

USTF TECHNICAL BULLETIN

RECOMMENDATIONS FOR ON-BOARD HANDLING OF PURSE SEINE-CAUGHT TUNA

IF YOU CATCH IT, FREEZE IT!

INTRODUCTION

Tuna quality is preserved only by the proper sequence of chilling and freezing on board the vessel. Preservation of quality must start at the point of capture because quality loss begins when a fish dies and it can never be improved, but it can be maintained with proper care. Tuna are commonly chilled and stored temporarily in refrigerated seawater (RSW) at 30°F. However, rapid chilling to 30°F and continued freezing is necessary to protect tuna quality against deterioration due to bacterial, enzymatic, or oxidative activity.

The United States Tuna Foundation (USTF), from 1992 to 1994, conducted a major tuna quality research project in the central/western Pacific Ocean. Research started at the point of capture and included at-sea handling and refrigeration, on-board quality experiments, offloading and cannery processing. This bulletin summarizes the important findings from the USTF project but also incorporates the findings of other related fish quality studies, as well as practical experience and detailed observations from knowledgeable individuals in the fleet.

The primary source for methods to maintain raw tuna quality on purse seiners is the refrigeration manual written by Frank D. Burns in 1985. This bulletin supplements that manual with updated information.

The highlights of what was learned on the recent USTF research trips, coupled with the practical experiences, are as follows:

- Brail the fish on the boat as quickly as possible with the least amount of physical damage. Speed is essential.
- Load only good fish. Stop brailing when in doubt.
- Pack the fish loosely in the well to allow for good RSW and brine circulation which hastens cooling and freezing rates.
- If fish are loaded into multiple wells, freeze the last fish first.
- Limit the amount loaded per day so as not to exceed the refrigeration capacity of the vessel. This will certainly vary by vessel, by day and relative to the fish already aboard.
- Freeze all of the fish as fast as possible. If you catch it, freeze it.

TUNA QUALITY CHANGES

Tuna used for canning are evaluated at the canneries by testing them chemically and organoleptically (looking and smelling) before they are processed and canned. Only good quality tuna are accepted for packing; marginal or bad quality tuna are rejected.

Good quality tuna is characterized by firm muscle and belly tissue and neutral odor, typical of freshly caught fish. The quality of tuna flesh deteriorates during handling, freezing and storage as a result of a combination of complex changes in the fish tissue caused by the fish's own enzymes, bacteria, chemical reactions and physical damage. The rate of degradation depends primarily upon the temperature of the fish—higher temperatures cause more rapid loss of quality. Rates of spoilage are also

affected by the length of exposure to these elevated temperatures, the biochemical condition of the fish, and the number and kinds of bacteria in and on the fish.

When fish die, spoilage starts because normal metabolism ceases while a series of physical changes begin. These changes are caused by a variety of processes including:

1. Physical damage which occurs during catching, handling and storage.
2. Growth of bacteria found in and on fish and the changes caused by their growth during unfrozen storage.
3. Activity of naturally occurring enzymes in the muscles and digestive system of the fish.
4. Oxidation by chemical action.

Physical Damage

Damaged fish will spoil faster than undamaged fish. This physical damage can occur in the sack, during brailing, or in the well while undergoing packing and freezing. Naturally, the physical damage will be worse during rough seas or large sets.

Bacterial Activity

Bacteria are the most important cause of seafood spoilage. Millions of bacteria are present in the surface slime, on the gills, and in the gut of fish. When fish die, bacteria and the enzymes they produce invade the flesh through the gills, along blood vessels, and directly through the skin and belly cavity lining. In the flesh, bacteria grow and multiply, producing compounds which are responsible for off-odors, off-flavors and decay.

Enzymatic Activity

Enzymes are naturally occurring compounds which dramatically increase the rates of chemical processes. After a fish dies many of these enzymes continue to function and produce undesirable effects, including the production of off-odors, degradation of the digestive tract and a breakdown of muscle tissue. The results are fish with off-odors, belly burn or mushy and pasty flesh.

Oxidative or Chemical Action

Oxygen and/or other chemical elements will attack unsaturated oils in fatty fish such as tuna causing rancidity, off-odors and off-flavors.

FACTORS AFFECTING QUALITY CHANGES

Spoilage and quality changes in seafood are affected by temperature, time and physical treatment. High temperatures increase the rate of spoilage while low temperatures slow spoilage. Fish handling and physical abuse can also affect spoilage.

Temperature and Time

Temperature is the most important factor influencing quality and spoilage rates. Rapid chilling and freezing are crucial in maintaining the quality.

Both enzymatic reaction rates and microbial growth rates are greatly influenced by temperature. Both processes are very active above 30°F. Even minor changes in the temperature range of 30° to 50°F have enormous effects on the growth of bacteria. Seafood spoilage is 4 times faster at 50°F than at 30°F and 2.25 times faster at 40°F than at 30°F. In the central/western Pacific, where sea surface temperatures are 82° to 87°F, tuna often come on board with internal temperatures of 90°F and higher. Spoilage at this temperature is approximately 30 times greater than at 30°F. Even though the bacteria and enzymatic activities have slowed substantially at 30°F, they have not stopped. Fish should be frozen as quickly as possible to halt these activities.

The important influences to maintaining quality of purse-seine caught tuna are:

1. Fish coming on board with high internal temperatures must have the heat removed quickly and be chilled to 30°F as soon as possible to slow the rate of deterioration.
2. Tuna must be frozen as soon as possible to a backbone temperature of 10°F to stop the microbial growth and enzymatic activities and greatly retard oxidative activities.
3. Storing frozen fish dry and as close to 0°F as possible is essential.

Physical Treatment

Rapid and careful handling, from the time the fish are in the net until frozen in the well, will help determine their final quality. Fish remaining in the sack for extended times have a greater chance of becoming soft and less resistant to physical damage. Damaged fish with abraded and broken skin are open to infiltration by bacteria from RSW and brine. Fish that are broken and/or smashed have intestinal damage that leaks bacteria and digestive enzymes into the gut cavity, externally into the surrounding medium and possibly into other fish, thereby hastening deterioration.

AT-SEA HANDLING

The principal responsibility of the chief engineer on a tuna vessel is to preserve the quality of the raw tuna. The safest way to ensure that quality is maintained is to match the vessel's capture rate to its refrigeration capacity, which is its rate or capacity to freeze the fish as quickly as possible. To maintain the quality of a highly perishable food such as tuna requires a comprehensive knowledge of: the characteristics of quality changes in fish, the effects of on-board handling on tuna quality, the ability to apply this knowledge to the rapidly changing conditions on the vessel during a fishing trip, the capacity of the vessel's refrigeration system at all times, and refrigeration principles. The important phases during at-sea handling are sackup and brailing, chilling, packing, freezing and storage. Refrigeration limits affect chilling, freezing and storage but can be affected by the packing density.

Sackup and Brailing

The length of time from sackup until fish are chilled is the most critical phase of handling because of the extremely elevated temperatures involved. The time fish are held at ambient seawater temperatures must

be minimized to limit quality changes and prevent rejects. During large sets there is considerably more chance for quality loss and physical damage due to the longer times fish are dead in the warm (82° to 87°F) seawater. Sea state or environmental conditions which can cause chafing can be significant factors affecting the initial fish quality. If the weather is rough, the problem is compounded because the fish will spend more time in the net and more physical damage will occur.

- Monitor fish quality from long and/or large sets carefully.

Don't ever bring marginal or bad fish on board. Do not waste well space and refrigeration capacity preserving fish that will not be accepted (cannot be sold). If fish are of marginal quality when brought on board, the best handling and freezing can only produce marginal quality frozen fish. The rate of quality loss can be affected by weight of fish in the sack, set size, sea conditions, and the recent feeding activity of the fish. Weight in the net and/or rough sea conditions cause abrasion of the skin and softening of the flesh. Actively feeding tuna are full of highly active digestive enzymes that continue to break down the tuna's own intestinal lining (belly burn) until the fish are frozen and enzyme activity ceases.

The last fish brought on board from a set are the fish that have been dead the longest in warm seawater and have spent the most time subject to existing sea conditions and movement within the net. Fish that are determined as acceptable for loading on board must be chilled and frozen immediately. Most fish with quality problems have a high temperature exposure for a prolonged period at some time in their handling history.

- The best way to maintain quality is to brail quickly.

The best way to maintain quality is to brail quickly and immediately reduce the internal temperature of the fish. This practice also reduces the amount of physical damage that may be sustained in the net due to the weight of the catch and the movement of the net, skiff and seiner. For tuna on feed, the fish must be frozen as quickly as possible to reduce damage by intestinal enzymes.

Chilling in RSW

The maximum rate of heat removal is related directly to the temperature differential between the warm fish and the cold RSW. Maintaining the RSW at the lowest temperature possible will help achieve the maximum chilling effect. Large reserves of RSW or the use of chillers are necessary to have continuously cold RSW.

To produce fish that conform to the highest standards, attention must be paid to these important handling and chilling procedures:

- *Holding fish at 30°F slows down quality degradation but DOES NOT stop it.* Bacterial growth and enzymes are still active at this temperature. Holding fish for more than a very short period of time at 30°F can result in extensive damage to the fish and higher rejects.
- The *last fish* to come on board from a set have been subject to the most temperature and physical abuse and must be chilled first. These fish *need the heat removed immediately* to preserve existing quality.

Packing Density

Packing density has a tremendous effect on reject levels. The ratio of RSW or brine (secondary refrigerant) to fish in a well must be sufficient to have good circulation over the well coils and through the mass of fish even after the fish are completely frozen. Tightly packed wells cause more fish-to-fish contact, thereby reducing the surface area exposed to the RSW or brine. Without good brine circulation around the fish, heat will be retained and chilling and freezing processes slowed.

- Packing densities

Packing densities in the United States fleet range from 70% to 85%; the Spanish shipyards rate their vessels' capacity based on 65% and some Asian fleets are reported at 60%.

Examples of Various Packing Densities And Percent (%) of Brine Lost

<u>Fish to Brine Ratio</u>	<u>85%</u>	<u>80%</u>	<u>75%</u>	<u>70%</u>	<u>65%</u>	<u>60%</u>
<u>Packing Density in Cubic</u>						
Feet/Short Ton	37.6	40.1	42.7	45.8	49.4	53.5
<u>Original Brine Space</u>	15%	20%	25%	30%	35%	40%
<u>Space Remaining When</u>						
Fish are Frozen	9%	15%	20%	26%	31%	36%
<u>Sample Well (2,500 FT³)</u>						
Capacity Gallons Water	18,700	18,700	18,700	18,700	18,700	18,700
Capacity Short Tons Water	78	78	78	78	78	78
Short Tons Tuna	67	62	59	55	51	47
Gallons Brine	2,758	3,747	4,676	5,606	6,565	7,494
<u>Gallons Brine After</u>						
Fish Expand	1,724	2,842	3,833	4,825	5,816	6,807
% of Brine Lost	37%	24%	18%	14%	11%	9%

- Factors affecting packing density

Packing density of a well is affected by various factors including: the firmness of fish, fish size and species, and the size and shape of the well (large wells are easier to overpack especially if fish are soft and brail volume is underestimated). Also there is the added problem of fish expanding during freezing. When the fish expand (usually about 6%) they displace the secondary refrigerant and change the fish-to-brine ratio so there is less fluid available to circulate and remove heat. Additionally, when the fish expand, the circulation channels within the fish mass are restricted or narrowed, thus slowing heat removal from the fish.

- Overpacking

Overpacked wells can crush the fish on or near the bottom of the well because of the additional weight and limited space for expansion. Soft fish overpacked in a well will slow unloading at the cannery and result in a higher amount of smashed or deformed fish of lower quality. Pumping a well dry when loading fish, or when changing from RSW to brine, can add to these problems. Every precaution should be taken to not overpack because of the above factors—*go to tails and no further*. However, every situation (set/well) is unique and the engineer must adjust the packing density to deliver the best quality fish.

Freezing

It is important to freeze the fish as quickly as possible to approximately 10°F, then dry the well and continue to take heat out of the fish down to

about 0°F. Most enzymes retain some activity as long as there is free fluid in the fish. Above 0°F there is still enough unfrozen fluid in the fish to allow quality deterioration to continue slowly. Bacterial activity may continue down to about 15°F, even though it is reduced greatly at 23° to 25°F.

The internal fish temperature will lag behind the brine temperature during chilling and freezing. The internal temperature of big fish, with greater body mass, can be warmer than the RSW and/or brine temperature for many hours until temperatures stabilize. Fish size will dictate the amount of this temperature difference; larger fish can lag several hours behind the brine temperature. *Be sure all fish are fully frozen before drying a well for storage.* Make certain the brine is at 10°F for at least 24 to 48 hours before drying the well to assure that the fish backbone temperature is at 10°F or lower.

Frozen Storage

It is important to hold the temperature as constant as possible during the storage phase. Damage to muscle tissue can be caused by fluctuations in temperatures even within the 0°F to 10°F range. Also when a well is dried, large temperature differences within the well may occur because of heat influxes from differently insulated surfaces such as the outside of the vessel, doors between wells, walls next to the engine room, or non-insulated well coamings. The temperature can be 0°F or less in the middle or bottom of the well but upward of 25°F just below an uninsulated coaming. Some type of *insulating material should be used* in the well coaming and over the hatch cover to keep the dried fish as cold as possible.

Refrigeration Limits

A vessel's "capacity" at any point in time is not the unfilled wells but rather the available refrigeration to preserve the fish coming aboard in the manner dictated by its condition. When fishing on large schools of tuna, *limit the tons of fish brought on board to that amount which can be chilled and frozen within the next 24-36 hours.* Monitor fish condition regularly as they are brought on board and treat *the last fish from a large set* with the highest priority; *chill and freeze it first.*

Adjust handling and freezing based on the condition of the incoming fish. When fishing is heavy, the catch rate or tons of good quality fish being brought on board needs to be matched with the vessels' refrigeration capacity and the engineers' abilities to handle and freeze. It is poor strategy to bring more fish on board than there is capacity to freeze. Properly handling and freezing the tuna that is already on board is more prudent than catching and loading more fish than can be frozen properly and eventually delivering a load with high rejects for such problems as physical damage, belly burn, off-odors, etc. *A vessel's true capacity is what it can properly freeze and preserve in a timely manner.*

EQUIPMENT

Condition and Maintenance of Refrigeration Equipment

The conscientious performance of routine maintenance of the refrigeration system will keep it operating at peak efficiency. Much of this maintenance can be performed after unloading the fish when there is little demand for refrigeration. This maintenance includes: purging non-condensables from

the condensers; inspecting and cleaning the condensers; removing oil from the receiver(s), accumulators, oil traps, and coils; cleaning the strainers; checking and replacing the anodes ("zincs") in the condensers, fish wells, and the compressor's water cooling system; and replacing leaking expansion or shut-off valves. The compressors should be serviced according to schedules provided in the manufacturer's operating instructions. The chief engineer should record in the engine room log, maintenance that has been conducted, along with his comments on the condition of the refrigeration system components.

Coils are a limiting factor in cooling a well and it is important that their efficiency be checked on a regular basis. Compressor oil escaping into the coils acts as an insulator, thus reducing coil effectiveness. The coils must be free of oil to maximize their effective surface area for heat exchange. Oil in a bank of coils may be seen when refrigeration is applied to an empty well and frost does not form on coils.

Well liners should be checked for cracks after each unloading. A cracked liner allows brine and other fluids to seep into the insulation reducing its effectiveness. Also, these fluids may seep back into the well, contaminating the fish. Cleaning and maintaining high standards of sanitation in the wells and on the vessel will help reduce potential contaminating agents and food spoiling microorganisms.

Operation of Equipment

In order to maximize output, it is important to have a good understanding of refrigeration principles. A fundamental understanding of how varying suction pressure affects refrigeration capacity is necessary. Always consult equipment specifications and tables on appropriate pressures, temperatures and tons of refrigeration.

Effective heat transfer requires maintaining a large and constant temperature differential between the primary refrigerant (ammonia - liquid and gas) in the evaporator coils and the secondary refrigerant (RSW and/or brine) in the wells. This is where chillers are beneficial. The temperature differential between the secondary refrigerant and the fish must be maintained until all the fish are completely frozen and the wells dried.

Record Keeping

Good record keeping on the exact loading sequence, dates and the specific use of refrigeration for each well is important in order to determine when, where and why a problem occurred. Working with cannery quality control and fleet personnel can help identify problem areas and solutions to prevent reoccurrence. Good record keeping is necessary to ensure maintenance is taken care of between trips or when the vessel is scheduled to the shipyard and will aid a relief engineer when he makes a trip.

CONCLUDING REMARKS

The following are the most important conclusions derived from the study:

Pack Loose - Reduce Rejects

Load only fish of good quality on board and then loosely pack the wells. Loose packing facilitates rapid heat removal during chilling, reduces

physical damage from crushing when fish are first loaded and soft, and further limits physical damage when the fish freeze and expand approximately 6% in volume. During the unloading of tightly packed wells, unloading time and physical damage are increased due to excessive barring and chopping of the fish out of the well.

Treat "Last" Fish First

The last fish brought on board from a set are the most vulnerable to deterioration and should be the first frozen. These fish have been held at elevated temperatures longer prior to loading, and may encounter further risk by being placed into a well which has already been warmed from fish previously loaded.

Base Catch/Day on Refrigeration Capacity Limits

The refrigeration capacity of a vessel changes daily due to fishing conditions and fish already on board. Do not exceed the vessel's refrigeration capabilities. It is better to spend a few more days on the fishing grounds and to deliver a load of fish where 100% is excellent and of saleable quality than to deliver a load where rejects eliminate profits.

Only Freezing Stops Degradation

Only freezing stops quality degradation and preserves the freshness of the fish on board the vessel. Fish should be chilled to 30°F within 8 hours of capture and frozen within 24 to 36 hours after being brought on board. Quality can never be improved after the fish dies but it can be maintained with proper care.

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Partial List of References

NOTE: Information in this bulletin is based primarily on findings from recent industry research conducted on tuna quality preservation and from the following:

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