are iced. Local practice varies, however, and in New York, for instance, scallop meats are usually shipped in bags of about 50 pounds, whereas in another city, wholesalers may sell scallops in containers holding 9 pounds.

Freezing and Cold Storage

By far the greatest percentage of sea scallop production is sold in the form of fresh meats. A smaller but still important part is frozen and held in cold storage. The peak of freezing activity occurs in the summer. In the packing of the scallops for freezing, several types of packages are used. The 5-pound and 10-pound carton is probably the most common package for wholesale use; the friction-top 1-gallon can is also used. The scallops are sometimes wrapped in cellophane sheets, in approximately 1-pound lots before being placed in the large cartons. Today the influence of consumer packaging has entered the industry, and part of the frozen production is put up in 7-ounce, 10-ounce, and other small-size packages that are overwrapped. Freezing is generally done in blast-type or multiplate freezers; the temperature of storage should not exceed 0° F.

ABALONE

The abalone is a single-shell marine gastropod or snail (Haliotis species) found on the Pacific coast from California to Alaska. Fishing, however, is almost entirely confined to the coast south of Monterey Bay, California. Because the fishery is so limited, it is protected by a law that prohibits the shipment of the product out of the State of California; abalone brought in from Mexican sources can be shipped out of state, however. These shellfish are taken by divers in waters ranging in depth from 30 to 100 feet. Owing to the difficulties in gathering abalone and the high cost of diving equipment, abalone steaks are a luxury item. The edible portion consists of the foot by which the animal attaches itself to the rocks.

In commercial processing, the animal is first removed from the shell, then the viscera is stripped off, and the foot or muscle is washed in fresh water. The abalone is trimmed of its tough outer surfaces, and the edge of the mantle is removed. Finally, the muscle is sliced, either by machine or by hand, across the grain into steaks about 1/2-inch thick, and in order to make it more tender, it is pounded on a block with a wooden mallet. The finished product is packed in 5-pound and 10-pound wooden boxes and shipped or refrigerated (Bonnot 1948). Only very small quantities of the steaks are frozen.

CLAMS

Four important species of clams are taken commercially on the Atlantic coast. These are the soft-shell clam (Mya arenaria), found from New England to the South Atlantic States; the hard clam or quahog (Venus mercenaria), which occurs along the entire Atlantic coast; the ocean quahog (Cyprina islandica), found widely scattered along the east coast; and the surf clam (Sipisula solidissima), available from Labrador to Cape Hatteras. The annual production of soft clams is diminishing in New England; however, a fishery for this clam is becoming established in the Middle Atlantic States. The fishery for the hard clam is centered largely in southern New England and the Middle Atlantic States.

On the west coast, the hardshell clam is probably the most important variety. The commercial production is limited primarily to the little neck or rock clam (Paphia staminea) and the butter clam (Saxidomus nuttali), which is similar to the eastern quahog. In recent years, much of the butter clam production has come from British Columbia, where it is relatively important in some areas. The razor clam (Siliqua patula), a thin-shelled clam, is a relatively important species on the Pacific coast and is found from California to the Aleutian Islands on surf-pounded ocean beaches.

Method of Harvesting

Various types of gear are used for taking clams. Where the beds are exposed at low tide, short-handled hoes or rakes may be used to dig the clams; in the southern states, forks and picks replace the hoes. When clams are taken in deeper water, long-handled rakes and tongs are employed. In the sail and powerboat fishery, dredges of various types are used in accordance with conservation laws of the different states (Tiller, Glude, and Stringer 1952). One type of large dredge may hold as many as 20 bushels of quahogs.

Size Designation

The clams are brought ashore in the shell and are then washed and graded into various sizes. The smallest legal-size hard clams, called "necks" or "little necks", bring the highest price and are used principally in restaurants. A clam slightly larger than the "little neck" is the "cherrystone." This is a popular size for serving raw or steamed in the shell. Clams larger than these are classed as "medium" or "chowders" and are used mostly in the preparation of chowder and for canning. Hard clams are shipped in barrels and bags; soft-shell clams are generally shipped in bushel baskets.

Processing

Soft-shell clams

Large quantities of clams are shucked for market. The clams are opened by inserting a knife between the two shells, and the meat is then cut loose from the shells. In shucking soft-shell clams, the syphon or "neck" is generally slit part way down the side, a surrounding dark-colored membrane is removed by hand, and the syphon is then cut off. The remaining meat is put into a container, such as a collander or a gallon can. The contents of a number of the filled containers may be dumped into a tank of tap water and washed by being stirred with a paddle, or sometimes the meats are sprayed with tap water. The clams are allowed to drain and are packed in containers, which may be friction-top gallon-size cans, for shipment.

Hard-shell clams

Quahogs, ocean quahogs, and surf clams are also opened with knives, but the meats, after being cut from the shells, are handled somewhat differently from the meat of soft-shell clams. The syphons are not removed from these meats. With quahogs, the meats are washed and, without any further treatment, are ready for packaging. The meats from the ocean quahog and surf clam have the dark portion (stomach) removed prior to washing. Since these meats are used mostly for the preparation of chowder, they are generally sliced or minced prior to being packaged. The friction-top, gallon can is commonly used for shipping these clams. Some plants wash the shucked clams by "blowing" them in a tank of water, similar to that used with oysters.

Freezing and Cold Storage

Clams in the shell are not usually frozen. Only relatively small quantities of clam meats are frozen, and these are largely hard clams that have been chopped or minced for use in chowders. They are packed in cartons of various sizes, with or without overwraps, and to a small extent, in 1-gallon friction-top cans. One newer type of package in use in New England is a polyethylene bag holding 2½ pounds of clams, the bag being held closed by a clip. Two of these bags are placed in a 5-pound carton; no overwrap is used. Freezing of clams may be done in blast, tunnel, multiplate, or other suitable types of freezers that are available. They should be stored at a temperature of 0° F. or below. Clams are said to lose their quality relatively fast when frozen and become tough or spongy, with a considerable loss of drip upon being thawed.

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SECTION 3

RAW, BREADED, OR PRECOOKED SEAFOODS

By John Holston, Chemist*

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ILLUSTRATIONS

HISTORY AND INTRODUCTION

The production of specialty items from marine food products has had a long and interesting history. Many attempts have been made to market a conveniently prepared compact item in accordance with the evolving principles of good marketing practice. The production of "ice fillets" (Huntsman 1931), the one-piece fish block (Crowther and Hopkinson 1953), the work on precooked foods (Osterhaug and Bucher 1945), the present-day fish fillet blocks and breaded fish squares and sticks, and the breaded raw or precooked shrimp and other items all attest to the continued interest on the part of the processor in product improvement.

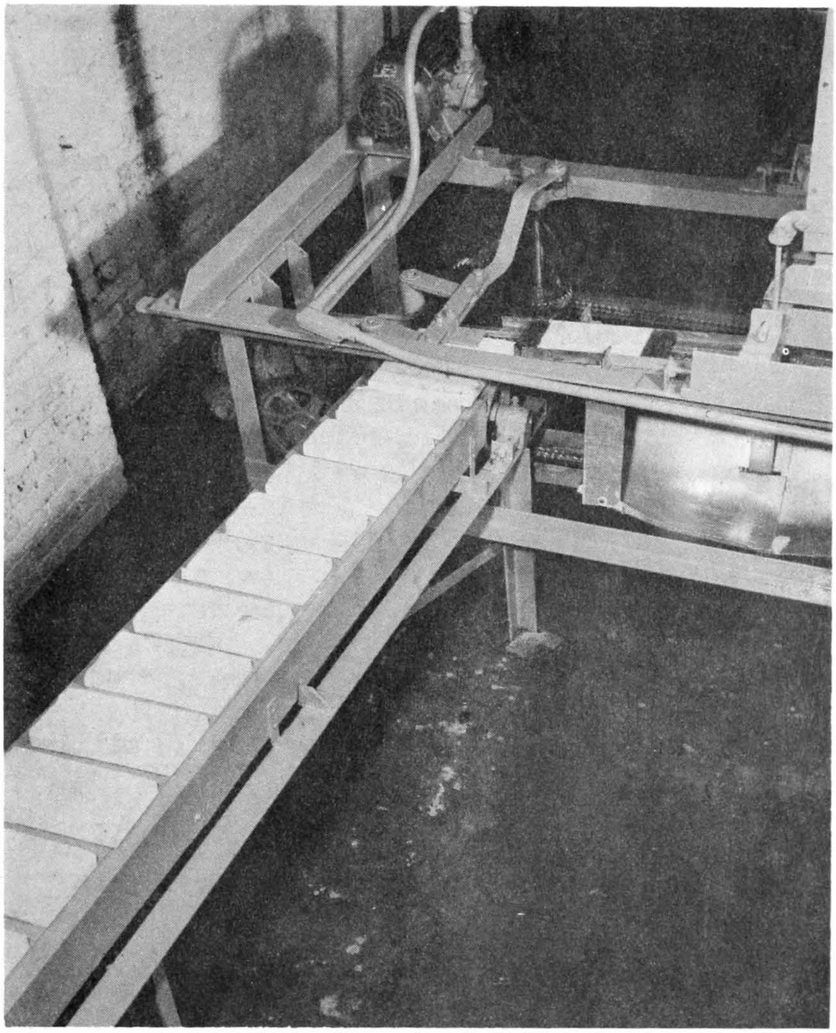


Figure 1.--Cartoned 1-pound fillet blocks being conveyed toward wrapping machine. Note uniformity of dimensions. This type of product ensures equal-size serving portions and simplifies cooking procedures in the home. (Photo courtesy of The Atlantic Coast Fisheries Company)

For many reasons, most of these innovations, until recently, were short-lived. The industry in general was averse to changes that involved substantial investments without assured return. There was a great lack of freezer-cabinet space at the retail level, and there was a widespread though baseless prejudice against the use of frozen foods as being unwholesome. Tremendous problems in safe distribution of frozen foods over long distances remained to be solved. Marketing and promotion techniques at the retail level were inadequate. Finally and most important of all, the consumer demand for such items was not great.

Today, most of these objections or problems have been solved or minimized.

Cabinet space has been enormously increased. Satisfactory marketing and distributing systems have been established. Prejudice problems have all but disappeared. The industry has been led by the successful innovations to accept and to go along with technological changes. Finally, great numbers of women--working or busy with social affairs--have demanded convenient, tasty, easily prepared seafood products.

In general, there is a great similarity in the breading and handling procedures used in the various breaded seafood industries. Differences exist mainly in the manner of initial preparation of the particular type of product. Other differences are due to economic practices peculiar to a particular region.

A detailed study of each industry is beyond the scope of this leaflet and would be repetitious. Instead, a systematic treatment of the fish stick industry--its problems, techniques, and handling methods--will be presented. Problems common to all breaded food industries will be emphasized. In addition, a short analysis of methods used in the preparation of breaded shrimp, breaded portion-controlled fish squares, breaded abalone patties, and fish pies, soups, and other products will be made.

BREADED PRECOOKED FISH STICKS

The fish stick is a uniform, compact, rectangular frozen portion of fish flesh that is cut or sawed from a fish fillet block and coated with a batter and breader; it may be either raw or precooked to the desired color. It is usually about 3 3/4 inches in length, 7/8 inch in width, and 1/2 inch in depth, and it weighs approximately 1 ounce. It is packaged and refrozen for storage and shipment. Fish sticks are comparatively new on the commercial scene, but their immediate acceptance by the public has caused a tremendous increase in production. From an initial production rate, in 1953, of 7 million pounds per year, production climbed to a rate of 50 million pounds per year, in 1954. The demand, in 1955, appeared to be leveling off at approximately 70 million pounds per year.

The production of fish sticks at present is largely restricted to Atlantic cod and to haddock as the raw materials. Other species that have been used include ocean perch, Pacific cod, and halibut. The choice of species is determined by such factors as price and frozen-storage life.

In general, the following processes are involved in the production of fish sticks:

1. Preparation of fish fillet blocks.
2. Sawing or cutting of fish fillet blocks into raw fish sticks.
3. Coating of the raw fish sticks.
4. Precooking of the coated raw fish sticks.
5. Cooling, packaging, and freezing of the coated precooked fish sticks.

Preparation of Fish Fillet Blocks

Fish Fillet Blocks: Definition, Sizes, Shapes

The raw fish sticks are prepared from frozen fish fillet blocks. A fish fillet block is a uniform, compact, and cohering mass of skinless fillets frozen together under pressure. There are at present many shapes and sizes of fish blocks, for the following reasons:

1. Each producer attempts to utilize fully the capacity of his freezer.

2. The fish stick manufacturer's methods of cutting fish sticks partially determine his requirements as to dimensions and weight of the fish blocks.

3. The size and weight of the fish sticks ultimately to be produced by the fish stick manufacturer also determine his requirements.

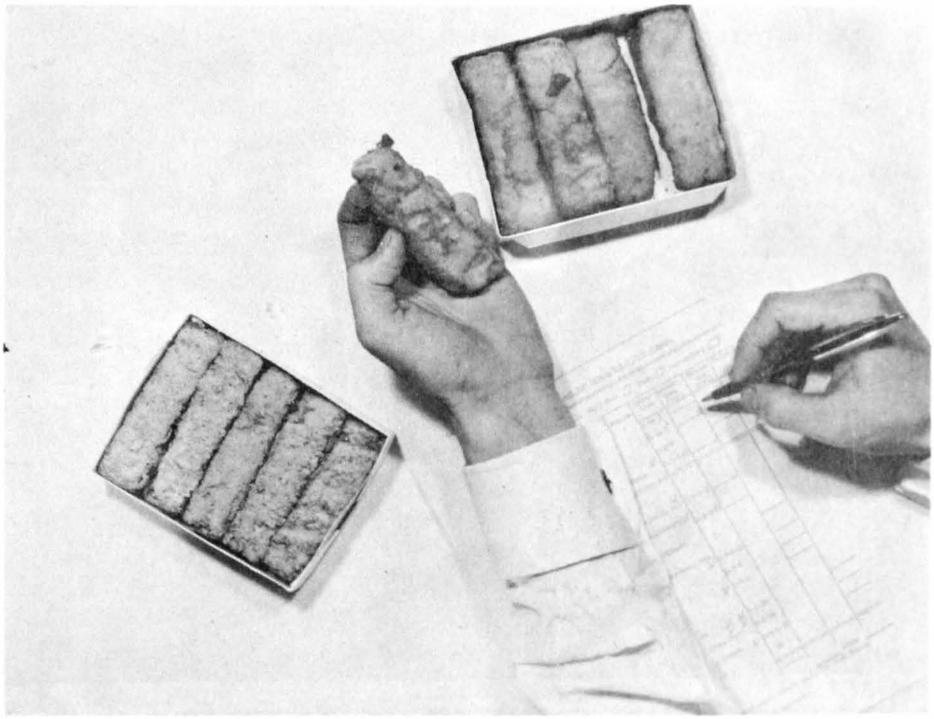


Figure 2.--The highly complex processing of fish sticks requires constant checking of the quality of the product. Packages and contents are being examined for maintenance of high standards of quality developed by the industry.

In practice, block dimensions vary from those specified by the purchaser. The degree of variation can be minimized by careful preparation of the blocks. The fish stick manufacturer, in addition to giving specifications as to dimensions, should establish tolerances for dimensional variation beyond which the blocks would be unacceptable to him. It is probable that no block should vary by more than 1/8 inch, in any dimension, from those specified. Tests performed at the Boston laboratory of the Fish and Wildlife Service have shown that a processor can easily meet such requirements.

Forming Fish Fillet Blocks

Methods of forming the blocks vary only slightly so that one example of preparation technique will suffice for illustration. The carefully prepared boneless and skinless fillets are laid in a waxed kraft fiberboard container either parallel to or perpendicular to the long axis of the container. The latter procedure is claimed by its advocates to

Figure 3.--Preparation of fish fillet blocks. Skinless fillets are carefully examined for the presence of bones prior to packing. (Photo courtesy of Diamond Fisheries, Inc.)

minimize breakage of the sticks during processing. In either case, the thick portion of the fillet is placed adjacent to an edge of the container, and the thin portion is placed in the center. The depression so formed is built up with fillets until the desired weight is obtained. Most processors add an extra 1/4 pound of fillets over and above the intended net weight to ensure against "void" formation during freezing.

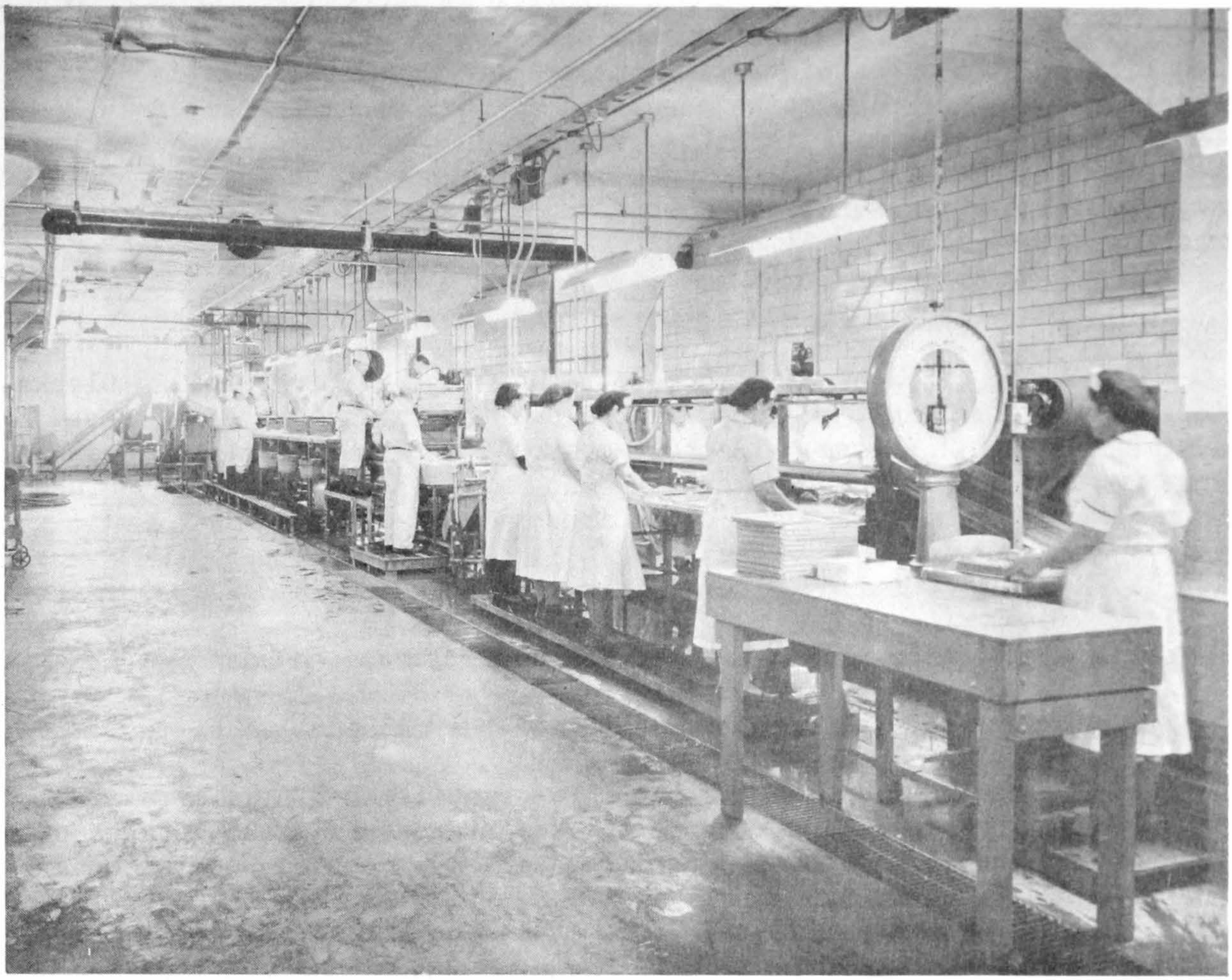


Figure 4.—Preparation of frozen fish fillet blocks. The carefully skinned and boneless fillets are packed into waxed fiberboard cartons and frozen in a multiplate compression freezer. (Photo courtesy of the Great Atlantic and Pacific Tea Company.)

Freezing Fish Fillet Blocks

The containers are then placed in a multiplate compression freezer. Two spacers, each 3/32 inch smaller in depth than the containers, are placed at the edges of each station. The result is a very slight compression of the containers when the plates are lowered. The compression smooths out the surfaces of the masses of fish. Further, since moisture-containing fish flesh will expand about 7 percent in volume during freezing, the compression thus exerted during the freezing process prevents undue localized expansion and forces the expanding fish flesh to fill all portions of the container. Spacers also prevent crushing and bulging of the thicker containers by the pressure exerted by the plates. Ultimately, when all the container is filled with fish flesh, the compression forces the still-expanding fillets to fuse together and form a single block of flesh.

Voids, the lack of fish in some portion of the block, are caused by lack of sufficient pressure on the block or by lack of sufficient fish fillets in the container. If spacers are used, the relative dimensions of the block, containers, and spacers are very critical. Other factors being equal, a matter of 1/32 inch of extra depth in the spacer will spell the difference between a good block having no large voids and one having voids that could prevent compliance with exacting buying specifications.

Sawing or Cutting Fish Fillet Blocks into Raw Fish Sticks

Many types of machines have been used in the cutting of fish blocks. Among them are scoring machines, heated cutting wires, bandsaws, gangsaws, and cutting devices. The most commonly used machines are bandsaws, gangsaws, and guillotine-type cutting machines. Each type has been used in an attempt to realize three objectives:

1. Rapid production, with a minimum of time and labor requirements.

2. Reduction or elimination of "sawdust" losses and damaged sticks.

3. Maximum safety for the operator of the machine.

In practice, compromises between the three requirements have been reached. The various processors have weighed the advantages and disadvantages of each machine and combination of machines and have decided upon methods considered most suitable to their individual requirements.

Bandsaw Cutting Operation

The bandsaw used may be any one of several commercial bandsaws designed for use in the food industry. Such saws are relatively easy to clean, and stainless steel is used on all surfaces in contact with the food. Motors are waterproofed to prevent damage during cleaning. The blade is usually corundum-tipped for resistance to wear. The advantages of using a bandsaw for cutting the sticks are:

1. The sticks produced are very uniform in shape and size.

2. Sawdust losses are relatively low when a blade of satisfactory characteristics is used.

3. Positioning of the blade is easily checked or adjusted.

Disadvantages of bandsaws are:

1. The costs are higher, owing to slow, repetitive operations requiring several machines.

2. More labor is required than with other types of cutting machinery.

3. Because of the exposed blades, the element of danger to the operator is always present.

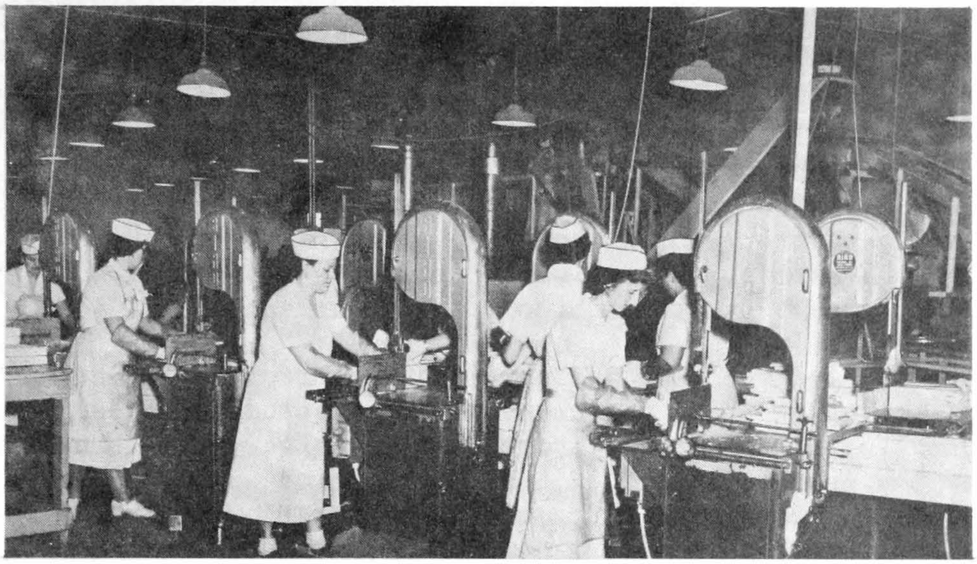


Figure 5.--A battery of eight stainless steel bandsaws used for cutting fish fillet blocks into fish sticks. (Photo courtesy of Biro Manufacturing Company.)

Gangsaw Cutting Operation

Gangsaw equipment is usually designed by the manufacturer to fit a specific processor's cutting operation. The assembly ordinarily consists of a series of circular saw blades, set at precise distances apart, on a single axis and is usually enclosed to allow room only for the entry of the block. The block is forced through the gangsaw blades as a result of pressure exerted, by the operator, on a block immediately behind it. The advantages of such a machine are:

1. It makes many cuts at one operation, reducing time and labor requirements.

2. It is safer to operate than a bandsaw, since the gangsaw blades are totally enclosed.

Two of the disadvantages of such machines are:

1. The difficulty in replacing the blade, or in adjusting it, or in checking its positioning.

2. The relatively large sawdust loss.

Prior to designing such a machine, careful consideration should be given to the characteristics of the blade, to minimize the amount of sawdust formed.

Guillotine-type Cutting Operation

The guillotine-type cutting machine consists of a very heavy, bevelled chrome-steel, horizontal or vertical reciprocating blade hydraulically driven at about 50 strokes per minute. The slabs of fish are fed past the knife either by gravity or by means of a belt. The knife is propelled with sufficient force to shear off successive portions of the slabs as they are fed into the machine. There is, as a result, no sawdust loss in such an operation. Incorrect design or improper use of the machine, however, leads to other types of losses: splitting of the blocks, shaving of the sticks, and formation of sticks distorted in shape or lacking in the required dimensions.

Performance is improved, and strain on the machine is lessened by "tempering" the block prior to the cutting operation. Tempering consists of allowing the frozen stored (0° F.) block to rise uniformly to a higher temperature (15° to 25° F.) just prior to use in the manufacture of fish sticks. Since the resistance to shear of a block of fish fillets is largely determined by the percentage of water that is frozen in the fish flesh, shearing is easier at the higher temperature than at the lower one. There is then a lesser tendency for the block to split and crack when struck by the wedge-like blade. Further, the lessened strains and stresses set up in the stick may reduce distortion or breakage of the finished sticks. A properly designed guillotine-type cutter has the following advantages:

1. There is no sawdust waste.

2. Time and labor costs are very low per unit of product prepared.

3. The production rate is very high per hour of operation.

4. The completely guarded knife is safe for use by a semiskilled person.

The disadvantages of the guillotine-type cutter are:

1. Cracking or damaging of fish blocks, when they are improperly handled, may cause greater waste than does that which occurs in the sawdust losses from the other types of machines.

2. The sticks are not always uniform in width.

3. Tempering the blocks increases labor and time requirements.

4. Repairing or repositioning the blade is costly in time and money.

Cutting Operation and Sawdust Losses

Three separate cutting operations are required to produce fish sticks from most styles of fish blocks. Although only two cutting operations are necessary with blocks that are prepared in thicknesses of 1/2 or 7/8 inches, there is a greater danger of breakage of these thin blocks during normal handling and shipping. For this reason, very few such thin blocks are prepared, most blocks being made in thicknesses of two or three multiples of 7/8 inch.

In the first cutting operation, the latter type of $1\frac{1}{2}$-inch-thick block is divided into three portions parallel to the long axis of the block. Each of the two cuts removes, as sawdust, a strip of flesh approximately 1/16 inch in thickness. The total loss is about 0.8 percent of the total block weight. Bandsaws are customarily used for this operation.

The second cutting operation splits the three portions into six slabs, each slab being one-half as thick as the original portion. Each of the three cuts removes another strip of flesh approximately 1/16 inch in thickness. The loss in this operation is approximately 2.5 percent of the total weight of the block. Bandsaws and gangsaws are customarily used for this second cutting operation.

The third cutting operation divides each of the six slabs into individual sticks. If a bandsaw is used, this is the operation causing the greatest waste, as sawdust; in some cases, the loss may approximate 6.5 percent of the total block weight. A guillotine-type cutting machine, which eliminates sawdust losses, is customarily used at this phase in the cutting of fish sticks. Processors using such cutting machines should prepare specifications for the dimensions of their blocks, with this fact in mind. A slab that produced 18 sticks would ordinarily lose 1 1/16 inches of flesh, as sawdust, when cut by a bandsaw during this third and final cutting operation. If guillotine cutters are used, the slab may be 1 1/16 inches shorter and yet produce the same quantity of sticks.

An operation that may involve wastage of from 8 to 12 percent of the raw material is an extremely important consideration in processing costs. Together, the three operations just described, even when carefully controlled, can cause from 300,000 to 800,000 pounds of sawdust waste in a plant using 8,000,000 pounds of fish blocks per year.

Coating the Raw Fish Sticks

The batter mixes and breader materials used in fish stick production are predominantly commercial products prepared in large volume by firms specializing in such items. A conception of the importance of the industry may be gained from the fact that the fish stick producers alone bought approximately 12,500,000 pounds of raw materials from these companies in 1954. Many companies in this field maintain large facilities for the development of special batter mixes and breader materials, to suit the requirements of the individual processor. As a result, most processors now have private coating formulas that produce fish sticks that are unique in flavor and appeal.

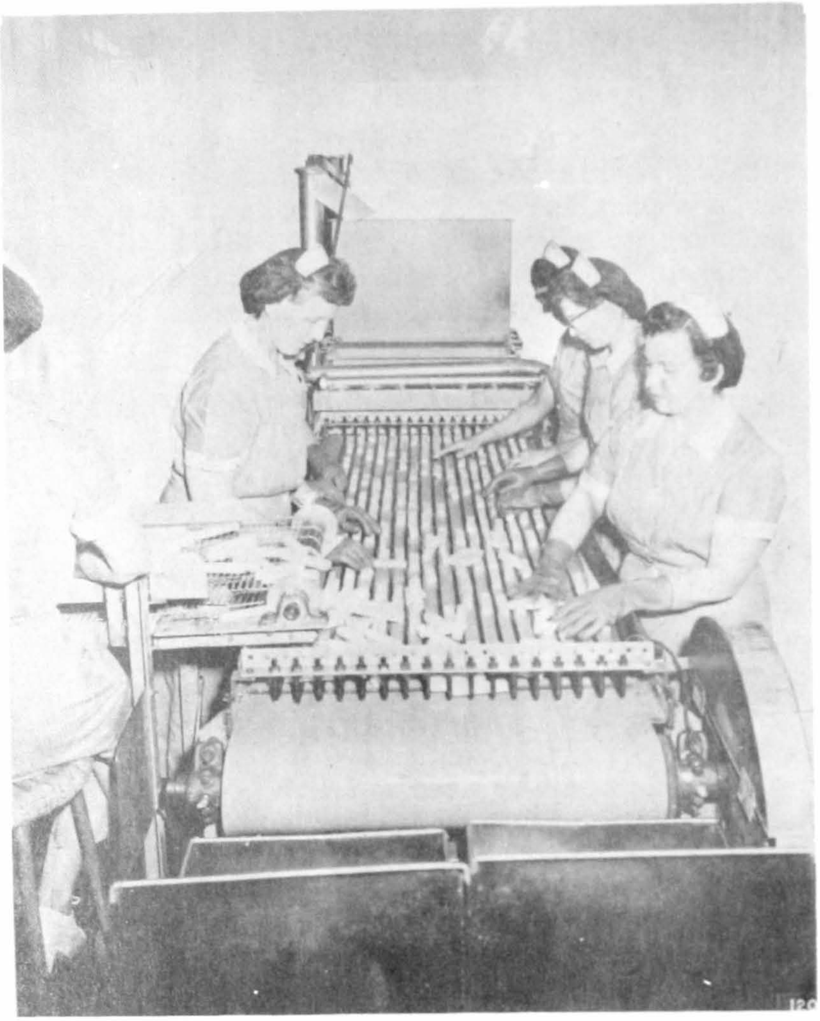


Figure 6.--The semiautomatic separation and alignment of raw fish sticks prior to application of batter and breader. This process minimizes the freezing-together of the sticks and ensures that each stick receives an adequate coating. (Photo courtesy of J. W. Greer Company)

Types of Coating Materials

Most commercial batter mixes are prepared from ground corn flour and corn meal and contain spices and nonfat dry-milk solids. A few seafood processors prepare their own batter mixes, which may vary from a simple solution of nonfat milk solids and water to elaborate mixtures containing viscosity-increasing agents such as methyl cellulose,or lactose or other nonsweet sugars.

Breader materials are even more diversified. In the main, the most widely employed breaders are based on use of either (1) ground, soft winter wheat cereals, (2) dried breadcrumbs, or (3) mixtures of these products. Small quantities of cracker meal and soy and potato flour are or have been used as either the sole or as the minor ingredients in breaders. The choice of a particular type or blend of ingredients is usually determined by the processor in consultations with his sales and production staffs and with technical representatives of the suppliers of the breaders.

Preparation and Use of Batter

Preparation of batter.--A typical batter may be made by dispersing 2 parts of dry batter mix in 3 parts of water. The resultant smooth suspension pumps easily and coats the raw fish sticks smoothly. The amount of solids suspended in a certain quantity of batter is quite critical: too dilute a suspension allows settling-out of the solids, and too concentrated a suspension is difficult to pump and to use efficiently. In properly prepared batters, the turbulence caused by the pumping of the batter prevents the settling-out of solids.

Properties of batter materials.--Viscosity, the degree of resistance to flow, can be related to batter-solids content and to weight pickup by the fish sticks during the coating process. A sufficiently accurate measurement can be made by noting the time required for a certain quantity of batter at a given temperature to flow through a small orifice in a container. Such figures are comparative only and should be related to time-measurements of a standard batter found to be satisfactory by the quality-control group. Other more elaborate apparatus may be used that measures viscosity directly.

The adhesion of batter to the frozen surface seems to be enhanced by predusting the sticks with dry batter mix prior to the application of the batter. The dry mix-solids provide a rough surface on which the batter adheres.

The amount of breader material pickup is determined by the viscosity (or rather, solids content) of the batter. Lirot (1955) found the relationship to be semi-logarithmic. To a certain degree, the more viscous (or more concentrated) the batter, the greater the pickup of breader material.

A higher solids content also appears to reduce weight losses during the subsequent cooking operation (Lirot 1955). Portions of the prepared mixes break down during heating to form glutens, which appear to seal off the surface of the flesh, minimizing moisture losses. Too high a solids content, however, prevents thorough cooking of the batter and results in a mushy, pasty coating on the finished stick even after they are reheated in the home. Usually, from 3 to 4 gallons of batter are prepared at a time, as needed, throughout the day. This procedure prevents (1) too long a period of use of one batch during which the balance of the batter may become bacterially contaminated or (2) loss by requiring the discarding of batches of batter during the several daily cleanings of the batter equipment.

Methods of Applying Batter to Fish Sticks

Manual processes.--Very few fish stick processors use wholly manual batter application processes. In one example of such operations, small stainless-steel open-mesh baskets of raw, cut fish sticks are placed in front of each worker at the batter tables. These tables have sunken, flush-mounted, stainless-steel tanks that contain the prepared batter. The baskets of raw fish sticks are immersed and swirled around in the batter. The baskets and contents are removed, allowed to drain, and are transferred to the breader tables. The disadvantages of such an operation are:

(1) The loss of batter is excessive, owing to splashing of baskets in the batter.

(2) Labor requirements are high, and production rates are inherently low.

(3) Spillage of batter on tables, floors, and personnel renders the plant unattractive and difficult to keep clean and sanitary.

Semiautomatic processes.--In more advanced equipment for application of batter to fish sticks, the raw cut sticks are conveyed to the wedge-shaped batter tank from the cutting operation.

The tank, mounted on a stand about 4 feet high, may be 4 feet in width by 6 feet in length. It is very shallow at the top, or feeding end, and about 18 inches deep at the bottom, or product end. Batter is pumped from the reservoir at the deep end through a perforated manifold along the top of the tank. The batter, under pressure, flows in a smooth stream from the shallow feeding end of the tank to the deep product end, where the pumping operation is repeated. An expanded metallic mesh conveyor belt extends over the deep portion of the tank, and the batter flows through the interstices of the belt.

The fish sticks are dropped into the flume by attendants, who then check to see that each stick is sufficiently coated with batter and that no sticks touch and freeze together. The flow of batter carries the sticks to the end of the tank, where they are caught on the conveyor belt and transferred to the breader operation.

This type of batter process has several disadvantages:

(1) The free-flowing sticks freeze together when they touch, necessitating separation by attendants and return to the batter tank in order that they can be re-covered with batter mix.

(2) Several attendants are necessary to ensure that each stick receives an adequate coating of batter.

(3) Carryover of excess batter on sticks and conveyor belt, unless removed, causes lump-formation in the loose breader materials at the next stage in the operation.

Automatic processes.--Automatic breader equipment receives the raw fish sticks directly from the cutting operation and completes the coating process, with a minimum amount of labor. This type of machinery performs the batter and the breader application in a continuous operation.

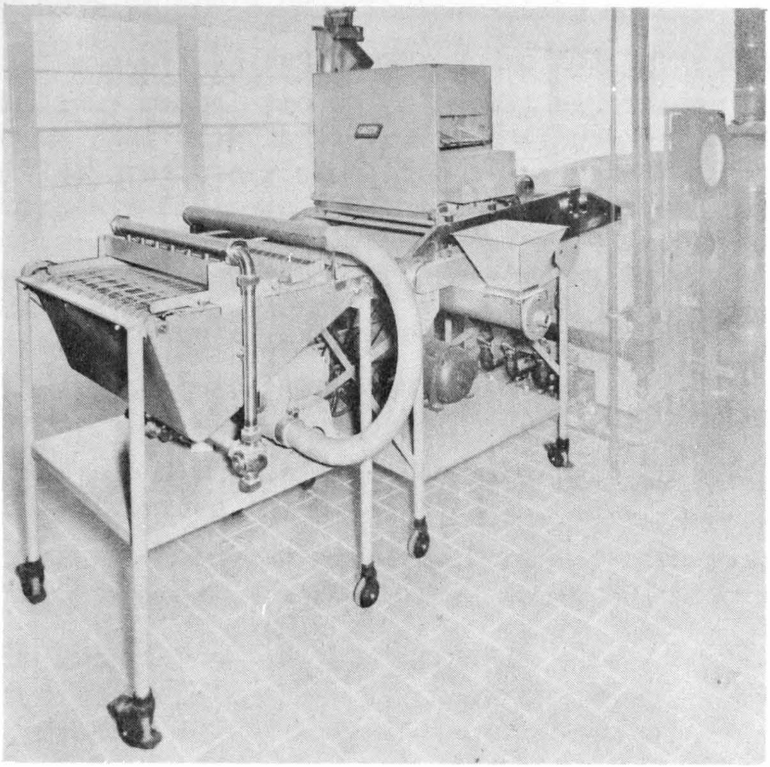


Figure 7.--Typical automatic batter and breader machines. The easily cleaned machines increase output by from 3 to 5 times over manually applied coating operations. (Photo courtesy J. W. Greer Company)

A manual or automatic "unscrambling" device may be set up immediately before the batter tank in order to separate the fish sticks and to feed them in equispaced rows into the batter tank. One type of automatic equipment consists of a set of parallel bars spaced about 1 inch apart and mounted at about the same distance above a flat, endless conveyor belt. The bars and belt cant slightly downwards at the end nearest the batter tank. When the equipment is in action, the bars are vibrated while the endless belt moves toward the batter tank.

The cut frozen sticks are fed onto the bars and, as a result of vibration, are properly spaced on the moving belt. From the unscrambler belt, the spaced sticks are gently fed onto the metallic mesh belt of the batter machine. In properly designed equipment, this separation of sticks, once attained, is easily maintained throughout the balance of the operation.

A modern automatic batter machine will smoothly coat about 2,000 pounds of fish sticks per hour. It may be refrigerated to hold batter temperatures below 50° F., to inhibit bacterial growth. The machine is about 3 feet in length, is constructed of stainless steel in the product zone, and is wedge-shaped with the deep end at the top, or feed end, of the tank. Batter is moved from the bottom of the wedge to a manifold extending over and about 3 inches above the conveyor belt by means of a motor-driven sanitary pump and piping. A steady curtain of batter falls from the manifold and forms a small puddle around the belt. The excess batter drains back to the tank. The raw, cut fish sticks, previously aligned and spaced, are conveyed through the puddle and curtain of batter. Thus, the bottoms, tops, and sides of the sticks are thoroughly coated. The coated sticks next pass under a blower, which removes the excess batter from both sticks and belt. The product is then transferred to the breader conveyor.

This type of machinery has the following advantages:

(1) A minimum in time, floor space, and labor is required per unit of finished product.

(2) Carry-over of excess batter into the breader tank is prevented.

(3) Freezing together of the batter-coated sticks is prevented.

(4) The product is smoothly and uniformly coated with batter.

(5) Drippage and spillage of batter is negligible, and the area around the batter tank is easily kept clean and attractive.

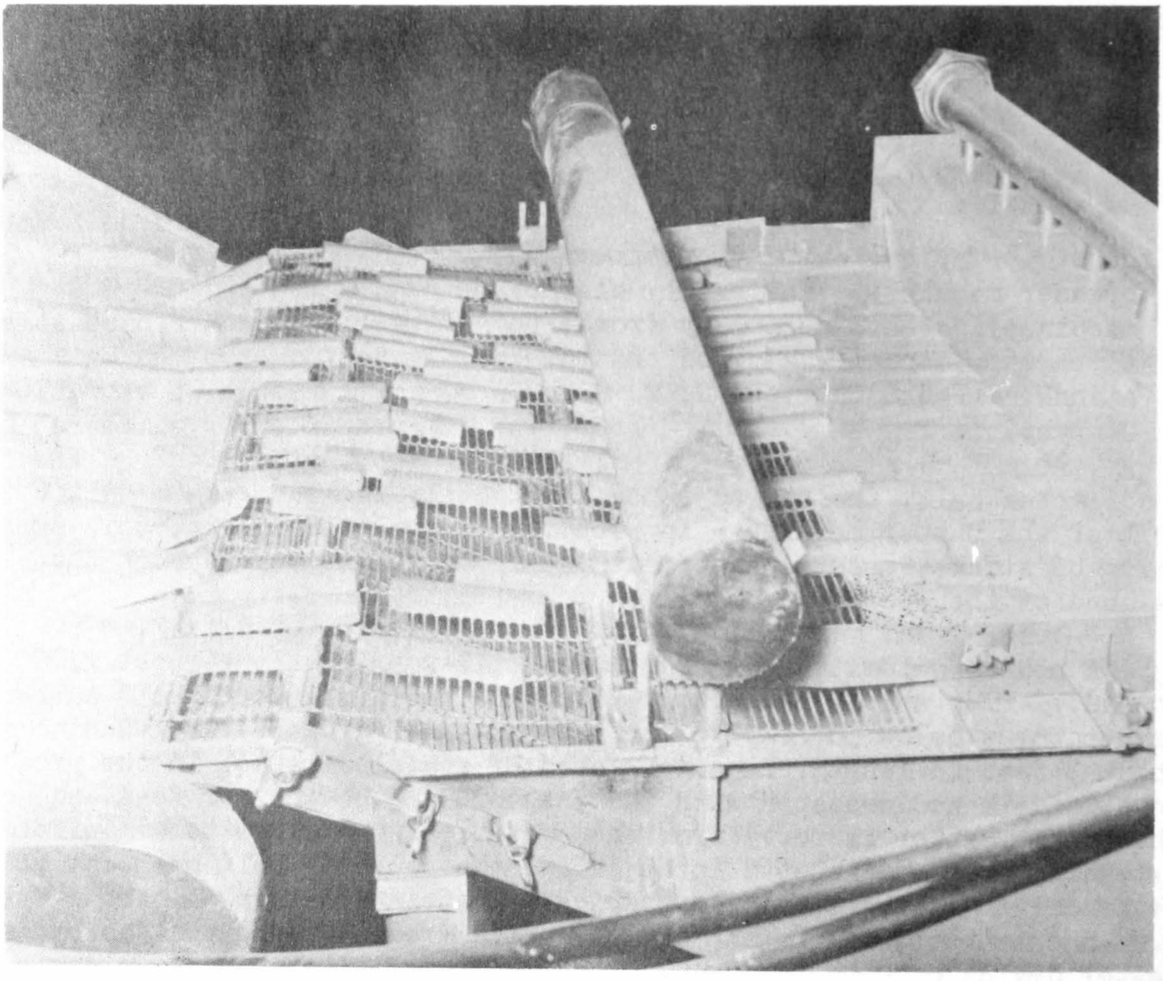


Figure 8.--Batter-coated raw fish sticks leaving batter machine. Effect of blower on carry-over of excess batter on fish sticks and conveyor belt is shown. Spacing and alignment of sticks has been preserved. (Photo courtesy J. W. Greer Company)

Methods of Applying Breader to Fish Sticks

Manual processes.--Very few processors of fish sticks use an entirely manual process of applying breader to their products. In such processes, baskets of batter-coated sticks are received from the batter tables previously described and are dumped into the breader tanks, which are flush-mounted in stainless-steel breader tables. The workers manually roll the sticks around in the breader. After the sticks have been sufficiently coated, a large-mesh screen basket is lifted from the tanks, raising both the breader material and the coated fish sticks. Excess breader materials fall through the interstices of the basket back into the tank. The basket is vigorously shaken to remove loose breader from the sticks and is then transferred to the cookers.

The disadvantages of such a process are:

(1) The loss of breader is excessive, owing to lump formation in the loose breader material from batter carry-over.

(2) Flour and breader materials fall on floors and tables during the process of applying breader to the sticks.

(3) Labor requirements are high, and the rate of production is relatively low.

Automatic processes.--In the most modern operations, the equipment for applying batter and breader to fish sticks has become so closely related as to constitute an integrated operation. The accepted automatic technique is, with minor variations, very similar to that used for batter application. The machine is constructed of stainless steel in the product zone and is powered by a $1\frac{1}{2}$-horsepower motor. The flexible stainless-steel wire breader-belt doubles back on itself and forms essentially a second belt at a slightly lower level. The breader material falls in a curtain from an overhead dispenser. An even flow of breader across the product zone is assured by a vibrator and hopper in the dispenser. The loose breader is carried with the belt to the point of direction change. Here, the product belt is vibrated by an eccentric, causing the loose breader material to fall through the mesh of the belt and into a hopper. A worm-gear in the hopper transports the loose breader to an automatic elevator that returns it to the overhead dispenser. These devices thus continuously recharge the dispenser with the surplus breader materials.

The spaced, aligned, batter-coated sticks are fed onto the layer of breader on the conveyor belt and passed beneath the curtain of falling breader, which covers the sticks to a depth of about $2\frac{1}{2}$ inches. This procedure ensures that the sides, top, and bottom of the fish stick receive an adequate coating. The coating is firmly pressed into the batter by a pressure device, which may be either a roller or a series of ascending and descending flexible rings actuated by a rod connected to an eccentric gear. After the sticks pass the vibration zone, they are freed of excess breader and, at the point of return traverse, are turned over in a fall to the lower belt. The fall is short--about 5 or 6 inches--but is necessary to remove any last vestiges of loose breader from the sticks. Removal of the loose breader prior to the cooking stage assists in the maintenance of the quality of the cooking oil. The sticks are then conveyed to the cookers.

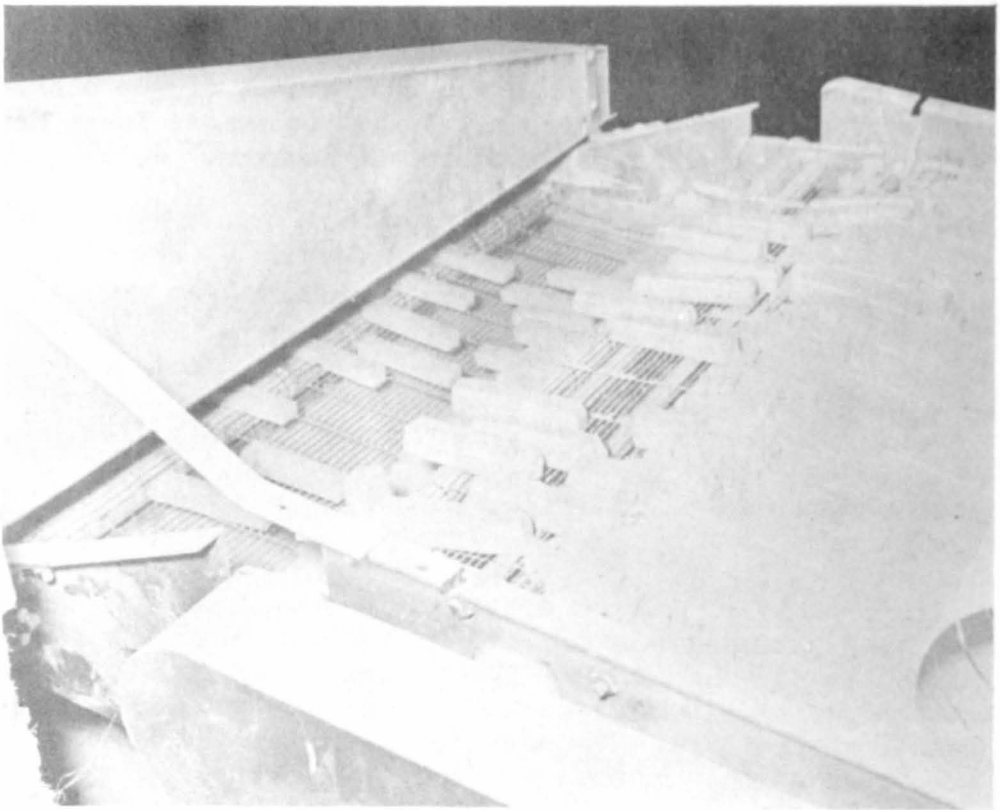


Figure 9.--Breader-coated raw fish sticks being conveyed from the breader machine. Effect of vibrator and of belt-reflection on removal of excess breader is shown. Patting device used to assure "set" of breader on sticks is shown at extreme right. (Photo courtesy of J. W. Greer Company)

Another modern automatic breading process utilizes a rotary machine that resembles a concrete mixer with openings at each end, and that tumbles the fish sticks in the breader. Raw batter-coated sticks are conveyed into the breader machine and are dropped on a layer of loose breader material. Sticks and loose breader are picked up and carried toward the other end of the machine in a series of tumbling movements induced by spiral baffles on the walls of the "mixer". The sticks and breader drop out onto a second conveyor, which transports the sticks to the cookers. The excess breader is screened out through the meshes of the conveyor belt.

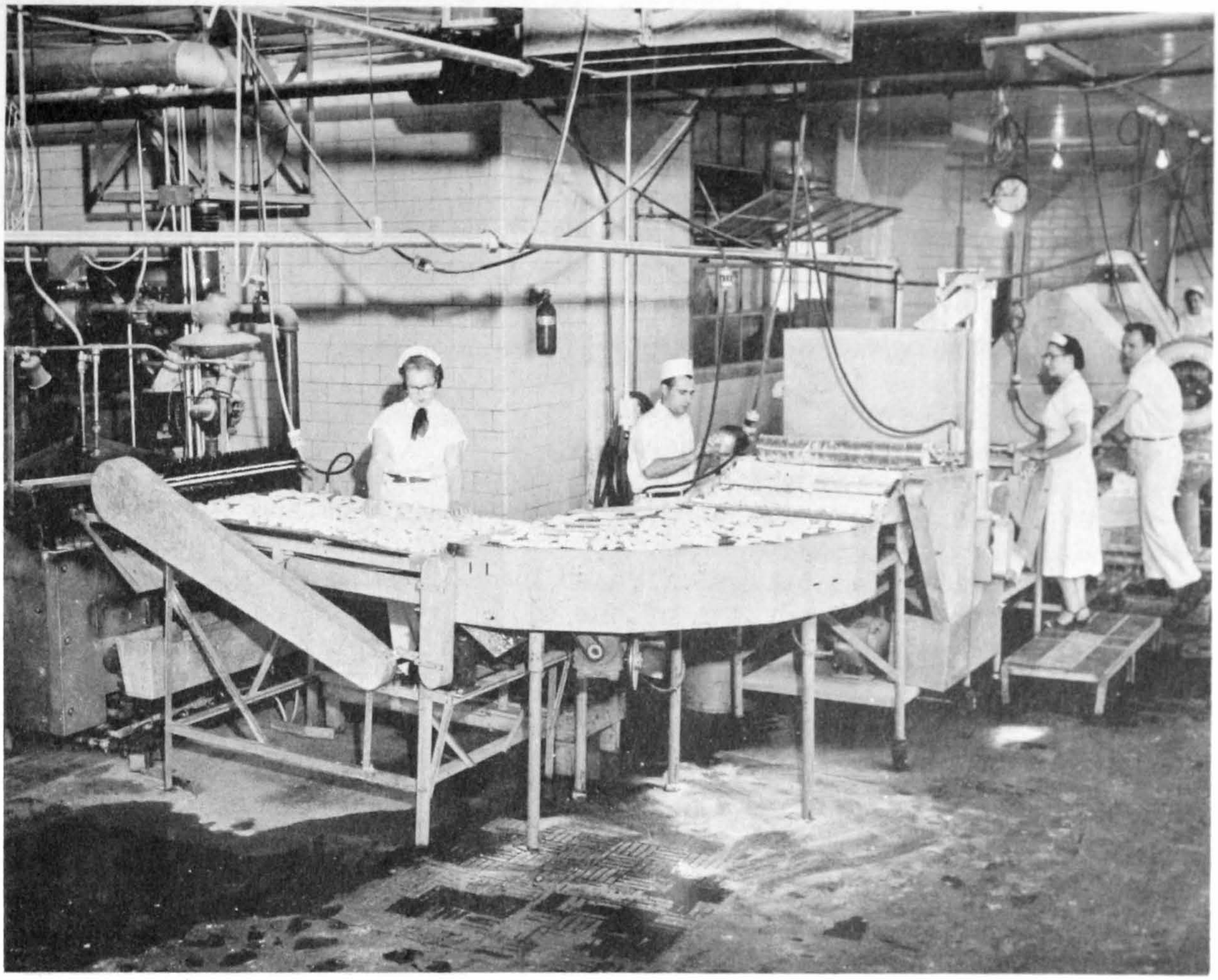


Figure 10.—Coated raw fish sticks leaving breader machine enter right-angle conveyor belt and are carried to the continuous cooker. Girl at left is examining breaded product for possible defects. (Photo courtesy of The Great Atlantic and Pacific Tea Company)

These automatic machines have the following advantages:

(1) The carry-over of excess breader into the hot oil and the incidence of loosely adhering breader on the sticks is minimized.

(2) Labor, space, and processing-time requirements are minimized, and production rates are high.

(3) There is very little loss of breader material by spillage or lump formation. Further, the neat coating-process area is attractive and is a pleasing place in which to work.

Precooking the Coated, Raw Fish Sticks

Cooking Oil Temperatures and Cooking Time

Upon completion of the breader operation, the breaded fish sticks are fried by immersion in heated cooking oil. The exact oil temperatures and cooking times used are adjusted by the individual processor to fit his needs. Many factors influence his decision; among these are the production rates in the plant, the product color and product yields desired, the quality of the oil, and the breakdown rate of the particular oil at different, elevated temperatures.

Factors affecting cooking time.--The three primary factors determining the cooking times to be used are (1) product color desired, (2) product yields, and (3) production demands. The first is determined by the type of breader material used, the temperature of the cooking oil, and the quality or freshness of the oil. The second factor is primarily a function of cooking time but is affected by oil temperature, type of breader used, and by the condition of the oil. The third factor is the fixed rate of production at which the cooker was designed to operate most economically.

Product color.--The choice of a particular color for the final product is usually made following conferences with the sales force. Consideration is given to the factors that would affect the development of the specified color. Corn-meal-base breaders produce a golden-yellow color, breadcrumbs a reddish-brown, and wheat cereals a golden-brown, after cooking. Once the desired product color is chosen, these breader ingredients may be selected or blended to result in the desired hue and intensity. By the adjustment of the cooking time and temperature, the degree of brilliance (or shade) desired may be attained. The rate at which the desired shade of color in a particular breader material is reached during cooking is determined by the cooking time and oil temperature. The higher the oil temperature, the less time required. Samples of the same lot of fish sticks cooked for 90 seconds in oil at 375° F. are very similar in color to those cooked for 60 seconds in oil at 390° F. The choice between the two oil temperatures would then be a matter of production requirements and of conservation of oil quality, other conditions being equal.

Product yields.--The changes in weight of fish sticks that occur during the cooking and cooling operation must be carefully controlled to bring about an economical and flavorful product. The coating operation causes a 20- to 25-percent weight increase in the 24- to 25-gram stick (Holston 1955b). Thus a raw breaded fish stick, designed to weigh 1 ounce (28.3 grams) upon completion of processing will, upon entering the cooker, weigh approximately 30 to 31 grams. The loss in weight during the cooking process is determined by the duration of the cooking period and the temperature of the cooking oil. The additional loss as a result of an increase in the temperature from 360° to 405° F. for a cooking period of up to 75 seconds is negligible. Fish sticks immersed for periods greater than 75 seconds undergo weight losses that increase linearly with the increase in cooking time. Because of its higher viscosity, old or "spent" oil is retained to a greater extent than is fresh oil. Thus, the use of spent oil decreases weight losses occurring during the frying process, but such use also decreases the storage life and palatability of the fish sticks.

Cooking Oil Absorption and Adsorption by Food Products

The absorption of cooking oils by fish sticks appears to vary between 5 and 15 percent of the weight of the cooked product. The usually accepted figure is about 10 percent of the product weight. Absorption and adsorption of the cooking oil by breaded food products during the frying process appears to be determined by (1) the breader composition, (2) the size of the breader particles, (3) the porosity of the breader material, (4) the increase in viscosity of the cooking oil by breakdown during use, and (5) the cooking time and the cooking oil temperatures, to minor degrees--if proper processes are used.

Effect of composition, grind, and porosity of breader material on oil absorption.--Several studies have indicated that when a wheat cereal (more than 50 percent of the sample passes a standard #60 mesh screen) breader material and fresh cooking oil are used, the oil absorption should be approximately 8 to 9 percent of the weight of the sticks. Bread crumbs, when used as a breader material, cause greater absorption of the oil, owing to the porosity of the dried material. The larger the bread crumb particles, the greater is the amount of oil absorbed. This effect may be minimized by a finer grind of the bread crumbs. Many different particle sizes of breader material may be obtained on request from the various suppliers.

Effect of viscosity of cooking oil on oil retention.--The two general types of oil breakdown during use are (1) hydrolysis, and (2) oxidation. One or both of these processes lead to an increase in the viscosity (or, roughly, increased resistance to flow) of the oil. Cooking oils, in such condition, are adsorbed or retained on the surface of the cooked food products to a greater extent than are fresh oils. An increase in retention of the oil, of approximately 2 percent of the product weight, occurs in such deteriorated oils. Thus, the use of a processing system whereby oil-breakdown is minimized, is of importance from the standpoint of adsorption. The outward manifestations of oil-breakdown may be recognized from the descriptions in the part of this section on the maintenance of quality of cooking oils.

Effect of oil temperatures and cooking times on oil absorption.--The usual spread of cooking times (60 to 90 seconds) and of cooking temperatures (375° to 405° F.) found in commercial operations has little effect on the amount of oil absorbed. The initial absorption is relatively rapid for the first 30 or 40 seconds of cooking. Absorption thereafter is relatively slow. If, however, the oil temperature is reduced below 360° F., the additional oil absorbed during the increased time necessary for the adequate cooking of the fish stick or seafood product will result in an extremely oily and unpleasing product. Fish sticks are not thoroughly cooked in the usual processing techniques, since they become too dry when reheated at home. Thus, an "adequate cook" means that the desired color is obtained, while the interior of the stick is only thawed.

The Choice of a Suitable Cooking Oil

Types of oil in use.--The decision as to which of the many cooking oils should be used is important to the processor. Corn, peanut, or hydrogenated oils seem to be of equal desirability, with hydrogenated oils affording the longer potential product storage life insofar as undesirable changes in cooking-fat flavors are concerned. Owing to the large variations in price and availability of peanut oil, corn oil has become the oil of choice among processors using low-melting-point (liquid) oils. Cottonseed and soy-bean oils have never been used to a great extent in the breaded precooked seafoods industry. Today, the hydrogenated (treated vegetable oil) and natural corn oils are used by the greater portion of the industry.

Effect of type of oil on processing procedures.--Sharp distinctions exist between the various characteristics of hydrogenated ("hard") oils and of liquid oils, and processing procedures must be varied to suit the particular oil chosen for use. An enumeration of these distinguishing characteristics follows:

(1) Use of a hard oil appears to ensure retention of good oil flavor during long storage of fish sticks. Storage studies at the Boston laboratory of the Fish and Wildlife Service have shown that storage for a period of 12 months of fish sticks containing hard oil is possible if all other quality-affecting variables are controlled. None of the samples prepared with liquid oils had a storage life in excess of 8 months.

(2) The high "freezing point" of hard oil speeds up the time required for the product-cooling process essential for precooked foods. The hard-oil coating rapidly cools to room temperature and "coagulates." With oils of lower freezing points, longer and more complex cooling processes are required to allow escapement of water vapor from the hot food products. Unless the vapor is "sealed in," as probably occurs with hard oils, or is allowed to escape, a heavy unsightly frost formation occurs in the sealed package during the freezing process.

(3) Upon emergence from the cooker, the sticks are crisp and relatively stiff. After extended cooling, the sticks become limp and soggy with increased incidence of breakage and damage during handling and packaging. Fish sticks prepared in hard oils require only a short cooling process, are packaged while still relatively stiff, and

apparently undergo a lower incidence of this type of damage.

(4) The packaging of precooked products prepared in hard oils is not as complex a problem as is that of products cooked in liquid oils. The latter require a glassine laminate on the interior of the package to prevent excessive oil-staining of the waxed, chipboard container. The laminate, where affected by moisture, becomes wrinkled and unsightly. No glassine is required for packaging of products cooked in "hard" oils.

(5) Hard oils may solidify in patches on the surfaces of food products while freezing. The solidified oil masks the natural golden-brown color and imparts to the frozen product a somewhat unsightly dull grayish color, which disappears upon heating. This solidification does not occur when liquid oils are used.

(6) Special procedures are required for melting hydrogenated oils prior to use in the cooker, as indicated in the section on fryer design. Such procedures are not required for the use of liquid cooking oils.

(7) To a discerning taster, a distinct flavor, feel on the palate, and odor characteristic of hard oils can be found in products prepared in such oils. Users of hard oils have found, however, that these characteristics are not noticed by ordinary consumers and, even when pointed out, are not considered particularly objectionable. Products freshly prepared in good quality liquid oils have a very pleasing flavor and aroma distinct from products processed in hard fats.

(8) "Welding", the mutual adherence of the frozen sticks, which requires knives and heavy pressure for separation, occurs commonly when hard oils are used for cooking. On the other hand, welding does not commonly occur when liquid oils are used.

Methods of Frying Fish Sticks

The two commonly used methods of frying breaded fish sticks are the batch process and the continuous process. The two methods differ, essentially, in that in the batch process, loaded trays of fish sticks are immersed in containers of hot oil, whereas in the continuous process, an endless belt conveys the sticks through the heated oil.

Batch-frying of fish sticks.--The use of a batch-frying process requires the placing of the fish sticks in trays. As the sticks leave the breader conveyor, they fall onto a shallow tray of interwoven metal mesh. The tray usually measures 23 inches by 32 inches and contains approximately 70 to 100 fish sticks. A worker supervises the operation and controls the number of sticks allotted to each tray. When the required number of sticks is obtained, the worker pushes the tray to one of four sorters and then places another empty tray in position for filling. The sorters arrange the sticks in fairly orderly formation on the trays to promote uniform exposure of the sticks to the cooking oil. The trays of fish sticks are next placed in a rack near the batch-fryer, for processing when space is available in the cookers.

A typical batch-fryer is initially charged with about 275 pounds of oil and produces from 175 to 200 pounds of fish sticks per hour. The thermostatically controlled, gas-burning fryer supplies approximately 120,000 B.t.u.'s of heat energy per hour. An automatic safety device cuts off the supply of gas if the flame is extinguished. Proper combustion for efficient heating is obtained by adjusting the air-gas mixture admitted to the burners. The gas flames are directed into stainless-steel tubes that pass through the oil chamber. A slight differential in atmospheric pressure, maintained by vertical flues attached to the ends of the flame tubes, assures that the hot gases are drawn through the heat-exchange tubes. The heat from the gases is transmitted by the tubes to the surrounding oil. Convection currents thus set up in the oil aid in the distribution of the heat throughout the tank above the tubes.

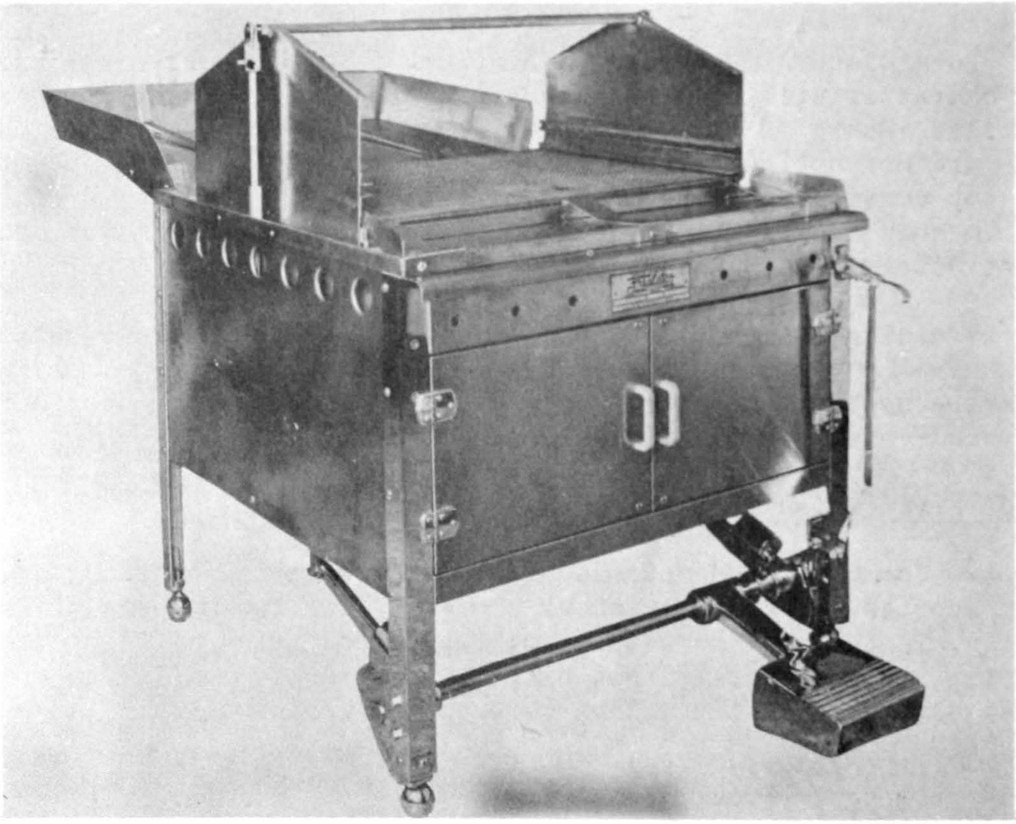


Figure 11.--A batch-type fryer used in the cooking of fish sticks. Foot-treadle is at base of fryer. Receptacle for trays is at top and chainage rack is at rear of fryer. (Photo courtesy of J. C. Pitman and Sons, Inc.)

The oil chamber of a batch fryer is usually cubical in shape above the heater tubes. Below the tubes, in one particular fryer, however, the oil chamber is triangular in shape. A very sharp reduction in oil temperatures--as much as 100° F.--can be observed between the oil above the tubes and the stationary, trapped oil below them, in this particular fryer. One advantage of such construction is that the breader materials that fall off the fish sticks during cooking, sink down into the relatively cool, stationary oil beneath the tubes and remain there. As much as 60 to 70 pounds of oil-soaked breader have been removed from such a tank after an 8-hour production of 1,600 pounds of cooked fish sticks. The entrapment of the breader material in the relatively cool oil, according to the manufacturer, minimizes charring of the breader and the consequent catalyzed breakdown of the cooking oil.

Cooking oil in use in batch fryers is very seldom discarded. Usually there is some form of oil filtration during use. The oil charge is removed for regularly scheduled cleaning of the fryer and then reused. Supplementary quantities of oil are added, as required,to make up for that absorbed by the product. Drainage of oil at the specified clean-up intervals is facilitated by two valves, the first being just above the flame tubes and the second being at the lowest point in the oil chamber below the tubes. The oil in the upper portion of the chamber is drained off into one container; then the oil in the lower chamber is drawn off to a second container. This method minimizes mixture of the clean oil at the surface with the oil containing the deposited breader materials.

To charge the fryer with breaded fish sticks, the worker removes the trays from the rack and slides them into a movable receptacle on top of the fryer. Though the receptacle can hold two such trays, some operators use only one tray at a time. This technique shortens the period required to bring the oil back to the desired cooking temperature and allows a slightly greater over-all production rate. If the temperature of the oil is within the established range, the receptacle containing the tray or trays of fish sticks is lowered into the oil by depressing a foot treadle, and a timing mechanism on the fryer is set for the desired cooking interval. After this period has elapsed, the timer causes a bulb to light. The worker, alerted, raises the receptacle from the hot oil. The tray of cooked sticks is pushed to a draining shelf in the rear of the fryer by insertion of another tray of raw sticks into the receptacle. After the lapse of a suitable interval, for drainage, an assistant transfers the tray to a cooling cage or tunnel.

One form of fryer that is presently available has an automatic timing mechanism. The trays of cooked sticks are raised from the hot oil automatically at the end of the appointed cooking period. This fryer has been used for the frying of both breaded shrimp and fillets.

A batch-type fryer has the following advantages:

(1) It is more readily adaptable to the varied demands of a small processor.

(2) It is inexpensive to buy and requires only a small space, which two factors together probably make it preferable for small, intermittent operations in which less than 800 pounds of product are produced per hour.

(3) It is claimed that this method of frying, owing to the segregation of the loose breading in the cool oil, is less destructive to the cooking oil than are the more drastic oil-heating processes used in some continuous cookers.

The disadvantages of a batch-frying process are:

(1) It is limited in capacity; a battery of these fryers is required to attain a production rate comparable to that of the smallest satisfactory continuous fryer.

(2) A larger labor force is required than for continuous frying processes of the same capacity.

(3) Oil waste arising from dripping, splashing, and spilling is greater than in the continuous process.

(4) It is difficult, if not impossible, to maintain uniform oil temperatures and cooking times throughout the operating period, in any one fryer and between fryers.

Continuous frying of fish sticks.--In continuous processes, the coated fish sticks are conveyed, as prepared, through a tank of heated oil. A continuous cooker is designed to maintain the proper processing temperatures, under full production rates, with a minimum temperature drop during cooking and with high efficiency of heat transfer.

A typical continuous cooker may be designed to produce up to 2,000 pounds of finished product per hour and to use either hydrogenated or untreated vegetable cooking oils. Such a machine might be 24 feet in length and about 5 feet in width. In general, the cooker, when the sides are removed, resembles a shallow, inverted trapezoid. It is equipped with a fume hood attached to an exhaust system. The fish sticks are conveyed through the cooking zone on an endless stainless-steel wire belt. A hold-down belt immediately above the conveyor may be used to ensure complete immersion of the product in the cooking medium.

The cooking oil is constantly circulated through the cooking zone, into the filter system, and over the heat-exchange surfaces. The initial charge of oil may be 200 gallons. At any one moment, approximately one-half of the oil is in the cooking zone, and the other half is being run through a coarse primary filter and reheated. Since flow rates of the

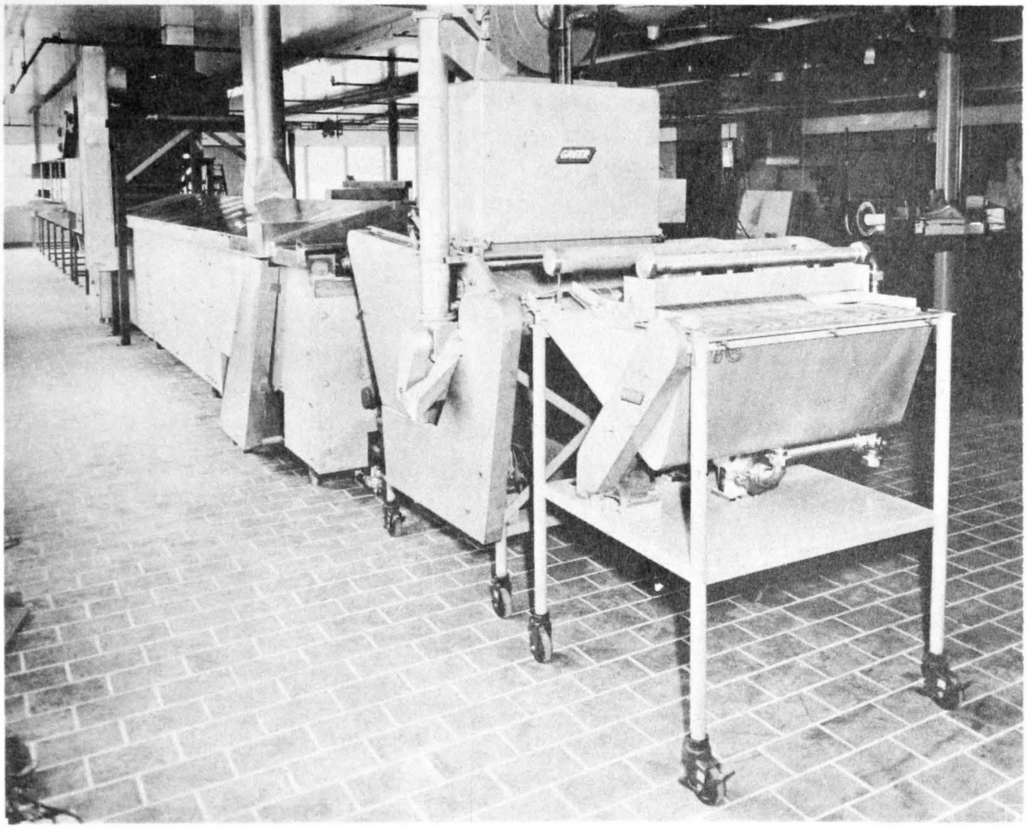


Figure 12.--View of continuous operation for processing of precooked fish sticks. Batterer and breader machines are in foreground. Continuous cooker, overhead multitier cooler and packaging tables are in the background. (Photo courtesy of J. W. Greer Company)

cooking oil may be as high as 200 gallons a minute, impelled by a high-temperature pump, the entire charge of oil may pass through the cooking zone, filter, and reheat cycle every minute. As a result, the oil-temperature drop in the cooking zone will not be large, and provided the heat-exchange surface is adequate for the cooking load, the proper operating temperature will be reattained during the reheat portion of the cycle.

A well insulated cooker having highly efficient heat transfer can produce 1,800 pounds per hour of finished fish sticks with a heat input of 1,000,000 B.t.u. per hour. Some cookers, owing to thermal stratification of slowly moving oil and high heat losses because of insufficient insulation, require the same quantity of heat for much lower production rates.

Two basically different designs for direct reheating of the cooking oil have been developed for continuous fryers. In the one type, several manifolds pass through the hot oil in a direction perpendicular to the long axis of the cooker. The burning gas fills the manifolds with the heated products of combustion. As in the batch-fryers, the manifolds act as heat-exchangers and, by conduction, heat the slowly moving oil in the tank. Convection currents thus set up in the oil by these differences in temperature tend to promote circulation of the reheated oil around the tank. These convection currents are further reinforced by the pumping of a portion of the oil through an external filter apparatus and back to the feed end of the cooker.

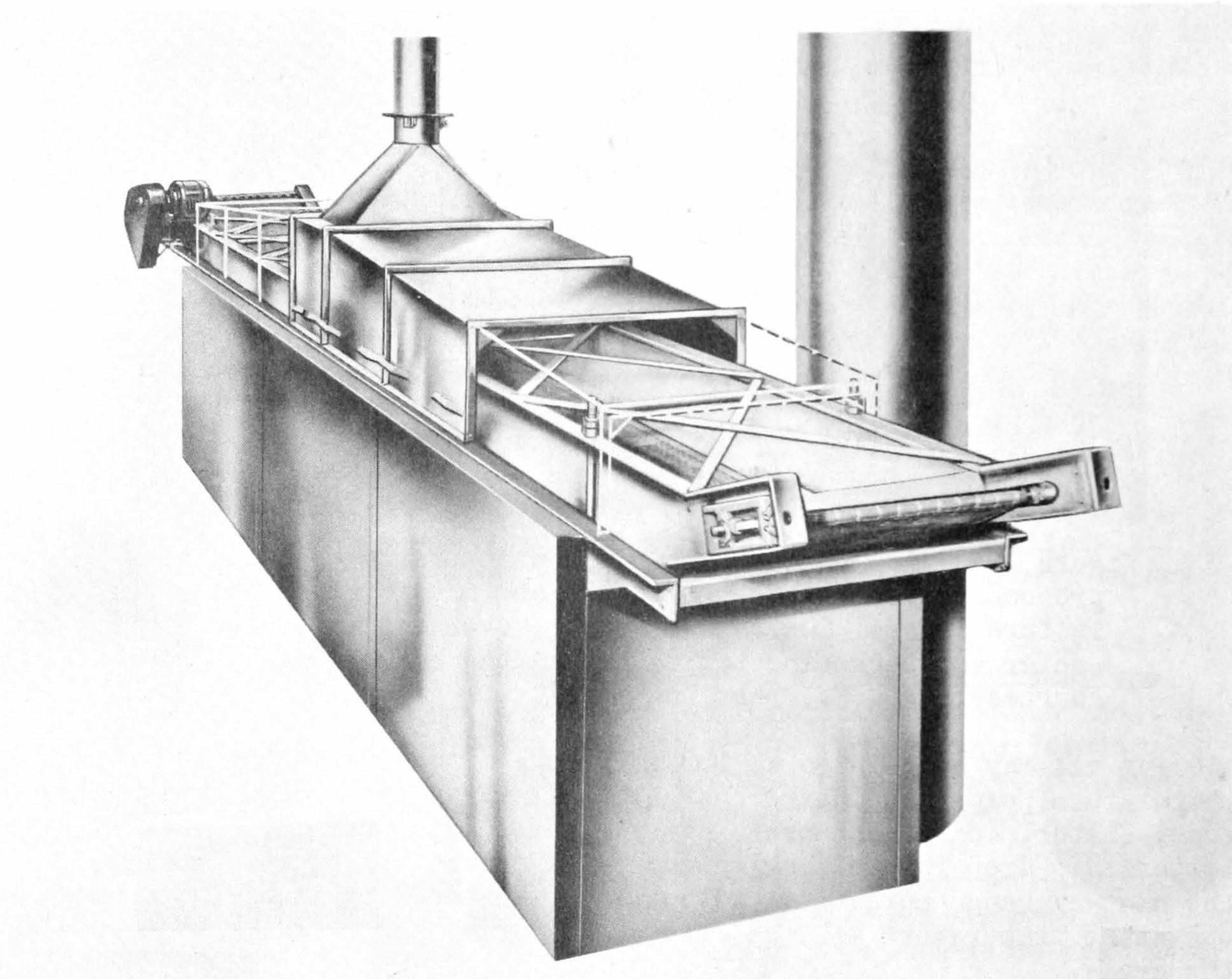
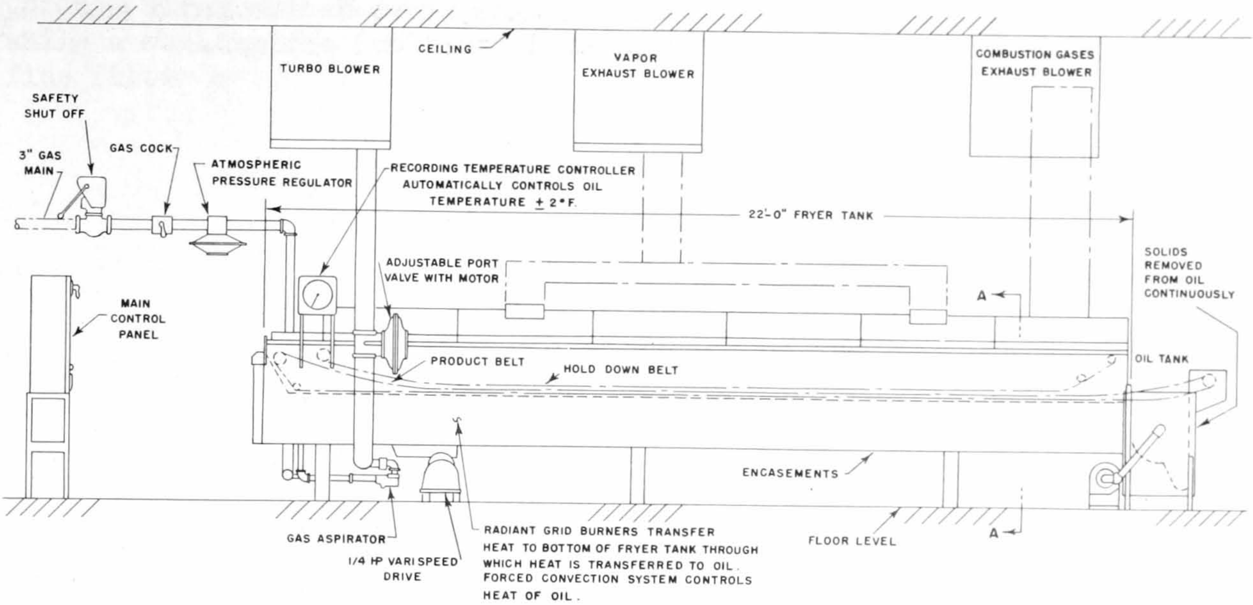
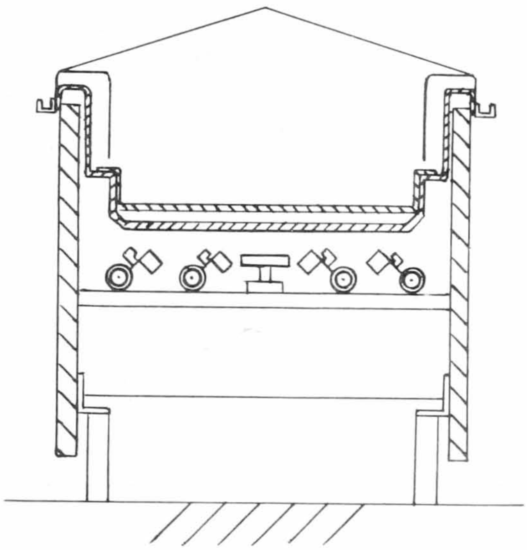


Figure 13.--View of continuous cooker used in fish stick processing. (Photo courtesy of Artisan Metals Products, Inc.)

The second major cooker design utilizes several long banks of refractory material, parallel to and immediately below the long axis of the cooker and to the oil flow. The refractory material is raised to white-heat by gas flames and, by radiation, heats the metal surface above. A thin film--approximately 640 pounds of oil every half minute--is pumped along the upper surface of this heated metal surface and thence back to the head or feed end of the cooker. The equipment, by radiation of heat



SIDE ELEVATION



SECTION A-A

Figure 14.--Schematic drawing of a radiant-heated, continuous, deep-fat fryer used for the cooking of fish sticks. (Photo courtesy of J. W. Greer Company)

over a large heat-exchange surface and by rapid movement of the oil in the tank in the form of a relatively thin film, through a complete cycle every minute, prevents thermal gradients in the oil and localized overheating.

Filter design.--Many types of filters have been studied and discarded in the search for a suitable filter for these continuous cookers. The filtering problem is of great interest to the processor because of the necessity for conservation of the initial high quality of the cooking oil. Decomposed oil imparts an unpleasant color and flavor to the cooked product and, if a quality product is to be made, must be discarded and replaced rather than be used by absorption in the food product.

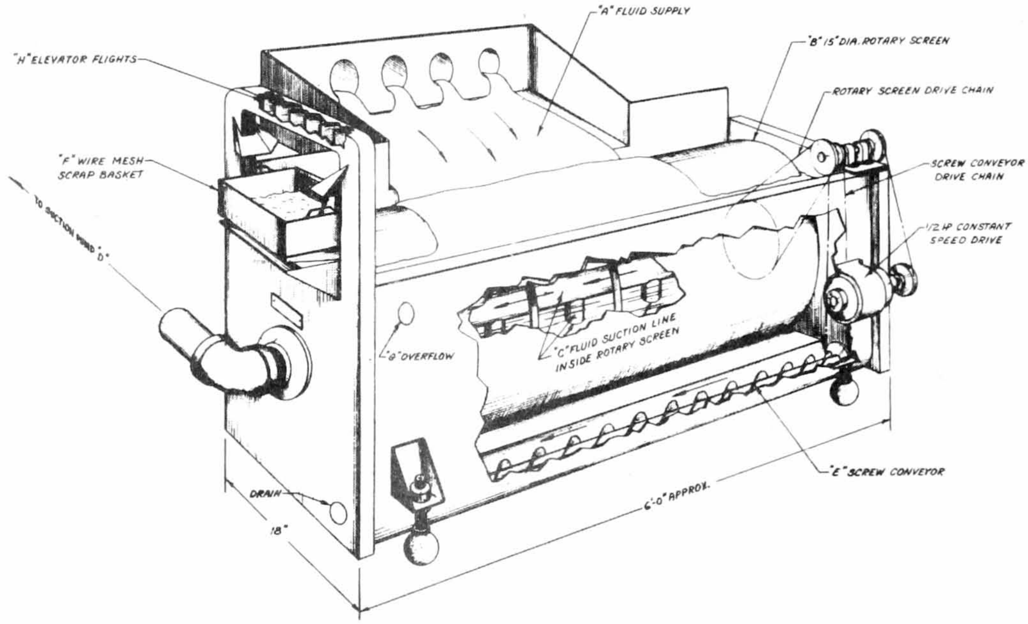


Figure 15.--Schematic drawing of a continuous primary filter for the removal of solids from cooking oil. Capacity of filter is 200 gallons per minute under ordinary processing conditions. (Photo courtesy of J. W. Greer Co.)

A major factor in causing oil decomposition is the breader material that falls from the fish sticks during the cooking process. The material is rapidly charred and appears to form decomposition products that accelerate the breakdown of oil. The decomposed oil is absorbed by the fish sticks, with the formation of an unpleasant, dark, off-color and a "scorched" oil flavor. Further, the excessively deteriorated oil must then be totally replaced instead of being used up by absorption in the product.

The first filters were of the multileaved filter-press type. The design was soon changed, owing to the slow rate of filtration and to the fact that the oil, while being filtered, was aerated, which accelerated the decomposition.

Another system uses a coarse fiber filter and a bed of fine filtering agent, such as diatomaceous earths, for a one- or two-stage filtration. The system is flexible in that a large quantity of oil can be passed through the coarse filter and back to the cooker in a minimum of time, while a small portion of the oil is allowed to percolate through the fine filter bed.

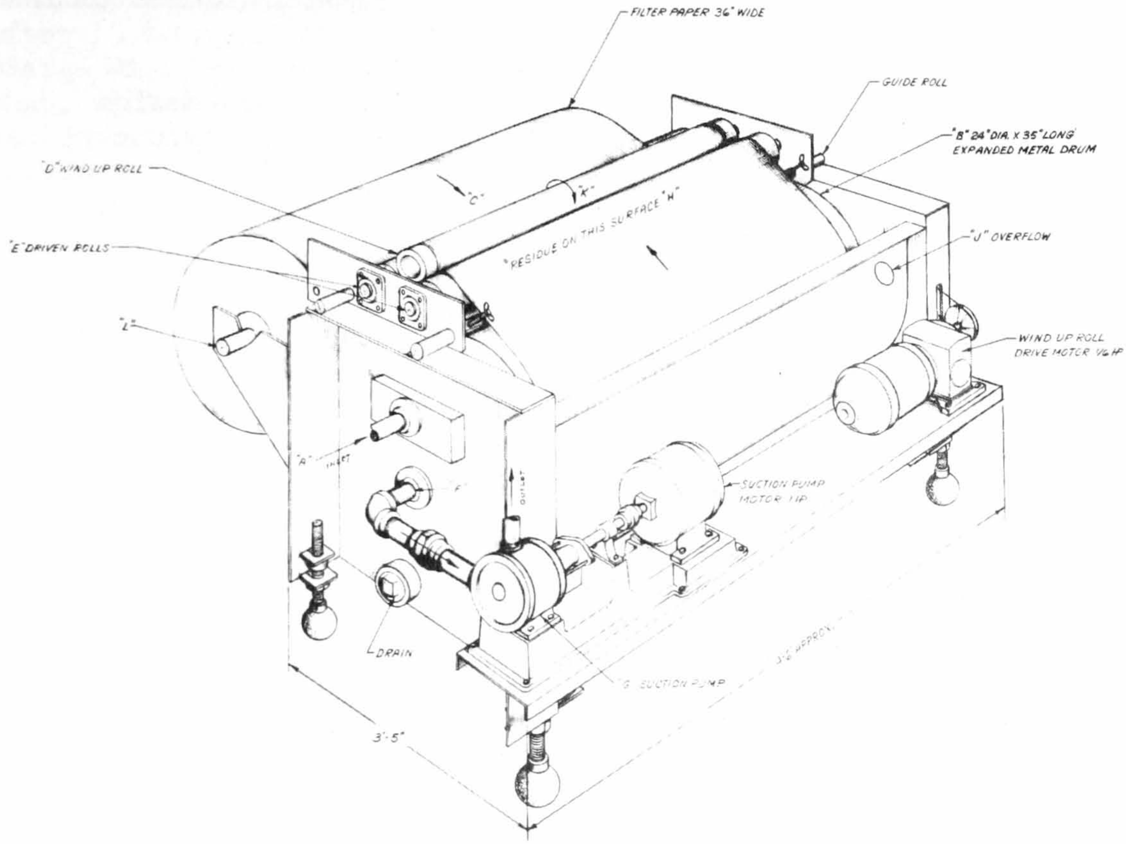


Figure 16.--Schematic drawing of an auxiliary continuous filter for the removal of very finely divided solid particles from the cooking oil. Capacity of filter is approximately 10 gallons per minute under ordinary processing conditions. (Photo courtesy of J. W. Greer Company)

A third system utilizes a fine-mesh screen on a revolving drum for rapid and continuous filtration of the hot oil. This filter is self-cleaning. The entire charge of oil (640 pounds) may be clarified in a period of 1 minute by passage through the filter. Suspended particles with a long axis or diameter of 0.2 millimeters or larger are removed, provided the amount of suspended material is not too great. The particles are removed from the tank by a screw conveyor and elevator system that deposits the particles in an external scrap container.

A fourth type of continuous filter system utilizes a roll of filter paper to achieve a very fine clarification of the cooking oil. The paper covers the expanded metal surface of an otherwise closed drum suspended in a tank. Cooking oil enters the tank and filters through the paper into the drum. A 1-horsepower suction pump removes the oil from the interior of the drum by means of a hollow pipe that also forms the axis of the drum. The filter-paper surface is constantly renewed from the roll of paper attached to the exterior of the tank. Such a system has a clarification capacity of 64 pounds of oil per minute. Suspended particles with a diameter or long axis of 0.02 millimeter (0.0008 inch) or greater are removed from the oil by this unit.

Basic design requirements in fryers.--Several important design requirements are common to all types of fryers. They are absolutely necessary for good operations, in terms both of economy and of a good-quality final product.

1. The fryers should not expose, to the oil, any copper, copper-containing, or other catalytically active metals that may cause its deterioration.

2. Care should be taken to minimize or eliminate "hot-spots" or localized over-heating of the oil. In a properly designed cooker the trapping of the oil in stagnant pockets or eddy-current areas is also minimized. The placement of baffles and of heating elements should be carefully planned in order that uniform and continuous oil movement will be facilitated. The greater the heat-exchange surface available to the moving oil, the smaller is the heat differential between the oil and the heat-exchange surfaces necessary to maintain a given oil temperature. Since most oils tend to breakdown at temperatures of about 450° F., heat-exchange designs that lead to temperatures as high as 1,250° F. in the heating tubes are obviously too high for the continued maintenance of quality in the cooking oil.

3. Any type of filtration system should be designed to prevent aeration of the heated oil. The exposure to the atmosphere of trickling streams of hot oil from a filter press should be avoided,since oxygen actively combines with heated oil to form breakdown products contributing undesirable flavors and odors to the product.

4. Water vapor or steam in the heated cooking oil also increases the rate of oil breakdown. Some exposure of the oil to steam from the product during cooking is unavoidable, but the return to the fryer of water driven out of the oil as steam is neither desirable nor unavoidable. An adequate system for the removal of cooker fumes serves two purposes:

(a) It prevents drip-back of the steam condensate from the hood of the cooker into the oil.

(b) The removal of oil vapors makes the plant a more pleasant place in which to work.

5. The fryer should be designed to use the absolute minimum charge of cooking oil that is necessary. Oil should undergo rapid turnover to prevent the accumulation of unpalatable flavor-and odor-producing breakdown products in the oil and subsequently in the food being cooked. For the usual cooking procedures in use in the industry, oil absorption by

fish sticks amounts to about 10 percent of the weight of the finished fish sticks. Thus, a plant that has a cooker holding 3,000 pounds of oil and that is producing 2,000 pounds of finished product per hour will have used approximately 200 pounds of cooking oil after each hour of operation. After 15 hours of operation, a quantity of oil equal to the original charge will have been added to the cooker. It has been found in practice that, with such a turnover, and assuming all other fryer-design requirements are met, the quality of the oil is maintained at a satisfactory level for long periods of time. This turnover enables the processor to maintain, for long periods, his desired cooking time and oil temperature and to turn out a finished product with a pleasant oil flavor and a uniform color. Careful and continuing supervision is required, however, to assure that a rapid turnover is due to absorption of oil by the product and not to spillage or to other factors affecting the turnover.

6. The cooker should be constructed to permit easy cleaning. The fume hood and the fish-stick conveyor should be easily removable. There should be no blind corners. All metal touching the hot oil should be of stainless steel. A steam-pressure-actuated cleaning device for scrubbing soiled surfaces with a high-pressure jet of a combined detergent-hot water mixture is effective for use on cookers and other plant equipment. Careful rinsing is required to remove all traces of detergent, since the alkaline extenders used tend to saponify the oil, and the surface-active ingredients may cause it to foam. Foreign flavors and odors may also be introduced from the residual detergent.

7. Cookers that are intended for use with hard fats as contrasted to liquid cooking oils should be equipped with a low-heat source or with an external preheater unit. Use of excessive heat to melt the hard, highly viscous hydrogenated fats causes burning and unnecessary breakdown of the fat immediately adjacent to the heat-exchange surface.

Cooling, Packaging, and Freezing of the Coated, Precooked Fish Sticks

The Cooling of Fish Sticks

After leaving the fryers, whether batch or continuous types, the fish sticks are subjected to a cooling process to permit dissipation of heat-induced water vapors that would otherwise appear as frost formation within the package during freezing. The cooling process should reduce the temperature of the heated sticks to approximately 90° to 100° F. and should be timed to minimize two factors affecting damage to the sticks during the subsequent packaging operation. The coating of the fish sticks, initially crisp and firm upon leaving the fryers but nevertheless difficult to handle because of the high temperature of the absorbed oil, becomes limp and somewhat mushy as the cooling process continues. Damage occurs (1) if sticks are too hot to handle and are dropped and (2) if the coating becomes so limp as to separate from the cooked and cooled sticks upon handling.

The cooling system, itself, may be a very simple plywood box equipped with a fan and with racks for the trays of fish sticks,or it may be an

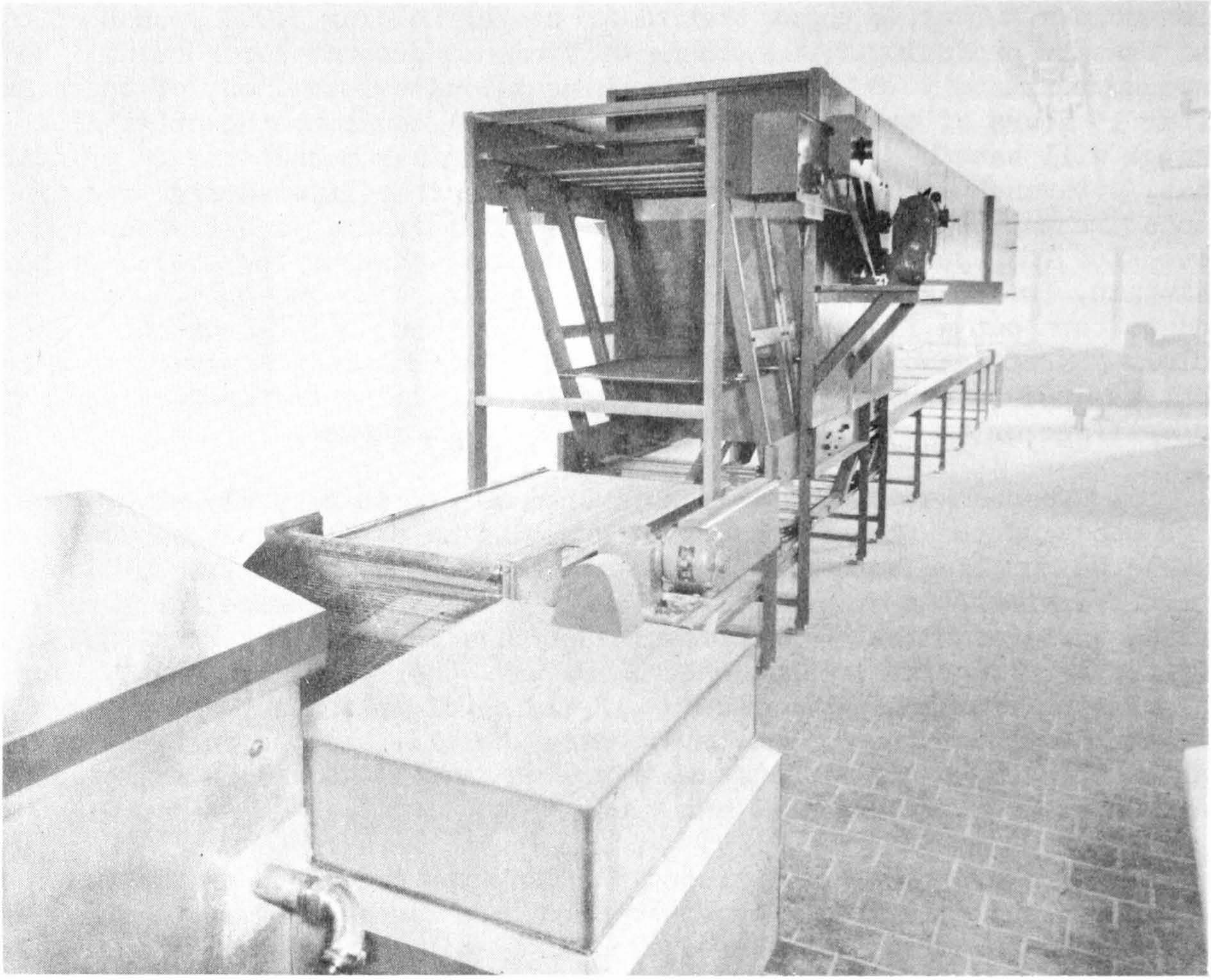


Figure 17.--View of multitier cooling tunnel for cooling of precooked fish sticks. Overhead installation permits savings in processing space. (Photo courtesy of J. W. Greer Company)

elaborate tunnel equipped with conveyor belts, air filters, and a battery of fans. Though refrigeration is not always necessary, it may be included to expedite the cooling process.

Frame coolers.--A simple cooling system for use with batch-frying operations may consist of a wooden box-like frame, sheathed on top and bottom and on two sides with plywood. Horizontal battens are placed at 4-inch intervals on the sides of the box to hold the trays of cooked fish sticks. The box is about 6 feet in height; its width and depth are determined by the dimensions of the trays used in the frying operation. An opening in the plywood sheathing on one side of the box allows cool air from an attached fan to be blown over the stacked trays.

Continuous coolers.--A cooler for continuous processes may be from 20 to 50 feet in length and may contain a single endless belt or a series of such belts. It is usually completely enclosed except for air-intakes, which are fitted with air-filters. The enclosure is composed of plywood, or as in at least one plant, of stainless steel. Cooled, filtered air is introduced at each of the air intakes and blown by the fans over the moving belts. Multipass belts that allow the sticks to fall any considerable distance from one belt to the next may cause much breakage or damage to the sticks. For this reason, a single-pass belt is preferable, if space permits.

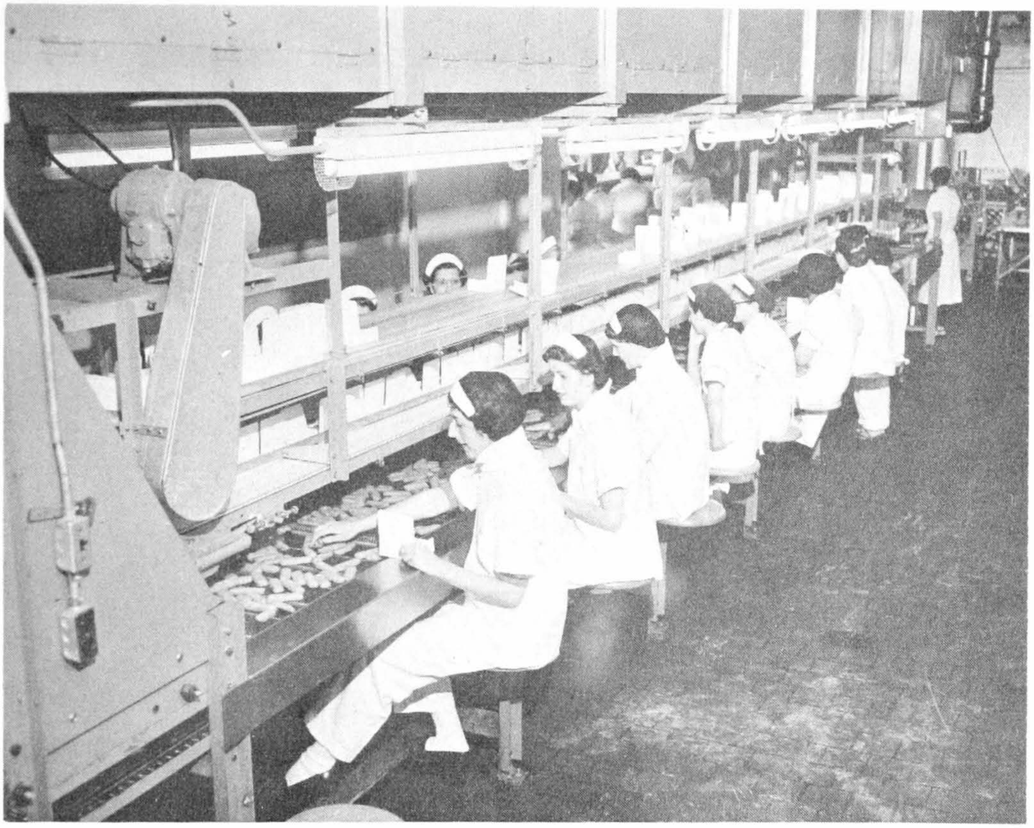


Figure 18.—Packaging of precooked fish sticks on continuous belt-type operation. Cooling tunnel can be seen overhead. (Photo courtesy of The Great Atlantic and Pacific Tea Company)

Construction underway as this is being written will allow one company to bypass the entire cooling, hand-packaging, and freezing operation. The sticks, upon leaving the cooker, pass immediately onto an endless belt in an insulated, multibelt air-blast freezer. One traverse cycle on a belt requires 5 minutes. In that period of time, the individual stick surfaces are sufficiently frozen to eliminate breakage and damage when dropped to the next belt. Completion of freezing takes place on the passage of the sticks downward from one belt-tier to another. The frozen sticks are then automatically packaged and overwrapped, and the wrapped packages are automatically placed in master cartons.

The Packaging of Fish Sticks

The individual cooked fish sticks, after being cooled, are conveyed to the packaging line. This line usually consists of a relatively long table with 3 endless plastic or rubber belts running down the center, the lowest belt being flush with the table top, the middle belt being about 12 inches above the table top, and the highest belt being 21 inches above the table top. The lowest belt conveys the loose fish sticks while the top belt carries empty containers. The middle belt conveys the filled containers to the wrapping machines. Some plants have workers who prepare the flattened chipboard containers and place them on the belts for filling by the packers. Other plants have machines that stamp out and form the containers from chipboard blanks. Production rates with such machines can reach 90 formed packages per minute.

Figure 19.--View of packaging line and automatic overwrapping of packages. (Photo courtesy of The Great Atlantic and Pacific Tea Company)

From 20 to 30 workers are required to package the sticks in a processing operation that produces 2,000 pounds of product per hour. The packers select and package those sticks that are acceptable as to conformity in size, color, and workmanship. Any sticks rejected for the first packaging operation are allowed to proceed to the end of the packaging line. There, 2 to 4 packers place the rejected sticks into 5-, 10-, or 30-pound containers for institutional or other use where the emphasis is on good quality and edibility but where the conformity requirements are less stringent.

The accepted sticks are packed in the rectangular, waxed, chipboard containers, which may hold 8 or 10 ounces of the sticks. Such a package may contain from 8 to 12 sticks, depending on the weight of the individual sticks. The filled containers are automatically overwrapped in cellophane or microcrystalline wax paper.

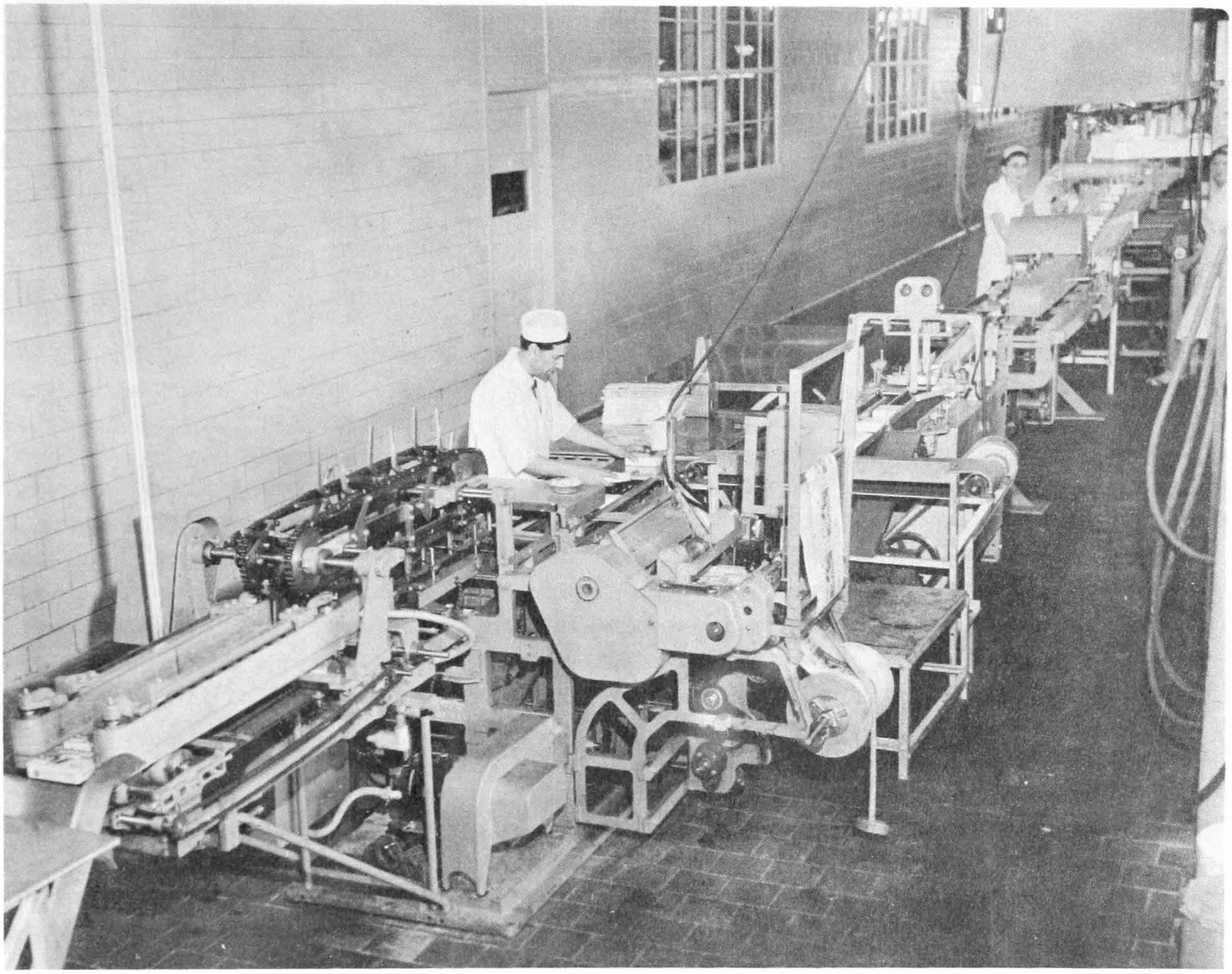


Figure 20.—View of automatic overwrapping machine. Weighing device to rear of overwrap machine is designed to throw out over- and underweight packages. (Photo courtesy of The Great Atlantic and Pacific Tea Company)

The Freezing of Fish Sticks

Many types of freezing systems, from the sharp freezer to the multistation compression-type freezer, have been used for the freezing of specialty items of seafoods. The most economical type of freezer to be used can be determined by a consideration of (1) the characteristics of the freezers, (2) the characteristics of the food products, and (3) the laws governing the rates of freezing.

Freezing rates are determined by (1) the geometrical shape of the product, (2) the thickness of the package, (3) the type and capacity of the freezer used, and (4) the initial temperature of the unfrozen product. These factors--in addition to those of softness or susceptibility of the product to crushing, production rates in the plant, labor costs in loading or unloading of the freezers, and "down-time" required for the loading or unloading--should be carefully considered prior to selection of a particular freezing system. For further details concerning the selection of a freezer, the reader is referred to Fishery Leaflet 427 entitled "Cold Storage Design and Refrigeration Equipment."

Figure 21.--View of battery of typical plate freezers used in the freezing of fishery products. (Photo courtesy of The Great Atlantic and Pacific Tea Company)

BREADED, "PORTION-CONTROL" FISH SQUARES

In recent years, a very large institutional demand for what are termed "portion-control" seafood products has developed. The Armed Forces and the large institutions such as hospitals and schools have all desired a conveniently prepared product in the form of individual serving portions. Each portion was required to be very similar to the others in shape, size, and weight so as to promote ease in planning, cooking, and serving.

The breaded fish "square" was developed to fill this need. It is usually made in the form of a rectangle of frozen fish that may, typically, be 4 by 3 by 15/32 inches. The raw-fish weight is generally adjusted so that, when breader is added, the total weight of the fish "square" is very close to 4 ounces. Such a fish square supplies the estimated amount of protein food needed for a single serving portion.

Processing of Fish Squares

The squares are prepared from frozen fish fillet blocks, usually by a sawing process. A typical block used for such purposes might have the following dimensions: 12 1/8 by 9 1/8 by 1 inches. The whole block is run through a guide and into a gangsaw containing 2 circular saw blades accurately positioned 4 inches apart. The original block is thus cut into three portions, each 4 by 9 by 1 inches. Each of these three portions is then placed on its side and guided into a circular saw set to split them into 6 equal slabs measuring 4 by 9 by about 15/32 inches. For the third and final operation, the 9-inch side of each of the 6 slabs is cut at 3-inch intervals to form 18 rectangles, each 4 by 3 by 15/32 inches. The individual portions or "squares" are then run through an automatic batter and breader machine, packed in 5-pound containers, and overwrapped. Since the frozen fish squares are not thawed or precooked, freezing is not necessary, and the packaged products are placed directly in the cold-storage room.

Recent Innovation

A more recent innovation in this field has been the test-marketing by several firms of such portion-controlled fishery products in consumer-size packages at the retail level. These frozen products--either breaded or unbreaded, and in several portion-size dimensions and weights--may possibly bring about the next technological revolution in the marketing of fishery products.

BREADED, RAW OR PRECOOKED FILLETS OR BITE-SIZE PORTIONS OF FISH

Prior to the introduction of fish sticks, breaded, raw, or precooked fillets and breaded, bite-size portions of fillets were gaining rapidly in public acceptance. The demand for fish sticks has lessened, at present, the demand for these items, and they are not now produced in large volume. Their production is, however, great enough to justify a summary of methods used in their preparation.

Preparation

Haddock, cod, flounder, or ocean perch fillets are carefully examined and freed of bones. The skins are removed, except in the case of ocean perch fillets. For bite-size portions, the fillets are then placed on a conveyor belt and run through a series of rotary knives. The knives cut the fillets into uniform pieces whose dimensions approximate 1 by 1 by 1/2 inches and whose weight is about 1 ounce each. If breaded fillets are desired, the rotary knives are bypassed. Because of the softness of unfrozen fish flesh and its tendency to flake along the muscular striations, the waste during the cutting of the bite-size pieces is a problem for the processor. The small portions of flesh are collected in 25-pound-capacity stainless-steel containers and stored at 32° to 38° F. until required for the breader operation.

Processing

Very few processors have attempted to place the batter and breader application systems or frying operations for fillets or bite-size pieces on a mechanized basis. Owing to the limited demand for these products, manual procedures are used. The fillets or bite-size pieces are dropped into the batter. Two workers, one on each side of the batter container, immerse the floating pieces of flesh in the batter to wet each piece thoroughly. The wetted pieces are lifted in a mesh basket, allowed to drain for a few seconds, and are then transferred to the breader equipment. As in the case of fish sticks, the batter should be kept cooled to below 50° F. to inhibit bacterial growth. Breader application procedures are similar to the manual procedures used for fish sticks, as previously described.

Batch-frying methods are used to fry the breaded products. Again the processing is very similar to that of the batch-frying of fish sticks. In general, the same cooking times and oil temperatures are used, and the same problems concerning maintenance of product quality are encountered.

The fillets are primarily intended for the institutional trade and are packaged in 5- or 10-pound waxed chipboard containers. Individual layers of fillets are separated by waxed paper. The containers are overwrapped with waxed paper and are placed in the freezers. The frozen products are stored at 0° F.

The bite-size portions are packed in consumer-size waxed chipboard containers and overwrapped with a microcrystalline wax paper. The product is frozen in a blast or plate freezer.

BREADED RAW OR PRECOOKED SHRIMP

The application of breader to shrimp began shortly after World War II in answer to the growing demand of housewives for convenience in the preparation of seafoods. This product received a very rapid acceptance, and production of consumer-size packages seems to have leveled off for the present, at a steady 17 million pounds per year. The next logical step--that of precooking--followed quickly after the introduction of breaded shrimp. Fried breaded shrimp, however, has never attained the same market volume as has raw breaded shrimp, possibly owing to the higher costs. The total production is probably about 5 to 10 percent of that for raw, breaded shrimp.

Processing of Breaded Raw Shrimp

After the fresh shrimp are headed, cleaned, peeled, and deveined (section 2), they are conveyed to the batter and breader operations. Many forms of batter are used: they may be composed of commercial wheat-flour mixes, of whole eggs, of milk and dried eggs, or of other mixtures developed by the processor. Breaders are more uniform and are primarily commercial preparations. There is a great diversity of methods for application of coatings to the shrimp. They may be wholly manual, semi-automatic, or fully automatic. Further, within the various plants, each of these types of operations may vary to suit available equipment or the processor's requirements. The same advantages and disadvantages that apply to these methods in the fish stick industry also apply in the breaded shrimp industry.

Manual Processes

In those plants using the manual processes for application of batter and of breader, a relatively large number of people are employed. Large rooms are filled with rows of tables, along each side of which lines of workers sit or stand. Before each worker is a container of shrimp, a batter pan, a breader pan, a small balance, and a supply of empty packages. The worker picks up the shrimp, dips it into the batter, and then into the breader. The shrimp is rolled in the breader, and the adherent material is firmly patted onto the shrimp to ensure "set." The shrimp is next placed in a package. After a sufficient number of shrimp have been added, any adjustment of contents necessary to obtain the proper weight is made. The package is finally closed and forwarded to the wrapping operation.

Semiautomatic and Automatic Processes

In plants using a partially mechanized process, the prepared shrimp are placed on a conveyor belt and carried through a tank of batter to the breader operation. This operation, using any one of the several previously discussed machines for the application of batter, requires a very much smaller labor force than does the completely manual procedure. The batter-coated shrimp are then manually rolled in the breader and patted for assurance of "set." The breaded shrimp are finally placed on a belt and conveyed to the packaging tables.

An interesting variation of the partially mechanized procedure for coating of shrimp is in use at a plant in the Southeastern United States. The prepared shrimp are individually suspended by the tail on a pin-studded rack. These racked shrimp are dipped into a batter and, after draining, are then sent through a specially designed breader apparatus. The batter and breader coat each shrimp to a point just below the tail segment. The breaded shrimp are then frozen individually in a blast freezer prior to being packaged.

Mechanized Processes

A completely mechanized operation for the application of batter and breader to the raw, prepared shrimp is very similar to that used in the breaded fish stick industry, as previously mentioned. This procedure is far superior to manual processes for the following reasons: (1) labor, space, time, and equipment costs are radically reduced; (2) the coating of the shrimp is more uniform; and (3) owing to reduction of spillage, the sanitary condition of the plant is improved, and coating costs are reduced.

Processing of Breaded, Precooked Shrimp

Preparation

A small portion of the total production of raw breaded shrimp is precooked prior to freezing. The actual cooking operation is similar to that in the fish stick industry. The frying time, however, is adjusted to fit both the size of the shrimp being processed and the product color desired. Cooking oil temperatures are usually maintained in the range of 375° to 390° F.

In general, for headed shrimp of 21 to 50 count per pound, the cooking times should not be less than 60 seconds nor more than 90 seconds. The 21- to 35-count shrimp are usually cooked for from 70 to 90 seconds in oil at 375° F. The smaller 36- to 50-count shrimp would be cooked to the same degree in from 60 to 80 seconds, at the same oil temperature. The ranges of cooking times stated allow for the production of breaded shrimp in the color range of pale yellow to golden brown, as desired.

Essentially the same batter mixes and breaded materials are used as in the fish stick industry. The same process-induced changes of moisture loss with cooking as balanced against oil and breader pickup result in approximately the same product yield as in fish sticks, provided breader pickup is not more than about 30 percent of the product weight. For example, 110 pounds of peeled, headed, deveined shrimp, when so breaded and fried, yields about 110 pounds of fried shrimp.

Methods of Frying

Batch-type fryers have been, until recently, the principal equipment used for the frying of shrimp. The newly developed continuous fryers are, however, now being introduced.

An interesting variant on the mechanical-batch-type operation has been developed in one plant. The peeled, headed, deveined shrimp are cooked in boiling water, then cooled. They are next rolled in a dry batter mix to ensure a dry surface for the subsequently applied batter coating. The dusted shrimp are manually dipped in batter and placed in a revolving cylinder of expanded metal lath to remove excess batter. A sleeve surrounding the cylinder returns this excess batter to the tank. The shrimp fall from the discharge end of the cylinder onto a revolving tray that is covered with breader falling from a vibrating shaker. The partially breaded shrimp are placed in rows on a tray with an expanded metal mesh bottom. The trays are pushed back and forth beneath a curtain of falling breader. Vigorous shaking of the tray causes the excess breader to fall through the bottom of the tray. The breaded shrimp are then transferred to a frying basket, and the whole is immersed in the cooking oil. A timing device activates the mechanism that lifts the trays from the oil at the end of the predetermined cooking period. The shrimp are cooled and dried in an air-blast. They are then packaged in consumer-size packages and frozen in a blast-freezer.

FROZEN FISH SOUPS AND CHOWDERS

A relatively recent step in the preparation and marketing of a diversified line of seafoods is the production, on a large scale, of frozen soups, bisques, stews, and chowders. Except for the canned soups, this field has hitherto been the domain of the small food processor. He prepared batches of soups and similar products for his restaurant or hotel-chain buyers and delivered the product daily. The product was not frozen, and it was usually of a premium quality, utilizing only the freshest of raw material and commanding a premium price.

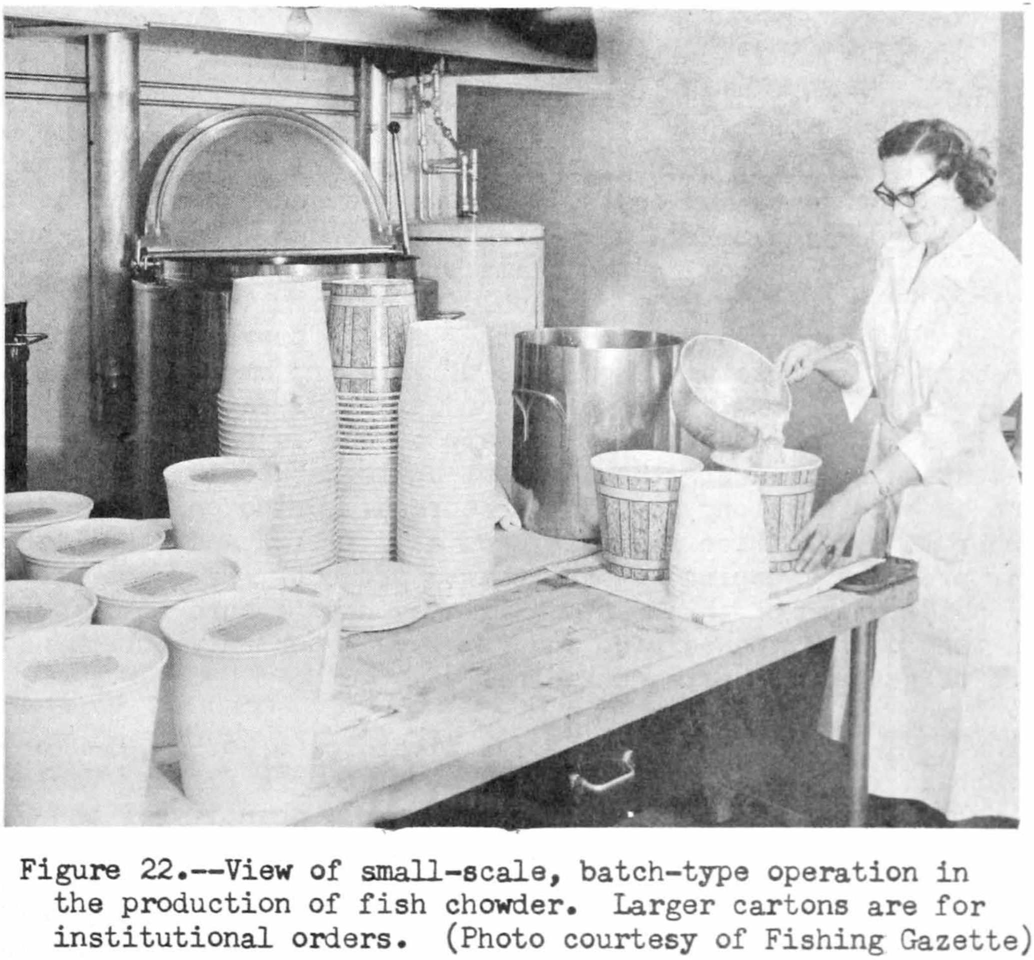


Figure 22.--View of small-scale, batch-type operation in the production of fish chowder. Larger cartons are for institutional orders. (Photo courtesy of Fishing Gazette)

The success of the frozen precooked foods, however, led the large food processors to consider production, on a large scale, of frozen soups and chowders ready for use in the home. This industry is as yet in its infancy, but it bids fair to become a large factor in food production. Seafoods are represented by clam and fish (haddock or cod) chowders, oyster stews, and shrimp bisques.

The industry has not, in general, stabilized on design of equipment or on techniques of processing. Very little information on production is available. Usually, the same techniques developed for steam-sterilized liquid canned soups are used, with replacement of the retorting processes by a freezing process and with formulas adapted to the requirements of a good-quality frozen product. The following information, brought up to date and adapted for freezing requirements, has largely been derived from publications of the Fish and Wildlife Service (Jarvis 1943).

Clam Chowder

Two types of clam chowder are frozen: the "Manhattan," and the "New England" styles. The latter differs from the former in that it contains no tomatoes, and the "stock" is prepared from clam juice instead of water. A typical example of processing of the New England-style clam chowder is as follows:

The choice of ingredients is determined by (1) costs, (2) flavor requirements, and (3) effects of freezing and storage upon quality of the ingredients. Soft clams, quahogs, or sea-clams are used, depending upon their relative abundance and costs. Quahogs and sea-clams give a stronger flavor to the stock and make a very pleasing chowder. Osterhaug and Bucher (1945) have found that cooking the clams prior to use results in a longer storage life. Potatoes to be used should be of firm texture; calcium salts may be added to "firm" the texture further and to prevent "mushing" during the processing. The potatoes should be of regular, smooth surface and have few eyes. Salt pork should be a good grade of fat brisket pork, fresh and free of rancidity. Pork is safe to use in canned frozen soups, but pork-containing products that are put up in cardboard containers should not be held for long periods in storage. Dried onions or dried onion powder is used. Rice flour is used as a filler and stabilizer. The stabilizer prevents "weeping" of the thawed product. Products prepared without consideration of this factor will (1) have a curd-like formation on the surface of the thawed soup and (2) have a tendency for the solids to settle out of suspension after standing.

In a well-designed operation, No. 1 picnic cans (or 1-, 5-, or 10-quart cardboard friction-top containers) move along a filling table on conveyor belts. At the first station, a measured quantity of the whole or roughly chopped clams is added. A similar quantity of diced, blanched potatoes is added at the next station. The cans are then passed under a filling machine that adds the exact amount of soup "stock" required to fill the can to the desired level. For the formula and method of preparation of the soup stock, the reader is referred to the section that follows on fish chowder.

Canned soups are normally prepared with head-space: that is, the cans are not completely filled. The head-space facilitates formation of a slight vacuum in the can after processing. A similar "head-space," but slightly larger, is required for the preparation of frozen soups to accommodate the normal expansion of the liquid emulsion during freezing. A certain amount of experimenting is necessary to determine the head-space necessary to prevent the formation of bulges during the freezing process.

Fish Chowder

Fish chowder (haddock or, in some cases, cod) is prepared during the fall and early winter seasons. Fish are relatively cheap and fresh, and high-grade potatoes are easily obtainable. The desirable characteristics of the various ingredients are much the same as in clam chowder.

The skinless, eviscerated, and washed fish may be steamed for a short period to facilitate removal of the flesh from the skeletons or frames. The various flesh trimmings left on the frames after this operation are used in the preparation of the soup "stock" or broth.

The soup broth is prepared by simmering the frames and trimmings in hot water for 2 hours. Approximately 2 pounds of water to 1 pound of flesh are used. The broth, when ready, is drained into a tank for use in the chowder stock.

The following is a commercial recipe for New England-fish chowder stock as presented by Jarvis (1943) and adapted for use in a frozen product:

50 pounds rice flour	56 gallons fish broth
18 pounds diced onion	25 gallons water
18 pounds diced salt pork	16 pounds salt

Onions are simmered, until soft, in an 80-gallon steam-jacketed kettle. The diced pork is then added. Rice flour (25 pounds) is beaten into 15 gallons of water to form a smooth creamy emulsion. When the pork is soft, 20 gallons of the fish broth is poured in the kettle. When the mixture reaches the boiling point, the rice-flour emulsion is added. The mixture is then brought again to the boiling point, and a second batch of emulsion, consisting of 25 pounds of rice flour and 10 gallons of water, is prepared. Twenty gallons of fish broth is poured into the boiling mixture, and when this, in turn, is boiling, the second batch of emulsion is added. When the mixture is brought to a boil for the fourth time, the indicated amount of salt and sufficient broth are added to bring the contents of the kettle to 80 gallons. The stock, after being boiled for the fifth time, is drawn off to a tank connecting with the filling machine.

As in the preparation of clam chowder, the cans or cardboard containers are moved along on a conveyor belt. At the first station, a measured quantity of the steamed fish is added. At the second station, an equal quantity of diced, blanched potatoes is added. The containers are then filled to the desired level with the fish stock, are sealed, and are finally delivered to the freezer.

OTHER SPECIALTY SEAFOOD ITEMS

The burgeoning specialty seafoods industry is also represented, in the retail freezer cabinet, by fish pies, prepared dinners, abalone steaks, crab and fish cakes, and scallops. The first are deep-dish pies in disposable aluminum plates. The dinners utilize seafoods as a portion of a complete meal that is precooked and frozen and that needs only be reheated in the home.

Fish Pies

Fish pies, at present, are made only from haddock and tuna. It is probable that, in the near future, other species will also be used. Ordinarily, the pies are made from the less esthetically desirable but flavorsome and edible portions of the fish. Potatoes, another vegetable, and a cream-sauce filler, prepared from rice flour, are added in addition to the fish. The pie dough is usually prepared from commercial mixes developed for frozen foods. Freezing of the prepared pies requires the same careful consideration of the physical characteristics of the product as do fish sticks. Long-term cold storage, with its possibility of unfavorable changes in flavor and texture, should be considered prior to choosing the ingredients.

Abalone Steaks

In the commercial preparation of abalone steaks, a relatively large waste-problem was encountered. The too-thin steaks, edges and pieces of steak broken off during the tenderizing process had little or no market value. These trimmings are now minced and forced under pressure into a metal tube (24 inches in length by 3 inches in diameter). The "cores" thus formed are stacked in blast-freezers and frozen. When the meat is needed for production, water is allowed to run over the metal tube, and the meat is released in the form of a cylindrical loaf. The loaf or core is then sliced in 1/4-inch-thick portions by an electric meat-slicing machine. The procedures from this point on are the same as those used for the processing of raw, breaded fillets. The breaded patties are packed in cellophane bags, placed in master-cartons, and stored in the cold-storage warehouse.

Breaded Scallops

The large adductor muscle of the inexpensive sea scallop is used in the breaded scallop industry. The scallop is shucked at sea, and the usable muscle is delivered to the processor in tightly packed, fine-mesh cloth bags. Each scallop muscle is sliced several times to form portions averaging about 2/5 ounce. The unfrozen portions are either manually or automatically battered and breaded. They may be either raw or precooked by procedures similar to those used in the fish stick industry. The coated portions are placed in 10-ounce, rectangular, waxed chipboard containers. The packages are then overwrapped with a microcrystalline wax paper, and the product is frozen and stored.

FUTURE REVISIONS

It has been impossible adequately to describe,in one chapter, the tremendous growth and diversification of seafood products in recent years. The industries are, as yet, in a state of flux with reference to processing details and equipment. Undoubtedly.also, some products will be taken off the market and others will be introduced. Future revisions of this leaflet will elaborate on those new products found to have promise.

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