Understanding and Controlling Histamine Formation in Troll-Caught Albacore Tuna: A Review and Update of Preliminary Findings from the 1994 Season

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Introduction

The collapse of the Pacific Northwest salmon fishery is causing fishermen to turn increasingly to the albacore tuna fishery as an alternative source of income. However, fishermen need to be aware of problems related to product safety. Improper handling of albacore can cause the fish to produce histamines, and this may cause consumers to fall ill with histamine poisoning.

The U.S. Food and Drug Administration implemented regulations that required acceptable HACCP (Hazard Analysis Critical Control Point) programs to be in place by 1997. The control plans for albacore tuna focus on the formation of histamine, a toxin that can be controlled by rapidly chilling and holding the fish at a low temperature. The FDA maximum level for histamine is 5 mg/100 grams, and any fish containing histamine above this level have to be discarded and destroyed. The regulations specify control measures to either document cooling procedures onboard each harvest vessel, measure histamine levels in fish offloaded at the dock, or take other steps to insure that the histamine level of the product does not exceed the standard.

Measuring histamine involves time-consuming and expensive laboratory procedures that might cause processors to avoid purchasing and processing albacore. For this reason, in 1994 we decided to focus on histamine control measures on fishing vessels. At that time the FDA recommended that albacore be chilled to 40 °F "as rapidly as possible." Our goal was to establish optimal chilling procedures by learning more about the relationships between internal fish temperatures and the ways those fish are chilled and stored onboard.

The scarcity of data on the formation and control of histamine prompted efforts to investigate onboard procedures that chill, rather than freeze, the fish. During the 1994 fishing season, Oregon State University initiated efforts to collect preliminary data by talking to fishermen, observing handling practices onboard fishing vessels, monitoring time and temperatures of chilling fish, and collecting samples for histamine analysis. The following is an account of the work that was accomplished during the 1994 season, with the cooperation of tuna trollers operating out of Newport, Oregon. Fishing took place 100 miles or more offshore, and trip times were between six and eight days.

Temperature Measurement

Instruments

Temperatures were recorded using a Ryan data logger model RTM2000 (Ryan Instruments), a Supco data logger model CR-87 series (Sealed Unit Part Company), and a manually read handheld thermometer by Daytona. The RTM2000 was equipped with three thermistor sensing probes, each 7 mm in diameter and situated at the tip of the cable. The CR-87 data logger had one thermocouple stainless steel sensing probe, which was 10 cm long and had a diameter of 2 mm. The Daytona thermometer, which did not store data, had two probes that were 4 mm in diameter. The Ryan had Celsius and Fahrenheit configurations, whereas the Supco and Daytona had a Fahrenheit configuration only.

Procedures

Temperature-sensing probes were inserted in various areas of randomly sampled fish (figure 1) to

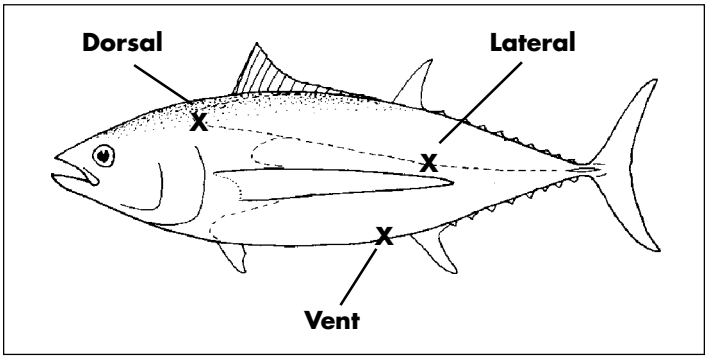

Figure 1. Different location of three probes to determine the area with the highest temperature. Probes labelled "lateral" and "dorsal" were inserted into the red, "hot" muscle. The probe labelled "vent" measured the temperature of the gut cavity. Adapted from Tuna and Billfish—Fish without a Country, *by J. Joseph, W. Klawe, and P. Murphy, 1988 (La Jolla, CA: Inter-American Tropical Tuna Commission), p. 56.*

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determine the location of highest temperature, that is, the section of the fish that presumably should take the longest to chill. Several series of measurements showed that the warmest flesh is the red muscle (figure 2). The sensing probes should be of stainless steel, preferably pointed and not more than 3 or 4 mm in diameter. The CR-87 was more successful in penetrating to the core than the probes produced by Ryan or Daytona and did not come out of the fish as readily. The larger probes of the Ryan and the Daytona were held in the fish less securely and tended to allow some water to leak about the sensor, resulting in incorrect temperature readings.

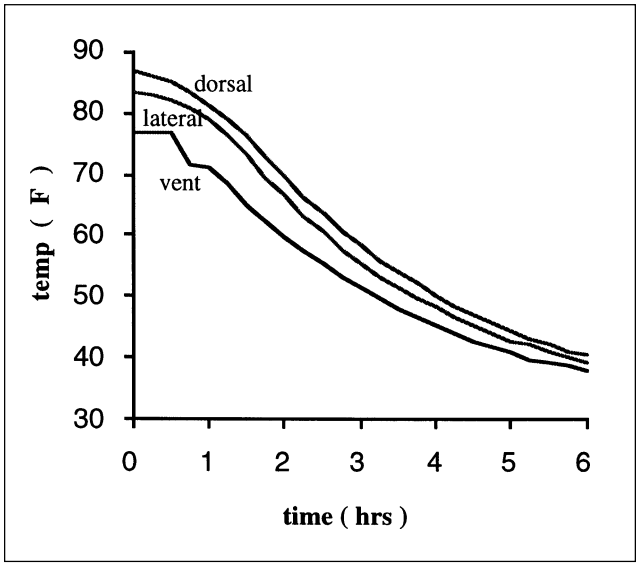

Figure 2. Temperature of fish with time, immersed in slush ice and measured at three different locations. Chill curves labelled "dorsal" and "lateral" describe the cool-down record of the red, "hot" muscle. The chill curve labelled "vent" is of the gut cavity; the probe did not enter the red muscle.

Cooling Procedures

Covered insulated plastic totes, divided diagonally into two compartments, were used as slush ice tanks for chilling fish. Each tote had an internal volume of about 30 cubic feet. Before adding the fish, we added seawater to the ice-filled totes to the top of the ice mass. For an optimum loading density of approximately 22 lb of fish per cubic foot, the maximum number of fish varied from about 35 to 45, for average fish weight of 18 lb and 12 lb, respectively. The division of these small tanks into two compartments decreased space available for fish, and tuna, because of their tapered shape, cannot be tightly packed, as smaller fish, such as whiting, can. As the ice in the tote melted, it was augmented periodically to maintain an ice-to-water ratio of about one-to-one. Fish remained in the slush ice tank until their core temperature had decreased to 40 °F or below. The quantity of ice available determined how often the water in the slush ice tank was changed. In general the water was replaced at the start of each day.

Agitation

Agitation prevents water in the tank from stratifying into warm and cold layers, reducing the effectiveness of the slush. In practice, the vessel's motion usually provided enough agitation, although the ice slush was occasionally stirred by hand.

Ice

The ice used had a rough cube shape and is an example of a "wet" ice. The wet surfaces, and possibly partial refreezing in the hold, caused large solid chunks to form. Ice then had to be broken up into usable pieces, but the resulting pieces had corners and rough edges. This ice caused some bruising of fish in the slush ice tank; there appeared to be additional bruising when the fish were stored in the hold. The damage in some cases was so severe that the sides of fish were lacerated, exposing flesh and bones.

Sampling

Fish, once hooked, generally took 1 minute to land. Vigorous struggling by the fish sometimes caused the fisherman to insert the gaff in the body, damaging and contaminating edible flesh. This problem occurred more often with larger fish (>20 lb), which were more difficult to land than smaller fish (~12 lb). Fish were pulled on board quickly and dropped to the deck, where they struggled violently. Fish were then bled by severing blood vessels between the gills and heart located on the lower jaw, and death occurred within 10 to 15 minutes. The time fish spent on deck before being placed in slush ice varied between 15 minutes and 4 hours, depending on the catch rate. Some fish were eviscerated before chilling, as an additional quality experiment. Gutting appeared to produce a higher-quality product than chilling and storing the fish whole.

Chill Rates

Fish placed in the slush ice had a faster chill rate than those that were chilled using ice only (figure 3 is typical). Figure 4 shows how fish size affects chilling rate: the core of 12-lb fish cooled to 40 °F in about 4 hours; 20-lb fish required about 2 additional hours to reach this temperature.

Histamine Formation

Fish samples collected during the 1994 season that had been chilled in slush ice and ice to 40 °F were

collected and analyzed for histamine levels at the Department of Food Science and Technology at Oregon State University. Samples taken from fish immediately after landing also were examined for histamine levels. Researchers used a high-pressure liquid chromatography technique to determine histamine concentrations in the samples. Sections from the front, middle, and end of each fish were mixed together, so histamine levels were an average. These sections contained red and white tissue, bone, and viscera. Twenty-two fish from three trips, ranging from 10 to 22 lb, were analyzed for histamine.

Histamine levels ranged from a high of about 1.5 mg to less than 0.5 mg per 100 g in all fish that had been chilled in slush ice. These concentrations are well below the maximum level (5 mg/100 g) required by the FDA.

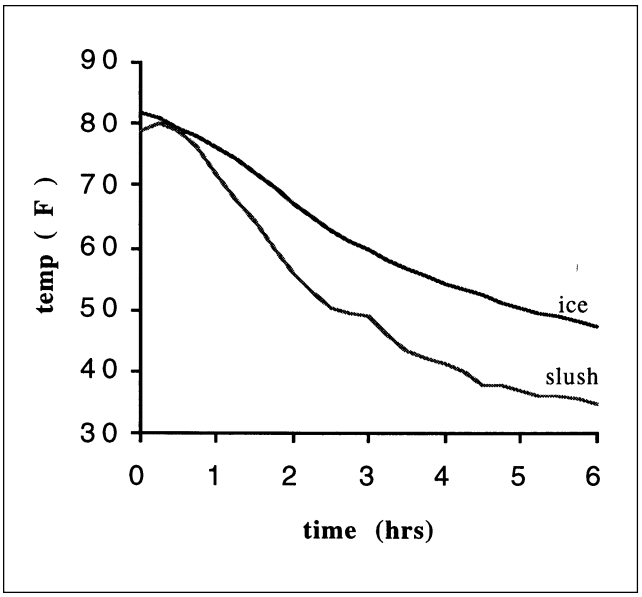

Figure 3. Chill curves of fish cooled in slush ice and in ice only.

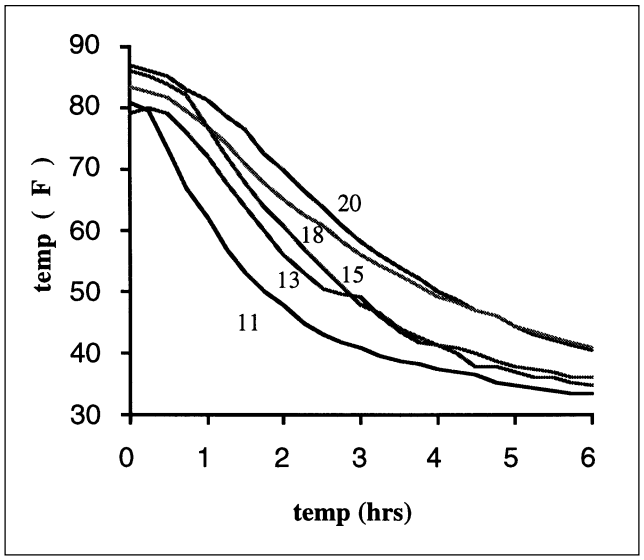

Figure 4. Chill curves of fish cooled in slush ice. The different curves represent fish of different weights, in pounds.

Recommendations

The 1994 research was used to develop controls of product safety and built on previous and current work to develop new products and markets for the Northwest albacore industry. Measures to control the safety of troll-caught albacore tuna are closely linked with those controlling quality. The development of quality assurance programs using HACCP guidelines will provide an efficient mechanism to improve product quality and market opportunities.

The first edition of the FDA's hazards guide *(Fish and Fishery Products Hazards and Controls Guide)*, published in September 1996, recommended that the internal temperature of tuna should be brought to 50 °F or below within 6 hours of death. This recommendation is consistent with our 1994 research, which showed that properly designed and operated chilling systems are capable of such chilling rates (figures 3 and 4). However, in the second edition of the *Hazards and Controls Guide*, published in January 1998, the FDA relaxed those safety recommendations on the basis of their own research. At present they recommend that fish 20 pounds or less and not exposed to temperatures of above 83 °F be placed in refrigerated seawater or brine within 9 hours of death or placed in ice within 12 hours of death. These conditions of weight and temperature are typical of albacore landed in the eastern North Pacific off the coast of the U.S.

The FDA recommendations are based solely on safety considerations regarding histamine formation and could result in fish that show obvious signs of spoilage (decomposition), which would violate the FDA's rules for good manufacturing practices. For this reason we recommend that first buyers of albacore screen and reject unfrozen albacore that show obvious signs of decomposition or are delivered with internal temperatures above 40 °F (the lowest temperature where histamine can form). By developing a HACCP plan with a Critical Control Point at receiving with a Critical Limit of "no obvious signs of decomposition" and "internal temperatures of 40 °F or less," first buyers can insure that the albacore they buy are both safe and high in quality.

There are several stages during the handling of fish where there is potential for bruising and contaminating the flesh, both threats to product quality. We suggest the following precautions.

- When landing fish, minimize the gaff penetration of usable meat. When fish are hauled onboard, a deck covering of foam pads reduces bruising when the fish are dropped to the deck.

- Club all fish on the head or spike them in the brain so that they are immobilized and cannot thrash about on deck. While being bled, fish could be placed in a "bleeding bin," a bin or tank containing seawater. This would help reduce bruising and begin the chilling process.
- Generally 4 to 5 hours were required to achieve a core temperature of 40 °F when the fish were placed in slush ice. If the catch rate was high (greater than thirty-five 20-lb fish every 4 hours, for example), fish remained on deck, since the slush ice tank did not have the capacity for this catch rate. Cooling the core temperature to 50 °F in the slush ice tank (2 to 3 hours) and then continue chilling on ice in the hold would reduce the time fish remained at temperatures that allow rapid histamine production.
- Use a second plastic tote as a bleeding bin or as a second slush ice tank.
- Find different ice types or practices that will minimize sharp-edged chunk formation and the resulting bruising or puncturing of fish.

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Additional Reading

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