John DeBeer,[1*] Fred Nolte,[2]
Christopher W. Lord[3] and Javier Colley[4]

[1*]Chicken of the Sea International, 2150 E. Grand Ave., El Segundo, CA 90245, USA
[2] Fred Nolte Consulting, 22503 West 5th Ave., Vancouver, BC, Canada V6K 1S9
[3] Pro-Tech International Consultants Co. Ltd., Sethiwan Residence 6A, 85 Sukhumvit 13, Klongtoey Nua, Wattana, Bangkok 10110, Thailand
[4] Chicken of the Sea Georgia Canning, 129 N. Commerce Drive, Lyons, GA 30436, USA

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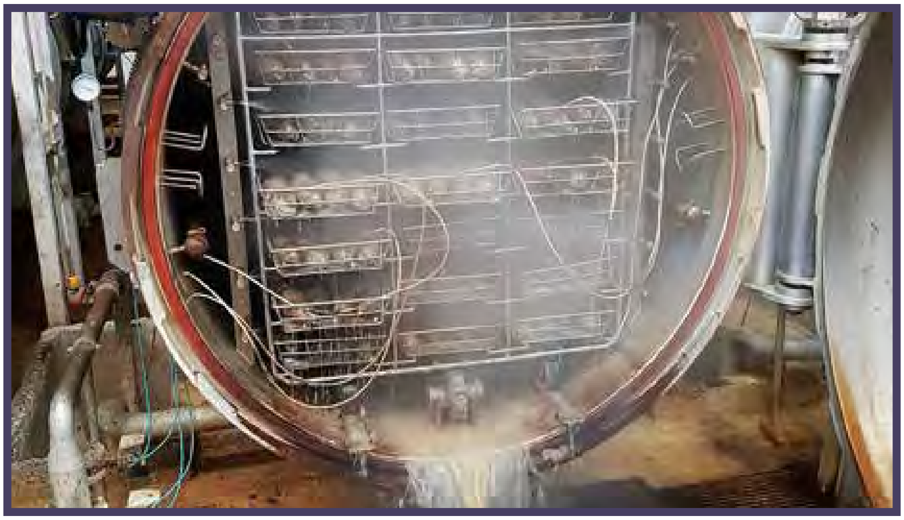
6200 Aurora Ave., Suite 200W, Des Moines, IA 50322-2864



Precooking Tuna: A Heat of Summation Analysis of Different Heating Profiles

ABSTRACT

A Heat of Summation model was developed to compare the number of minutes of temperatures over 60°C to which tuna meat is subjected during precooking in conventional atmospheric and in vacuum precookers, using various steam heating profiles. The Heat of Summation model was developed using finite difference methods. Lower precooking temperatures resulted in lower Heat of Summation values, but longer times were required to precook the fish to a core temperature of 60°C. In the end, the available precooking capacity combined with the desired product appearance and texture will determine which cooking temperature profile and equipment to use.

INTRODUCTION

This manuscript reports on a study that modeled, analyzed, and compared different steam temperature precooking profiles for precooking tuna. The advantages and disadvantages of precookers capable of using these profiles are compared. The comparison is of precooking either with a constant steam precooker temperature or with various other controlled steam precooking temperatures profiles. The target audiences for this research are tuna cannery management as well as operations and quality control personnel.

Hazard Analysis Critical Control Point programs

All seafood sold in the United States must be processed according to a Hazard Analysis Critical Control Point (HACCP) program as specified in the Fish and Fishery Products Regulation and enforced by the U.S. Food and Drug Administration (FDA) *(12)*. The FDA published the latest Fish and Fishery Products Hazards & Controls Guidance (4th ed.) in 2011 *(25)*.

Scombroid toxin (histamine) formation, a hazard in the tuna business from catch to can *(15)*, is entirely preventable with proper processing times and temperatures, either cold or heat. The histamine molecule is heat and cold resistant, so *prevention* of toxin formation is the only control *(25)*. The HACCP Guidance *(25)* and other publications *(1)* advise time and temperature controls to prevent histamine formation on tuna catcher boats and in tuna processing factories.

*Author for correspondence: Phone: +1 760.670.6141; Fax: +1 858.362.9211; Email: john.debeer@thaiunion.com

Tuna canning

Commercially canned tuna is produced through a sequence of processing steps that must be controlled with HACCP Critical Control Points (CCPs) and Critical Limits (CLs) of times and temperatures. A flowchart of the tuna canning process has been provided in DeBeer et al. *(9)*.

Processing tuna for canning is essentially separating the head, entrails, skin, bones, and red meat from the desired white, or light, meat muscle. The head, entrails, skin, and bones are generally used for fish meal, the red meat for pet food, and the white/light meat for human consumption.

The conventional commercial tuna canning process consists of at least nine essential steps, including heating (cooking) the tuna twice. The tuna is generally received frozen at the processing factories. The processing steps start with sorting the frozen fish by size, then thawing, butchering, precooking (the first heating step), cooling, deskinning and cleaning (separation of the red meat and bones from the edible loins), filling and sealing the cans, cups, or pouches, retorting (the second heating step), and cooling the retorted containers inside and then outside the retorts *(7)*. The success of each step depends on the correct completion of the previous step, and all steps impact the recovery of cleaned loin meat. Recovery is measured as a percentage of the weight of cleaned edible loins recovered divided by the original weight of the round fish *(5)*.

The primary reason for precooking the tuna is to denature and stabilize the meat from butchered, whole fish to make it easier to clean *(3)*. This initial heating step takes place in precookers of various designs and sophistication, but most tuna precookers use live steam as the heating medium *(3, 7)*. The phase change for the conversion of water from liquid to gas (steam) and back occurs at 100°C at sea-level atmospheric pressures. The temperature changes with different pressures, so, for example, retorting (the second heating step) uses higher pressures to reach higher temperatures. In a vacuum precooker (VPC), the pressure can be controlled by vacuum pumps or other means to provide lower pressures, which cause the steam to change phase at lower temperatures, thereby making it possible to cook with live steam at temperatures below 100°C.

Precooking the fish to the correct backbone temperature is important for several reasons: (a) reaching the correct core temperature and denaturing the muscle protein so it can be separated easily from the red meat, skin, and bones, (b) serving as a HACCP CCP to control the potential hazard of histamine formation *(1)*, and (c) allowing inspection for honeycomb *(13)* and other visual defects.

The most important prerequisite for effective and uniform precooking is to sort and group the fish by size (sizing) at the frozen fish reception area so that similarly sized fish enter the thickness-dependent steps of thawing, precooking, and cooling together *(6, 16)*. This sizing step helps produce consistent fish core temperatures during processing. Sizing the fish can be done manually or mechanically, but the best tuna processing practices include a sizing step of some kind. It has never been the experience of the authors that all the fish delivered are of a uniform size; thus sizing becomes a critical first step for maximizing recovery.

If tuna are overcooked, moisture, fish oils, and soluble proteins are driven out of the fish *(3)*, so recovery is lost. This recovery loss is not easily noticed, because the losses become just part of the cookout juice along with the condensed steam (water) at the bottom of the precooker. Sometimes precooker cycles are extended by 60 min or more to allow for thawing at the center of the larger fish before all the fish can be cooked to the proper core temperature *(6, 16)*. This excess precooking time results in even more recovery loss, which shows why fish should be completely thawed before precooking. The sizing, thawing, and precooking steps are probably the most critical of the actionable items for recovery *(5, 6, 16)*, although others are also important.

There is also a danger of undercooking the fish. Undercooked fish shows raw or undercooked meat near the backbone, and the soluble protein, which is not completely denatured, can form a white curd in the retorted can. The recovery loss in this case is caused by failure of the light/white meat protein to separate cleanly from the red meat or the skeletal bones. Undercooked fish also has a higher risk of histamine formation if there is any delay in processing *(6)*.

The 2011 HACCP Guidance document *(25)* recommends a CL of 12 h for processing of canned tuna from the start of thawing until the start of the retort process, unless the heating step is shown to be sufficient to control the histamine forming bacteria (HFB). Since the HACCP Guidance document was published, several papers have been published that provide evidence that reaching a minimum core temperature of 60°C for precooked tuna will result in a 5-log reduction in HFB. The analysis is based on studies using *Morganella morganii*, the most heat resistant and histaminogenic of the HFBs *(1, 8, 10, 17)*. The inhibition of HFB by precooking was followed by factory validation that precooking to a proper core temperature does inhibit HFB growth *(1)*. With a precooking CCP, the factory will gain at least an additional 12 h of processing time after the end of precooking *(1)*. This a huge advantage for the factory, essentially more than doubling the processing time, which is needed for larger fish. The methods for verifying the tuna core temperatures at the end of precooking are provided by DeBeer et al. *(8, 9, 10)*.

Precooking methodology

The three general methods for precooking tuna, each using specialized equipment, are (a) conventional atmospheric precookers (CAPs), with the steam vented naturally into the atmosphere *(7)*, (b) vacuum precookers (VPCs), in which the pressures and resulting steam temperatures can be controlled up or down by water sprays and vacuum pumps *(26, 27)*, and (c) heated water baths open to the atmosphere, historically used primarily in Europe *(18)*. The first two methods are by far the most prevalent and will be described in some detail. The different heating profiles for CAPs and VPCs are described by DeBeer et al. *(7)*. The water immersion system will not be further discussed.

The shapes of the precookers help define their purpose and usage. A CAP is generally a box-shaped object with straight sides and doors, designed to hold rectangular fish racks. Steam generally enters from pipes near the bottom and leaves through vents at the top. Pipes and valves at the bottom allow the condensed steam and fish juices to drain by gravity. A VPC is cylindrical, with circular doors that can withstand the various pressures and vacuums created. The condensed steam (water) and fish juices are pumped out during the processing cycle. There are two sets of water sprays, one to spray on the fish to cool the fish as needed and the other to spray on the inside of the VPC hull to collapse the steam and to assist in creating the vacuum and in lowering the pressure and temperature *(4)*.

A CAP *(Fig. 1)* allows steam at 100°C to enter the precooker at full flow at the start of precooking. A vent or vents are open to the atmosphere so that air can escape to be replaced by live steam. The live steam condenses on the cooler fish, releasing the latent heat of vaporization into the fish and thus heating the fish, while the lost condensed steam is replenished by means of an automatic steam controller. The steam continues to be added to the precooker as needed and heats (precooks) the fish so they can be cleaned easily.

With a VPC, a computer-controlled program controls the precooking cycle, relying on temperature probes to monitor the core temperatures and to stop the steam and start the cooling cycle. In a VPC, a vacuum pump is used to create the initial vacuum for removing the free air at the start of the precooking cycle to be replaced by steam (venting) and to provide vacuum during the cooling phase. An example of a VPC temperature profile is shown in *Fig. 2*. This shows a common steam temperature profile range from 100°C down to 65°C, called step-down precooking *(16)*. The temperature depends on the pressure, so, depending on the pressure, the steam at these different temperatures will condense on the cooler fish. The latent heat of vaporization is still transferred to the fish, but the fish are precooked at lower temperatures. This provides a gentler heating profile than that with a

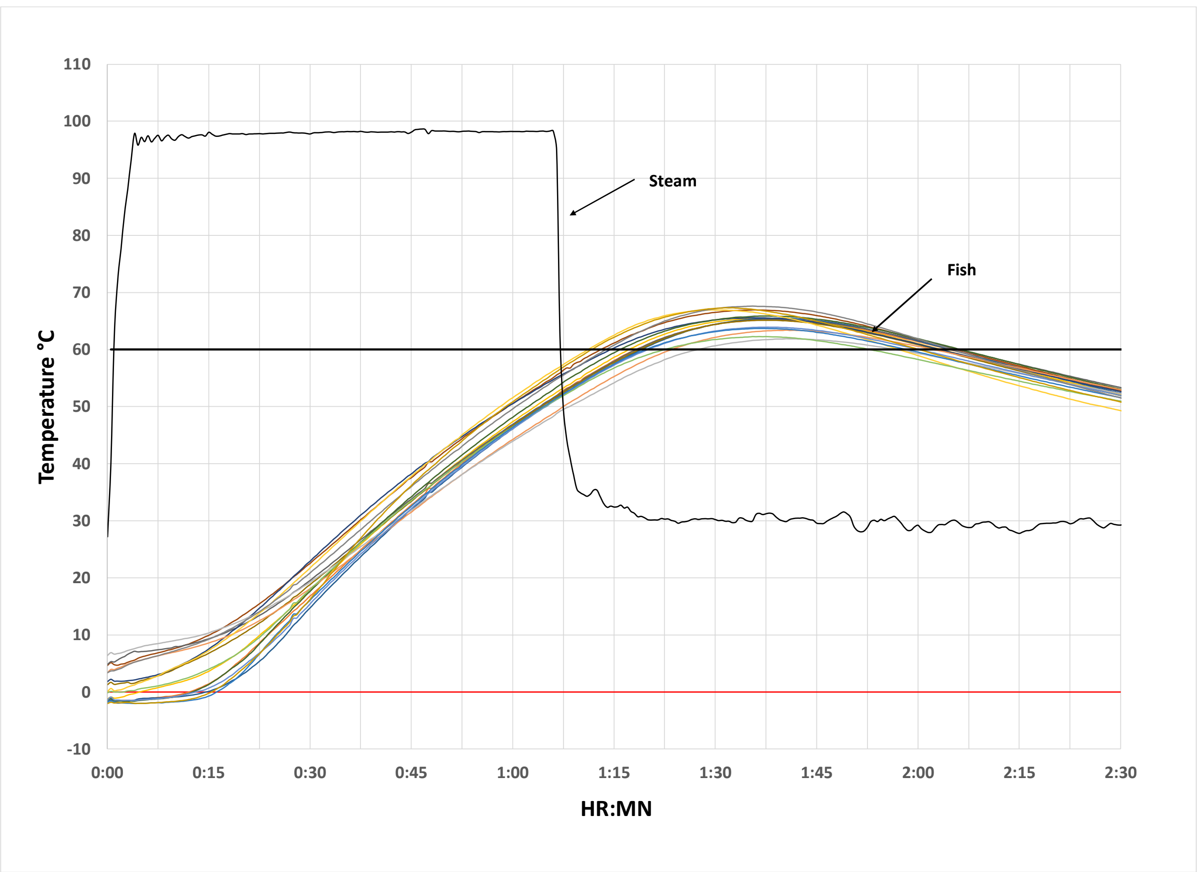


Figure 1. Temperature profile from conventional atmospheric precooker (CAP) – 2 to 2.2 kg Skipjack.

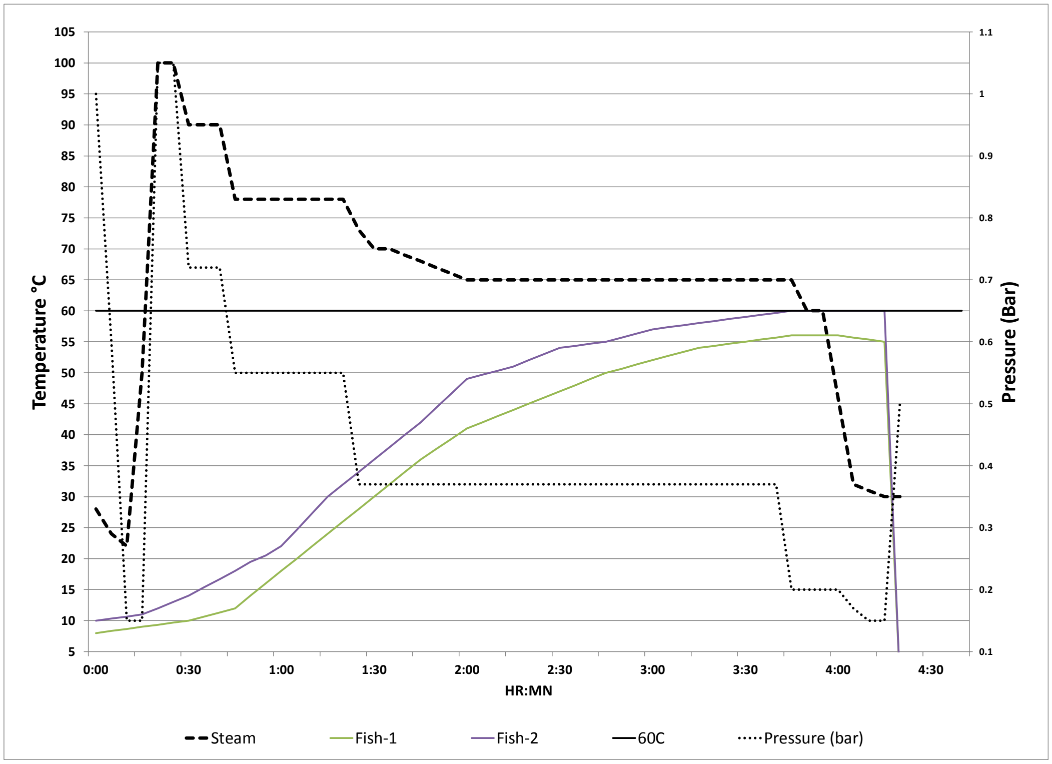


Figure 2. Vacuum Precooker Heating Profile (VPC) – 20 kg Albacore split in half.

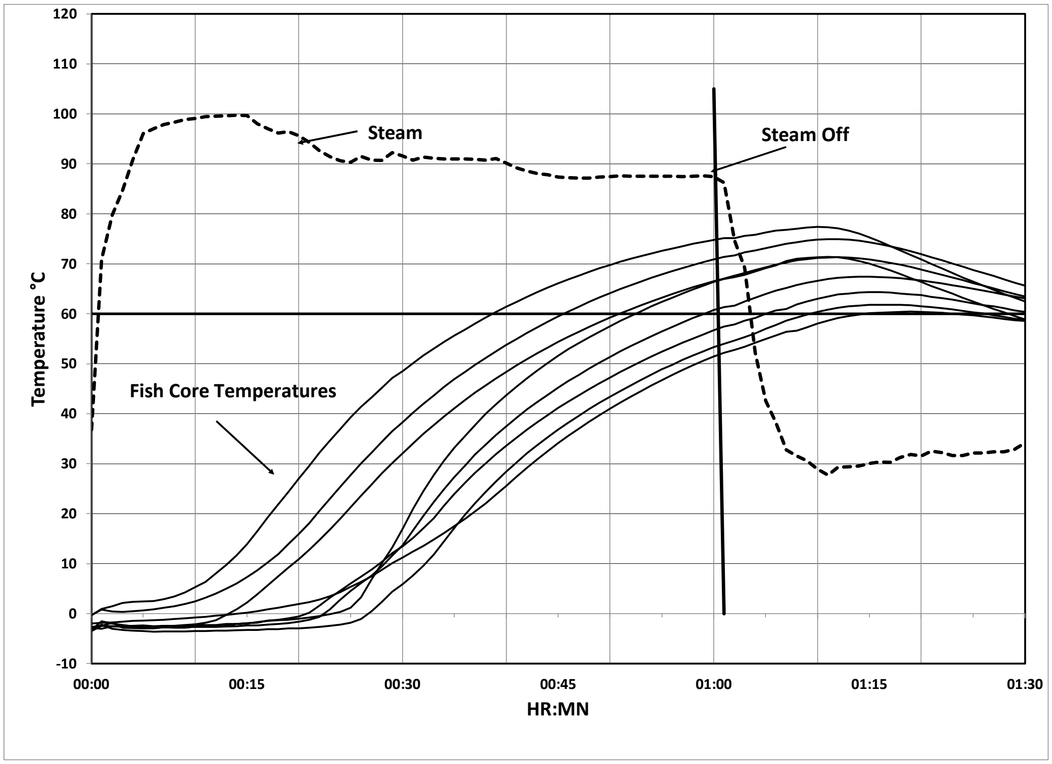


Figure 3. Step-down precooking profile in a conventional atmospheric precooker (CAP) – 1 to 1.4 kg Skipjack.

constant 100°C. Note that the core temperature of Fish #2, *(Fig. 2)* did not reach 60°C. This data profile was collected well before the 2011 HACCP Guidance *(25)*, when the minimum target core temperature was 57.2°C (135°F) *(19)*.

The target minimum backbone or core temperature is 60°C or an equivalent time and temperature that provide the needed minimum 5-log reduction of *M. morganii* and other HFB populations *(1, 8, 17)* and allow the white/light meat to be separated easily from the skin, bones and red meat. The operators learn from experience when to turn the steam off and how to use precooking time/temperature tables. The increase in fish core temperature after the steam stops is called overshoot *(18)*. Typically, after the fish are cooked, they are removed from the precooker to a cooling area, where water misters spray water on the fish to cool them (water-spray zones or sidespray) before they are transferred to a chill room. Sidespray is much more effective if adequate air circulation is provided to assist in the cooling cycle *(16, 19, 20)*.

Effective cooling can also occur under vacuum within the VPC. After the steam heating has stopped, more vacuum is applied, and water is sprayed on the fish. Note in *Figure 2* that the partial pressure drops to less than 0.2 bar, and the steam or chamber temperature to 30°C, for some minutes during the cooling cycle. Perez-Martin et al. estimate that cooling is six times faster in a VPC than in a CAP *(18)*. Some of the water evaporates, and heat is removed from the fish as the water evaporates. This is a very effective method of cooling the fish *(18)*. Because the fish is cooled under vacuum, no free oxygen is available to oxidize the fish meat, so light meat stays lighter and albacore stays whiter. *Precooking and cooling under controlled atmosphere are key to preventing oxidation and retaining the color in tuna meat (6).*

The End Point Internal Product Temperatures (EPIPTs) are collected after the fish are unloaded from the CAP to determine whether the minimum core temperature has reached 60°C. The sample size and data collection techniques and analysis are described in DeBeer et al. *(9, 10)*. If, however, the fish are to be cooled within the VPC, the fish need to be monitored with internal temperature probes to determine whether a minimum core temperatures of 60°C has been reached. The precooker controller controls the EPIPT and the cooling process *(26, 27)*. One feature of the VPC is that, if the last stage of the precooker cycle has a steam temperature of 70°C, none of the fish core temperatures will exceed 70°C. This means that fish with a lower internal temperature at the start of precooking (partially frozen) can and will catch up with the other fish, so the backbone temperatures are more uniform at the end of the precook cycle *(6, 16)*; however, this is actually a disadvantage, because the precooking cycle becomes extended.

A step-down precooking profile can be used either in a CAP *(Fig. 3)* or a VPC, but as discussed, a VPC with the vacuum pumps and water spray valves working together can control a step-down heating profile more accurately and faster than a CAP *(6)*. To lower the ambient temperature in a CAP, air is allowed to enter the precooker vessel, but the internal pressure must stay the same as the outside air pressure, or the vessel may collapse. The temperature reduction is more gradual and takes longer than in a sealed VPC. The resulting air/steam mixture is less efficient at precooking the fish, and thus more time is needed to satisfy the precooking CCP and CL of 60°C. Therefore, for the heating profiles in this paper, the CAP will use a 100°C ambient cooking temperature and VPCs will be used for the various step-down and other profiles.

Each of the precooking heating regimes applies different amounts of heat to the tuna. Because faster cooling time are possible in a VPC, the total preparation time may be equal or even shorter *(18)* than in a CAP, although the length of time the fish remain in the VPC for the cook and cool cycle is longer than in a CAP. The cook/cool cycle in a CAP system consists of cooking in the precooker but cooling outside the precooker, in the sidespray zone, compared with a VPC, where all can occur within the precooker.

Some important lessons can be learned from *Figure 3.* Note the initial temperatures (ITs); while some of the fish are completely thawed to 0°C, some are well below 0°C, meaning they still have ice at the core. This ice must melt before the temperature can rise. The authors acknowledge that there is no definitive freezing point of tuna and that 0°C is used as a practical reference point for the sake of this discussion. To be able to cook these fish with ITs below 0°C to a final minimum 60°C core temperature, the properly thawed fish were cooked to 77°C (i.e., overcooked). The minor fish size variation is probably less important than the presence or absence of a frozen core *(6)*.

Cook values and heat of summation

"Cook value" means the measurement of heat treatment with respect to physical and chemical degradation or sensory quality attributes, e.g., nutrient degradation, textural changes, or appearance of foods *(2, 14)*, and is determined by measuring the extent of cooking and nutritional loss during processing in a manner similar to that used for determining the D-value in retorting, except that the reference temperature is 100°C instead of 121°C, and the z-value is 33°C. The D and z-values depend on the nutritional factor being measured. These must be determined by studying the effects of heat, the same way that bacterial or spore D and z-values are determined *(14)*. The cook value could be related to factors such as protein denaturation, moisture loss, scorch, or anything else that can be measured numerically.

Cook values must be determined and validated experimentally for specific attributes. There is no standard method of assessing cook values during precooking of tuna, but there is a way to measure the cumulative effect on different portions of the tuna during precooking. The concept of "heat of summation" (HOS) will be used to compare the various precooking temperature profiles of CAPs and VPCs. Insofar as the degradation of many measurable attributes of a product is a direct result of heating received, it follows that a measure of accumulated heat would serve as a predictor of that degradation. Hence HOS, as a measure of accumulated heat, would provide a useful predictive tool for optimizing a process, without the need to conduct extensive determination of Cook D values and z-values.

Heat of summation

The internal temperatures of tuna meat resulting from different steam temperature precooking profiles can be compared with each other using the same concept as "degree-days" used in the agricultural industry *(24)*. A degree-day is the sum of the mean daily temperatures above 50°F, e.g., 30 degree-days means 30 days in which the mean temperature is over 50°F by one degree. In this paper, an internal degree-minute (deg-min) will be used instead of degree-days of external exposure. Deg-min will be defined as the sum of temperatures higher than the target for the core temperature over many segments of the fish. Thus, only those segments with temperatures greater than the target will contribute to the summation calculation.

A finite difference temperature model described in DeBeer et al. *(7)* was used to calculate the HOS. In this model, the cross-sectional area of the fish was divided into 31 virtual concentric ring segments. As the external temperature changes, the heat passes from the surface of the fish through the interior meat to the core during heating and from the interior back to the surface during cooling; therefore, during precooking some portions of the fish are either increasing in temperature or decreasing in temperature, depending on the changing surface temperature.

The finite difference model can be used to track the temperature and time spent at that temperature for each segment of the fish. The calculation for each segment will vary depending on the different sizes and thicknesses of the fish, so fish of the same size and thickness were used for all the calculations. HOS is the sum of the values calculated for these segments for the time needed to reach the target at the core. The cooling portion was not modeled, for technical reasons. This method provides a way of comparing the heating portion of the precooking process, although it may not be the best method for estimating "cook values." The HOS can be thought of as another way to express "cook value," using deg-min as the measure instead of nutrient degradation *(2, 14)*.

Bell et al. *(3)* describe changes in tuna muscle structure during heating; there are changes in the muscle protein components actin, myosin, and collagen, as well as protein denaturation, muscle shrinkage, and moisture loss. They showed that the peak of collagen denaturation is 59°C. Stagg et al. *(23)* and Ruilova-Duval *(22)* report that heat-stable endogenous proteases (cathepsins) are active in skipjack and albacore tuna between 50°C and 60°C, which is right in the target zone for the core temperature at the end of precooking. Cathepsins are proteases (enzymes) that break down muscle proteins, causing muscle softening; thus, the fish should not spend too long in this temperature zone and should be chilled quickly after precooking to prevent unnecessary losses in yield and quality *(21)*.

A core temperature of 60°C for controlling the HFB has been validated *(1)*, so 60°C was chosen as the target temperature for the HOS calculation. Therefore deg-min is the sum of [(x°C–60°C)] where x°C is the temperature of a single segment for a unit of time. For example, if a segment of fish is 70°C for 5 min, that segment would have experienced (70°C–60°C) * 5 min, or 50 deg-min. If a segment on the outside is at 100°C for 5 min, that segment would have experienced (100°C–60°C) * 5 min, or 200 deg-min. All segments will have different temperatures from the outside to the core, and the deg-min values for all of these segments will be summed as the fish is heated to the stopping point.

The objective of this study is to compare the total precooking times and HOS values for the various precooking steam heating temperature profiles. Fish that are properly sorted by size and uniformly thawed have a fairly predictable time for precooking, so the precooking can be stopped before the fish are overcooked *(7)*. Overcooking can occur rather quickly if the steam temperature remains at 100°C when the minimum batch core temperature goal of 60°C is reached, because the higher temperature of the outer layers will continue to pass heat to the inner layers. This contrasts with heating profiles of the VPCs, where the temperature starts at 100°C, with subsequent steps-down to lower pressure and steam temperature to slow the heating rate.

Actually, CAP precooking times are generally accurately estimated by an experienced operator. If there are core temperature probes in the fish, the steam is turned off when the temperature passes a certain minimum point, because of the planned overshoot *(18)*. All VPCs are computer controlled, while only some CAPs are computer controlled *(6)*.

METHODS & MATERIALS

Different ambient steam temperature profiles were modeled for total precooking time, using the finite difference spreadsheet described in DeBeer et al. *(7)*. The heating profiles included (a) straight line precooking temperatures (temperature held constant) at different steam temperatures, (b) different step-down scenarios, (c) profiles reducing the temperature continuously from 100°C downward, and (d) a continuous changing heat triangle profile. A total of 17 profiles were modeled. To keep things uniform, the steam was turned off when the simulated core temperature was certain to reach 60°C and no more with the overshoot *(18)*. The times for each stage and the total times were recorded, as well as the HOS value. The time was measured from steam-on until steam-off; then the next time period (overshoot) was measured after steam-off until the core temperature reached 60°C. Step-down heating profiles included a maximum of four steps used (three steps down). To keep things uniform, a single size category was used (8 kg fish, 17.9 cm thick) to model the various profiles. An exponential regression line was plotted for the total cooking time from an initial temperature (IT) of 0°C to a core temperature of 60°C versus the heat of summation values.

RESULTS

The results of testing each profile and values of the HOS are listed in *Table 1*. The values of the HOS ranged from 10,537 deg-min for fish precooked in a straight-line profile at 70°C to 33,871 deg-min for fish precooked with a straight-line profile at 120°C. Only one of all these profiles was of a CAP with a temperature of 100°C, where the HOS was 27,360 deg-min. The most common profiles experienced by the authors are those that step down starting with 100°C and stepping down to 70°C; these ranged from 20,885 to 24,465 deg-min.

An exponential regression line *(Fig. 4)* was calculated for the total cooking time required to go from an IT of 0°C to a core temperature of 60°C versus the HOS values (R^2, 99%). Thus, no matter which scenario was tested, the heat of summation is very highly correlated with the total time for the core temperature to reach 60°C; that is, the longer it takes to cook the fish, the less the fish flesh is exposed to high temperatures. This is an ideal situation, and no precooking fish profile will exactly mimic these results, but it does give a very good general indication of the time and heating impact of different step-down precooking profiles and should help in designing various precooking profiles.

TABLE 1. Heat of Summation results from different heating profiles

Type of Heating Profile	Steam Temperature Profile	Hr:Mn							Deg-Min
		Step 1	Step 2	Step 3	Step 4	Minutes to Steam off	Heating Step to 60°C	Total minutes to 60°C	HOS
Straight line	120°C	1:28				1:28	0:44	2:12	33,871
	110°C	1:38				1:38	0:41	2:19	30,178
	100°C *	1:51				1:51	0:40	2:31	27,360
	90°C	2:08				2:08	0:40	2:48	22,873
	80°C	2:38				2:38	0:34	3:12	18,072
	70°C	3:30				3:30	0:33	4:03	10,537
Step down from 100°C	100/90°C	0:35	1:30			2:05	0:37	2:42	24,465
	100/90/80°C	0:35	0:35	1:07		2:17	0:37	2:54	21,934
	100/90/80/70°C	0:35	0:35	0:35	0:45	2:30	0:31	3:01	20,885
Step down from 90°C	90/80°C	1:10	1:14			2:24	0:37	3:01	20,806
	90/80/70°C	0:45	0:45	1:24		2:54	0:34	3:28	16,263
Gradual step	99/97/94/90°C	0:11	0:30	0:30	0:52	2:03	0:37	2:40	24,867
Continuous step down	100 / 92	1:58				1:58	0:40	2:38	25,904
	100 / 82.5	2:07				2:07	0:37	2:44	23,670
	100 / 70.4	2:22				2:22	0:38	3:00	20,826
Triangle profile	70 / 87 / 71	1:24	1:14			2:38	0:37	3:15	17,382
	71 / 90 / 70	1:17	1:14			2:31	0:37	3:08	18,672
Fish size	17.9 cm Thick, ~ 8 kg Tuna								
* CAP or VPC									

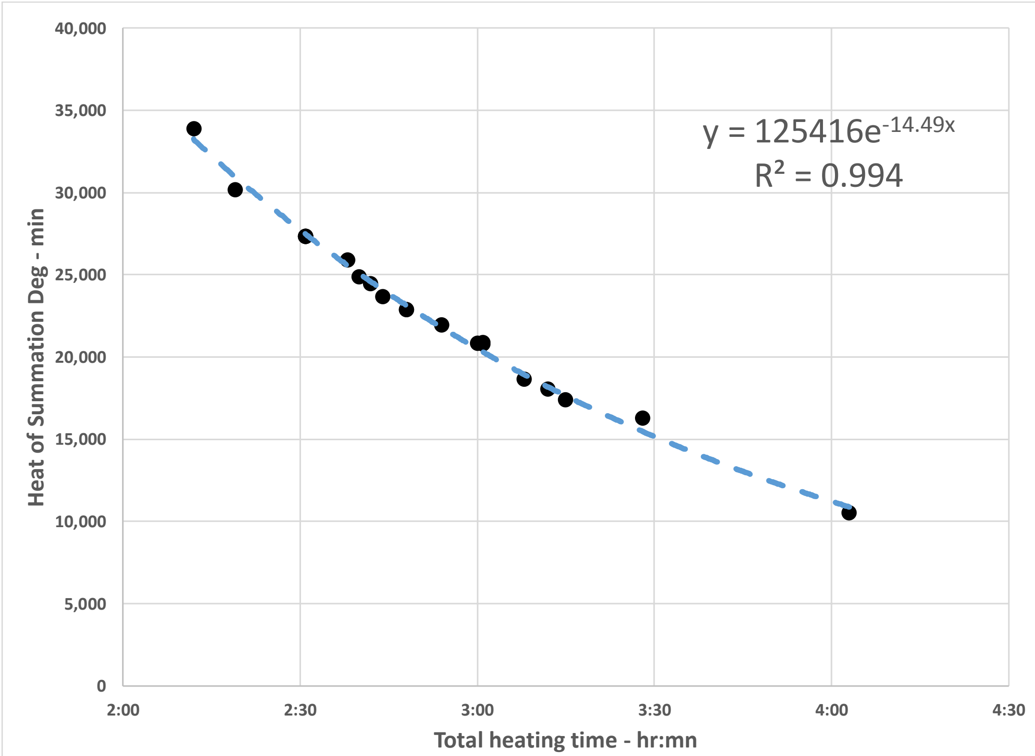


Figure 4. Heat of Summation versus Precooking Time – 8 kg tuna.

DISCUSSION

The three constraints on choosing between CAPs and VPCs, with their various step-down steam temperature heating profiles, are (a) time available for the fish size being processed, (b) time the core temperature spends in the 50°C–60°C temperature range (cathepsins zone), and (c) time the outer portions of the fish spend in the 90°C–100°C zone. The factory management will want to maximize recovery of the tuna and to minimize all of the items just listed. This will require a comparison of precooking time and temperature profiles versus recovery, fish color, and fish texture for each fish size.

Dr. Jun Weng, patent holder for the FMC/JBT controller for the JBT VPC (26, 27) and a world expert on using VPCs, started with a 10 min, 100°C precooking temperature and then adjusted the time and temperature in a stepwise fashion to minimize the "cook value" for the maximum period of time available. His idea was that the 10-min, 100°C cook killed the surface bacteria *(16)*.

To minimize excess heating to the fish, the operations team needs to make certain the fish are completely thawed prior to precooking, so that there is no excess lag time when the fish are being thawed in the precooker. Because a minimum core temperature of 60°C is a HACCP critical limit, the outside of the unthawed fish is overheated if it is precooked longer than necessary while the inside is thawing. This is a waste of energy; the fish is overcooked, resulting in a loss of moisture/fat/protein and lower recovery, and more fuel is burned to produce the excess steam required. Precooking time is reflected in capital costs, because the longer it takes to precook a batch of a given size of needed tuna, the more extra precooking capacity is needed in equipment and floor space *(6, 16)*. However, there may also be a need for the attributes of fish cooked in a VPC, for example, whiter product color. In the end, the balance between these two, recovery and product attributes, and the time available to precook and cool a load of tuna will determine the heating profile depending on the fish size.

The outer portion of the fish and the thinner tail sections are the parts that suffer the most from overcooking *(26, 27)*. The core of the tuna is rarely overcooked; the danger is undercooking. The VPC with the controlled stepdown precooking profile was designed to help offset these situations, but even fish precooked in VPCs need to be thawed properly.

CONCLUSIONS

While the most common method of precooking is with a CAP, use of the VPC method has advantages:

1. This vacuum-controlled cooking and cooling occurs in a minimum oxygen environment, reducing the oxidation and subsequent darkening of the fish (a real advantage

for retaining lighter color with all tuna species *(6)*, but especially albacore).
2. The cylinder-shaped VPC vessel allows the operator to add pressure or create vacuum at will, by use of computer software, without danger of a vessel collapse.
3. The slower precooking process allows fish with different ITs to finish cooking to more consistent backbone (core) temperatures.
4. The initial cooling can be evaporative by adding water spray, which adds moisture to the fish surface, collapsing the steam and creating a vacuum to cool the fish faster. The water touches the hot fish and evaporates, cooling the fish while maintaining recovery. This results in faster cooling, an advantage for lowering the meat temperatures quickly through the cathepsins-active zone.
5. The fish can then be further cooled under vacuum, or both doors can be opened, and forced air and water spray can be used to cool the fish further or the fish can be moved into the sidespray cooling zone.

The disadvantages of a VPC precooker are:
1. There are higher purchase (capital) costs.
2. The step-down profiles require longer precooking times, and, with vacuum cooling, the fish remain in the precooker so that the actual occupancy of the precooker unit is even longer.
3. Generally, fewer fish are precooked per cycle, because the chamber is round rather than rectangular, so that more fish can be precooked in a standard precooker of the same length.
4. Because of the internal water spray equipment, VPCs require more routine maintenance.
5. The operator can use a controlled thaw (ramp up heating) to finish the thawing process, if needed or desired; not recommended by the authors.
6. Unless the fish are properly thawed, there is a tendency to overcook the outside of the fish, losing recovery. A VPC is not a panacea for bad thawing; there is no panacea for bad thawing. Tuna can be precooked to a 60°C backbone starting with frozen fish, but the outer portions will be badly overcooked, and recovery will surely suffer.

Properly preparing the fish for precooking so that the entire precooker batch is of the same size group and uniform ITs, with no frozen fish, is very important. Proper preparation is the key to success. The importance of sorting the fish into different size groups (sizing) and thawing these fish together to a consistent IT cannot be overstated. These are the least expensive and most effective methods of increasing recovery.

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