CHARACTERIZATION OF WASTES FROM BLUE CRAB PROCESSING FACILITIES

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As environmental legislation becomes more stringent, the blue crab industry is being challenged to develop technically and economically feasible methods to manage their liquid and solid wastes. The blue crab industry is one of the largest seafood processing industries in Virginia. Almost 50 blue crab processing firms are presently certified by the Bureau of Shellfish Sanitation, Virginia Health Department (R. E. Croonenberghs, 1991, Richmond, VA, Virginia Department of Health information bulletin). The industry is economically vital to many communities of the Chesapeake Bay and its tributaries. In 1989, there was a total landing of 206.7 million pounds of blue crab in the United States valued at $1 million dollars. The Chesapeake region produced 89 million pounds of this total (11). Solutions to the waste management problems are essential for the future of many blue crab processing facilities. Some of the solutions will require the application of innovative technology, while others will result in substantially increased production costs.

In the 1970’s, the United States Environmental Protection Agency (EPA) developed documents which defined effluent limits for segments of the seafood processing industry. The regulations were then adopted by the states. Compliance with these limits was obtained, in most cases, with minor plant modifications that did not require large capital investments and operating costs. During the last decade, citizen and environmental groups have encouraged more stringent legislation in an effort to achieve a cleaner environment. Individual states have established waste disposal standards that exceed current U.S. EPA requirements.

The restoration of water quality in the Chesapeake Bay has become a goal of states which border the Bay and its tributaries. In Virginia, the State Water Control Board (SWCB) has initiated a vigorous program to remove pollutants from the Bay. As a result, new standards for the disposal of liquid and solid wastes have been established. The new standards, many of which substantially exceed previous standards, have resulted in: the loss of public landfills; highly regulated waste transportation regulations; the inability of municipal systems to accept industrial wastes; waste disposal surcharges; and perhaps most importantly, new liquid effluent standards for discharge into receiving waters. Many blue crab processors have reported serious waste disposal problems as they are unable to consistently comply with their current allowable pollutant discharge limits.

Waste management is difficult for blue crab processing firms for several reasons. In general, crab firms are less capitalized and do not have the economics of scale when compared to some other seafood industries. Treatment systems with the ability to produce the desired effluent quality may not be economically feasible. Chemical, biological and physical treatment may be required to reduce the strength of processing plant effluents.
(7,12). These treatment processes will be expensive and require adequate planning to avoid unfavorable economic impact.

Secondly, the location of processing plants also creates problems. Most blue crab processing facilities are located in rural areas on bodies of water. These facilities usually do not have access to municipal waste treatment plants. Land application and lagoon treatment are often not viable treatment options due to the high water table and wetland limitations. Some larger crab plants are located in cities with access to municipal treatment systems. However, these plants are often assessed substantial surcharges unless the concentration of their waste is reduced. There is also a possibility that municipal treatment systems may be forced to reject crab wastes due to the rapid population and industrial growth that is pushing municipal waste treatment systems to maximum operating capacity. Furthermore, plants located in metropolitan areas often lack the space needed for treatment systems. The plants are usually tightly bordered by water, parking lots and/or neighboring industries.

Finally, in Virginia, as the SWCB is in a period of transition in implementing new standards, different crab processing firms are often monitored for different effluent constituents. This discrepancy can even appear in two adjacent crab plants. The inconsistency of the regulations makes it difficult for the industry as a group to address its waste disposal alternatives.

The blue crab processing industry faces serious solid and liquid waste disposal problems. Approximately 14% of the live crab results in food for human consumption with the remainder as byproducts or waste (5). Consequently, processing firms will need to develop in-plant programs that will include: water conservation and recovery processes, improved by-product recovery systems and the development of industrial products from wastes (including foods, feeds, or biologics). The achievement of such a goal presents substantial economic and technical obstacles and may be one of the greatest challenges in the future.

The objective of this project, funded by the National and Virginia Sea Grant Programs, was to characterize waste streams and identify ways to reduce waste quantities and strengths at three blue crab processing facilities. The bulk of this paper deals with characterization of wastes generated during processing, but some treatment studies are presented. The results of additional treatability studies will be presented in later publications.

MATERIALS AND METHODS

Plant processes

The waste streams of each individual process in three blue crab processing plants were characterized. The three plants studied are all located in Virginia. The first plant sits on the Rappahannock River in rural surroundings. The second and third plants are located in downtown Hampton, Virginia. For the purposes of this paper, the processing facilities will be designated plant #1, #2 and #3 respectively. Two trips were made to plants #1 and #3. Three trips were made to plant #2.

The typical steps for processing live blue crabs are shown in Figure 1. The unrefrigerated live crabs are usually delivered by boat or truck to processing plants. The crabs are weighed, then dumped into large stainless steel baskets. During the winter dredging season, the crabs are directed through a tumble spray washer prior to being dumped into baskets. This washing step is essential for dredged crabs because they are covered with sand and grit from being buried in sand.
Figure 1 - Flow diagram of blue crab processing.
After washing, the crabs are placed into horizontal or vertical retorts, and cooked by steaming for 7 to 23 minutes at 121°F and 15 psig (9). The main objectives of cooking are to facilitate removal of meat from the shell, give the product a characteristic crab meat odor and flavor, and reduce microbial populations.

Following cooking, the crabs are moved to a room where they are air-cooled to ambient temperatures within thirty minutes. Before the cooled crabs are moved to the cooler (33°F to 40°F), they must be cool enough that steam is no longer rising from them. If cooked crabs were moved immediately to the cooler, steam rising from the crabs would condense on the ceiling of the cooler and drip back down on the crabs. This could potentially contaminate the cooked crabs (10,14).

Two different processes are used to prepare the crabs for removal of the meat (picking): a wet process and a dry process. In the wet process, crabs are backed (carapace removed) and declawed first. The crab bodies are then washed by hand or machine and the meat is removed immediately, or the bodies may be refrigerated overnight. The dry process, most commonly used in the Chesapeake Bay area, does not include the washing step. Each picker backs, declaws, and removes all meat from each crab (4).

Picking meat from the crab is labor intensive and is sometimes supplemented in a few large plants by mechanized picking. The Harris Claw machine combines hammer mills with brine-tank flotation to remove the meat from claws. The Quik-Pik machine uses high speed vibration to remove body meat from the crab (4,13). The Quik-Pik process may also include a bobber which mechanically cuts off the legs, removes the carapace and then removes the viscera from the remaining core using spray jets and brushes. The bobber produces a concentrated effluent.

After the picking process, the meat goes through a deboning step in which any remaining shell fragments are removed from the meat by hand. The deboned meat is then packed fresh, frozen or pasteurized.

In plant #1, crabs are processed by hand picking and the Harris Claw machine. The second plant uses both of these processes but also uses the Quik-Pik machine. The third plant uses only hand picking. In the first and second plants, the following processes were characterized: cooking, hand picking, Quik-Pik (plant 2 only), Harris Claw, and cleanup. In the third plant, only the cooker effluent was characterized. In this paper the cooker effluent will be called "retort water", effluent from the Quik-Pik process will be called "Quik-Pik bobber liquid".

Several different effluent streams were produced in the Harris Claw process. These streams were characterized separately and are named as follows: claw wash reel, shell liquid, brine bath and claw meat conveyor wash. At the start of the process, the claws are usually washed in a tumble spray process resulting in the "claw wash reel" effluent. The claws are then shattered as they pass through a hammer mill and the resulting meat and shell fragments fall into a tank of approximately 70% saturated brine solution. Due to the differing specific gravities between the meat, shell fragments and brine solution, the meat floats to the top of the tank while the shell fragments settle to the bottom. The shell pieces are carried out of the tank by a conveyor where they empty into a perforated receptacle. The shell conveyor carries a large quantity of the brine solution out with the shell fragments and is responsible for the "shell liquid" effluent. The perforations in the receptacle allow the liquid to run out leaving only the shell remaining.

The meat that floats to the top of the tank is carried off by another conveyor belt where it is washed with potable water through a spray nozzle to reduce the salt content.
Meat on the conveyor is also checked by hand to ensure removal of any remaining shell bits. This "claw meat wash water" provided a third effluent stream from the Harris Claw process. The final effluent from this process is the brine bath. The brine tank is filled only once or twice during a processing day, but is continually being refilled as solution spills over in the tank or is carried out by the conveyor belts.

**Process flows and volumes**

In the process characterizations, effluent flow rates and volumes were determined in the following ways. First, the water line which fed the Harris Claw process at plant #1 had a flow totalization meter. Omega FTB series turbine flow totalization meters were placed on several individual feed lines of the Harris Claw and Quik-Pik process at plant #2. The effluent volumes produced over a given period of time could be read directly from the meters.

Some effluent streams, such as the shell liquid effluent, could not be read directly from totalization meters. In this case, the time required for the effluent to fill a calibrated five gallon bucket was recorded. When the bucket method was used, several samples were collected during process operations and the results averaged to improve the accuracy of the measurement.

The volume of the Harris Claw brine tanks was determined by measuring their dimensions. This volume was multiplied by the number of times the brine tanks were dumped and refilled during the day. Some solution was removed from the brine tanks by the meat and the shell fragment conveyor belts. This volume was accounted for in the measurements of those respective effluent streams.

Finally, the volume of the retort water was determined in two separate ways. At plants #1 and #2, retort water flowed through pipes which discharged at the edge of the docks. The cooker water was collected by placing a five gallon bucket over the end of the pipe, and then repeatedly transferring the contents of the bucket to a large calibrated receptacle, until the cooking cycle was complete. At plant #3, the pipe exiting the cooker was attached to a fire hose. The fire hose was connected directly to a 55 gallon industrial drum where all the fluids from a cook were collected.

**Sample collection, preservation and transport**

Samples of each effluent were collected in the following manner. First, a grab sample of a given effluent was collected in a clean, five gallon bucket when a process was operating at full speed. The contents of the bucket were mixed thoroughly and then transferred into 500 ml polyethylene bottles. At this time, the temperature and pH of the sample were taken. Half of the samples were then acidified to a pH of 2.0 or below for preservation. All samples were immediately placed on ice in a barrier container.

Two exceptions to the method of collection were the retort water from the cookers and the brine bath from the Harris Claw process. For the retort water, all the fluids from a cooking cycle were collected in a 55 gallon receptacle. The contents of the drum was mixed thoroughly with a paddle to homogenize the sample. Samples were then transferred to polyethylene bottles by a hand pump. The entire effluent stream from the cook was collected after it was determined that the characteristics of the retort water changed substantially during the cooking cycle and a single grab sample would not be representative.
The samples of the brine bath were collected at the end of the Harris Claw process cycle just before the contents of the brine tank was dumped. The same brine solution was used for the entire processing period and therefore was most concentrated at the end of the cycle.

After all samples had been collected, they were packed on ice and transported by car to VPI & SU's Environmental Engineering Analysis Laboratory in Blacksburg, Virginia. The samples were then placed in a 4 °C refrigerator until all analyses were performed. All tests on non-acidified samples were completed within 48 hours of collection and all tests on acidified samples were completed within 28 days as prescribed by EPA sample preservation methods (6).

Analytical procedures

Effluent samples were analyzed for the following: pH, temperature, chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD₅), total suspended solids (TSS), volatile suspended solids (VSS), total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH₃N), total phosphorous, oil and grease (O&G) and chloride (Cl). The criteria used in selecting these tests was to include those that are now regulated, those that may be regulated in the near future, and those that might impact treatment works or the environment.

All samples were performed in accordance with Standard Methods for the Examination of Water and Wastewater (1) with the following notations:

- BOD₅ samples were not seeded with the exception of those used in the acidification treatability study. With the acidified samples, the pH was adjusted to approximately 7.0. The samples were then seeded with effluent from a municipal activated sludge facility. Quality control samples made from standard glucose solution were included.

- Following distillation, TKN and NH₃N were determined by titration with 0.02N H₂SO₄.

- Chloride was determined by means of ion chromatography (Dionex model 2010i chromatograph) with a cross-linked polystyrene/divinyl benzene column, flow rate of 2 ml/min and pressure of 1,000 psi.

- Total phosphorus was determined using the ascorbic acid method with persulfate digestion. Absorbance values were determined with a Beckman DU-6 spectrophotometer at a wavelength of 880 nm. A standard curve was produced for each set of samples.

Treatability studies

Three limited treatability studies were performed on individual effluent streams from blue crab processing plants. In the first tests, settling and filtration of effluent samples were performed. COD, BOD₅, TSS, VSS, TKN, NH₃N, and total phosphorus were determined for each effluent type before settling, after settling and after filtration. To obtain settled values, collected samples were mixed and then allowed to settle at room temperature for one hour. The supernatant from a sample was then analyzed for the above constituents. To obtained filtered values, samples were filtered through Whatman grade 934AH glass-fiber filters. Analyses were performed on the filtrate.

Second, retort water, Harris Claw shell solution and Harris Claw brine bath was acidified to test for removal of COD, BOD₅ and TSS. The authors noted that when the pH of the effluent samples was adjusted to 2.0 or below with concentrated H₂SO₄ for preservation purposes, coagulation of the contents occurred due to the denaturation of
proteins and perhaps other substances. The coagulated material floated to the top of the sample for the retort water and settled to the bottom of the Harris Claw shell and brine bath solutions.

To test treatability through acidification, the pH of the three samples was decreased to 2.0. The samples were then allowed to sit undisturbed for 24 hours. The respective supernatants and supernatants were then removed and the remaining solution was tested for COD, BOD\textsubscript{5} and TSS. As noted earlier, BOD\textsubscript{5} test samples were increased back up to approximately pH 7.0 and seeded with activated sludge effluent. More testing needs to be done using a range of pH values and settling times to gain a better understanding of the treatment method.

Finally, an aerobic treatment study of the cooker water was initiated using a bench-scale, sequencing batch reactor (SBR). A 12 liter SBR was filled with 10 liters of retort water from plant #1. The reactor was then seeded with 2 liters of return activated sludge from the Blacksburg-VPI Sewage Authority Plant. The contents were reacted for 18 hours. Mixing and aeration were accomplished with lab supplied air through two six inch air stones. Even with two large air stones, aerobic conditions were not maintained. Severe foaming problems also occurred. The initial mixed-liquor suspended solids (MLSS) was 2,440 mg/L. After 18 hours of reaction, the MLSS was 8,360 mg/L. The air was turned off at the end of the 18 hour cycle and the contents allowed to settle for 30 minutes. The supernatant was then analyzed for COD, BOD\textsubscript{5} and TSS. More rigorous studies are planned in the future.

RESULTS AND DISCUSSION

The results of the effluent characterizations from three blue crab processing plants are shown in Table 1. Overall, plant characterizations were done in plant #1 and plant #2. Retort water was also characterized at plant #3. The given flows and volumes correspond to the pounds of finished crab meat product processed during that day of production. The exception is for retort water, which is represented in terms of pounds of live crab per cook.

Table 1 shows that blue crab processing typically produces relatively high concentration, low volume wastewaters. Similar results have been found by other researchers (2,3,7,8,12). For example, effluent concentrations exhibited the following ranges: BOD\textsubscript{5} = 410-28,500 mg/L, TSS = 400-33,400 mg/L, TKN-N = 50-3,400 mg/L, NH\textsubscript{3}-N = < 10-330 mg/L and TP = 7-320 mg/L. The total daily process volumes for these facilities never exceeded 20,000 gallons per day (gpd). When no mechanized processes operated during a day, the total effluent volume was typically around 2,000 gpd. The mechanized processes were responsible for the majority of the effluent volume.

The COD values are only slightly larger than the BOD\textsubscript{5} values in most cases and the VSS typically constitutes a very high percentage of the TSS. The BOD\textsubscript{5} was 32-98% of the COD, and the VSS was 19-93% of the TSS. These results imply that the wastewater consists largely of highly degradable organic matter.

The Harris Claw process displayed a great variability in effluent quality between and within the plants. Only plant #2 actively used the crab claw reel washer during the site visits. The variability of this process may be related to when and where a particular batch of crabs was harvested, and whether they were put through the tumble spray washer upon arrival.
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Shaded trip #’s are results from plant #1; unshaded trip #’s are for plant #2; & denotes trips to plant #3.
* denotes pounds of live crab, other weights are of final product; @ denotes gallons per cook.
The Harris Claw shell liquid and brine bath exhibited extremely high chloride concentrations (100,000-144,000 mg/L). The brine bath was kept approximately 70% saturated with sodium chloride to maintain efficient separation of the meat and shell fragments. On one site visit to plant #2, it was noted that 3,440 pounds of salt were used to produce 2,250 pounds of claw meat. The high chloride concentrations are of concern because of the potential toxicological effects to microorganisms in biological treatment systems. The shell effluent and the brine bath contained a large percentage of non-volatile suspended solids due to sand and components of the shell.

The claw meat conveyor wash effluents displayed high variability. The differences result from plant #1's use of four to five times more conveyor wash water to process the same amount of product. However, the loadings produced by each plant for this effluent were approximately the same because the high volume effluent was more dilute (Table 2). In the plants that used the Harris Claw process, the claw meat conveyor wash water produced a greater effluent volume (1,800-9,715 gpd) than any other process. Since this effluent is relatively dilute, it offers potential for use in diluting some of the more concentrated effluents for biological treatment. However, the character of this relatively dilute effluent substantially exceeds permit limits and still possesses chloride concentrations that could be inhibitory/toxic in the wrong environment (3,100-15,275 mg/L).

Representative effluent volumes and concentrations for the Harris Claw cleanup, the Quik-Pik cleanup and hand pick cleanup were the most difficult of any process to obtain. Some of these process rooms used as many as five different hoses during cleanup. The runoff from these hoses often flowed into several different drainage channels. The character of the cleanup water changed continuously during wash down. The quantity of water used for wash down also varied each processing day. This variation was probably due to such factors as the individual doing the wash down, how dirty the process room had become, and the particular plant studied. Typically, grab samples were taken near the beginning of cleanup and the quantity of water used was determined by flow meters or by timing the use of hoses for which the flow rate had been previously determined. Composite sampling methods should be performed to obtain more reliable results in the future.

The Quik-Pik process was used in plant #2 only during days of very high production to support the hand pick operations. The Quik-Pik bobber produced the only substantial effluent stream from this process. The bobber effluent was extremely concentrated (BOD₅ = 7,000-17,000 mg/L, TSS = 5,100-12,000 mg/L, TKN = 1,030-2,000 mg/L and TP = 230-320 mg/L) and contributed significantly to the total plant effluent loadings on days when it was used. The bobber effluent was also the only process plant process with significant concentrations of oil and grease (260 mg/L).

The retort water was studied in more detail than other processes because it was used in all plants and it typically produced the majority of pollutant loadings from each plant (Table 2). It should be noted that the values in Table 2 are per cook of live crab. Each of these plants will typically have 6 to 20 cooks per day. This corresponds to a retort water volume of 400-1,000 gallons per day. The cooker water character and volume remained very consistent within and between each plant. BOD₅ concentrations were greatest in the cooker water, ranging between about 14,000-30,000 mg/L. The TKN, NH₃-N and total phosphorous values were also very high. The suspended solids values, however, were typically lower than most other processes (TSS = 650-2,000 mg/L).

The temperature of the retort water was high during discharge 64 to 91°C. The high temperature is of concern when discharging to receiving waters. Some processors currently have discharge permits which place limits on the discharge temperature of their
Table 2 - Typical effluent loadings from three blue crab processing plants.

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All units are lbs/day/1,000 lbs product (except for retort water which is lbs/day/1,000 lbs of live crab). Shaded trip #’s are results from plant #1; unshaded trip #’s are for plant #2; & denotes trips to plant #3.
retort water. The high temperature also complicates biological treatment methods. A cooling step would be required prior to discharge into a biological system.

The three blue crab processing plants studied currently have no liquid waste treatment systems other than screens in some drains and hand sinks to capture large solids. The facilities discharge all effluent overboard into tributary or river water adjacent to the plant. Some dilute, cleanup effluents from plants #2 and #3 discharge to municipal treatment systems.

Certainly, a rigorous study of pretreatment and treatment alternatives for these effluents must be investigated. Some initial treatment studies are presented herein, including settling and filtration of the major process effluents, acidification and coagulation of the more concentrated effluents and aerobic biological treatment of the retort water using a SBR.

Results of the settling and filtration tests are shown in Tables 3 and 4. Settling tests were done to see if sedimentation basins offer promise for reduction of solids, degradable organics and nutrients. Settling appears to work fairly well for effluents that contain high initial solids concentration including the Harris Claw and Quik-Pik process. However, final solids concentrations are still well above current limits (TSS values ranged from 410-12,000 mg/L after settling). One very important result is that settling has very little effect on COD and BOD₅ removal and may not be a viable method for reducing these parameters. Only 3-36% of BOD₅ was removed by settling. Even after filtration through glass-fiber filters, significant concentrations of BOD₅ and nutrients remained (after filtration: BOD₅ = 1,260-17,000 mg/L, TKN-N = 180-3,040 mg/L and TP = 22-270 mg/L). The results suggest that substantial quantities of soluble material are in these effluents, and biological and/or chemical treatment processes are necessary to meet current regulatory standards.

Acidification of samples with high concentrations of soluble organics was examined to determine the potential reduction of BOD₅ and TSS (Figure 2). TSS and BOD₅ of the retort water were reduced by approximately 40% and 30%, respectively. The brine bath and shell liquid had an over 90% reduction in TSS and a nearly 50% reduction in BOD₅. The finished effluents were still well above permit limits (BOD₅ = 7,580-24,850 mg/L and TSS = 480-2,160 mg/L after acidification), but acidification shows promise as a pretreatment method.

The results of aerobically treating retort water in a sequencing batch reactor are provided in Figure 3. The BOD₅ was reduced by approximately 50%. The TSS increased by about 20%, probably the result of newly formed biomass. Due to the high oxygen demand of the retort water, it was difficult to maintain aerobic conditions in the reactor. Aerobic treatment of this waste will require a large oxygen input that may be costly. Also, a significant amount of foam was produced during the process that may complicate aerobic treatment methods.

CONCLUSION AND REFERENCES

The processing effluents from three blue crab processing plants in Virginia were characterized. It was determined that nine types of liquid waste streams contributed the majority of the pollutant loadings from these plants. Most of these effluent streams were highly concentrated. For example, the retort water from the cookers exhibited the following concentrations: BOD₅ = 14,000-29,000 mg/L, TSS = 650-6,200 mg/L, TKN = 2,500-4,000 mg/L, NH₃-N = 70-160 mg/L and total phosphorous = 100-185 mg/L. The Harris Claw process produced effluent streams with chloride concentrations exceeding 100,000 mg/L.
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<th>BOD (mg/l)</th>
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<td>-</td>
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</table>

Samples settled for 1 hour; samples were filtered through glass-fiber filters.

* denotes pounds of live crabs.

1 denotes per cook of 1300 pounds of live crab.

Retort data from plant #3; other data from plant #2.
Table 4 - Settling and filtration of effluent samples from a blue crab processing plant.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>PRODUCT (lbs)</th>
<th>VOLUME (gal)</th>
<th>TKN (mg/l)</th>
<th>NH3-N (mg/l)</th>
<th>TOTAL P (mg/l)</th>
<th>SET. SOL. (ml/L)</th>
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<td>9</td>
<td>91</td>
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</table>

Samples settled for 1 hour; samples were filtered through glass-fiber filters.
* denotes pounds of live crabs.
I denotes per cook of 1300 pounds of live crab.
Retort data from plant #3; other data from plant #2.
Figure 2 - Removal of BOD₅ and TSS by acidification of previously settled retort water, shell solution and brine bath.
Figure 3 - Aerobic biological reduction of retort water BOD$_5$ and COD in a sequencing batch reactor.
Settling and filtration studies were done on these effluents. The organics and nutrients in the wastes were highly soluble and very little reduction of COD, BOD₅, TKN, ammonia and total phosphorus was achieved by these methods. Acidification of the concentrated effluents caused some coagulation of the contents. Acidification achieved TSS removals of 40-95%, and BOD₅ removals of 40-50%, thereby showing promise as a pretreatment method. Finally, aerobic treatment of the retort water in a SBR achieved approximately 50% removal of COD and BOD₅ after 18 hours of reaction time. Though the treatment methods above effected some good removals, effluent residuals remained well above permit limits.

Thus, among the waste management problems faced by the blue crab industry are: high organic and nutrient concentrations, high retort water temperatures, potential toxicity to biological treatment systems from brine effluents, intermittent daily and seasonal flow patterns, adequate space for locating treatment systems and low working capital to pay for technically feasible treatment methods.

REFERENCES


COMPARISON OF MANUAL AND AUTOMATED BRINE SYSTEMS
FOR BLUE CRAB MEAT RECOVERY

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Seafood Laboratory
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Morehead City, NC 28557

INTRODUCTION

Brine floatation has been used successfully for the recovery of blue crab meat for over 40 years. The (Harris) machines have provided commercial processors with an economically viable means for recovering crab claw meat (5). The meat is separated from the shell by dropping crushed claws into a dense brine solution. Meat, having a lower specific gravity than brine that is typically maintained at 60 to 70 salometer degrees (i.e., 177 to 210 grams NaCl per liter), floats to the top of the tank where it is directed over a spillway onto a dewatering and inspection belt system. The heavier shell sinks to the bottom of the tank where it is picked up by a conveyor mechanism to be discarded as scrap.

Although providing a cost effective means for recovering claw meat, the machines are virtually unchanged in design and operation from the early models and do have several drawbacks. First, the salt content in the meat increases and is variable which can lead to marketability problems. Secondly, the machines require frequent monitoring and manual adjustments in order to operate correctly. This is because both brine volume and density (sodium chloride content) will vary during operation due to spillage, salt uptake in meats and dilution effects. For adequate separation of meat from shell, sodium chloride content must be maintained at a high enough level to facilitate floating of meat. Therefore, during the course of 2 to 7 hours of operation, brine tanks must be closely monitored and small amounts of fresh or saline water added. In effect, the machines are not "fail-safe." In recent years, attempts have been made to improve the design and efficiency of Harris machines by adding an automated microcontroller to the system. The microcontroller is designed to read the density of the brine solution (i.e., specific gravity) and add automatically either brine or fresh water as needed for maintaining the tanks at predetermined sodium chloride levels (6).

The objectives of this study were: 1) to monitor brine tank composition (total suspended solids, TSS; total dissolved solids, TDS; dissolved protein, DP; sodium chloride, NaCl) of both automated and manually operated systems in order to compare their ability to maintain brine concentration during operations, 2) to monitor the consistency in meat quality produced (defined as percent NaCl and moisture) under both operations; and, 3) to determine if observed meat quality fluctuations are correlated with fluctuations in the brine composition under which they were processed.
METHODS

Observations and sample collection were made at two NC blue crab processing facilities during the summer of 1991. Washington Crab Company (Washington, NC) and Fulchers' Point Pride Seafood (Oriental, NC) were industry cooperators in a NC Pollution Prevention project designed to assess water use patterns and water and wastewater reductions options for crab meat processors using the brine floatation technique.

Brine Composition

Samples were collected from Harris machine operations at the junction of the floatation tank spillway and the dewatering/inspection belt (Figure 1) every 15 to 20 minutes during 5 hour runs of both automated (microprocessor) and manually controlled systems. The brine was collected in a shallow pan as it spilled into the overflow/reservoir tank. One liter of the brine was immediately transferred to an Imhoff cone and allowed to settle undisturbed for one hour to determine the total settleable solids (TSS) content (7).

The remaining brine solution was measured for density using glass hydrometers (Fisher Scientific, Atlanta, GA) calibrated in salometer units, percent NaCl and specific gravity and for refractive index using a standard hand-held refractometer (American Optical, Buffalo, NY). Temperature of samples was measured with a mercury in glass thermometer and recorded. The microprocessor LED display in salometer units (KelTech, Inc., Roanoke, VA) was recorded during operation of the automated system.

The total dissolved solids (TDS) fraction of the solution (defined as solids passing through a 0.45 micron filter) was obtained by passing representative samples of brine through a series of 5 filtration steps. The procedure is schematically represented in Figure 1 and includes: 1) glass wool wrapped in cheese cloth to remove coarse particulates of shell and meat; 2) Whatman No. 1 filter paper (Whatman International Ltd, Maidstone, England); 3) Whatman No. 54 filter paper; 4) glass fiber filter (Gelman Instrument Co., Ann Arbor, MI); and, 5) 0.45 micron cellulose nitrate membrane filters (Whatman International Ltd, Maidstone, England). Twenty to thirty milliliters of filtrate were collected for each sample taken. Filtrates were placed in clean containers and kept on ice. All samples were refrigerated in the laboratory until analyses could be performed (within 24 hours of collection) for TDS, DP and NaCl.

Total dissolved solids (TDS) content was determined by evaporating a 5 ml aliquot of sample in clean preweighed test tubes at 103-105 C until constant dry weights were achieved. Duplicate analyses were performed for each filtrate. Chloride content in ppm was determined utilizing No. 1176 Quantab chloride titrator strips (Environmental Test Systems, Inc., Elkhart, IN) on samples diluted with distilled, deionized water. Values were corrected for dilution and converted to the corresponding NaCl levels. The Quantab chloride titrator method has been used successfully for determining NaCl content of a variety of high protein foods (8).
Figure 1. Sample collection for brine, A and meat, B & C and schematic of procedure for total dissolved solids.
Dissolved protein (DP) content of filtrates was measured using the Bio-Rad protein dye binding assay (3). Bovine serum albumin (BSA) was used as a standard protein for calibration. Laboratory tests indicated that normal brine concentrations (ca. 210 g/L) encountered in the flotation tank did not interfere with the Bio-Rad protein assay using the standard procedure given (2).

**Crab Meat Composition**

Crab claw meat was collected from the inspection line every 15 to 20 minutes during operations. In all instances, effort was made to collect meat samples corresponding in time with the brine samples collected. The samples were placed in Whirlpak bags (Baxter Scientific, Charlotte, NC) and stored on ice for transport back to the laboratory.

During automated runs, unprocessed crab claws were sampled from the incoming conveyer belt midway through the operational period for comparison with meat recovered through brine floatation. During manual operations, unprocessed claws were collected at eight intervals to assess the variability of incoming crab meat quality and to compare with finished product qualities.

On return to the laboratory, meat samples were refrigerated until they could be analyzed the next day for NaCl content using the Quantab chloride titrator procedure (4). The percent moisture content of meat samples was determined in triplicate by weight loss after oven drying at 103 to 105 C for 18 hours (1). In addition, unprocessed and processed meat samples were frozen and sent to North Carolina State University’s Department of Food Science for Kjeldahl-protein analyses (1).

**RESULTS AND DISCUSSION**

General observations made during automated and manually controlled operations are discussed in greater detail in the preceding paper entitled, "Waste reduction in mechanical blue crab claw processing operations." Specific data collected during experimental runs are summarized below.

**Brine Composition**

Figures 2b and 3b show the results from density and refractive index measurements taken during manual and automated operations, respectively. In both cases, measurements using refractive index and specific gravity did not provide sufficient resolution to show variability in brine solutions. A NaCl hydrometer showed better resolution. However, the salometer calibrated hydrometer, which is the type commonly used by industry operators, showed the best resolution. The microcontroller LED readings agreed well with the manually determined salometer readings (Figure 3b).

When the LED readings were plotted along with measured TDS levels, good agreement at the beginning and end of the operational period was shown (Figure 3a). However, during the middle of the run, LED readings showed some discrepancy from those measured by the TDS procedure. The LED readings indicated that the tank was being maintained between desired levels while TDS levels actually measured fell below these values.
Figure 2  Brine composition (A) and field parameters (B) measured during manual Harris machine operations.
Automated Brine Composition

![Graph showing brine composition over time](graph1.png)

Automated Field Parameters

![Graph showing field parameters over time](graph2.png)

Figure 3  Brine composition (A) and field parameters (B) measured during automated Harris machine operations.
Accounting for this discrepancy would require further investigation although it should be noted that the locations where the two readings were taken differ. The microprocessor sensor (LED) was positioned in a small stainless steel surge tank located adjacent to the main flotation tank. While measured DS levels were made on brine taken at the spillway/inspection tank interface. The TDS and NaCl composition in the flotation tank during manual operations held steady although slightly higher than the desired levels (Figure 2a).

Figures 2a and 3a illustrate that total dissolved solids (TDS) content in the flotation tank can be nearly accounted for by NaCl alone. Dissolved protein (DP) content in the brine does increase with processing time (Figures 4a and 4b). However, protein concentrations never exceeded 2 g/L which is negligible in its affects on the density of a 150 to 250 g NaCl/L solution.

The pattern of increase for DP in the brine over time for both operations paralleled the increase in total settleable solids (TSS) measured (Figures 5a and 5b). Linear regressions (Figures 6a and 6b) of TSS versus DP concentrations gave correlations of 0.90 and 0.84 for automated and manual runs, respectively. This suggests that the amount of settleable solids (consisting largely of small meat particles) building up in the brine over time exerts a direct effect on DP content in the solution.

**Crab Meat Composition**

During automated and manual operations, the percent moisture of recovered crab meat was constant (Figures 6a and 6b). Meat moisture content increased approximately 5 percent (Table 1). Sodium chloride content of processed claw meat was more variable than moisture (Figure 6a and 6b). The levels approximately tripled from pre-processing levels (Table 1) and was slightly higher over all for meats recovered during the manual process. Recall that the brine in this process was found to be higher in sodium chloride levels (200-250 g/L) compared to the automated process (140-200 g/L). This suggests a direct relationship between brine concentration and the salt content found in recovered meats. However, when mg NaCl/g meat was plotted against brine concentrations (Figures 7a and 7b), no direct correlation was found (R² values of -0.15 and as -0.58, respectively).

### Table 1. Salt and moisture content of blue crab claw meat.

<table>
<thead>
<tr>
<th>Sample</th>
<th>System</th>
<th>NaCl (mg/g)</th>
<th>Moisture (%)</th>
<th>NaCl at 80% Moisture</th>
<th>NaCl at 80%</th>
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</thead>
<tbody>
<tr>
<td>Unprocessed Automated</td>
<td>10.14 ± 0.00</td>
<td>77.99 ± 0.53</td>
<td>10.4</td>
<td>1.04</td>
<td></td>
</tr>
<tr>
<td>Manual</td>
<td>9.37 ± 1.64</td>
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<td>9.61</td>
<td>0.96</td>
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</tr>
<tr>
<td>Processed Automated</td>
<td>29.42 ± 4.26</td>
<td>84.09 ± 0.76</td>
<td>27.99</td>
<td>2.8</td>
<td></td>
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<tr>
<td>Manual</td>
<td>33.99 ± 4.92</td>
<td>82.55 ± 1.39</td>
<td>32.94</td>
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<td></td>
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</table>
Figure 4. Total dissolved solids (TDS), NaCl and soluble proteins (DS) in automated (A) and manual (B) Harris machine systems.
Automated TSS and SP

![Graph: Automated TSS and SP with R² = 0.90]

Manual TSS and SP

![Graph: Manual TSS and SP with R² = 0.84]

Figure 5. Correlation of total settleable solids (TSS) and dissolved proteins (DP) in automated (A) and manual (B) Harries machine systems.
Automated Crabmeat Quality

Manual Crabmeat Quality

Figure 6. Crab meat qualities during automated (A) and manual (B) Harris machine systems.
Covariance Brine and Meat Salt

Figure 7. Covariance of crab meat chloride content in automated (A) and manual (B) Harris machine systems.
No differences were found in protein content of claw meat processed early and late during manual operations (Table 2). Protein levels for processed meat was found to be 36 percent lower than protein levels for unprocessed meat. Although salt, moisture and protein data suggest no difference in product quality at the beginning and end of processing runs, the meat visually appeared quite different. Meat produced early in the run was lighter in color, contained larger particles and was softer in texture. Meat produced later in the run was dark in color, had smaller particle sizes, was grainier in texture and generally was less appealing.

Table 2. Proximate composition of blue crab claw meat recovered by brine floatation.

<table>
<thead>
<tr>
<th>Crab Meat</th>
<th>Protein, %</th>
<th>Moisture, %</th>
<th>Protein, % (at 80 % Moisture)</th>
<th>Protein, % Loss</th>
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<tr>
<td>Unprocessed</td>
<td>21.58 ± 0.47</td>
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<td>Processed (Early)</td>
<td>14.44 ± 0.62</td>
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<tr>
<td>Processed</td>
<td>14.61 ± 0.25</td>
<td>82.90 ± 0.23</td>
<td>14.10</td>
<td>36.3</td>
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CONCLUSIONS

Results suggest that both automated and manually controlled systems for operating Harris machines can adequately maintain the process within desired operating conditions. Whether or not installation of an automated microcontroller would be beneficial to a particular operation depends on the mechanical reliability of the controllers. Cost of the equipment could be assessed in terms of the savings gained from offsetting the need for skilled labor.

Meat quality, particularly salt content, appears to be a function of several variables in addition to salt concentration in the floatation tank. Loading rates and tank circulation patterns both of which pertain to the amount of time that the meat is exposed to the brine are important variables that warrant further study. Seasonal changes in crab meat composition and processing temperature of crab claws are two other variables that processors believe affect recovery efficiency and meat qualities (J. Johnson, Washington Crab Co., Washington, NC, personal communication, 1991).

Although wastewater proteins (DP) did not seem relatively high compared to the salt content of the brine, amounts were significant in terms of protein losses. Considering the protein and product quality losses incurred during processing, further technological improvements in the Harris machine systems are warranted.
ACKNOWLEDGEMENTS

This project was sponsored in part by the NC Department of Environment, Health and Natural Resources, Office of Waste Reduction, Pollution Prevention Program, the University of North Carolina Sea Grant College Program and the North Carolina Cooperative Extension Service. The authors express their appreciation to Chris Fulcher and Glen Barnes of Fulchers Point Pride Seafood, Inc. and Harold Stephenson and Jim Johnson of Washington Crab Company for use of their facilities and valued assistance. We thank KelTech, Inc. of Roanoke, Virginia for the cooperation and suggestions given. Jutta Malbaum, Reino Korhonen, Joyce Taylor and Robin Lazenby provided technical help and assistance. The use of trade names in this publication does not imply endorsement by North Carolina State University, nor criticism of ones not mentioned.

REFERENCES


ABSTRACTS

FISHERY DISEASES, ENVIRONMENTAL QUALITY AND HUMAN HEALTH

E.J. Noga
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The environment plays a critical role in the expression of disease in aquatic animals. There is considerable empirical evidence that many diseases in fishery populations are associated with human activity. Some of the best indicators of environmental degradation include shell disease, fin erosion, skin ulcers, and neoplasia. Although these syndromes are clearly associated with polluted environments, the mechanisms responsible for their development are uncertain and a precise cause and effect relationship to anthropogenic factors has yet to be demonstrated. Nonetheless, they serve as useful bioindicators of impacted environments and in some cases, might be indicators of risk to human health from contamination of seafood products.

PATHOGENIC VIBRIOS AND SHELLFISH

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Unlike many of the disease-producing bacteria and viruses that may be present in coastal waters, the presence of bacteria of the genus Vibrio show no correlation with pollution. These bacteria are normal flora in coastal waters and shellfish and occur in high numbers in oysters. At least 11 species of Vibrio are known human pathogens, and infections with most, such as V. parahaemolyticus, typically results in mild to severe gastrointestinal disease. Other species, such as V. cholerae, have long been involved in worldwide epidemics, and may lead to significant mortality. More recently, V. vulnificus has received increased attention as it, of all microorganisms occurring in coastal waters, is now realized to be the major cause of seafood-related deaths in the United States. This paper will describe the various human pathogenic vibrios, concentrating on V. vulnificus. To be discussed will be the clinical aspects and epidemiology of the disease produced by V. vulnificus, its "viable but non-culturable" state and our most recent findings regarding its interactions with shellfish, including the possibility that commercial depuration will not be an effective method of removing the potential health hazard presented by this bacterium.
PHAGOCYTIC INTERACTION OF CLAM AND OYSTER HOMOCYTES WITH VIBRIO VULNIFICUS

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The morphology, hematological parameters, and behavior of both clam and oyster hemolymph cells were studied when challenged with capsulated, non-encapsulated, and viable but non-culturable Vibrio vulnificus. Two general classes of hemocytes (granular and agranular) were found to exist in both the quahog, Mercenaria campechiensis, and the eastern oyster, Crassostrea virginica. Transmission electron microscopy revealed three sizes of electron dense granules. Both granular and agranular hemolymph cells were capable of colchicine-sensitive pseudopodial movement and spreading. A higher number of non-encapsulated and viable but non-cultured V. vulnificus were associated with both clam and oyster hemocytes when compared to the encapsulated V. vulnificus. Phagocytosis was serum dependent and heat colchicine sensitive. Temperature increased the V. vulnificus hemolymph association. The morphology of these cells as determined by high scanning and transmission electron microscopy showed some similarity to mammalian mononuclear phagocytes.

THE EFFECTS OF IONIZING RADIATION AND HIGH ENERGY ELECTRON BEAMS ON MOLLUSCAN SHELLFISH WITH RESPECT TO VIBRIO VULNIFICUS

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A three to four log cycle reduction in bacterial number was observed upon exposure to oysters to ionizing radiation (\(^{60}\)Co at 1.0, 2.0 and 5.0 kilorays. The shelf life of irradiated oysters was also monitored. Fifty percent of the irradiated oysters were dead within 12, 10 and 7 days at 1.0, 2.0 and 5.0 kilorays of exposure, respectively. Cultures of virulent and non-virulent Vibrio vulnificus were quite radiosensitive as no colony forming units could be detected after 0.5 kiloray exposure. Furthermore, survival curves were plotted for virulent and avirulent V. vulnificus, and subsequent D\(_{10}\) values were calculated.
THE DETECTION AND INTERPRETATION OF CADAVERINE AND
PUTRESCINE LEVELS IN FISHERY PRODUCTS AS
INDICATORS OF DECOMPOSITION

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The presence of cadaverine and putrescine in decomposed fishery
products has been determined for a variety of species, including tuna, mahi mahi,
snapper, cod, crab meat, scallops, shrimp and sea trout. The formation of these
compounds as a function of decomposition temperature and time has been studied
in mahi mahi and has been compared to the amount of histamine formed. The
relationship of these compounds to sensory evidence of decomposition will be
discussed, and the practical use of the two compounds with respect to quality
control and surveillance programs will be addressed.

MODIFICATION OF GLC METHOD:
RAPID SCREENING TEST FOR PUTRESCINE AND CADAVERINE

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The gas-liquid chromatographic (GLC) method of Staruszkiewicz and Bond
for the determination of putrescine and cadaverine has been modified to provide
a rapid screening test for diamines in fishery products. The amines were extracted
from fishery products by using 75 percent methanol in water. A dried residue of
the hydrochloride salts of the amines was prepared and an internal standard
(hexanediamine) was added. Derivatives were made by heating the dried residue
with pentafluoropropionic anhydride in ethyl acetate for 30 minutes at 50 C.
Toluene was added to the reaction mixture to adjust the ethyl acetate
concentration to 30 percent. A 100-ul portion of this mixture was purified on a 30-
ml alumina-N solid-phase extraction (SPE) column, consisting of 1,000 mg of
neutral alumina. The derivatives were eluted with 8 ml of 30 percent ethyl acetate
in toluene. Putrescine and cadaverine were determined by GLC with electron
capture detection on a column of 3 percent OV-225 at 175 C. In the range of 1 to
60 µg/g, the results obtained using the SPE columns were comparable to those
obtained using the standard glass columns. The SPE columns reduced cleanup
time prior to GLC separation from 1 hr to 10 min, which requiring less space and
eliminating the washing of glass columns. The differences between SPE columns
will also be discussed.
INHIBITION OF HEAT STABLE PROTEASES IN INTACT FISH FILLETS

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The flesh of several fish species, such as Alaskan arrowtooth flounder, can possess high levels of heat-activated proteases. This can limit use of the fish flesh in surimi, mince or fillet forms because the texture rapidly degrades under all but the most rapid cooking conditions (such as by microwaves). We have previously shown that beef plasma, egg white and one of the components of these materials, alpha-2-macroglobulin (alphalin), effectively inhibit these proteases when incorporated into surimi prepared from several fish species. The present study additionally demonstrated their effectiveness when used to treat intact arrowtooth flounder muscle via vacuum infusion. Beef plasma and alphalin were found to be equally effective in inhibiting proteolytic degradation of the infused arrowtooth flounder muscle, but egg white was much less effective. However, egg white is an effective inhibitor in certain species such as Atlantic menhaden. Use of alphalin has the advantage of broad spectrum effectiveness with no discoloration or flavoring of the flesh.

THE USE OF OZONE TO DEGRADE RED TIDE TOXINS

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Gymnodinium breve toxins were exposed to ozone treatment in both extracted form and in intact whole cells. Samples displayed a three log reduction in the total amount of toxin (PbTx-1, -2, -3, -5, -7 and -9) recovered after 10 minutes as determined by HPLC analysis. Ozone effectively killed the red tide dinoflagellates when directly contacted ozone and when exposed in a pre-ozonated ASW environment. Both samples, when examined by light microscopy, displayed little difference between the direct and indirect ozone treatments. Reduction in toxin levels directly correlated with reduction of toxicity as observed using by a fish (Cyprinodon variegatus) bioassay.
DISTINGUISHING WILD FROM CULTURED FISH USING
DIFFERENCES IN FATTY ACID PROFILES

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This paper provides the results of a two-year cooperative research effort between the National Marine Fisheries Service (NMFS), Charleston Laboratory’s Marine Forensics Program, and the South Carolina Wildlife and Marine Resource Division (SCWMRD). The first objective of the research effort was to develop a biochemical method to distinguish wild from cultured fish. The second objective was to use the edible portion of the fish as the test material. This research effort was initiated because of concern by SCWMRD that a successful hybrid striped bass aquaculture industry might result in an increase in the illegal capture of wild striped bass and its hybrids from South Carolina waters for sale to commercial markets. In this study, over 1,500 wild striped bass and its hybrids were collected four times a year over a two-year period, from Lakes Hartwell, Thurmond, Murray, Wateree and Moultrie. Cultured hybrid striped bass and diet samples were collected from the Waddell Mariculture Center in South Carolina and from three commercial aquaculture operations. In addition to visual interpretation of the data, Linear Discriminant Analysis was used to classify fish into wild or cultured categories and collection site. Classification into wild and cultured categories was 100 percent accurate. Classification of fish into collection site categories ranged from 75 to 100 percent accuracy.
ACCELERATION OF LIPID OXIDATION DURING COOKING OF REFRIGERATED MINCED CHANNEL CATFISH MUSCLE

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Minced channel catfish muscle was refrigerated for periods up to seven days. At 0, 2, 5 and 7 days, preweighed samples were analyzed either before or after baking for fatty acid composition, thiobarbituric acid reactive substances (TBA-RS), fluorescent pigments and tocopherol content. No differences were noted between the raw and cooked product in polyunsaturated fatty acids (PUFA) at all sampling periods. In addition, no loss of PUFA was seen with increasing length of refrigerated storage. Although increases in the amount of TBA-RS and fluorescent pigments were recorded in all cooked products over that of raw product, the amount of increase varied with the length of refrigeration. Larger increases in TBA-RS were found after cooking two-day refrigerated samples than 0 day samples, whereas cooking of five- and seven-day-old samples led to much smaller increases in TBA-RS. In contrast, the largest increases in fluorescent pigment content after cooking were found in the five-day refrigerated samples. No change in the tocopherol content was seen with storage of raw samples. Loss in gammatocopherol upon cooking remained fairly constant (15%) whereas losses of alpha-tocopherol were greater in the two- and five-day refrigerated samples (40%) than in the seven-day refrigerated sample (14%).

CONSIDERATIONS FOR THE DEVELOPMENT OF CRAB PASTEURIZATION PROCESSES

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Spoilage of pasteurized crab meat can be due to a variety of reasons including faulty can seams, temperature abuse and/or the presence of microorganisms able to grow at refrigeration temperatures. An apparently new species of Clostridium was found to cause spoilage in pasteurized crab meat. This organism is psychrotrophic and can grow at temperatures as low as 2°C. Spores of this organism were able to survive a pasteurization process with an F16 185 of 85 minutes. Considerations for the development of crab pasteurization processes will be discussed.
ELIMINATION OF *LISTERIA MONOCYTOGENES* AND EXTENSION OF SHELF LIFE IN FRESH CRAB MEAT BY ATMOSPHERIC STEAM

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Fresh lump meat from blue crab (*Callinectes sapidus*) was processed in a modified blancher until the internal temperature of monitored lumps reached the designated temperatures of 175°F (80°C) or 185°F (85°C). Control and heated meat placed in eight-ounce containers was stored in ice in a commercial refrigeration unit. Analyses included *Listeria* count (Oxford agar, 30°C), *Staphylococcus aureus* count (Baird-Parker agar, 42°C), aerobic plate count (20°C), texture measurement (Instron), color measurement (Minolta Color-meter, L*a*b* scale), and sensory panel evaluations for appearance, taste, odor and texture. On Day 1 only, samples were also tested for percent moisture content, total coliforms and fecal coliforms. Samples were tested over the apparent shelf life of the meat, determined by a borderline score in sensory evaluation and unacceptable microbial counts. Steam treatments resulted in the elimination of *Listeria monocytogenes*, confirmed by inoculated pack studies. Steam treatments also controlled the growth of *S. aureus*. The processed meat also had a one to four log reduction in aerobic plate counts, thus extending shelf life by as much as two weeks, upheld by sensory panel evaluations. The use of steam enhanced several sensory attributes and contributed no additional moisture to the meat.

FUNCTIONS OF AND USES FOR PHOSPHATES IN THE SEAFOOD INDUSTRY

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The use of phosphates in muscle food systems has been investigated since the 1950s. Crawford (1980) evaluated the effect of one to two minute dips of 6 percent sodium tripolyphosphate on mechanically peeled shrimp (*Pandalus jordani*) and determined that the yield was increased by 12 percent. This short-term treatment caused a case hardening of the flesh, which resulted in more efficient separation from the shell and the retention of muscle moisture. The economic impact of short-term phosphate dips to shrimp resulted in greater than $65 million in the first eight years of use to the ex-plant value of the product to Oregon alone. The use of phosphates and blends to other seafoods has expanded. Its importance is directly related to the sensitivity of seafood myofibrillar proteins and denaturation at chill storage temperatures. Retention of water holding capacity of the muscle is vital to the retention of natural juices and thus prevents economic fraud due to fluid losses during shipment and prior to sale.
ON-BOARD CRYOGENIC FREEZING OF SEA SCALLOPS

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Freezing a product does not improve its quality. It simply maintains the quality of the product which was inherent at the time of freezing. The factors which influence the quality of the final product quality include the raw material, handling prior to freezing, the freezing process, handling after freezing and storage before distribution.

We compared the freezing process, cryogenic with liquid CO$_2$ vs a-visor mechanical plate freezing for its effect on product quality. Both prerigor and postrigor scallops were included in the study and quality aspects covering microbiology, sensory, thaw loss, moisture/protein ratio, etc. were studied.

It is on two counts that one estimates value to the processor: the worth of the product and the reduction in loss. On both counts, cryogenic freezing was found to be better than mechanically (plate) frozen scallops.

INTERACTIONS OF ZINC IONS AND SUCROSE FOR CYROPROTECTION OF SURIMI

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Previously a remarkable synergistic effect of zinc ions with carbohydrates in the cyroprotection of certain enzymes was reported by other workers. For example, at 0.6 mM ZnSO$_4$ the level of sucrose needed to protect phosphofructokinase activity could be lowered by two orders of magnitude. Studies were conducted to determine whether a similar effect might be observed in the cyroprotection of surimi by sucrose and other carbohydrates. A model system was employed involving rapid freezing and thawing of actomyosin solutions followed by evaluation of myosin Ca$^{2+}$-ATPase activity as an indicator of protein denaturation. Initial tests with ZnSO$_4$ levels varying 0.05 to 1.0 mM were disappointing in that rapid loss of ATPase activity was effected by increasing levels of ZnSO$_4$. Further investigation with even lower levels ZnSO$_4$ and sucrose showed that in contrast with other reported protein systems there appears to be little if any increase in cyroprotection with addition of ZnSO$_4$ to surimi.
WASTE REDUCTION IN MECHANICAL BLUE CRAB CLAW PROCESSING OPERATIONS

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Pollution prevention through source reduction, water reuse, and recycling has become increasingly important to seafood processors in light of stricter environmental regulations, decreased profit margins and greater international market competition. This study focuses on in-plant management practices, process modifications and employee education programs in mechanical operations for recovery of blue crab claw meats. Discussion will focus on how seafood processors can make "pollution prevention pay" and become a more responsible and environmentally aware industry.

RECOVERY AND FOOD UTILIZATION OF SURIMI LEACHWATER PROTEINS

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Earlier this year we reported results of a comparative study of various methods of protein recovery from surimi leachwater, including ultrafiltration, ultrafiltration coupled with diafiltration, precipitation by pH shifting, and ion exchange. The latter method, which is now commercially used to produce an excellent quality whey protein isolate, has now been scaled up in the pilot plant with comparable recovery rates to earlier bench-scale trials. A progress report will be given on the testing of the protein recovered by ion exchange as a filler material for surimi.