Handling Whiting Aboard Fishing Vessels

JOSEPH J. LICCIARDELLO

Introduction

The same fundamental principles for handling fresh fish in general aboard fishing vessels apply to whiting. Therefore, this article will review the factors which influence the quality of fish aboard fishing boats and will offer recommendations for optimizing quality. Where specific information relative to whiting is available, it will be stressed. It is realized, however, that the fisherman often works under adverse conditions; in this circumstance, some of the recommended practices might be difficult to carry out.

General Considerations

Spoilage of fish commences the moment they 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 feed that may be in the gut, leading to torn bellies and softening of the flesh; and 3) from oxidation of lipid material, resulting in rancidity. In lean fish which have been gutted, spoilage invariably results from bacterial action; whereas, in fatty fish, loss of quality due to oxidative rancidity may precede bacterial spoilage. Rancidity does not seem to play an important role in the spoilage of chilled whiting.

Joseph J. Licciardello is with the Gloucester Laboratory, Northeast Fisheries Center, National Marine Fisheries Service, NOAA, Emerson Avenue, Gloucester, MA 01930.

Factors Affecting Quality

Washing

It is extremely important that the fish be iced as soon as possible after emptying the nets. However, prior to icing, the fish should be washed to remove mud, blood, and intestinal contents which may have been expelled as a result of the intense pressure developing when the nets are hoisted out of the water. Unless the washing operation is executed thoroughly and efficiently, the entire effort can be a waste of time and resources (Castell et al., 1956; MacCallum et al., 1963). 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 also offer the advantage of being geared to a conveyor device for transporting the fish to the hold for stowage with a minimum of handling and in a regulated flow, thus allowing for proper icing (Waterman, 1965).

Bleeding

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

Gutting

Because of the large number of fish usually captured in an average whiting tow, evisceration would be labor intensive and is not carried out except possibly (depending on the economics) with the large fish referred to in the trade as "king whiting." If the fish are to be gutted, it is imperative that this operation be done properly. 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 remained attached to the vent resulted in obnoxious odors in that section of the fillet, and extension of the knife cut beyond the vent into the muscle caused a more rapid deterioration in that area of the fillet removed from the fish (Castell et al., 1956). It is often the practice to remove gills from large fish, particularly in the summertime; this action retarded the development of off-odors and spoilage when the fish were examined as whole gutted fish, it had no effect on the quality of fillets cut from these fish (Castell and Greenough, 1956). 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 was observed that washing eviscerated fish in chlorinated (50-60 ppm) seawater under pressure rinsed the blood and slime off the fish more effectively than did plain seawater (Linda and Slavin, 1960). The odor or color of the flesh was not affected.

Handling

Whiting is a soft textured fish 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, also, a stiffening of the muscle due to contraction (Amlacher, 1961). Bacterial growth on fish does not commence until rigor mortis has been resolved. Thus, to optimize quality, it is necessary that the total 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 the glycogen content at death. A high glycogen content and a low temperature above freezing both serve to prolong rigor. As an example of temperature effect, the duration of rigor for trawl-caught whiting was 20 hours for storage at 0°C (32°F) compared with 11 hours for storage at 12°C (53.6°F) (Cutting, 1939). Rigor mortis is of longer duration when the fish has exerted less muscular activity prior to death resulting in a higher glycogen content (Amano et al., 1953). Bramsnaes (1965) cited results of several studies which demonstated that rigor mortis developed earlier and disappeared sooner in trawl-caught fish compared with 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; and, 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 (Reay, 1949). It is generally acknowledged that whiting do not have as long a chilled storage life compared with other gadoids (Reay and Shewan, 1949; Mendelsohn and Peters, 1962). This may be related to the fact that resolution of rigor in whiting has been found to be much quicker than in other gadoids (Cutting, 1939).

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 10^3 to 10^5 per square centimeter (Georgala, 1958; Spencer, 1961), but through mishandling and contamination from the deck and in the 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 adventitiously 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 20-25°C (68-77°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 (Spencer and Baines, 1964; Ronsivalli and Licciardello, 1975) as the temperature is lowered and approaches 0°C (32°F), the growth rate of fish spoilage bacteria is drastically retarded. It has been shown that a reduction in storage temperature of 3 degrees at just above freezing adds proportionately more to the keeping time of fish than a similar reduction at a higher temperature (Castell and MacCallum, 1950). Consequently, it behooves the fisherman to rapidly lower and maintain the temperature of the fish to 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

Fresh-water 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 5-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 (1 pound) of fish from 12.8 to 0°C (55-32°F), and an additional 0.182 kg (0.4 pound) is required to maintain the fish away from the pen surfaces, to cool the hold, and remove heat leaking into the hold (MacCallum, 1955b).

From these requirements, a ratio of 0.454 kg (1 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 commonly used (Dassow, 1963). In a survey of handling practices aboard whiting vessels in the New England region, it was found that an average of 0.454 kg (1 pound) ice was used for 1.73 kg (3.8 pounds) fish; however, the range was 1:1.8 to 1:8.2 (Peters et al., 1964).

Ice of small particle size such as 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, also, is less damaging to the flesh in comparison with large chucks of ice (Waterman, 1971). 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 washes away blood and bacteria laden slime as it slowly trickles down through the fish.

Storage of ice in a refrigerated compartment is desirable, however, 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 (Anonymous, 1959): Cover the floor of the pen with a layer of ice 20-30 cm (8-12 inches) deep. A 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, and in the case of large fish, the cavity should be filled with ice.

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

In a survey of whiting fishing vessels, it was observed that the fish were usually bulk stored in pens with no shelving (Peters et al., 1964). This practice should be condemned. At the depth of about 3 m (10 feet) found in the unshelved pens of these boats, the pressure on fish at the bottom was calculated to be 780 pounds per square foot (3,900 kg/m^2) (Punchochar and Pottinger, 1947; Peters et al., 1964). These bottom fish are not only poorer in texture compared with the top of the catch but may also have lost 10-12 percent of their original weight (Ellison, 1934; Castell et al., 1956). This situation is exacerbated when the vessel encounters storming seas, and the penned fish are subjected to a physical pounding. Another precaution which must be observed is that species of dissimilar keeping quality should not be stowed together. Thus, for instance, whiting, cod, and plaice having storage lives of approximately 9, 12, and 18 days respectively should be stored separately on long trips (Bramsnaes, 1965).

Cleanliness in the Pens

Optimal quality of fish aboard a fishing vessel is obtained in part by maintaining as low a bacterial load on the fish as possible through sanitary handling practices and by preventing multiplication of the bacteria present by means of adequate cooling. It has been demonstrated that heavy bacterial loads imparted to fish through improper handling aboard fishing boats resulted in shorter shelf life (Castell et al., 1956; Huss et al., 1974).

Although the ice used for cooling the fish has often been found to be a source of bacterial contamination, a prime source of contamination is from slime-ridden boards (Castell et al., 1956; Georgala, 1957; Reay and Shewan, 1960). The bacterial flora of these pen boards is comprised predominately of the psychrophilic types which are ultimately responsible for the typical spoilage of fresh fish.

When fish are stored in pens and firmly pressed against the pen boards, anaerobic conditions prevail at the interface, and these bacteria (predominately pseudomonas species) under these circumstances produce a type of spoilage referred to as "bilgy" fish because it is suggestive of bilge water (McLean and Castell, 1956).

Methods of prevention include cleanliness in the pens and sufficient ice around the fish to maintain aerobic conditions. A thorough cleansing and hosing of the hold and pens after each trip, particularly with a sanitizing agent such as hypochlorite or a quaternary ammonium compound, is strongly recommended (Cutting, 1953; Linda and Slavin, 1960). The use of harbor water which is usually grossly contaminated is to be avoided.

Application of an approved detergent either with a pressure sprayer or by hand scrubbing will greatly facilitate the removal of slime and other organic matter and enhance the effectiveness of the sanitizing agent. With unpainted, porous, slime soaked wooden pen boards, a significant reduction in bacterial count is not usually effected by washing and sanitizing (MacCallum, 1955a).

Resin impregnated wood and particularly metal lined or metal such as aluminum alloy when used for pen construction are most effectively cleaned by washing and sanitizing. Lining the pens with a disposable plastic sheeting such as 6 mil polyethylene is a simple but effective method of protecting fish from pen boards (Tretsven, 1969). The use of paint, although advocated for many years, is now considered of dubious value since moisture can enter into the wood through cuts and abrasions in the coating and promote anaerobic bacterial growth and rotting of the wood. Treatment of the pen boards with a wood preservative such as copper-8-quinolinolate was recommended to prevent wood rot (Tretsven, 1969).

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 in particular is reduced; and, 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 may be a slightly 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, otherwide the "bilgy" type of spoilage may result.

Seawater Ice

Seawater ice has a slightly lower melting point than freshwater ice, and, thus, offers the advantage of cooling fish at a slightly faster rate and to a lower temperature (Peters and Slavin, 1958). There is a disadvantage in that it melts faster than freshwater ice and has to be replenished which necessitates carrying a greater initial load aboard the vessel if obtained from shore based plants. In addition, it cannot be transported to the fishing grounds without being cooled to subfreezing temperatures, or else the concentrated brine contained in the ice would quickly drain off (Eddie, 1961). It is believed that the real advantage of seawater ice may reside in its ability to be easily manufactured at sea where freshwater ice is not available (Slavin, 1965).

Refrigerated Seawater

The benefits of using refrigerated seawater (RSW) or refrigerated brine for storing fresh fish on board a fishing vessel have been stated as: 1) 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 (Stern and Dassow, 1958). 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.

As previously stated, the rate of bacterial growth on fish is depressed considerably by a slight decrease in temperature in the region of 0°C. Storage of whiting in RSW at −1°C (30°F) extended the storage life about 3 days compared with ice storage. Whereas the RSW held fish did not lose any soluble protein (compared with a slight loss for iced fish), there was a significant increase in sodium chloride content which would restrict its use in low sodium diets (Cohen and Peters, 1963a, b). The frozen storage life at −17.8°C (0°F) was comparable for whiting stored for 2 days in either RSW or ice. Beyond a 2-day holding period, the RSW fish had the longer frozen storage life (Peters et al., 1963). Thus, for trips of short duration, the full potential benefit of RSW storage of whiting may not be realized.

In another independent study, summer-caught whole whiting kept on ice for 5 days were considered unmarketable because of very soft texture while fish held in RSW still maintained a firm texture after 5-6 days (Hiltz et al., 1976). The results of this study also confirmed the previous finding that better frozen storage characteristics were obtained with fillets from RSW fish compared with ice fish. Enzymatic production of formaldehyde (and dimethylamine), which is mainly responsible for the development of toughness in the hakes during frozen storage, was less pronounced in the RSW fish.

Although it is now generally regarded that the storage life of whole fish is longer in RSW than in ice, the shelf life is limited by the uptake of water and salt, particularly with the lean fish and with some species by the development of oxidative rancidity. The salt concentration of whiting fillets cut from whole fish stored 5-6 days in RSW was reported to be 0.82-0.85 percent (Hiltz et al., 1976). This salt concentration was not considered objectionable but rather was said to enhance the acceptability of the bland flavored whiting.

A problem common with all fish species held in RSW is the eventual growth of spoilage bacteria in the brine with the production of foul odors which can be imparted to the fish (Roach et al., 1961). The bacterial growth can be suppressed through the addition of antibiotics or carbon dioxide to the seawater (Steiner and Tarr, 1955; Barnett et al., 1971) or by irradiating the seawater with ultraviolet or gamma rays (Peters et al., 1965; Nickerson and Licciardello, 1965). Of these various treatments the use of CO_2 would be the preferred one, although it should be pointed out that with prolonged storage in carbonated RSW, textural deterioration may occur.

Chilled Seawater

For the small boat fisherman, the benefits of RSW storage can be attained without the requirement for a mechanical refrigeration system through the use of chilled seawater (CSW) or slush ice. This entails stowage of fish, ice, and seawater in tanks in the ratio of 3:1:0.5-1. The exact proportions for maintaining temperatures slightly below freezing (0°C) depend on temperature of the fish and seawater and duration of the trip. Successful results have been reported with herring and mackerel (Lemon and Regier, 1976; 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 is maintained.

Recommendations

Following a comprehensive study of the whiting fishing industry for the purpose of improving the quality of landed whiting, the following recommendations were made (Peters et al., 1964): 1) Wash the fish prior to storage in the hold, 2) shelve fish pens at no greater than 4-foot intervals (or box at sea), 3) use 1 pound of ice to each 1.5 pounds of fish (for short trips less ice might suffice), 4) reduce dockside layovers to less than 14 hours, and 5) consider use of refrigerated seawater aboard vessels (hold fish no more than 4 days in ice or 7 days in RSW).

To this list of recommendations, the following should be added: 6) Careful and rapid handling of the fish on deck to reduce their exposure to sunshine and high temperature, 7) prevention of fish from coming in direct contact with pen boards, and 8) addition of a sanitizing agent to the wash water.

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