Section III. Processing and Presentation

Processing and Preservation of North Atlantic Groundfish

Robert J. Learson and Joseph J. Licciardello

INTRODUCTION

North Atlantic groundfish represent a variety of bottom-dwelling species including cod, haddock, pollock, hakes, and flatfish.

Spoilage begins the moment fish are taken out of the water. The rate of subsequent deterioration is affected by certain intrinsic factors such as species, size, season, fishing grounds, etc., and by extrinsic factors, such as handling practices, which are subject to human control. Spoilage of fish during storage at temperatures above freezing is the composite result of three different activities: 1) bacterial decomposition; 2) autolytic enzyme action, either from tissue or digestive enzymes or from certain feeds that may be in the gut, leading to torn bellies and softening of the flesh; and 3) oxidation of lipid material, resulting in rancidity. In lean fish which have been gutted, spoilage invariably results from bacterial action. In fatty fish, loss of quality due to oxidative rancidity may precede bacterial spoilage.

FACTORS AFFECTING QUALITY

Washing

It is extremely important that the fish be iced as soon as possible after harvesting. However, prior to icing, the fish should be washed to remove mud, blood, and intestinal contents that may have been expelled as a result of the intense pressure developed when the nets are hoisted out of the water. Unless the washing operation is executed thoroughly and efficiently, the catch effort can be a waste of time and resources. If the washing is to be conducted manually with a hose, a copious amount of water under pressure should be used. Mechanical cylindrical washing machines are efficient and offer the advantage of being geared to a conveying device for transporting the fish to the hold for stowage. This reduces handling and allows for proper icing (Waterman, 1965).

Bleeding

Although not feasible with large catches of small fish, bleeding prior to evisceration is a desirable practice. It results in a lighter-colored flesh and also removes heme compounds which promote oxidative rancidity. Bleeding is usually accomplished by cutting the throat. It is recommended that the fish be allowed to bleed in seawater for about 15 minutes before washing.

Gutting

Gutting of larger groundfish species such as cod, haddock, pollock, and hakes should be carried out immediately after harvest. Gutting flounders and other flatfish is generally too labor-intensive and the time required may have a deleterious effect on quality, especially during summer months. Rupture of the intestines could contaminate the gut cavity with intestinal contents and accelerate spoilage. Failure to remove the last few inches of intestine, which remain attached to the vent, can result in obnoxious odors in that part of the fillet. Extension of the knife cut beyond the vent into the muscle can cause a more rapid deterioration in that area of the fillet (Castell et al., 1956). It is often the practice to remove the gills from large fish, particularly in the summertime; this action retards the development of off-odors and spoilage when the fish are examined as whole gutted fish. The benefit to be gained from washing fish after gutting appears to be related to the efficiency with which the evisceration is performed. Nevertheless, it has been observed that washing eviscerated fish in chlorinated [50 to 60 parts per million (ppm)] seawater, under pressure, rinses the blood and slime off the fish more effectively than does plain seawater (Linda and Slavin, 1960). The odor and color of the flesh were not affected.

Handling

Some species of groundfish are particularly susceptible to bruising. Consequently, rough handling aboard the vessel should be avoided. Bruising of freshly-caught live fish usually results in discoloration of the flesh. Although this effect is not apparent with freshly-caught dead fish, it has been shown that bruised fish do not keep as well as undamaged fish (Castell et al., 1956).

Effect of Rigor Mortis

Rigor mortis in muscle is characterized by the formation of lactic acid from glycogen with a subsequent lowering of pH and a stiffening of the muscle due to contraction. Bacterial growth on fish does not start until rigor mortis has begun. To optimize quality, it is necessary that the time to resolution of rigor be maximized.

Lowering the body temperature close to freezing delays the onset of rigor. The duration of rigor is also a function of body temperature and glycogen content at death. A high glycogen content and a low temperature above freezing both serve to prolong rigor. Rigor mortis is of longer duration if the fish has exerted less muscular activity prior to death. This results in a higher glycogen content. Results of several studies demonstrated that rigor mortis developed earlier and disappeared sooner in trawl-caught fish compared to fish caught with hand lines. This was attributed to struggling, crushing, and anoxemia in the trawl-caught fish. It is also believed that the shorter the trawler haul is, the better the fish will keep. In any given catch of trawl-caught fish, some of the fish may still be alive when the nets are hoisted on deck; thus, there may be a variation among the fish in the amount or degree of struggle expended prior to death. This could account in part for the variability in keeping-quality within the same catch of fish. The onset and duration of rigor vary with different species. In general, flatfish exhibit a more extensive rigor than round fish.

Effect of Temperature

The most important single factor controlling spoilage of fresh fish is storage temperature. Temperature regulates the onset of rigor mortis and also the lag period and growth rate of spoilage microorganisms.

The flesh of freshly-caught fish is sterile (Procter and Nickerson, 1935). The microorganisms that are present are located on the skin in the slime layer, gills, and gut. Initially, the numbers on the skin are essentially low, averaging about l03 to 105 per square centimeter (Spencer, 1961; Georgala, 1958), but through mishandling and contamination from the deck and the holding pens, the bacterial load can increase quite rapidly. The types of bacteria that eventually induce spoilage in iced North Atlantic (temperate waters) fish are termed psychrophilic or psychrotrophic, which signifies a tolerance for low temperatures. They constitute the natural microflora of newly caught fish and may also be picked up during subsequent handling (Shaw and Shewan, 1968; Shewan, 1961). These bacteria are capable of growing at temperatures slightly below freezing; however, they grow most rapidly in the temperature range of 20° to 25°C (68° to 77°F) (Hess, 1950). Although the relationship between storage temperature and spoilage rates of fish has been shown to be approximately linear within certain temperature limits (Ronsivalli and Licciardello, 1975; Spencer and Baines, 1964) as the temperature is lowered and approaches 0°C (32°F), the growth rate of fish-spoilage bacteria is drastically retarded. Consequently, it is necessary for the fisherman to rapidly lower and maintain the temperature of the fish as close to freezing as is possible in order to obtain maximum shelf life. This can be accomplished by the judicious use of various cooling media.

Chilling

Freshwater Ice

The amount of ice required for a trip will depend on the season, length of trip, size of the catch, and insulation of the boat. For a five-day summer trip in North Atlantic waters, it has been calculated that 0.113 kg (0.25 pound) of ice is adequate for cooling 0.454 kg (l pound) of fish from 12.8° to 0°C (55° to 32°F), and an additional 0.182 kg (0.4 pound) is required to maintain the fish away from the holding pen surfaces, to cool the hold, and to remove heat leaking into the hold (MacCallum, 1955).

From these requirements, a ratio of 0.454 kg (l pound) of ice to 0.681 kg (1.5 pounds) of fish was recommended to ensure landing high-quality fish. In practice, in northern waters in uninsulated holds of wooden vessels, a ratio of 1:2 (ice to fish) is recommended (Dassow, 1963).

Ice of small particle size such as that produced in a flake-ice machine or finely-crushed block ice is recommended since it permits more intimate contact with the fish for more efficient cooling, and is less damaging to the flesh as compared to large chunks of ice. A mechanical refrigerating system installed in the hold can lessen the requirement for the amount of ice to be carried. However, air temperature at the pens should not be allowed to go below freezing since one of the benefits of ice, in addition to cooling and providing aerobic conditions around the fish, is that the melt water gradually washes away blood and bacteria-laden slime. The holding pens should be designed to allow melt water to escape into the bilges.

Storage of ice in a refrigerated compartment is desirable, because crushed ice held at temperatures above freezing tends to fuse into a solid mass which has to be broken up manually or put through a crusher prior to use.

The precise method of icing varies with the construction of the hold and layout of the pen for a particular vessel. A satisfactory method for most vessels employing bulk storage is as follows (American Society for Refrigeration Engineering, 1959): Cover the floor of the pen with a layer of ice 20 to 30 centimeters (cm) (8 to 12 inches) deep. similar amount should be placed along the sides of the pen. A layer of fish not exceeding 15 cm (6 inches) deep should then be placed on the ice and covered with a 20 cm (8 inches) layer of ice. Fish and ice should be mixed together.

Successive layers of ice and fish should then be built up in the same manner until an overall depth of 1.2 m (4 feet) is reached, at which point shelf boards are inserted and the stowage process repeated. Gutted fish should be placed with the belly cavity down. In the case of large fish, the cavity should be filled with ice.

For proper cooling, it is important that intimate contact be made between fish and ice. When fish were piled in layers 38 to 46 cm (15 to 18 inches) deep and interspersed with thinner layers of ice, the fish at the center of these layers often required 24 to 36 hours to cool to approximately the temperature of melting ice (Castell et al., 1956).

Boxing at Sea

Some of the problems encountered in bulked pen storage can be eliminated by boxing in ice at sea (Waterman, 1964). The crushing effect of excessive pressure is reduced; in addition, there is a greater opportunity for the catch to be carefully and speedily handled during stowage and after discharge from the boat. There is a greater space requirement aboard the vessel for boxed fish. As with pen stowage, the fish should not be packed in direct contact with the surfaces of the box; otherwise the "bilgey" type of spoilage may result.

Refrigerated Seawater

The benefits of using refrigerated seawater (RSW) or refrigerated brine for storing fresh fish on board a fishing vessel are: l) greater speed of cooling, 2) less textural damage due to reduced pressure upon the fish, 3) lower holding temperature, 4) greater economy in handling the fish due to time and labor saved, and 5) longer effective storage life of the fish. The real advantage of RSW compared with freshwater ice appears to be that the brine temperature can be maintained at about -1°C (30°F), which is just above the freezing point of fish.

Although it is now generally regarded that the storage life of whole fish is longer in RSW than in ice, shelf life is limited by the uptake of water and salt, particularly with lean fish species, by the development of oxidative rancidity.

A problem common with all fish species held in RSW is the eventual growth of spoilage bacteria in the brine, producing foul odors which can be imparted to the fish.

Chilled Seawater

For the small-boat fisherman, the benefits of RSW storage can be obtained without a mechanical refrigeration system through the use of chilled seawater (CSW) or slush ice; that is, stowage of the fish, ice, and seawater in tanks at the ratio of 3:1:1. The exact proportions for maintaining temperatures slightly below freezing (0°C) depend on the temperature of the fish and seawater and the duration of the trip. Successful results have been reported with herring and mackerel (Hume and

Baker, 1977). With this system, it is important that ice and seawater be mixed together just prior to loading with fish and that efficient circulation be maintained.

In general the use of RSW or CSW is not recommended for long fishing trips unless the eventual market is a filleted product. Both RSW and CSW systems produce a bleaching effect, and whole fish will exhibit cloudy eyes, bleached skin, and bleached gills which will reduce acceptability on the dressed-fish market. However, in terms of fillet quality, the product is highly acceptable and fillet shelf-life will often exceed that of traditionally iced fish. Some work carried out at the NMFS Gloucester (Massachusetts) Laboratory demonstrated that the addition of 1 percent potassium sorbate to the water phase of CSW systems greatly reduces bacterial growth.

FREEZING AT SEA

Over a period of 40 years much research and many commercial ventures have been undertaken relating to freezing North Atlantic groundfish at sea.

In the past few years, because of the relative collapse of groundfish stocks in the waters of the Northeast United States and eastern Canada, frozen at sea (FAS) product has become highly marketable.

The basic principles and technology for producing high quality FAS groundfish have not changed dramatically over the years. The fish must be of high quality and properly bled, gutted, and washed. Freezing dressed fish and/or fillets should be carried out in blast or plate freezers, and the packaging or glaze should be sufficient to prevent freezer burn and dehydration. For best quality, the product should be stored at -25°C, or below.

A major problem with FAS product is the effect of rigor mortis. If the product is frozen pre-rigor or during rigor, the fish must be allowed to pass through rigor upon thawing.

Freezing fillets cut from pre-rigor fish is generally not recommended, especially for fish blocks and shatter packs. If the fillets are not allowed to pass through rigor prior to cooking, the result will be a relatively flavorless and rubbery textured product.

PROCESSING SHORESIDE

The ice used for storage at sea contains blood and slime — an excellent medium for the growth of spoilage bacteria. Therefore, upon receipt at either dockside or the processing plant, all fish should be immediately re-iced.

Fish that are pre-rigor or in rigor should be iced down and allowed to pass through rigor prior to filleting.

Before filleting, the fish should be washed. Research reported by the Virginia Polytechnic Institute demonstrated that an agitated wash significantly reduced the level of spoilage bacteria. The use of 10 to 15 ppm sodium hypochlorite in the wash water was effective.

All filleting operations should be carried out quickly, preferably in a refrigerated environment. The fillets, steaks, etc., should be trimmed, candled, and washed in a continuous process. Ideally, the product should not be exposed to temperatures above 10°C for more than two hours. Temperature profiles of filleting operations in plant temperatures of about 13°C indicate that the final fillet temperature should not exceed 5°C.

USE OF BRINE

It is common practice to wash or rinse groundfish fillets with a solution of 2 to 5 percent saltwater (brine). This process eliminates blood, scales, and slime from the fillets or steaks prior to packing. This practice, with proper temperature controls and routine sanitation maintenance, is generally recommended. However, the improper use of brine systems can be detrimental to fish quality. Since brine solutions solubilize proteins, the brine quickly becomes an excellent medium for bacterial growth, especially without temperature control. Care should be taken to refrigerate brine systems, and the brine should be routinely discarded and replenished several times per day.

Another issue related to the misuse of brine systems is economic fraud. Brine tanks, especially in conjunction with the addition of sodium tripolyphosphate, can be used to "soak" fillets to add weight to the product. Soaking fillets in brine also acts to mask poor quality. Since the added water is not bound to protein, the result to the consumer is excessive shrinkage due to drip loss in storage and subsequent cooking.

PACKING AND SHIPPING

All products should be pre-chilled prior to packing and shipping. Based on research carried out at the NMFS Laboratory in Gloucester, Massachusetts, a general "rule of thumb" is that for every 24 hours fish are exposed to temperatures one or two degrees above 0°C, the product will lose one day of quality shelf-life. Fillets, steaks, etc., not chilled prior to packing or not properly refrigerated during distribution, could lose several days of quality shelf life during shipment. For example, fish fillets packed and transported at 5°C could lose as much as three days of quality shelf-life in a 24-hour period.

Modified Atmosphere (MAP), Vacuum Packing (VP), Irradiation

After death and the time immediately after rigor mortis, the primary changes in fish quality are related to biochemical reactions where autolysis (self digestion) is the major factor and bacterial activity is of little consequence.

Since MAP and VP only relate to the retardation of spoilage bacteria, there is little to be gained in preserving high quality products using MAP and VP.

These packaging and processing procedures will increase total edible shelf life but only in the intermediate quality range. The same is true for irradiation where the treatment will eliminate spoilage bacteria, but the resulting shelf-life extension will only be in the marginal quality range.

The use of MAP and VP for bulk shipment with good temperature control, however, is an acceptable practice. In bulk shipments modified atmosphere packing reduces spoilage bacteria during distribution. When the shipment is broken down for final packing and storage, etc., the product will undergo its normal spoilage pattern. Because bacterial degradation or spoilage is significantly retarded during the distribution period, several days of edible shelf-life can be gained.

MAP and VP of fresh product may represent problems, especially in retail packs. Since the product is not undergoing normal aerobic bacterial spoilage, most of the key indicators of degradation such as odor and discoloration are not readily evident. A vacuum-packed fillet or steak may have all the visual characteristics of a high-quality product. However, if the product is degraded to the point where severe anaerobic spoilage has occurred, the consumer may be assaulted by foul odors.

There also exists the potential development of *Clostridium botulinum* toxin in MAP or VP products if they are temperature-abused (above 42°F). In North Atlantic groundfish the incidence of this organism is extremely low and possible health hazards are minimal. However, with extreme temperature abuse, there could be a potential public health problem.

FREEZING AND COLD STORAGE

Only high-quality groundfish products should be frozen. The freezing process only preserves the initial quality, which will never improve beyond the quality of the original raw material. In reality, although rapid freezing and cold storage at temperatures below -25°C have shown superior quality retention, the United States consumer still continues to demonstrate his/her perception that frozen products are inferior to fresh products in terms of quality.

For frozen groundfish the packaging materials are important for quality retention. Moisture- and oxygen-impermeable materials are essential. During frozen storage, groundfish are susceptible to dehydration and "freezer burn" which will result in textural toughening and oxidative rancidity.

Products packaged simply with sealed bags ("air packs") are not recommended. These will very quickly become "frosted" and the quality will degrade rapidly.

For food service, "layer" or "shatter" packs are preferable. In this procedure, the fillets/steaks are packed in single layers on sheets of plastic film. This allows the end user to peel off layers of frozen fillets or steaks without thawing the entire container.

All fish products should be frozen as quickly as possible. Research has shown that rapid freezing reduces the size of ice crystals in the flesh which results in a better product texture. It is also recommended that the product should only be frozen to an internal temperature equivalent to the intended cold storage temperature. Fish products frozen to temperatures below the intended cold storage temperature will increase the relative size of ice crystals when the temperature equilibrates to the higher frozen storage temperature. This can result in textural changes in the finished product.

Cold-storage holding temperatures should be as low as possible. In general, -18°C storage is not recommended for seafoods. High quality shelf-life has been shown for non-fatty species such as cod and haddock stored at –18°C from three to five months. Fatty species — e.g., mackerel — will only retain high quality for two to three months. In comparison, storage at -30°C will retain high quality eight to 10 months for lean species and six months for fatty species. For export to Japan, storage temperatures of -40°C or below are recommended.

Fluctuating cold-storage holding temperatures should be avoided. Fluctuating temperatures result in a cycle of increasing and decreasing ice crystal size in the frozen product. This constant cycle eventually will produce increased drip loss and textural toughening of the product.

THAWING

Frozen fish can be thawed in a number of ways, including in water or air, and also by cooking directly from the frozen state. For preserving high quality, defrosting should be carried out under refrigeration. Thawing at warm temperatures can result in dehydration and potential bacterial spoilage. Thawing in cold water is recommended for packaged products. Unpackaged products should not be thawed in water, since the water will solubilize proteins and result in significant flavor loss.

Some products, especially fillets, steaks, or portions, can be defrosted by using microwaves. Microwave tunnels at 915 Megahertz (MHz) are commonly used to temper fish fillet blocks to about –10°C for automated slicing into fish sticks or fish portions. Most home or restaurant microwave ovens have an output of 2450 MHz. Since the heating chracteristics of this frequency are much faster than 915 MHz and the depth penetration is shallower, this method is not generally recommended. However, many microwave ovens are equipped with "defrost cycles" where the frozen product is subjected to successive pulses of microwave energy. Using the "defrost" cycle, microwave ovens can be very effective for defrosting seafoods. It is recommended that microwaves should only be used as a method to partially defrost seafoods. Attempting to fully defrost by microwaves usually produces "hot spots" where some parts of the product become cooked.

REFERENCES

American Society for Refrigeration Engineering. 1959. Fresh fishery products. In *Refrigeration Applications — Air Conditioning, Refrigeration Data Book*. New York.

Bramnsaes, F. 1979. Quality and stability of frozen seafood. In *Quality and Stability of Frozen Foods*. W. B. Van Arsdel, M. J. Copley, and R. L. Olson (eds.), pp. 217-236. Wiley Interscience, New York.

Castell, C. H., W. A. MacCallum, and E. H. Power. 1956. Spoilage of fish in vessels at sea. *Journal of the Fishery Research Board of Canada* **13**:21-39.

Dassow, J. A. 1963. Handling of fresh fish. Pp. 275-287 in *Industrial Fishery Technology*. M. E. Stansby and J. A. Dassow (eds.). Reinhold Publishing Co., New York.

Dyer, W. J. 1971. Speed of freezing and quality of frozen fish. In *Fish Inspection and Quality Control*. R. Kreuzer (ed.), pp. 5-81. Fishing News (Books) Ltd., London.

Dyer, W. J. and J. Peters. 1969. Factors influencing quality changes during frozen storage and distribution of frozen products, including glazing, coating and packaging. Pp. 317-322 in *Freezing and Irradiation of Fish*. R. Kreuzer (ed.). Fishing News (Books) Ltd., London.

Georgala, D. L. 1958. The bacterial flora of the skin of the North Sea cod. *Journal of General Microbiology* **18**:84-91.

Heen, E. and O. Karsti. 1965. Fish and shellfish freezing. Pp. 353-418 in *Fish as Food*, vol. 4. G. Borgstrom (ed.). Academic Press, New York.

Hess, E. 1950. Bacterial fish spoilage and its control. *Food Technology* **4**:477-480.

Hume, S. E. and D. W. Baker. 1977. Chilled seawater system for bulk holding sea herring. *Marine Fisheries Review* **39**(3):4-9.

Huss, H. H. 1995. Quality and quality changes in fresh fish. FAO Fisheries Technical Paper No. 348. Fisheries Department, FAO, Rome.

Jason, A. C. 1982. Thawing. In *Fish Handling and Processing*. Aitken, Mackie, Merritt, and Windsor (eds.). Torry Research Station, Aberdeen, Scotland.

Johnston, W. A., F. J. Nicholson, A. Roger, and G. D. Stroud. 1994. Freezing and refrigerated storage in fisheries. FAO Fisheries Technical Paper No. 340. Fisheries Department, FAO, Rome, Italy.

Lane, J. Perry. 1964. Time-temperature tolerance of frozen seafoods. *Food Technolology* **18**:1100-1106.

Learson, R. J. and J. J. Licciardello. 1986. Literature reporting of shelf-life data: What does it all mean? *Rev. Int. Froid.* **91**:179-181.

Licciardello, J. J. 1980. Handling whiting aboard fishing vessels. *Marine Fisheries Review*. Jan. 1980.

Licciardello, J. J., and D. O. Entremont. 1987. Bacterial growth rate in iced fresh or frozen-thawed Atlantic cod. *Journal of Food Protection* **49**(4):43-45.

Licciardello, J. J. 1990. Freezing. In *The Seafood Industry*. Van Nostrand Reinhold, New York.

Linda, A. H. and J. W. Slavin. 1960. Sanitation aboard fishing trawlers improved by using chlorinated seawater. *Commercial Fisheries Review* 22(1):19-23.

MacCallum, W. A. 1955. Fish handling and hold construction in Canadian North Atlantic trawlers. *Fisheries Research Board of Canada Bulletin* 103-161.

Nicholson, F. J. 1973. The freezing time of fish. Torry Advisory Note No. 62. Torry Research Station. Aberdeen, Scotland.

Olavie, E. Nikkil, and Reino R. Linko. 1956. Freezing, packaging, and frozen storage of fish. *Food Res.* 21(1)42-46.

Pottinger, S. R. 1951. Effect of fluctuating storage temperatures on quality of frozen fish fillets. *Comm. Fish. Rev.* 13(2):19-27.

Procter, B. E. and J. T. R. Nickerson. 1935. An investigation of the sterility of fish tissues. *Journal of Bacteriology* 30:377-382.

Ronsivalli, L. J. and D. W. Baker. 1981. Low temperature preservation of seafood: a review. *Marine Fisheries Review* 43(4).

Ronsivalli, L. J. and J. J. Licciardello. 1975. Factors affecting the shelf life of fish. *U. S. Atomic Energy Commission Activities Report* 27(2):34-42. Oak Ridge, TN.

Shaw, B. G. and J.M. Shewan. 1968. Psychrophilic spoilage bacteria of fish. *Journal of Applied Bacteriology* 31:89-96.

Shewan, J. M. 1961. The microbiology of seawater fish. Pp. 487-560 in *Fish as Food*, vol. 1. G. Borgstrom (ed.). Academic Press Inc., New York.

Slavin, J. W. 1963. Freezing and cold storage. In *Industrial Fishery Technology*, M. E. Stansby (ed.). Krieger, Huntington, NY.

Slavin, J. W. and J. A. Dassow (eds.). 1971. Fishery products. In *ASHRAE Guide and Data Book*. American Heating, Refrigeration and Air Conditioning Engineers, New York.

Spencer, R. 1961. The bacteriology of distant water cod landed at hull. *Journal of Applied Bacteriology* 24:4-11.

Spencer. R. and C. R. Baines. 1964. The effect of temperature on the spoilage of wet fish. *Food Technology* 18:769-773.

Torry Research Station. 1965. Quick Freezing of Fish. Torry Advisory Note No. 27, Aberdeen, Scotland.

Waterman, J. J. 1964. Bulking, shelving, or boxing? Torry Advisory Note #15. Torry Research Station, Aberdeen, Scotland.

Waterman, J. J. 1965. Handling wet fish at sea and onshore. Pp. 133-148 in *Fish Handling and Preservation: Proceedings of Meeting on Fish Technology*. Scheveningen, Sept. 1964. Organization for Economic Cooperation and Development, Paris.

Processing Blue Crab, Shrimp, and King Crab

Donn R. Ward

INTRODUCTION

Crustaceans comprise a relatively small proportion of the marine food products marketed. However, given the diversity of species, the high prices they command, and the fact that species are marketed as cooked, ready-to-eat products, they are an extraordinarily important group.

BLUE CRAB

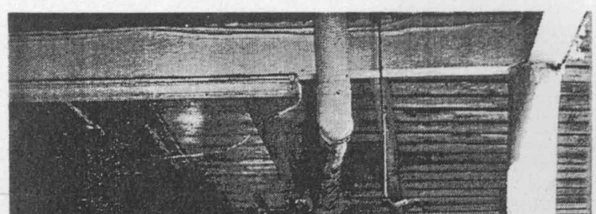
The scientific name of the blue crab, *Callinectes sapidus*, describes three notable attributes of the species. "Calli" is the Latin word for beautiful; "nectes" and "sapidus" the Latin words for swimmer and savory, respectively. The blue crab is thus a beautiful swimmer crab and is also tasty to eat.

PROCESSING

Crabs arrive at processing plants either directly from boats or in trucks which have transported the crabs from other landing sites. The crabs are weighed, then dumped into large stainless steel baskets. During the winter dredging season, the crabs are run through a tumble spray washer prior to being dumped into the baskets. The washing step is essential for dredged crabs because they are covered with sand and grit from being buried in the sandy bottom. While some processors will wash only dredge crabs, others wash all incoming crabs irrespective of season (Figures 1, 2, 3).

Although subsequent handling and cooking methods vary depending on regional customs and state laws, the processing of blue crabs has not changed dramatically since fresh crabmeat was first marketed in the late 1800s. It is a very labor-intensive industry, with most of the picking still done by hand. (See the end of this chapter for steps involved in removing the meat from the crab.) This is a major problem for the industry. In recent years it has been very difficult for processors to find local workers with the essential skills, or interest in developing the skills, to remove the meat from crabs. As a consequence, many processors have resorted to bringing in foreign nationals as seasonal labor.

Currently, the industry processes live crabs either under steam pressure or in boiling water. Some states, such as Maryland, North Carolina, and Florida, have regulations which stipulate that "crabs shall be cooked only under steam pressure." Some regulations go so far as to stipulate cold point temperature minimums; for example, the rules governing crabmeat operations in North Carolina declare, "Crustacea shall be cooked under steam until the internal temperature of the



Figures 1. Cooking live crabs in a horizontal retort.

Figure 2. Performing thermal penetration studies with thermocouples to establish an adequate cooking process.

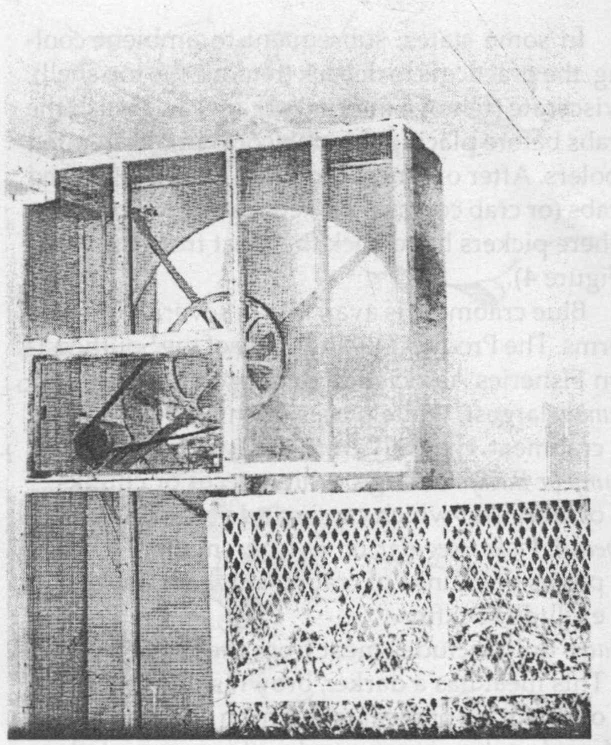


Figure 3. Air-cooling cooked crabs prior to refrigerated storage.

center-most crab reaches 235°F (112.8°C)." The regulations for processing crabs in Texas simply state, "Crabs shall be cooked so as to provide a sterile crab."

Cooking live crabs in a steam retort is the most common processing method. Traditionally, there has been a general lack of uniformity among processors with respect to the times and temperatures used in the steam cook process, state regulations notwithstanding. Regulatory authorities prefer long cook times at high temperatures due to the destruction of microorganisms, which are found as part of the natural microflora of the crab. From the processor's perspective the issue is not just killing microorganisms; it is also economics. The higher the temperature and/or the longer the cook time, the lower the yield of picked meat. The reduction in yield is the result of moisture loss from the edible tissues. Short cook times cause less drying of the meat and, therefore, produce greater yields. Since the average yield of picked meat from a blue crab is approximately 10 percent, this is a problem to which crab processors are acutely sensitive. Furthermore, processors in states that allow crabs to be boiled are clearly at an advantage with respect to yield. Cooking under pressurized steam results in significant moisture loss; this is not an issue when cooking in boiling water.

After cooking, crabs are moved to a cooling room and air-cooled to ambient temperature. The cooling room is usually a screened area or well-ventilated room with exhaust fans to remove the steam rising from the hot crabs. Before crabs are moved to the cooked crab cooler (33° to 40°F/0.6° to 4.4°C), they must be cooled to the extent that steam is no longer rising from them. If cooked crabs were moved immediately to the cooler, without a precooling period, steam rising from the crabs would condense on the ceiling of the cooler and drip back on the crabs. This could potentially contaminate the crabs and result in what is termed a "sour crab." Furthermore, this could serve as a source for contamination with the bacterial pathogen *Listeria monocytogenes*.

In some states, subsequent to ambient cooling, the practice is to deback (remove the top shell), eviscerate (remove internal organs) and wash the crabs before placing the crab cores in refrigerated coolers. After overnight cooling, whole debacked crabs (or crab cores) are taken to the picking room where pickers hand-pick the meat from the crabs (Figure 4).

Blue crabmeat is available in several different forms. The Product Quality Code of the Southeastern Fisheries Association defines these forms as:

Jumbo: largest, white pieces or chunks of crabmeat, typically from the backfin.

Lump or Backfin: large, white pieces or chunks of crabmeat which can include backfin.

Special, Flake, Regular, or Deluxe: smaller, white pieces or chunks of crabmeat which usually exclude backfin.

Claw: only includes meat from the crab claw. This meat has a darker, brownish tint than the other forms of meat taken from the crab body.

Minced: crabmeat removed and/or separated from the shell by a physical process that actually minces the meat.

Mixed: any combination of meat as requested.

Cocktail Claws: clawmeat intact on the claw with the shell removed, except for the forward tip to be used as a handle.

As mentioned previously, the technology used in processing blue crabs has changed little in the past century. Most of the picking is still done by hand. In recent years, however, increasing efforts have been made to perfect various machines for picking meat from the blue crab. Cockey (1980) noted that the different design principles for extracting meat from the crab include vacuuming, squeezing the meat from the legs and bodies with rollers, throwing the meat from the cores by centrifugal force, shaking meat from the core by vibration, or crushing in a hammer mill and separating the meat from the shell by brine flotation. These machines and methods have met with varying degrees of success. Since the mid-1980s, several companies have used meat/bone separators to recover residual meat remaining on the waste from the hand-picking operation. Typically, the material recovered is sold to pet food manufacturers.

One major disadvantage of the machines mentioned is that none allows removal of the backfin portion as one large lump. Inasmuch as consumers desire to purchase crabmeat in lump form and are willing to pay a premium price, it is doubtful that hand-picking will give way completely to machine-picking in the near future.

There have been several attempts at developing "imitation lump," by binding the smaller flake meat pieces into larger pieces. The author is not aware of any firms currently involved in manufacturing such a product. This type of product is different from the imitation crabmeat (usually imitating meat from king crab legs) often seen on salad bars. This latter product is the result of surimi technology.

PASTEURIZATION

Most muscle protein foods, particularly seafoods, are quite perishable. Under normal refrigeration, fresh crabmeat has a shelf-life of approximately seven to 10 days. This relatively short shelf-life places responsibility on all those involved in the processing and marketing channels to handle the product appropriately and quickly. One alternative to the shelf-life problem is freezing. Although blue crabmeat can be frozen successfully, few processors do it because it has traditionally suffered from the same stigma that has affected all frozen seafoods. Another alternative has been pasteurization.

Traditionally, pasteurization of blue crabmeat was understood to involve heating hermetically sealed containers to a cold point temperature (slowest heating point) of 185°F (85°C) and holding for at least one minute. This understanding worked well as long as the industry pasteurized meat in one-pound (454 g), 401x301 cans [4 1/16 inches (10.3 cm) in diameter by 3 1/16 inches (7.8 cm) in height]. In recent years the industry has begun to pasteurize in containers of various sizes, shapes, and composition. This change made it necessary to define crabmeat pasteurization in a more scientifically precise manner. Information on pasteurization processing standards can be obtained from the Blue Crab Industry Association, 1901 N. Fort Meyer Drive, Suite 700, Arlington, VA 22209 (Figures 5 , 6, 7).

Pasteurization extends the shelf life of blue crab meat by destroying the bacteria that would cause spoilage of the fresh product under normal refrigeration conditions. Pasteurized crabmeat,

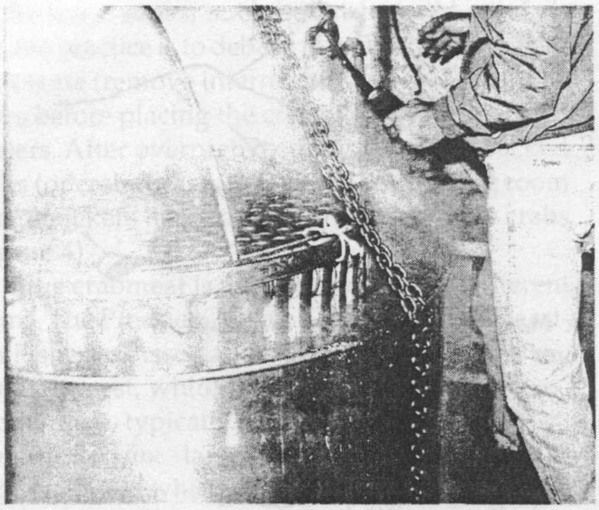


Figure 5. Removing one-pound cans from the pasteurization tank.

like pasteurized milk, must be kept refrigerated. However, since the normal spoilage microorganisms have been destroyed, pasteurized crabmeat has a shelf life of at least six months. Once the can has been opened, the crabmeat should be used within five to seven days.

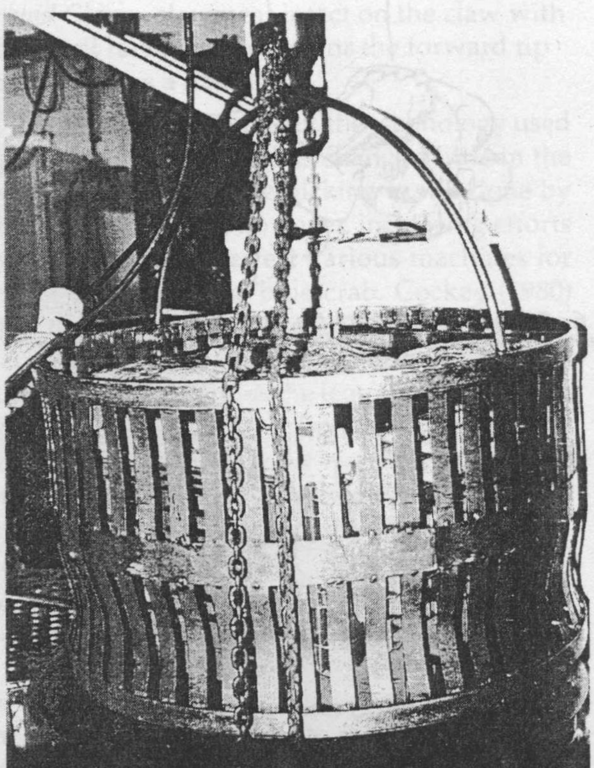


Figure 6. Pasteurization of crabmeat in flexible films.

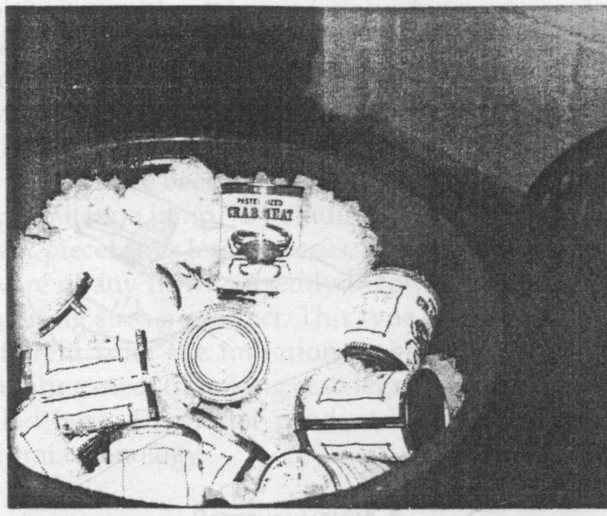


Figure 7. Cooling pasteurized crabmeat in wet ice.

Pasteurization allows processors to inventory product during periods of crab abundance. Furthermore, it allows consumers, particularly those in inland markets, to purchase crabmeat year-round. And just as importantly, the pasteurized product is almost indistinguishable in taste and texture from the fresh product.

Regulatory agencies are currently enforcing a zero tolerance for the microorganism, *Listeria monocytogenes*, on all cooked, ready-to-eat foods such as crabmeat. Since normal pasteurization procedures destroy the organism, some processors concerned with the regulatory repercussions associated with isolation of the bacterium from their product are trying to establish greater market interest in pasteurized crabmeat.

SHRIMP

The commercial shrimp industry is one of the largest seafood industries in the United States both in value and quantity of product caught. There are two commercially important shrimp fisheries: the North Pacific and Alaska area, and the southern fishery located in the South Atlantic and Gulf of Mexico.

In the southern fishery, there are three major commercial species: the white shrimp (*Penaeus setiferus*), the brown shrimp (*Penaeus aztecus*), and the pink shrimp (*Penaeus durarum*). In some areas vessels return to port daily; boats equipped with freezers or adequate ice storage may remain on the fishing grounds for two to three weeks. In recent years, the domestic penaeid shrimp industry has reached a steady-state production condition in terms of available wild resources, and they must compete with an increasing amount of cultured penaeid species from international sources.

Handling of shrimp on board the vessel is critically important. On completion of a tow, the contents of the net are dumped on the deck of the vessel, and the shrimp are separated from the "trash" (i.e., anything that is not shrimp). The latter is usually discarded overboard. Crew members quickly remove the heads of the shrimp by hand, and the "headed" shrimp are then shoveled into baskets and washed with a stream of water.

It is important to head and wash the shrimp before storage. Although the procedure is referred to as heading, in fact crew members remove not just the head but the entire cephalothorax section, which contains the gills and many of the organs associated with the digestive tract. Studies have shown that removal of this section removes a significant source of bacteria as well as active enzymes that can hasten deterioration of the shrimp. Thorough washing is important since this further reduces bacteria and enzymes.

Once headed and washed, two different methods can be used to preserve the catch: icing or brine freezing. Boats using ice usually immerse each basket of shrimp in a "dip" solution prior to placing the shrimp on ice in the vessel's hold. The dip retards the formation of black spot (see later discussion).

Another method of preserving shrimp at sea is brine freezing. According to an article written by Bruce Cox of Texas A&M University, the use of freezers aboard shrimp vessels has been both cursed and applauded by boat owners. The process can produce very favorable results, but attention to detail is important. The following information on brine freezing was adapted from Cox's article.

The proper use of freezer brines is very important. An efficient brine should rapidly freeze shrimp or bring them close to freezing, so that they can be completely frozen in the boat's hold. Proper brine freezing helps prevent black spot and dehydration. Correct mixtures of salt, corn syrup, and dip powder (sodium bisulfite) effectively retard dehydration and black spot formation.

Salt in the proper concentration (23 percent) reduces the freezing point of a brine tank -6°F (-21°C), whereas only slightly less salt significantly affects the freezing capabilities of the brine tank. Corn syrup in the brine mixture coats the shrimp with an elastic coating and helps prevent black spot and dehydration. Regular table sugar becomes brittle and will flake off during the trip. Corn syrup acts as a chemical reducing agent, robbing the black spot enzymes of oxygen which is required to complete the black spot reaction. The syrup coating also holds moisture inside the shrimp, preventing dehydration. Sodium bisulfite (dip powder), like corn syrup, is a chemical reducing agent that effectively binds oxygen so that it is unavailable to the enzymes responsible for black spot formation.

Approximately 50 pounds (22.7 kg) of headed shrimp are placed in open mesh sacks and then submerged in the brine tanks. Shrimp should not be allowed to soak for more than 15 or 20 minutes; otherwise the shrimp will become too salty and eventually toughen. Once brine freezing is complete, the bags are placed in the freezer hold.

At the dock, boats that stored shrimp on ice will flood the hold to melt the ice. The shrimp are then removed by vacuum pumps to wash tanks in the processing plant. Bags of brine-frozen shrimp are off-loaded from the boats and emptied into thaw tanks. Shrimp remain in these tanks for five to 10 minutes to allow the frozen shrimp to separate.

From this point on, whether the shrimp were iced or frozen, the process is much the same. The shrimp are graded according to size. Size grades of shrimp are expressed as "count," meaning the average number of shrimp to the pound. Following are the common commercial size categories:

Less than 10	
10-15	41-45
16-20	46-50
21-25	51-55
26-30	56-60
31-35	61-70
36-40	More than 70