INTRODUCTION

On April 1, 1993, North Carolina regulators at the Department of Environment, Health, and Natural Resources announced that all blue crab meat sold or processed within the state must be packaged in tamper-evident containers. The regulators were addressing concerns about consumers opening crab meat containers to examine the contents before purchasing the product. State authorities approved several general types of tamper-evident packaging. Similar requirements have been adopted in other states, are pending, or are being considered for action.

This report describes our efforts to learn the effects of new tamper-evident packaging on the quality and safety of fresh blue crab meat. Little or no information was available to the blue crab industry, regulatory officials, or packaging manufacturers detailing the effects of the tamper-evident containers on head-space gases, microbial growth, chemical decomposition, sensory quality, or shelf life. The probability of toxin production by *Clostridium botulinum* at refrigeration temperatures also needed to be evaluated. Crab processors and regulators needed this basic information to determine the safety and effectiveness of the new containers.

METHODS

Chemical, microbiological, physical, and sensory changes in fresh special blue crab meat were monitored during 18 days of iced storage at 0°C and 13 days of refrigerated storage at 4°C. The meat was packaged in four types of retail containers:

1. 12 oz copolymer polyethylene cups that are currently used by most crab processors. The containers were supplied by the Virginia Design Packaging Corporation of Suffolk, VA

2. 12 oz copolymer polyethylene cups with heat-shrink tamper-evident low density polypropylene seals from Virginia Design Packaging
Fresh special blue crab meat was packed into 18 containers each of the four packaging types. Three packages of each container type were randomly selected for sampling on the following iced storage days: 3, 6, 9, 12, 15, and 18. An initial composite of fresh meat used to pack the four cup styles served as the zero day sample for all container types.

Oxygen and CO₂ levels were measured from the headspace of each container using an Illinois Instruments 3600 headspace analyzer. Crab meat quality was estimated through chemical, microbiological, sensory, and physical analyses of a three-container composite sample for each of the package types. Ammonia levels (Ward et al., 1978) and pH (Helrich, 1990) were measured with specific ion electrodes. Total volatile base nitrogen values were analyzed by MgSO₄ extraction with a micro-Rjeldahl steam distillation unit (Woyewoda et al., 1986). Aerobic, anaerobic, and psychrotrophic plate counts were enumerated by standard dilution and culture techniques (Speck, 1984). Anaerobic plate count samples were incubated in anaerobic jars at 32°C for 48 hours. A Minolta Chroma Meter CR-200 (Minolta Corporation, Ramsey, NJ) was used to detect Hunter L, a, b color values of the meat (Hunter and Harold, 1987). A seven member trained panel developed sensory odor profiles on a continuous scale from zero to six with zero being none detected and six the strongest possible response for ammonia, sour, putrid, and crab odors (Cardello, 1981; Civille and Liska, 1975; Civille and Szczesniak, 1973; Gates et al., 1984a, Gates et al., 1984b, Jellinek, 1985). The panel's subjective like or dislike of meat color and appearance was rated on a continuous scale from zero to six.

Statistical analyses were performed on physical, chemical, sensory, and microbiological data by means of PC SAS (SAS, 1987). SAS GLM and Duncan's multiple range test at the 0.05 level were used to detect significant differences among sample containers and days of storage. Correlation analyses detected significant relationships among measured parameters and storage time for iced and refrigerated crab meat samples.

RESULTS AND DISCUSSION

Iced Storage

There were no significant differences in pH levels among the four sample containers (Figure I). Ammonia levels gradually increased between six and twelve days of storage. The North Carolina pull tab containers had significantly greater mean ammonia levels than the cups with the heat-shrink seals on day 12 and higher levels than the control and the heat-shrink sealed samples on day 15. Mean ammonia levels increased rapidly for all container types between 12 and 18 days of storage (Figure 2). Total volatile base nitrogen increased gradually after nine days of storage. Levels in the control sample were significantly less than all other samples on day 18 (Figure 3).
Oxygen levels decreased with time and varied considerably among the four iced containers. Levels in the control samples ranged between approximately 20% and 3% O₂. Oxygen levels in the other containers dropped to less than 1% by the end of the study. On day three the control samples had significantly greater O₂ levels than the other cups. The North Carolina tamper-evident tab containers contained significantly less oxygen than any other containers on day three. Oxygen levels in the tamper-evident-tab containers were lower than those found in the control samples on day six. No significant differences were measured for days 9, 12, and
Total Volatile Base Components of Packaged Crab Meat

Store d at 0°C

Figure 3. Mean total volatile base nitrogen levels of packaged crab meat stored at 0°C in the control and three tamper-evident containers

Percent Oxygen in Headspace of Packaged Crab Meat

Stored at 0°C

Figure 4. Mean percent oxygen levels of packaged crab meat stored at 0°C in the control and three tamper-evident containers

15. On day 18, the control samples contained more oxygen than the aluminum end and North Carolina tamper-evident tab cups (Figure 4). Carbon dioxide levels increased with time. Levels in the aluminum-end cans were significantly greater than those found in the control cups on days 3 and 18. The shrink-wrap sealed containers had greater CO₂ levels than the control and the North Carolina tamper-evident tab containers on day nine (Figure 5).

Aerobic plate counts were not consistently different among the four containers over 18 days of iced storage. Plate counts increased rapidly after nine days of storage. All meats exceeded
Percent Carbon Dioxide in Headspace of Packaged Crab Meat
Stored at 0°C

![Graph showing percent carbon dioxide levels](image)

**Figure 5.** Mean percent carbon dioxide levels of packaged crab meat stored at 0°C in the control and three tamper-evident containers.

Log Aerobic Plate Counts of Packaged Crab Meat
Stored at 0°C

![Graph showing log aerobic plate count populations](image)

**Figure 6.** Mean log aerobic plate count populations determined for packaged crab meat stored at 0°C in the control and three tamper-evident containers.

10^6 CFU/g by day 15, reaching the end of their microbiological shelf life (Figure 6) (Gates et al, 1993). Anaerobic plate counts increased with time, most rapidly between 6 and 18 days of storage. No consistent differences among the four storage cups were observed (Figure 7). Psychrotrophic plate counts showed no consistent differences among the containers during iced storage (Figure 8).

Although Hunter L or whiteness values were lower for meat collected from the aluminum-end cups through 15 days of storage, the differences were not statistically significant (Figure 9). Hunter a or relative redness and Hunter b or relative blueness levels
Figure 7. Mean log anaerobic plate count populations determined for packaged crab meat stored at 0°C in the control and three tamper-evident containers.

Figure 8. Mean log psychrotrophic plate count populations determined for packaged crab meat stored at 0°C in the control and three tamper-evident containers.

showed no consistent differences. The sensory panel found no subjective differences in meat color or appearance among the four sample containers.

Panel analyses found no consistent significant differences among the four container types for ammonia, sour, putrid, or crab odors.

Several monitored parameters had significant correlation coefficients with storage time. The results were statistically
Figure 9. Mean Hunter L color values determined for packaged crab meat stored at 0°C in the control and three tamper-evident containers.

Figure 10. Mean pH levels of packaged crab meat stored at 4°C in the control and three tamper-evident containers.

**L Values of Packaged Crab Meat Stored at 0°C**

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**Refrigerated Storage**

As shown in the iced storage part of the study there were no consistent pH differences among the containers. However, pH levels

**pH Values of Packaged Crab Meat Stored at 4°C**

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<td>8.4</td>
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</table>

significant at the 0.05 level and had correlation coefficients greater than 0.7. Combined percent carbon dioxide (0.7381), aerobic plate counts (0.8121), and ammonia concentrations (0.8451), correlated well with storage day for all containers. Psychrotrophic plate counts (0.956), aerobic plate counts (0.9191), and oxygen levels (-0.868) had the highest correlation coefficients. The putrid odors recorded from control packages also correlated well with storage time (0.702).
Ammonia Contents of Packaged Crab MeatStored at 4°C

Figure 11. Mean ammonia levels of packaged crab meat stored at 4°C in the control and three tamper-evident containers

decreased between zero and nine days of storage (Figure 10). Ammonia levels increased between 6 and 13 days of storage. On day six the aluminum-end cups had greater ammonia levels than the other containers. The control containers had significantly higher ammonia concentrations than the North Carolina tamper-evident tab containers on day nine and greater concentrations than all other containers by day 13 (Figure 11). Total volatile base nitrogen increased rapidly between 6 and 13 days of storage. The aluminum-end containers measured greater TVB-N than all other packages on day six. TVB-N levels in the aluminum-end containers and the control samples were greater those found in the other containers on day nine (Figure 12).

Total Volatile Base Components of Packaged Crab MeatStored at 0°C

Figure 12. Mean total volatile base nitrogen levels of packaged crab meat stored at 4°C in the control and three tamper-evident containers
Percent Oxygen in Headspace of Packaged Crab Meat Stored at 4°C

![Graph showing percent oxygen levels over days for control and tamper-evident containers. Oxygen levels decreased with time and varied considerably among the four cups. Levels in the control containers ranged between approximately 18% and 7.5% O₂. Oxygen levels in the other containers approached zero during storage. Refrigerated control samples had higher oxygen levels than the other containers on all sample days and were significantly greater on day six (Figure 13). Carbon dioxide levels increased with time. Levels in the control containers were significantly greater than those found in the other cups on days 9 and 13 (Figure 14).](image)

Figure 13. Mean percent oxygen levels of packaged crab meat stored at 4°C in the control and three tamper-evident containers.

Percent Carbon Dioxide in Headspace of Packaged Crab Meat Stored at 4°C

![Graph showing percent carbon dioxide levels over days for control and tamper-evident containers.](image)

Figure 14. Mean percent carbon dioxide levels of packaged crab meat stored at 4°C in the control and three tamper-evident containers.
Log Aerobic Plate Counts of Packaged Crab Meat

Figure 15. Mean log-aerobic plate count populations determined for packaged crab meat stored at 4°C in the control and three tamper-evident containers.

Log Anaerobic Plate Counts of Packaged Crab Meat

Figure 16. Mean log anaerobic plate count populations determined for packaged crab meat stored at 4°C in the control and three tamper-evident containers.

The aluminum end plastic cans had the highest aerobic plate counts on days three and six. Plate counts from the control samples were greater than other samples on days 9 and 13. All samples exceeded 10^6 CFU/g by day six (Figure 15). The results from the anaerobic plate counts were similar. The aluminum end plastic cans had the highest counts on days three and six. Counts from the control cups were greater than other samples on day 13 (Figure 16). Psychrotrophic plate counts showed no consistent differences among the four package types (Figure 17).
Log Psychrotrophic Plate Counts of Packaged Crab Meat

Figure 17. Mean log psychrotrophic plate count populations determined for packaged crab meat stored at 4°C in the control and three tamper-evident containers.

Aluminum-end containers had the lowest Hunter L values or whiteness levels on days 3, 6, and 9. Aluminum-end L values were significantly less than control cup and North Carolina tamper-evident tab containers on days six and nine. Control samples were significantly whiter than the North Carolina cups on day nine. The controls were whiter than the heat-shrink sealed products on day 13 (Figure 18). Hunter a and Hunter b measurements showed no consistent differences among the containers. As with the iced samples, the sensory panel revealed no significant differences among the sample containers.

L Values of Packaged Crab Meat

Figure 18. Mean Hunter L color values determined for packaged crab meat stored at 4°C in the control and three tamper-evident containers.
The variables that correlated well with storage day for all combined containers were the same parameters found during 0°C storage except for the deletion of percent CO₂ and the addition of total volatile base. The microbiological determinations had the highest correlation values with storage time at 4°C: anaerobic plate counts (0.928) psychrotrophic plate counts (0.913), and aerobic plate counts (0.894). Total volatile base (0.857), ammonia (0.845), and oxygen (-0.703) levels also correlated significantly with storage time. Putrid odor did not correlate well with storage time for combined samples. Control (0.769), shrink-wrap (0.713), and aluminum-end (0.703) containers developed relatively high individual putrid odor correlation coefficients. Meat packed in control containers also had high correlation values for ammonia (0.768) and crab odors (0.751).

A collateral study (Harrison et al., 1994) looked for toxin production by *Clostridium botulinum* during inoculated pack studies at 4°C and at the abusive temperature of 10°C. No toxin was detected following 18 days of storage at 4°C or following 15 days of storage at 10°C. The crab meat was obviously spoiled at 18 and 15 days, respectively.

CONCLUSIONS

Control samples in industry standard plastic fresh meat cups generally maintained higher oxygen levels than meat packaged in tamper-evident containers. No consistent differences in quality or shelf life were detected among the four package types. Market shelf life was limited to six days for meat held at 4°C and 15 days for meat held at 0°C in all sample containers. The collateral work by Harrison et al. (1994) shows that toxin production by *Clostridium botulinum* neither occurred following 18 days of storage at 4°C nor after 15 days of storage at an abusive temperature, 10°C. Spoilage occurred before any toxin production.

The study suggests that blue crab processors can safely use new tamper-evident packaging. New blue crab meat packaging options have little or no effect on product quality or shelf life. Processors may choose appropriate packaging options using price, packaging quality, market appearance, and ease of production as the deciding criteria.

ACKNOWLEDGEMENTS

This research was sponsored in part by the National Oceanic and Atmospheric Administration Office of Sea Grant under Grant #NA 26 RGG 373-01 and by the National Fisheries Institute. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its subagencies. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notation that may appear hereon. The use of trade names in this publication does not imply endorsement by the University of Georgia, nor criticism of similar ones not mentioned. The authors thank the following individuals and companies for their dedicated assistance with this project: Jack Amason of Sea Garden Seafoods, Liping He, The King Plastic Corporation, David Lewis of The Lewis Crab Factory, Triplas Incorporated, and Min Zheng.
REFERENCES


EVALUATION OF COOLING RATES FOR ATMOSPHERIC STEAMED BLUE CRAB MEAT

David P. Green¹, Mario Ferruzi² and Brent Fulcher³
¹NC State University Seafood Laboratory
PO Box 1137
Morehead City, North Carolina 28557
²Duke University Department of Chemistry
Durham, North Carolina 27708
³Craven Crab Company
New Bern, NC 28560

The application of moist heat (atmospheric) to fresh (cooked) blue crab meat offers several commercial advantages and disadvantages for processors. Some of the advantages are improved microbiological (Rippen et al., 1988) and sensory (Gates, 1977) qualities for hand-picked meats. In addition, research indicates that the heat process is effective for assuring the control of the potential pathogen, Listeria monocytogenes (Rippen et al, 1993). Use of atmospheric steam when applied to crab meat was determined to provide a high margin of safety, at least a 20 D-process for Listeria monocytogenes (Scott A), when heated internally to 75°C (Hackney et al., 1991). Disadvantages in the process are reduced lump meat integrity, the need for strict controls to prevent product recontamination and overcoming regulatory concerns for its proper industry use (Fulcher, 1994).

This presentation summarizes some of the experiences gained in a commercial setting with atmospheric steam for in-line quality assurance. Specific objectives of the study were to evaluate the heat process for adequacy to control Listeria monocytogenes and to evaluate the cooling process for the purpose of reducing the opportunity for post-process contamination.

MATERIALS AND METHODS

An atmospheric steam tunnel of approximately six feet in length was constructed of stainless steel and operated by Craven Crab Company of New Bern, N.C. The tunnel was equipped with a temperature (steam) controller, time-temperature recording thermometer and indicating thermometer. Fresh crab meat hand-picked from blue crabs cooked under pressure at 15 psig for 10 minutes was
used to evaluate both heating and cooling curves by four product types: lump, backfin, special and claw.

**Part I**

Preliminary evaluation of steam distribution within the tunnel was performed using a portable potentiometer (Model No. 3087, Yokogawa Corp. of America, Newman, GA) equipped with copper-constantan (type-T) thermocouple wire and two inch stainless steel (s.s.) needle thermocouples (Ecklund-Harrison Technologies, Inc., Fort Myers, FL). Air temperatures were monitored within the tunnel at 12 inch intervals (6 locations). Heat penetration studies were performed on the four product types to establish standard operating procedures (SOPs) and to determine a process schedule (i.e., time and temperature).

After process standardization was achieved, a total of nine heat penetration profiles were obtained for each of the four product types studied. These data were obtained by inserting a thermocouple in the largest portion of crab meat centered on a perforated s.s. tray. Each tray held two pounds of meat that was leveled to less than one inch in thickness. Heat penetration profiles were monitored with a hand-held thermometer (Model HH-21, Omega Instruments, Inc., Stamford, CT) equipped with type-T thermocouple wire and a two inch s.s. needle thermocouple (Ecklund-Harrison Technologies, Inc., Fort Myers, FL).

**Part II**

Exit temperatures for the atmospheric steamed crab meat were measured and air cooling monitored with the hand held thermometer during transfer from the perforated s.s. trays to sanitized solid s.s. trays. Samples were allowed to air cool approximately 10-15 minutes in the solid s.s. tray before packing into standard 16 oz. copolymer polyethylene cups (Venture Plastics, Inc., Monroeville, Ohio). The containers were weighed, capped and sealed with tamper evident low density polyethylene seals and packed on ice (50 pounds per waxed corrugated cardboard box). Product cooling rates on ice were monitored with use of molded plastic thermocouples (Ecklund-Harrison Technologies, Inc., Fort Myers, FL) inserted through the top of the snap-on lids for the 16 oz. polyethylene containers. Temperature profiles for packed crab meats during cooling were monitored until the core meat temperature approached 10 °C.

**Air-cool versus hot-fill packing**

A comparison of cooling rates for crab meat allowed to air cool prior to packing on ice versus direct hot-filling and then packed on ice was performed in order to evaluate the effects of initial meat temperature on cooling rates. The hypothesis was that the rate of cooling would be faster for “hot-fill” packing compared with “air-cool” packing since the driving force (e.g., heat) would be greater. The hot-fill
technique would reduce the potential for recontamination of product after steaming by decreasing the time that meat is exposed to the plant environment (i.e., air).

Special crab meat was chosen for the purpose of this comparative study. Cooling rate profiles of crab meat were obtained for air-cool and hot-fill process techniques, respectively, according to procedures described in Part II. Due to the difficulty in handling crab meat at high temperatures, no samples were packed by hand with temperatures exceeding 65.5°C.

Model simulations

In order to simulate temperatures greater than 65.5°C, a mathematical spreadsheet (Quattro Pro for Windows, Version 5.0, Borland International) and model generator (MathCAD 2.0, Addison-Wesley) were used to curve fit cooling data and extrapolate initial meat temperatures outside the experimental range obtained at the processing plant. By generating models for these cooling rates a better understanding of how to improve the atmospheric steam process could be obtained. Models were developed using the following exponential equation:

\[ T_t = T_{sur} + T_0 * e^{-(K*t)} \]  

\( T_t \) is the meat temperature at any time, \( t \), \( T_{sur} \) is the surrounding temperature. \( T_0 \) is the initial temperature minus the surrounding temperature. \( K \) is the rate constant and \( t \) is time. This model clearly shows that the temperature at any time \( t \) is dependent not only on the surrounding temperature but also on the initial meat temperature.

The constant \( K \) which determines exactly how fast the meat will cool can be calculated with the following equation:

\[ \frac{\ln(T_t - T_{sur})}{T_0} = \frac{K}{t} \]  

It can be seen from equation (2), that if time remains constant and the surrounding temperature is constant then crab meat with the higher initial temperature will have a faster cooling rate. This translates simply into the fact that the hotter a body is the faster that it cools. Knowing this, the question now becomes at what initial meat temperature does this make a significant difference in the cooling time? Since only a small difference in cooling time was actually observed between air-cool and hot-fill packing of meat, it was further hypothesized that there must be an optimum temperature in which to pack crab meat to obtain the maximum cooling rate and
minimize the chances for product recontamination.

**Laboratory analyses**

Duplicate 16 oz. samples of lump, backfii, special and claw crab meat before (control) and after atmospheric steaming (air cool only) were collected. Samples were evaluated at the NCSU Seafood Laboratory for pH, moisture, color, aerobic plate count (35°C) and sensory qualities according to methods described in Henry (1991). Meat stored on ice for 21 days was evaluated for aerobic plate counts by standard methods (APHA, 1984) in order to determine shelf life of steamed product and non-treated controls.

**RESULTS AND DISCUSSION**

**Part I** Evaluation of the atmospheric steam process.

A representative steam distribution pattern for the atmospheric tunnel under standard operating procedures is shown in Figure 1. Positions 1 and 6 are not given due to lower temperatures near inlet and exit-positions of the tunnel.

Two significant observations were made. First, temperatures inside the tunnel fluctuated as a result of the steam controller. And secondly, temperatures recorded were higher (88.6 to 91.4°C) than the indicating thermometer (87.8°C). Reasons for the fluctuations and higher temperatures observed may be explained by the relative heat sensitivity of the potentiometer compared to the less sensitive steam controller.
and indicating thermometer.

In addition to steam distribution patterns, a series of heat penetration profiles were obtained for the various product types in order to establish standard operating procedures and a process schedule. It was determined that a process schedule of 4 minutes and 15 seconds at 87.8°C would deliver sufficient heat to all four product types.

Figure 2 shows the slowest heating curves from nine observations for each of the four product types studied. Internal meat temperatures reached 79.4°C in 3 minutes and 45 seconds. Final temperatures exceeded 85°C for all product types at 4 minutes.

Harrison and Huang (1990) first determined decimal point reduction times (D-values) for inactivation of Listeria monocytogenes (Scott A) in blue crab meat. D-values of 40.43, 12.00 and 2.61 minutes at 50, 55 and 60°C were found. Hackney et al. (1991) found similar D-values of 12.4 and 2.4 at 55 and 60°C for Listeria in blue crab meat. Based on an inoculated pack study with Listeria monocytogenes, a process achieving an internal temperature of 75°C was adequate to achieve at least a 7D process (Hackney et al., 1991). The heat penetration profiles shown in this study (85°C) would be sufficient to provide a D-value for L. monocytogenes of several hundred fold.
Part II Evaluation of the cooling process.

Air cooling of atmospheric steamed crab meat was accomplished by transferring meat from perforated s.s. trays on exit from the tunnel to solid s.s. trays. This transfer resulted in a temperature drop of 15°C from exit temperatures. Allowing the meat to cool in the tray for an additional 10-15 minutes prior to packing further lowered meat temperature depending upon the relative thickness of the sample. Hot-filled crab meat was immediately packed into plastic cups after transfer (not allowed to air cool) to the solid s.s. trays.

Figure 3 shows cooling rate differences between air-cool and hot-fill packing of crab meat after placing on ice. Both samples rapidly cooled to below 37.7°C in less than one hour and were virtually identical (14.5°C) after two hours on ice. The primary difference observed was the initial cooling rate. Even though the two packing techniques yielded only a small difference in cooling time, the results are significant. Further studies were conducted to simulate conditions where crab meat would be directly filled into containers from the end of the tunnel without handling. This packing technique would minimize exposure of crab meat to environmental conditions in the packing room.

By using a mathematical spreadsheet and model generator, cooling times for initial temperatures outside the experimental conditions could be approximated. This task was accomplished by noting trends in cooling rate constants observed for initial meat temperatures. These trends were used as a base line and extrapolated in order to achieve a good estimate on rate constants at higher initial temperatures. Figure 4 shows that as the initial meat temperature increases, a rise in the rate constant occurs resulting in a drop in time to reach a specified temperature.
The accuracy of the model was tested by comparing predicted cooling times with a set of actual data obtained in the field. The $T_{12.7}$ model estimates were found to be within +/- 10 minutes of the actual experimental values. From the results found in this study, the benefits of hot packing can be seen. Direct filling of crab meat at an exit temperature of 82.2°C would reduce the amount of time to achieve a final product temperature of 12.7°C by 25% (i.e., 135 min at 65.5°C compared with 100 min at 82.2°C) and minimum the opportunity for the occurrence of post-process contamination of meat.

Crab meat quality

Product quality is critical when using hot-filling techniques especially where plastic containers are subjected to static cooling conditions (e.g., packed on ice). The plastic insulates the meat, trapping heat inside, and reduces heat transfer rates. The importance of this is significant because of the relative heat sensitivity of blue crab meat to discoloration (Boon, 1975; SFA, 1988). For the most part, blue crab meat is pasteurized at temperatures less than 87.8°C. Due to this concern, crab meat samples were examined for moisture, pH, color and sensory qualities.

Table 1 contains the results from laboratory analyses performed on lump, backfin, special and claw meats before and after atmospheric steaming. No differences were found in pH, moisture, or color as a result of steam treatment. Higher moisture content and color differences (darker and more red-blue) were found between body and claw meat samples. An insufficient number of samples were analyzed to statistically compared these differences and no attempt was made to evaluate changes over time of storage.
Table 1. Laboratory analyses on control and treated crab meat samples.

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<td></td>
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<tr>
<td>Control</td>
<td>7.46</td>
<td>79.98 + 0.01</td>
<td>51.80 + 0.11</td>
<td>4.00 + 0.07</td>
<td>6.49 + 0.11</td>
</tr>
<tr>
<td>Steamed</td>
<td>7.46</td>
<td>79.99 + 0.02</td>
<td>49.65 + 0.20</td>
<td>4.22 + 0.09</td>
<td>5.87 + 0.10</td>
</tr>
</tbody>
</table>

Figure 5 shows the relative shelf life of lump and special crab meat before and after steaming. Aerobic plate counts were performed over 21 days storage of meat on ice. Steamed samples showed an extended shelf life of 7 days over controls with lump meat exhibiting the lowest APC of all samples tested, less than 25,000 APC/g after 21 days at 0°C. It can be observed in Figure 5 that initial meat qualities (APC, 35C) were well below the state health standard of 100,000 cfu/g. Enhanced GPMs and employee training were implemented by Craven Crab for Listeria control prior to use of atmospheric steam for in-line quality control.
Sensory evaluations of lump, special and claw meats before and after steaming were performed by trained staff at the NCSU Seafood Lab. No (lump, claw) or little (special) free liquid was observed in one pound containers of meat stored for 48 hours on ice. Steamed lump meat was judged to be less yellow and glossy and slightly gray, drier and more fibrous that controls. Steamed claw meat was slightly darker, drier and noticeably sweeter that controls. Steamed special was slightly darker with a noticeable dark concentric ring at the meat surface.

CONCLUSIONS

The present method of air cooling atmospheric steamed crab meat prior to packing requires additional handling by employees and has poential for air-borne contamination of the product. Hot filling of crab meat reduces this risk with a slight increase in the cooling rate obtained. The potential for developing direct filling techniques with atmospheric steamed crab meat is evident. This study demonstrated the adequacy of the atmospheric steam process for control of Listeria monoctyopenes. It offers industry several opportunities for reducing cooling rates of atmospheric steamed crab meat thereby reducing the opportunity for post-process contamination. Develop of rapid cooling techniques and the proper application of the atmospheric steam process by the U.S. blue crab industry would provide consumers with crab meat of higher bacteriological quality and a greater margin of safety.

ACKNOWLEDGEMENTS

The authors acknowledge the assistance of JoAnna Tharrington and Suzanne Lockhart for performing analyses for color and microbiological quality, respectively. Special thanks to Mario Ferruzi, a chemistry major at Duke University, Durham, N.C. and Mr. Brent Fulcher, President of Craven Crab Company, New Bern, N.C. This project could not have been possible without their cooperation and assistance. This work was partially supported by a grant from the National Sea Grant Program, National Oceanic and Atmospheric Administration, to the NC Sea Grant Program under Project No. A/AE10C and the North Carolina Cooperative Extension Service-The use of trade names in this publication does not imply endorsement by North Carolina State University, nor criticism of similar ones not mentioned.
REFERENCES


AN ECONOMIC ANALYSIS OF THE DOMESTIC AND FOREIGN MARKETS OF VARIOUS COASTAL HERRING AND ASSOCIATED SPECIES

B.C. Posadas, C.D. Veal, M-L. Jahncke, and J.A. Gooch
Coastal Research and Extension Center
Mississippi State University
27 10 Beach Boulevard, Suite l-E, Biloxi, MS 39531

“This project was funded by the NOAA/National Sea Grant College Program, US. Department of Commerce, under Grant Number NA16RG0155-02, the Mississippi-Alabama Sea Grant Consortium, and Mississippi Agricultural and Forestry Experiment Station/Mississippi State University.”

INTRODUCTION

This paper describes the potential domestic and foreign markets of selected coastal herring and associated fish species, namely: chub mackerel (Scomber japonicus), Gulf butterfish (Peprilus burtii), round herring (Etrumeus teres), and Spanish sardine (Sardinella aurita) The coastal herrings and associated species have great potential as human food. Potential domestic and foreign markets exist for Gulf fishes as food products. It would be beneficial if the factors limiting the consumption of these underutilized species are identified.

Limited economic information are available on the domestic and foreign markets of the coastal herring species. Lea and Roy (1976) conducted an economic feasibility study on processing of groundfish from the Gulf of Mexico. Perkins (1977) prepared an economic evaluation on canned fish products for export to Nigeria. Perkins (1978, 1981) also studied the economic potential for Spanish sardines, and the possibility for a sardine fishery in the Northern Gulf of Mexico. Raizin and Regier (1986) evaluated the impact of domestic wholesale demand for canned sardines on market accessibility of potential Gulf of Mexico Products. Thrash (1986) evaluated the commercial feasibility of harvesting, processing, and marketing Gulf butterfish and concluded that a strong market potential existed for the fish species. Dufrene (1988) reported that the lack of a good, consistent market for the fish was the most significant factor affecting a major fishery developing for Gulf butterfish. A one-month commercial exploratory fishing operations conducted in the Gulf of Mexico showed that quantities and sizes of Gulf butterfish that were commercially valuable can be caught and that the fish can be successfully marketed in Japan. Additional
market and economic studies focusing on other Gulf species are needed in order to more fully exploit their potential.

MATERIAL AND METHODS

Several methods were used to identify product forms of selected fish species landed, produced and consumed in existing and potential domestic and foreign markets. First, mailed interviews were conducted with seafood marketing firms handling mackerel products. Second, letters requesting for information regarding prices and product forms were sent to Commercial or Fisheries Officers of U.S. embassies in countries where landings of the selected fish species were reported. Third, relevant market data were collected from various statistical publications covering domestic and foreign markets. The statistical data collected include potential yields of selected domestic fisheries, landings and values, ex-vessel and wholesale prices, product forms, processing production and trade.

Potential yields Three levels of potential yields of the selected domestic fisheries are reported, namely long-term potential, current potential and recent average yields. The long-term potential yield (LTPY) is the maximum long-term average yield or catch that can be achieved through conscientious stewardship, by controlling the fishing mortality rate to maintain the population at a size that would produce a high average yield or harvest (USDC 1991). Current potential yield (CPY) is the yield or catch that will maintain the current population level or biomass or stimulate a trend toward a population that will produce the long-term potential yield (USDC 1991). The recent average yield (RAY) is the reported fishery landings averaged for the three-year period (USDC 1991). These yield levels are used to determine the status of utilization of the fishery resource.

Annual world and domestic landings. Annual landings by producing countries, by domestic and by state commercial fisheries are reported for a period of at least ten years starting from 1980. National and state landings were obtained from the Fisheries Statistics Division and Regional Fishery Statistics offices of the National Marine Fisheries Service (NMFS). The world and by country catches were obtained from the Yearbook of Fishery Statistics of the Food and Agriculture Organization of the United Nations (FAO, 1980-90a).

Ex-vessel and wholesale prices The domestic ex-vessel price was obtained from the ex-vessel value and the quantity of commercial landings. The ex-vessel prices in foreign commercial fisheries were solicited through mailed questionnaires to Commercial Sections of U.S. embassies abroad, and NMFS and other publications. The data collected on ex-vessel prices in foreign commercial fisheries, however, are very limited. The weekly ex-vessel price of the North Carolina butterfish landings reported by the NMFS office in New Orleans is published in the Fisheries Market News Report by Urner Barry Publications (NMFS, 1991-93).
The wholesale prices of selected fish species at six wholesale markets in Japan are monitored by the NMFS office in Long Beach. These prices are reported on a monthly basis at the Fisheries Market News Report published by Urner Barry Publications (NMFS, 1991-93). The wholesale price of fresh butterfish at the New York Fulton Fish Market collected by NMFS in New York is reported, at most, three times per week by the Fisheries Market News Report published by Urner Barry Publications (NMFS, 1991-93).

Marketing margins were computed to show the relationship between prices of butterfish products in different market levels. These margins are expressed in absolute ($/lb) and relative (%) terms. The marketing margin measures the difference between the average monthly wholesale price of fresh whole butterfish at the New York Fulton Fish market and the average monthly ex-vessel price of North Carolina butterfish landings.

**Forms of fish and fishery products.** The forms of fish products landed, produced, and consumed were identified by using NMFS (1988-89, 1987-91, 1991-93), FAO (1980-90b) and GLOBEFISH (1991) publications, interviews with commercial officers of U.S. embassies, and a survey of fish marketing companies handling mackerel products. Mailed interviews were conducted with Commercial or Fisheries Officers in U.S. embassies abroad based on the list of major producing countries published by FAO (1980-90a). Limited amount of information on fish production, prices and product forms, however, were provided by Commercial or Fisheries Officers who responded to the questionnaire.

A survey of fish marketing companies handling mackerel was conducted to collect marketing data on Pacific mackerel. A total of 39 questionnaires were mailed to companies based in California. About 49 percent or 19 seafood marketing companies responded to the mailed interviews, and 13 completed interview schedules were used in the analysis of the survey results.

**Production and trade.** The data on the domestic production of processed fish products were collected from the Annual Summaries of Frozen and Processed Fishery Products (NMFS, 1988-89) and the Fisheries of the United States (NMFS, 1980-92). The prices of domestic fishery products were derived from the value and quantity of domestic fishery production. The foreign production data were obtained from the Yearbook of Fishery Statistics (FAO, 1980-90b) which did not include data on the value of foreign production.

Domestic wholesale trade data of butterfish products at the New York fish markets were collected from the NMFS-Economics Data Office in New York and NMFS (1991-93). NMFS (1991-93) reports these data, at most, three times a week, while the New York office of NMFS provided a monthly summary of these data.
The foreign demand for U.S. exports of fish and fishery products could be affected by several factors ranging from its own price, prices of related products, foreigners’ disposable income, exchange rates, and foreigners’ tastes and preferences. In addition, restrictions to foreign trade imposed by importing countries such as tariffs and non-tariff barriers could limit the flow of goods into their economies. The current trend toward trade liberalization under the new General Agreement on Tariffs and Trade (GATT) may bring about changes in international trade in fishery products. The specific tariffs and non-tariff barriers (NTB’s) imposed by Asian, EEC, West African and North American countries on small pelagic fish species are discussed in Salapare (1991), INFOFECHE (1991), MacPherson (1990) and Barnett (1994). The economic implications of the above-mentioned trade barriers on the export demand of the selected underutilized fish species are not discussed in this report.

**Harvesting and handling costs.** The use of on board storage facilities would enhance the quality of fish upon delivery. The costs of harvesting and handling can be estimated by using existing data regarding the use of selected methods in the Gulf of Mexico by commercial or experimental fishing boats. Ernst and Brown (1982) prepared an overview of the engineering and economics of refrigerated (RSW) and chilled (CSW) sea water systems. Uebelhoer (1984) reported that an on board RSW system was much less expensive to operate than conventional icing and produced consistently superior fish at the dock.

Vecchione (1987) stated that the ability to process the butterfish catch adequately is of utmost importance in maintaining the quality necessary to sell the fish in Japan, the primary market. Vessels outfitted with onboard freezers could be improved further by equipping them with refrigerated-seawater holding tanks. This would prevent extremely large catches from spoiling on deck before they can be processed completely. The added costs of shipping the butterfish products from the landings points to the wholesale or export markets should not exceed the marketing margins between these market levels.

**III. RESULTS AND DISCUSSION**

**Chub Mackerel**

**Potential yields.** The long-term potential yield of the Pacific mackerel fishery is about 28,000 mt (USDC, 1993). A higher current potential yield amounting to 36,000 mt (USDC, 1993) has been reported. With a recent average yield of 23,000 mt (USDC, 1993), the Pacific mackerel fishery appears to be fully utilized.

**World landings.** The reported annual landings of chub mackerel by all producing countries are 2.0M mt in 1980-85 and 1.7M mt in 1986-90. The major producing countries of chub mackerel in 1980-90 are Japan, the former U.S.S.R., Ecuador, China, and South Korea. The share of Japanese landings to world landings decreased from 44.0% in 1980-85 to 36.5% in 1986-90. The former U.S.S.R.
reported a fairly stable share of about 17.8% of world landings during the entire period. Ecuador, China, and South Korea landed about 10.0%, 7.8%, and 6.1% of world chub mackerel landings in 1980-90, respectively.

**Domestic landings.** Since there are no consistent official reports of commercial landings in the Gulf of Mexico states, domestic landings and ex-vessel prices reported in this paper refer to the California and Oregon fisheries. The average annual landings of the U.S. chub mackerel fishery increased from 34,285 mt in 1980-85 to 38,953 mt in 1986-91. This fishery contributed an increasing share to world chub mackerel landings from 1.7% in 1980-85 to 2.4% in 1986-90. Current data released by NMFS office in Silver Spring showed lesser Pacific mackerel landings in 1992 and 1993.

**Domestic ex-vessel prices** These nominal ex-vessel price of chub mackerel fell from $0.09/lb in 1980-85 to $0.07/lb in 1986-91. In deflated terms, ex-vessel prices deteriorated from $0.09/lb to $0.06/lb during the two time periods under consideration.

**Japanese ex-vessel prices.** The annual landings of fresh Pacific mackerel at 51 landings ports in Japan averaged 326,798 mt in 1987-92. Landings value was $238.8M per year. Average ex-vessel price was $73/lb or $0.33/lb.

**Japanese wholesale prices.** In 1987-92, the six wholesale markets in Japan moved about 29,573 mt of fresh Pacific mackerel per year valued at $92.8M. Wholesale price of fresh fish in these markets averaged $3,139/mt or $1.42/lb.

About 13,444 mt of frozen Pacific mackerel worth $36.7M arrived each year at the six wholesale Japanese markets in 1987-92. Typically, these frozen fish products were sold at $2,732/mt or $1.24/lb.

**Product forms.** Fish processors in the U.S. Pacific coast are canning Pacific mackerel for human consumption and pet food. The fish species is sold in the domestic market in several product forms namely: canned, fresh, frozen, dried, and smoked or kippered. This fish is also used by fishermen as bait either in live, fresh or frozen form. Frozen Pacific mackerel products are also exported. A staff member of NMFS office in Long Beach stated that U.S. Pacific mackerel products were exported to Japan in 1991 when Japanese landings were low.

The results of the FCA (1988) marketing project indicated that the preferred form of Pacific mackerel exported to Fiji Islands was one-pound size, whole or headed and gutted fish in frozen blocks. The project also experimented on seasoned, crumbed, precooked, and frozen nugget-shaped Pacific mackerel product, packed raw mackerel fillets, and headed, gutted, tail off, individually quick frozen mackerel product.
The survey of California-based seafood marketing companies handling mackerel products revealed different forms and sizes of Pacific mackerel bought and sold. The annual sales of these seafood companies ranged from $1.0M to $100.0M and had been in the seafood business between 10 to 44 years. The most preferred forms bought and sold by seafood companies are frozen, fresh, chilled, canned, salted, smoked and dried. These companies like the fish whole, filleted, headed, gutted, skinned and tail off. The industrial uses of this fish are pet food or animal feed, baitfish, food additive and protein concentrate. The preferred size for whole fish ranged from 0.5 lb to 4.0 lb, with most of the companies specifying the 1.0 - 2.0 lb size. For those companies which handled filleted fish, the preferred size was 4.0 - 10.0 oz. Generally, seafood companies canning Pacific mackerel are using 15-oz containers.

The Japanese supply of Pacific mackerel consists primarily of fresh landings and frozen imports. Japanese fish processors produce several Pacific mackerel products including boiled and canned in water, canned in oil, and canned in other packs. Most of these processed fish products are exported by Japan to several countries (NMFS, 1991-93). Typically, Japanese exporters sold their frozen chub mackerel products mostly to North Korea, Taiwan, Singapore, Philippines, Thailand and Canary Islands. Saudi Arabia, Kuwait, Yemen and Angola are the major destinations of the canned in oil chub mackerel products exported by Japan. The major importers of Japanese chub mackerel canned in water are Italy, Greece, Ghana, Papua New Guinea, and Micronesia.

**Processing**. The average world production of frozen chub mackerel products are 396,000 mt in 1980-85 and 438,342 mt in 1986-89. Based on FAO (1980-90b) fisheries commodities statistics, the principal producing countries of frozen chub mackerel products in 1989 are Japan (94.9 %), Peru (3.7%), Ecuador (1.1%), Italy (0.2%), and Chile (0.1%).

The annual world output of canned chub mackerel fell from 76,582 mt in 1980-85 to 49,373 mt in 1986-90. Morocco and Japan produced 31.7% and 23.1% of world canned production of chub mackerel, respectively. The rest of the primary producing countries of canned chub mackerel products are Argentina (12.0 %), Brazil (12.0 %), South Korea (11.6%), Chile (6.7%), Ecuador (1.6%), and Peru (1.1%).


Annual exports of canned in oil chub mackerel products from Japan decreased from 3,661 mt in 1987 to 227 mt in 1992. The typical export price of canned in oil chub mackerel products was $2.386/mt or $1.08/lb. The value of Japanese exports
of canned in oil chub mackerel products declined from $7.1M in 1987 to $1.0 million in 1992.

A declining trend in both the volume and value of Japanese exports of chub mackerel products in other packages was observed. Export volume fell from 4,249 mt in 1987 to 1,169 mt in 1992. The value of exports also fell from $6.1M in 1987 to $3.0M in 1992. However, export price rose from $1,440/mt or $0.65/lb to $2,543/mt or $1.15/lb in 1992.

Japanese exporters generally sold their frozen chub mackerel products at average prices ranging from $663/mt or $0.30/lb in 1986 to $1,232/mt or $0.56/lb in 1992. The volume of frozen chub mackerel products exported by Japanese traders consistently declined during the period.

The price of Japanese imports of frozen chub mackerel (and sardine or Atlantic mackerel) products averaged $942/mt or $0.43/lb in 1987. The average import price rose slightly to $1,003/mt or $0.46/lb in 1992.

Gulf Butterfish

*Potential yields* A comparison of the long-term or current potential yield with the recent average yield show that both the domestic Atlantic (*Peprilus triacanthus*) and Gulf butterfish (*Peprilus burti*) fisheries were underutilized fishery resources in 1988-90. The current or long-term potential yield of the Atlantic butterfish fishery was approximately 16,000 mt (USDC, 1991). During the years 1988-90, however, the recent average yield of the fishery was about 2,500 mt (USDC, 1991). This average yield represents around 15.6% of the potential yield of the fishery during the 1988-90 fishing seasons. An average 19,700 mt (SEFC, 1992) were harvested annually from the Gulf butterfish fishery during the 1986-90 fishing seasons. This yield accounts for about 74.3% of the estimated 26,500 mt (SEFC, 1992) current or long-term potential yield during the 1986-90 period.


The Atlantic butterfish fisheries landed an average 5,328 mt/yr. The major producing countries of Atlantic butterfish are the U.S. and Japan. About 95.5% of total landings were harvested from the U.S. butterfish fisheries. Total landings persistently fell from 6,159 mt in 1980 to 4,724 mt in 1985 and 2,965 mt in 1990.
The Gulf butterfish (and harvestfish) landings were mostly reported by Venezuela at an average of 89 mt annually. The Venezuelan butterfish (and harvestfish) landings generally rose from 83 mt in 1980, 112 mt in 1985, and 184 mt in 1990 (FAO 1980-90a).


The butterfish caught by the Japanese trawl fleet in the East China Sea as compiled by NMFS in Pascagoula, Mississippi averaged 2,237 mt for the Period 1980-88. Japanese butterfish catch generally rose from 827 mt in 1980 to 1,358 mt in 1985 and 3,160 mt in 1988. The 1988 butterfish landings, however, were less than half the 6,703 mt landed by the Japanese trawl fleet in 1987.

The decline in Japanese butterfish landings generated a shortage of the fish species in the Japanese markets. This situation created market opportunities for similar species from both domestic and foreign fisheries to fill up the shortfall in Japanese butterfish landings.

**Domestic landings.** The annual butterfish landings in the U.S. showed a downward trend over time. The landings in 1980-85 averaged 6,352.9 mt/yr. However, annual landings declined to about 3,434.2 mt in 1986-91. Recent data from NMFS-Silver Spring office indicated higher butterfish landings in 1992 and 1993. The total deflated value of butterfish landings averaged $4.5M and $3.8M in 1980-85 and 1986-91, respectively.

The three major producing states of butterfish are Rhode Island, New York and New Jersey. The state of Rhode Island landed an average 71.7% of total domestic butterfish landings in 1980-91. Each of the New York and New Jersey fishery landed less than 9% of total landings during the entire period.

Regionwise, the New England and Middle Atlantic regions reported most of the butterfish landings during the period. The New England butterfish fisheries landed 78.7% of total domestic landings. An average 16.2% of total landings was registered by the Middle Atlantic butterfish fisheries.

**Gulf of Mexico landings.** Due to the confidential nature of butterfish landings data, no consistent time-series data can be presented for the Gulf of Mexico states. The published commercial landings data from NMFS office in New Orleans seem to suggest that limited quantities of butterfish were caught in the Gulf of Mexico states. However, it was reported that an average 19,700 mt (SEFC, 1992) were harvested annually from the Gulf butterfish fishery from 1986 to 1990. It has been cited,
however, that off-shore Gulf of Mexico shrimp fleet incidentally caught 80-97% of the total annual butterfish catch since 1986 (SEFC, 1992).

**Ex-vessel prices.** The domestic ex-vessel price of butterfish averaged $0.32/lb in 1980-85 and $0.59/lb in 1986-91. In New England, the ex-vessel price of butterfish averaged $0.29/lb and $0.64/lb in 1980-85 and 1986-91, respectively. Similar trends are observed in the Middle Atlantic ($0.42/lb and $0.54/lb), the Chesapeake ($0.30/lb and $0.39/lb), and the Gulf Coast ($0.22/lb and $0.46/lb). The average ex-vessel price of the Pacific butterfish (*Peprilus simillimus*) fell from $0.98/lb in 1980-85 to $0.73/lb in 1986-90.

The butterfish ex-vessel prices in the Gulf of Mexico states also showed the same trend over the entire period. In Alabama, the ex-vessel price rose from $0.17/lb in 1980-85 to $0.30/lb in 1986-91. An increase from $0.20/lb in 1980-85 to $0.40/lb in 1986-91 was noted in the Louisiana butterfish landings. Similarly, the Mississippi butterfish landings were valued from $0.27/lb in 1980-85 to $0.42/lb in 1986-91.

**Forms of fish and fishery products.** In the U.S., butterfish has been generally processed into fresh or frozen fillets or dressed form (NMFS, 1988-89). In New England, NMFS (1988-89) reported that butterfish was also processed into fresh or frozen fillets form. Fresh whole butterfish are delivered to the NY Fulton fish market from several states by truck and imported from Ecuador by air (NMFS, 1991-93 and NMFS office in New York). A senior staff member of NMFS office in Long Beach indicated that butterfish landed in California are probably sold fresh in the local markets. The results of a survey conducted in New York (NYSDS, 1989) showed that several seafood establishments were selling fresh or frozen whole, dressed or fillets, and smoked butterfish products.

Exports of fresh and frozen butterfish products were reported in various countries (MAFMC, 19991). A Commercial Specialist of the U.S. embassy in Hamburg wrote that butterfish products were imported into the former Federal Republic of Germany exclusively for human consumption only in frozen and smoked forms. This information was gathered by the specialist from German fish importers, wholesalers, frozen fish processors, Federal Fish and Seafood Institute, and Fish Industry and Wholesalers’ Association. Responses to letters of inquiry sent to Commercial Officers in other selected U.S. embassies suggested that there were no specific market information available at that time regarding butter-fish.

**Domestic wholesale trade.** Based on the data provided by the NMFS office in New York, the deliveries of fresh whole butterfish at the New York Fulton fish market from all states of origin fell from 338.5 mt in 1990 to 187.1 mt in 1991, 197.9 mt in 1991 and 298.5 mt in 1993. The major suppliers of butterfish to the New York Fulton fish market are New York, Rhode Island, New Jersey, Connecticut, and North Carolina. The New York butterfish fishery supplied between 30.6% to 50.9% of total deliveries from 1990 to 1993. Rhode Island delivered between 7.7% and 28.7 percent
during the same period. The butterfish fisheries of New Jersey, Connecticut, and North Carolina sent about 10% each to the New York Fulton fish market.

The total deliveries from the Gulf of Mexico states to the New York Fulton fish market were about 50.9 mt in 1990. After that year, no significant deliveries of Gulf butter-fish to the New York Fulton fish market were reported.

**Domestic wholesale prices.** The monthly wholesale prices of fresh whole butterfish at the New York Fulton fish market were reported by size of fish. The grades of butterfish based weight are as follows: small, 80-100 g; medium, 100-150 g; and large, >150 g (Vecchione 1987). The average wholesale price of small butterfish were $0.48/lb in 1991, $0.58/lb in 1992 and 0.59/lb in 1993. The medium and mixed-sized butterfish were sold at $0.78/lb in 1991 and 1992, and $0.60/lb in 1993. The large butterfish were sold on the average at $0.98/lb in 1991, $0.91/lb in 1992, and $1.03/lb in 1993. For all sizes of butterfish, the average wholesale prices were $0.81, $0.71, and $0.77/lb in 1990, 1992, 1993, respectively.

The marketing margins between the average monthly ex-vessel price in North Carolina and the average monthly wholesale price in New York were measured in both absolute and percentage terms. In absolute terms, the marketing margins fell from $0.55/lb in 1991, to $0.30/lb in 1992, and to $0.39/lb in 1993. In relative terms, the marketing margins decreased from 234.9% in 1991 to 93.1% in 1992, and to 125.2% in 1993.

**Japanese wholesale prices** Differences in auction prices for Atlantic and Gulf butterfish were observed at the Tokyo Central Wholesale Market from April 1988 to March 1990. The butterfish from the Gulf coast states were sold at relatively lower prices (64.1%) than those coming from the New England states. The average wholesale price for Gulf butterfish was $1.36/lb as compared to $2.13/lb for the Atlantic butterfish. Gulf butterfish were sold at wholesale prices ranging from 29.7% to 72.8% of the wholesale prices of Atlantic butterfish auctioned in Japan during the period. About 71.4 mt of Gulf butterfish and 74.8 mt of Atlantic butterfish were auctioned each month at the Tokyo wholesale market. Due to the differences in the average auction prices, the average total value of Gulf butterfish was about 58.4% of that of the Atlantic butterfish.

**Foreign trade** The annual volume of butterfish exported by the U.S. to foreign markets averaged 4,050 mt in 1981-85 valued at $6.6M or $0.75/lb. The average butterfish export price rose to $1.05/lb in 1986-90 with 2,422 mt valued at $6.3M. As the average annual butterfish exports fell further to 1,420 mt in 1991-93, total value decreased to $3.9M while average price rose to $1.22/lb. On the average, about one-quarter of U.S. butterfish exports were sold in December. Between 10.4% to 18.1% were exported in November, January, February and March.
The major importing country of U.S. butterfish products is Japan. Japan imported an average 4,038 mt, and 2,304 mt of butterfish in 1981-85 and 1986-90, respectively. The concentration of U.S. butterfish exports to Japan fell from 99.6% in 1981-85 to 92.3% in 1986-90. The Japanese market paid a relatively higher price (103.4%) than the average price received by U.S. butterfish exporters during the later period. The list of importing countries includes Canada, UK, France, former West Germany, Italy, Taiwan, Belgium, Luxemburg, and Spain. Varying quantities of butterfish were exported by the U.S. to these countries at different prices.

**Harvesting and handling costs.** A one-month commercial exploratory butterfishing operations was conducted by a New England firm in the Gulf of Mexico in May-June 1986 (Vecchione, 1987). The total amount of butterfish landed by two fishing vessels was 212.9 mt. All the butterfish shipped were sold at prices ranging from $0.58 to $0.7/lb or at an average price of $0.63/lb. The total cost of unloading and storage amounted to $18541.76 or an average of $0.04/lb. It was further cited that the cost of unloading and storage differed between Pascagoula, Mississippi ($0.02-0.03/lb) and Lake Charles, Louisiana ($0.04/lb). Different shipping routes and destinations resulted to different shipping costs ranging from $0.02/lb to $0.07/lb, or an average of $0.03/lb. The estimated net profit, excluding the special marketing costs in Japan, was $137,081, $2,285/vessel/day or $0.29/lb. The total cost of landing the fish can be imputed from the bid price made by the commercial fishing firm amounting to $2,100/vessel/day, or $0.27/lb.

Dufrene (1988) reported that the cost of retrofitting an 88-ft steel hull shrimp trawler in the northcentral Gulf of Mexico was about $60,000. Good catches of butterfish were made from June 14 to October 28, 1988 at both west and east of the Mississippi Delta. A total of 77.1 mt of various sizes of butterfish were reported landed in 11 landing dates or an average of 7.0 lb per landing date.

**Round Herring**

**Potential yields.** According to Houde (1977), there are eight discrete populations of round herring worldwide, namely: western Atlantic, eastern, central and western North Pacific, Indo-Pacific, western Indian Ocean, Red Sea and Eastern Pacific. In the U.S., recorded populations of round herring occur from Cape Cod to the Gulf of Mexico. The best estimate of potential annual yield of the eastern Gulf of Mexico fishery ranges from 50,000 to 250,000 mt. Round herring are fished commercially off Japan and South Africa.

**World landings.** The world landings of red-eye round herring (*Etrumeus teres*) rose from 38,696 mt/yr in 1980-85 to 51,042 mt/yr in 1986-90. The major producers of red-eye round herring are Japan and Romania. Japan landed about 94.4% of all *Etrumeus teres* landed in 1980-90. The world landings of whitehead’s round herring (*Etrumeus whiteheadi*) increased from 32,911 mt/yr in 1980-85 to
48,693 mt/yr in 198690. The primary producing nations are South Africa (99.99%) and Romania (0.01%).

**Japanese landings.** According to the Commercial Section, U.S. Embassy in Tokyo, Japanese round herring are mostly landed in Tottori, Kumamoto, Yamaguchi and Nagasaki Prefectures in western Japan. Fishing season is primarily in September to October. Fresh package for auction at landing ports is 30 kg random weight. Average annual landings of round herring (*E. teres*) or *urume iwashi* in 1980-85 were 35,666 mt, valued at 129 yen/kg or $0.25/lb. In 1986-90, annual landings rose to 49,240 mt and sold at 101 yen/kg or $0.32/lb.

**Domestic landings.** There were no records of commercial landings of round herring in the Gulf of Mexico before 1993. The NMFS office in Miami reported that about 0.01 mt of round herring were landed in Florida (West Coast) and valued at $19 or $0.09/lb. However, there are other domestic fisheries in the U.S. which can provide insights into the trends in landings, values and prices of herring species. The commercial Atlantic herring (*Clupea harengus*) fisheries landed about 43,182 mt annually in 1980-91 valued at $5.2M or $0.05/lb. The Pacific herring (*Clupea pallasi*) fishery landed an average 55,021 mt/yr in 1980-90 worth $36.4M or $0.30/lb. The Florida (West Coast) thread herrings (*Opisthonema oglinum*) were harvested at an annual rate of 158.4 mt in 1980-85 and 1,315.4 mt in 1986-90. The annual value of the fishery was $0.244M in 1986-90 or $0.05$/lb. Thread herrings in Florida are mostly landed between the months of May and October. Based on the landings data provided by the Beaufort Laboratory of NMFS, thread herrings are also caught in North Carolina waters. Annually, about 1,224.7 mt were landed in 1980-85, 1,179.3 mt in 1986-90, and 2,177.2 mt in 1990-93. The commercial value of the fishery was limited to about $0.239M in 1993 or $0.04/lb.

**Product forms.** The Commercial Section of the U.S. Embassy in Tokyo provided a good description of the various forms of round herring products in Japan. Japanese herrings are sold fresh at retail outlets but the most common product is *maruboshi* or fish dried in the round. Whole fish is first soaked in about 3% salinity brine water, then dried naturally or mechanically to a moisture level below 30%. Salt content of the finished *maruboshi* is about 5%. This process is said to enhance fish flavor and shelf life at retail outlets. Two kilograms of finished *maruboshi* are laid on flat plastic or card board trays, six of which are packed in master cartons. They are stored frozen and consumed lightly grilled at home. The meat of fresh *urume iwashi* harvested in winter is said to be firm and good for grilling. A limited quantity is said to be frozen for bait in the longline tuna fleet. Landed quantity is said to be too small to allow fish meal production. The use for pet food is unknown. The Embassy is not aware of any Japanese imports of fresh or frozen round herring from overseas. It may be imported in cans but statistics are difficult to identify since this import category includes other species.
**Japanese wholesale trade.** An average of 19.8 mt were handled annually in Japanese fresh wholesale market for round herring in 1986-90. The typical wholesale price of fresh round herring was about 337 yen/kg or $1.06/lb. The wholesale quantity of dried in the round Japanese round herring or *maruboshi* in 1986-90 remained relatively stable at about 499 mt. The average wholesale price of dried round herring was about 1,350 yen/kg or $4.30/lb. The U.S. Embassy in Tokyo reported that retail prices of *maruboshi* are about 300-300 yen per 100 gram package.

Spanish Sardine

**Potential yields.** According to Johnson and Vaught (1986), Spanish sardine (*Sardinella aurita*) occurs throughout the Gulf of Mexico, northward to Massachusetts and southward to Rio de Janeiro, Brazil. Fisher (1978) as cited in Johnson and Vaught (1986) also stated that the species is also common in the eastern Atlantic, Mediterranean Sea and the Western Pacific Ocean. There are no current USDC (1991; 1993) estimates of the potential yields for the Gulf of Mexico Spanish sardine fishery. Johnson and Vaught (1986) cited Reintjes (1979) estimate of the potential yield of the Florida Spanish sardine fishery as between 60,000 to 120,000 mt. The recent average yield based on the 1989-91 landings of the Florida (West Coast) Spanish sardine fishery was about 928.2 mt.

In the U.S. Pacific Coast, the Pacific sardine (*Sardinops sagax*) fishery has been managed by the state of California (Leet et al. 1992). Since the early 1980’s, sardines were taken as incidental catch to southern California fishery for Pacific and jack mackerel. A growing directed Pacific sardine fishery has been allowed under an increasing annual quota since 1986. USDC (1993) estimates for current and long term potential yields are 22,000 mt and 250,000 mt, respectively. Based on the 1990-92 annual landings of 10,000 mt (excluding Mexican landings) of the Pacific sardine fishery, USDC (1993) categorized the fishery as fully utilized.

**World landings.** Annual world landings of Spanish sardines rose from 137,061 mt in 1980-85 to 320,797 in 1986-90. Based on the reported landings in 1980-90, the major producing countries of Spanish sardine are the former U.S.S.R. (50.17%), Venezuela (28.94%), Ghana (10.91%), Romania (6.72%) and Mexico (1.94%). The reported Spanish sardine landings in the U.S., Togo, Cuba, Gambia, Benin and Grenada accounted for less than 1% of the average annual world landings during the period. A report made by INFOFECHE (1991) indicated that the Spanish sardine fishery in Ghana landed about 33,417 mt/yr in 1980-85. The average landings in Ghana during the same period based on the previously reported landings by FAO (1980-90a) was about 8,800 mt. In addition, the same INFOFECHE (1991) report also indicated that the Spanish sardine artisanal and industrial fisheries of Cote D’Ivorie landed about 19,940 mt in 1980-85 and 26,529 mt in 1986-89.

**Domestic landings.** The Florida (West Coast) Spanish sardine fishery is currently the most important if not the only commercial Spanish sardine fishery in the
U.S. Landings consistently increased since 1980, reached a peak in 1987 and started faking since 1988. A Florida Sea Grant Extension Agent estimated that in the 1990’s, the number of boats fishing for Spanish sardine fell to about one-fourth of its size in 1988. The average landings of the Florida Spanish sardine fishery in 1980-85 was about 1,451.5 mt valued at $0.29M. A higher average annual landings was reported in 1986-91 amounting to 1,678.3 mt and valued at $0.41M. The peak of the monthly Spanish sardine landings in 1977-86 occurred in June with most of the landings concentrated from April to August.

**Ex-vessel prices** The deflated ex-vessel price of the Florida Spanish sardine fishery averaged $0.10/lb during the entire period. The rapid increase in annual landings forced the deflated ex-vessel price down from $0.15/lb in 1980-85 to $0.06/lb in 1986-90.

**Forms of fish and fishery products** INFOFECE (1991) describes the West African market for small pelagic fish species including Spanish sardine. Benin imported the species in frozen form packed in 27-kg cartons. The fish species was imported frozen whole by Cote D’Ivoire. The consumers in this country preferred the fish species over 20 cm in size, 7-8% in fat content, and boxed in 20-kg cartons. Ghana, Nigeria and Togo liked round sardinella which are either sun dried, smoked dried or hot-smoked. Johnson and Vaught (1986) reported that in the U.S., Spanish sardine are generally used as bait or frozen animal food. They also suggested possible use of the species in the production of surimi or minced fish products.

**Harvesting and handling costs.** The findings of the deepwater purse seine-refrigerated sea water system exploratory fishing project conducted by Raffield Fisheries (Uebelhoer, 1984) showed that the profitability of a vessel can be improved by harvesting large quantities of surplus species and using an on-board refrigeration system to quickly chill them. This project used a new 62-ft fiberglass fishing vessel (Fisherman’s Bride) equipped with an independently powered onboard marine refrigeration and brine spray freezing system.

The refrigerated seawater (RSW) chilling system consisted of two parts, namely: the refrigeration section and a brine spray freezing unit. The fishing vessel was also equipped with fish locating electronics and communication equipment. A spotter plane was used to search for and locate fish over a much larger area during the project. The initial investment cost on the fishing vessel, electronics and communication equipment, RSW system and purse seine was about $0.41M.

During the 60-day purse seining operations, the Fisherman’s Pride landed about 676.2 mt of assorted fish. The major fish species caught were ladyfish (31.0%), Spanish sardine (15.9%), jack crevalle (14.5%), bonito (13.9%) and menhaden (10.2%). The total landing value of all fish species caught was $113,066.36 or $0.0825/lb. Using one-half of the actual harvest rate during the project, it was estimated that the annual total cost of fishing and handling can be fully covered by the
ex-vessel value of landings. The estimated average cost of fishing and handling was $0.0839/lb, consisting of average fixed cost ($0.0188/lb) and average variable cost ($0.065/lb). With the opportunity costs of operator’s labor, management and capital included, the return on investment for the fishing project was $56,682/yr or 13.7%.

CONCLUSION

Chub mackerel, Gulf butterfish, round herring and Spanish sardine products were traded in both domestic and foreign markets. In the domestic markets, the consumption of these fishery products were generally limited to fresh and frozen whole and fillets, dried, smoked and canned product forms. Excluding butterfish, these species were also widely used as fishing bait and pet food. Another possible use of Spanish sardine is in the production of surimi or minced products.

Fresh and frozen forms of mackerel, sardine and herring were traded domestically and internationally in many Asian countries. Canning in water, in oil and in other packs were also widely practiced in these countries to provide both for their domestic markets and foreign countries. Production of fish products from these species also included salting and smoking. The decline in landings and development of processing industries (mainly canning) in these countries enhanced the demand for imports of these species. The Japanese demand for fresh and frozen imported butterfish was constrained by the size of the Japanese landings of the species.

Several West African countries imported mackerel, herring and sardine products generally in frozen and canned form. Consumers in these countries preferred these species because they were cheap and had high fat content. The high fat content of the species allowed fish smoking, a preferred means of preserving fish due to the lack of freezing or refrigeration facilities at home. The traditional suppliers of these fish products were the fishing fleets of the former Eastern European countries.

Western European nations imports of herring, mackerel and sardines consisted of fresh and frozen whole and unprocessed forms, prepared mainly canned products, and dried, salted and smoked fish products. Several European countries imported butterfish in fresh and frozen form. Smoked butterfish were also imported by Germany for human consumption.

REFERENCES


EFFECT OF WASHING WATER pH ON COLOR AND LIPID OXIDATION OF MINCE AND SURIMI MADE FROM GULF MENHADEN

J. L. Silva1, R. Eddari-Lynn, M. Jahncke2
and J. O. Hearnsberger3
1Department of Food Science and Technology, Box 9805, Mississippi State Univ., Miss. State, MS 39762;
and 2National Seafood Inspection Laboratory, National Marine Fisheries Service, Pascagoula, MS.
3Deceased

INTRODUCTION

The period 1975-1987 witnessed a market growth in the consumption and acceptance of surimi, minced and water-washed fish muscle tissues, in the form of manufactured items such as shellfish analogs. The estimated U.S. supply of surimi products increased from 2.7 to over 45.4 million kg during this same period (Vondruska, 1987).

Diverse species of fish have been used as raw material for surimi. Alaska pollock (Theragra chalcogramma) has been the primary fish used for crableg analogs but recently access to U.S. fishermen has been limited by the U.S. declaration of a 200-mile fisheries conservation zone. In addition, due to fishing pressure, alternative species such as Atlantic and Gulf menhaden (Brevoortia patronus and B. tyrannus, respectively) and Pacific whiting (Merluccius productus) have been investigated for surimi production. A growing interest in the use of dark-fleshed fish species for mince and surimi has developed during the so-called “Age of Engineered Seafoods”. Dark-fleshed, oily fish have been traditionally used for feed, oil and fertilizer production. With the increasing realization of the potential health benefits of engineered seafoods, red-fleshed, oily fish species are now regarded as possible sources of omega-3 unsaturated fatty acids in the diet (Lanier et al., 1988).

U.S. commercial fisheries landings for Gulf menhaden were 539,200 mt in 1993 (NMFS, 1993). Gulf menhaden are regarded as an industrial fish species. Before these fish can be utilized for human consumption, various problems need to be addressed For instance, the improper on-board handling and storage of these fish, the lack of processing equipment suitable for heading and eviscerating small-sized fish, and the fact that these fish are fatty and dark-fleshed fish make them unacceptable for direct human consumption (Babbitt, 1986). However, due to its good gelling properties (Anonymous, 1989), menhaden has a potential as a protein
matrix in which other seafoods could be combined to formulate various seafood products if flavor and color of the mince could be improved.

This work was to evaluate the effects of various pH buffered water-washing treatments on the Hunter color, hematin content, carotenoid content, TBA and, carbonyl values of menhaden mince and on moisture content of the gel.

MATERIALS AND METHODS

Preparation of Fish Mince

Gulf menhaden were caught off the Florida coast, chilled and held in slush ice (1 to 3°C) on the boat until processed (< 48h). The fish were transported to the Mississippi State University (MSU)/National Marine Fisheries (NMFS) Experimental Seafood Processing Laboratory at the Coastal Research and Extension Center, Pascagoula, MS. About 113 kg of fish were processed (Fig. 1) in June 9, July 23, and July 28, 1992 using commercial equipment: a Model M-072 Lapine Fish Heading Machine and a Model M-017 Lapine Fish Gutting Machine (Pisce s Industries, Ltd., Wells, MI).

The dressed fish exited the cutting area to enter a Model NDX13 deboner with 5-mm holes (Bidun Machine Construction Co., Ltd., Japan) to separate fish flesh from bones, skin and scales. The deboning process is also called a mincing process. A portion of the nonrefmed menhaden mince recovered from the dressed fish (about 14kg for each replication) was placed in wax coated storage boxes. The boxes (1.6 to 1.65kg) were stored in the walk-in freezer (-30°C) until they were shipped overnight on dry ice to the MSU Food Processing Laboratory, Miss. State, MS. The boxes were then stored in a walk-in freezer (-17°C) upon arrival on campus.

pH Washing Treatments

The mechanically deboned fish muscle (MDFM) was thawed at 4°C for 48 h before use.

Buffer Preparation

Phosphate buffers of pH 5.0, 6.0, 7.0, 8.0, 9.0, and 10.0, ± 0.2 and same ionic strength were prepared with analytical grade NaH₂PO₄·H₂O and Na₂HPO₄, (Fisher Scientific, Fair Lawn, NJ) by the procedures of Gomori (1955). Chilled distilled water was used to make the different buffer solutions which were then stored at 4°C until used.

Buffer and Water Washings

There were seven pH treatments, including a control (potable water, pH = 6.8). The washing process called for a batch wash system as follows:
- First cycle (4 parts of water to 1 part of mince): One kilogram of MDFM was
Whole Fish
  \[\text{Dehead} \quad \text{(M-072 Lapine)}\]
  \[\text{Eviscerate} \quad \text{(M-o 17 Lapine)}\]
  \[\text{Debone} \quad \text{(NDX13 Bidun, 5mm)}\]
  \[\text{Freeze Mince} \quad \text{(-30°C)}\]
  \[\text{Thaw} \quad \text{(4°C, 48 h)}\]
  \[\text{Wash, 3 Cycles} \]
  \[\text{Dewater} \quad \text{(YS200 Bidun)}\]
  \[\text{Cryoprotectants} \quad \text{(4% Sucrose, 4% sorbitol, 0.25% STPP)}\]
  \[\text{Freeze Surimi} \quad \text{(-17°C)}\]
  \[\text{Thaw} \]
  \[\text{Salt} \quad \text{(2%)}\]
  \[\text{Chop, 3 min.} \quad \text{(VCM 40 Hobart)}\]
  \[\text{Adjust H}_2\text{O} \quad \text{to 78\%} \]
  \[\text{Chop, 6 min.} \]
  \[\text{Stuff} \]
  \[\text{Cdok} \quad \text{(40 min., 90°C)}\]
  \[\text{Gel}\]

Figure 1, Menhaden Mince and Surimi Processing Flowchart.
washed with four liters of phosphate buffer at different pHs at 4°C. The mixture was manually stirred for 3 min, allowed to settle for 15 min and filtered through a double layer of fine cheese cloth. The water was pressed out by hand and floating particles of fat were removed.

Second and third cycles (5 parts of water to 1 part of mince): The fish paste from the first cycle was washed with five liters of potable water at 4°C. In the 3rd cycle, 0.15% (w/w) of NaCl was added. After each cycle, the mixture was hand stirred for 3 min, allowed to settle for 5 mm and then filtered through a double layer of fine cheese cloth. The fish paste was further pressed using a Model YS200 Screw Dehydrator (Bidun Machine Construction Co., Ltd., Japan) to reduce the moisture content. Washed meat was weighed to separate samples used for different chemical analyses from the one used for the preparation of the gels.

**Preparation of Surimi Gels**

The fish paste was mixed with 4% sucrose (commercial granulated refined sugar), 4% sorbitol (Neosorb 20/60, Roqueete Corporation, Gurnee, IL) and 0.25% sodium tripolyphosphate (BK-Landenburg, Corp., Cresskill, NJ) on a w/w basis in a household mixer (Kitchenaid, Hobart Manufacturing Company, Troy, OH) (Fig. 1). The total mixing time was 3 min at speed 4; subsequently, the surimi was stored in a 0.076-mm polyethylene bag at -20°C until used.

The surimi was thawed overnight in a refrigerator then chopped with 2% (w/w) NaCl in a silent cutter (Model VCM40, Hobart Manufacturing Company, Troy, OH) for 3 min. An additional 6 min of chopping was performed with a sufficient amount of ice-chilled water (2 ± 1°C) to adjust the moisture content to 78%. The chopped paste was stuffed into 3cm diameter cellulose casings, and cooked at 90°C for 40 min in a water bath. The heat induced surimi gels were cooled in running tap water for 20 min. The prepared gels were allowed to equilibrate to room temperature overnight and then cut into 3 cm dia. and 2 cm long cylindrical shapes for color measurements.

**Chemical Analysis**

The fish paste saved for chemical studies was stored for 24 h at 4°C prior to analysis.

Total carotenoid pigments were determined calorimetrically (OD₄₆₀) after extraction on 25g of fish paste, as described by Saito and Regier (1970). The OD at 460 nm was multiplied by a factor of 2 to express the results as µg carotenoids/g sample. The concentration of the carotenoids were determined at pH 5.0, 6.0, 7.0, 8.0, 9.0, 10.0 and control.

The hematin content of the menhaden fish was determined on 5g of fish paste by the alkaline hematin method as described by Karlsson and Lundstrom (1991).
Hematin concentration, expressed as ppm hematin/g sample, was calculated using the following equation:  

\[ \text{ppm} = (5/50)(97.261(\text{OD}_{700}) - 0.0751) \]

Oxidative deterioration of the lipid components (rancidity) was evaluated on log sample using the 2-thiobarbituric acid test of Tarladgis et al. (1960). The optical density was read at 538 nm and readings multiplied by a factor of 7.8 to express the TBA reactive substances (TBARs) results as mg of malonaldehyde/kg sample (Sinnhuber and Yu, 1958).

The carbonyl content (moles/g) was determined by the method for trace quantities of carbonyl compounds as described by Siggia (1963). Results were converted to \(\mu\)mole/g by multiplying by 10^6.

Moisture content of unwashed menhaden mince, pH treated menhaden paste and the control were determined by method 950.46, drying under vacuum at 95 to 100°C (AOAC, 1990). Values were reported as percent moisture on a wet weight basis.

**Color Measurement**

Hunter "L" (lightness), "a" (+ indicating redness) and "b" (+ indicating yellowness) values were measured by a Hunter Labscan 6000 0/45° Spectrocolorimeter (Hunter Associates Laboratory Inc., Reston, VA). The instrument was calibrated using a white Hunterlab color standard tile no. LS-13601 (\(L_0=90\), \(a_0=0.16\) and \(b_0=0.48\)). The fish samples (at room temperature) were placed on to a 60x15mm (dia x ht) clear Pyrex© culture petri dish cover and over a 2 in. port. Hunter "T", "a", and "b" values were recorded for all pH treatments of both menhaden paste and heat-induced surimi gel.

The hue angle, \(\tan^{-1}(b/a)\) and total color difference \(AE=[L-L_0]^2+(a-a_0)^2+(-b_0)^2]^{1/2}\) were calculated for menhaden mince.

**Statistical Analysis**

All data were analyzed using a randomized complete block design with three replications (blocks). Blocks consisted of three batches of menhaden fish processed June 9, July 23 and July 28 1992, respectively. The treatments consisted of unwashed mince, paste/gel washed with tap water (control), and paste/gel washed with phosphate buffers at pH 5.0, 6.0, 7.0, 8.0, 9.0 and 10.0. Analyses were performed using the GLM procedures of the Statistical Analysis System (SAS, 1985). Means were separated where significant differences were found using least significant differences (LSD) test (SAS, 1985) at the 5% level of significance.
RESULTS AND DISCUSSION

Chemical Analysis

There were no differences (P>0.05) in carotenoids content, on a dry basis, due to wash treatments (Table 1). Due to their aliphatic and aliphatic-cyclic molecular structure composed of carbon isoprene groups, carotenoids are fat-soluble pigments. Consequently, aqueous washing treatments do not extract these pigments.

Total heme pigment extraction was affected (P>0.05) by washing medium pH (Table 1). Washing with phosphate buffers of pH 8.0 or lower resulted in lower (P>0.05) hematin than unwashed products. The pigment content decreased by 74%, from 1.07 ppm in the unwashed fish mince to 0.27 ppm in the tap water washed sample. Dawson et al. (1988) reported that heme pigments are more soluble in low salt concentrations (Froning and Niemann, 1988), possibly facilitating their removal by the washing solution.

There were no differences (P>0.05) in TBARs due to wash treatments. The TBARs varied between 8.40 for unwashed mince and 4.53 mg of malonaldehyde/kg for mince washed with pH 5.0 water (Table 1). These values are considered to be high for frozen seafoods (Sinnhuber and Yu, 1958) and may result in unacceptable products by consumers. Disruption of muscle membrane system caused by deboning was postulated to increase the rate of lipid oxidation by exposing labile lipid constituents to oxygen (Sato and Hegarty, 1971). Hall (1987) stated that a rupture of the organized cellular structure brought together lipids, catalysts and enzymes involved in lipid oxidation.

Nakayarna and Yamamoto (1977) reported that rancidity was detected at TBA values of 1.50 and 3.00 in different fish species. However, malonaldehyde is not the only end product of lipid peroxidation (Buege and Aust, 1978). Furthermore, Slabyj and True (1978) reported that high TBA values did not necessarily reflect rancidity in some samples.

There were differences (P<0.05) in carbonyl values due to wash treatments (Table 1). The application of water washing to raw fish mince decreased carbonyl values in mince. Carbonyl values decreased by 50% from 0.463 in the unwashed raw fish mince to 0.233 µmole/g in the tap water-washed sample but were not different (P>0.05) among washed minces.

Carbonyl values reported in the fish mince washed with a pH 5.0 phosphate buffer were usually higher than in those washed with alkaline pHs. This may be attributed to lipid oxidation by nonheme proteins (proteins associated with free inorganic forms of iron, copper, or cobalt), which have been reported to be responsible for about two-thirds of oxidation (Decker and Schanus, 1986) and found to be pH sensitive; the catalytic effect of the iron being higher at acidic pH values.
<table>
<thead>
<tr>
<th>Treatments</th>
<th>Carotenoids (dry basis) (ppm)</th>
<th>Hematin (dry basis) (ppm)</th>
<th>Carboxyls (µmole/g)</th>
<th>TBARs (mg/malonaldehyde/kg)</th>
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<tbody>
<tr>
<td>pH 5.0</td>
<td>1.07&lt;sup&gt;NS&lt;/sup&gt;</td>
<td>0.27 bc</td>
<td>0.320 ab</td>
<td>4.53&lt;sup&gt;NS&lt;/sup&gt;</td>
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<td>0.270 bc</td>
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<td>0.23 bc</td>
<td>0.170 bc</td>
<td>5.90</td>
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<td>0.90</td>
<td>0.17 c</td>
<td>0.157 c</td>
<td>5.00</td>
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<td>pH 9.0</td>
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<td>0.67 ab</td>
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<td>0.150 c</td>
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<td>0.27 bc</td>
<td>0.233 bc</td>
<td>6.67</td>
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<td>1.07 a</td>
<td>0.463 a</td>
<td>8.40</td>
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<tr>
<td>Overall Mean</td>
<td>0.83</td>
<td>0.43</td>
<td>0.246</td>
<td>6.05</td>
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<tr>
<td>CV (%)</td>
<td>45.24</td>
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<td>36.01</td>
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<tr>
<td>SEM</td>
<td>0.14</td>
<td>0.08</td>
<td>0.078</td>
<td>1.87</td>
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<tr>
<td>LSD (0.05)</td>
<td>0.66</td>
<td>0.49</td>
<td>0.155</td>
<td>2.39</td>
</tr>
</tbody>
</table>

abc- Means within columns not followed by a common letter differ (P<0.05).
NS- No significant differences
CV - Coefficient of Variability
SEM - Standard error of the mean
LSD - Least significant differences at 5% level of probability
Labuza (1971) suggested that the protein part of hemoprotein molecules normally hinders the catalytic function of the iron, and in the denaturation of the protein part of hemoprotein molecules could expose iron to lipids.

Mean moisture values of menhaden mince and menhaden gel as affected by different washing treatments are shown in Table 2. Menhaden mince from meat washed with water pH 8.0, 9.0 and 10.0 had higher (P<0.05) moisture than those washed with low pH buffer or tap water. Moisture content for any washed mince sample was higher (P<0.05) than for the unwashed mince sample. No differences (P>0.05) in gel moisture were found, since this was made to a target 78% moisture (Fig. 1).

It was noticed that water removal from the washed menhaden mince during the dewatering step was particularly difficult as the water pH increased (data not shown). Ball et al. (1984) reported a similar direct relationship between increased washing solution pH and increased moisture content in washed poultry meat. The increase of water binding properties of muscle proteins was attributed to an adjustment of pH away from the protein isoelectric point, in mechanically deboned poultry meat (Dawson et al., 1988).

Color

Hunter “L”, “a”, hue value, and, total color difference (AE) of menhaden mince of washed treatments was different (P<0.05) from the unwashed. The most dramatic effect of water washings was a 84% reduction in redness (“a” value), from 4.49 to 0.72 (Table 3). The fish mince Hunter ‘L’ value was reduced by 10 units after washing, but wash pH did not have any effect.

Hue angle values (Table 3) increased from 68.74 in the unwashed fish mince to 86.97 in the tap water washed sample. There was no additional increase in the hue values when different phosphate buffers were used. As the red color was removed, the fish mince decreased in darkness, and hues other than red tended to predominate. Total color difference (AE) values between untreated and treated samples decreased (P<0.05) with washing.

The changes in color of the washed mechanically deboned fish mince during the cooking step could be attributed to the denaturation of any remaining myoglobin to denatured metmyoglobin (Francis and Clydesdale, 1975). Fogg and Harrisson (1975) reported that myoglobin in pure solution denatured when heated to 85°C. Francis and Clydesdale (1975) stated that upon cooking, salmon flesh was lighter in color and hue shifted from red to orange-red. Contamination of menhaden mince with skin, bone and scale indicated too high deboner belt pressure and an improper feeding of the deboner. Fish fed skin side down were used, forcing more bone and scale through the drum perforations along with the fish mince. This outcome could have been avoided by adjusting the belt pressure of the deboner and orienting the split fish so that the deboner perforated drum was in direct contact with the white muscle (bone
Table 2. Mean moisture values of menhaden gel as affected by different washing treatments.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mince Moisture (%)</th>
<th>Gel Moisture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH 5.0</td>
<td>81.30 b</td>
<td>77.90 ab</td>
</tr>
<tr>
<td>pH 6.0</td>
<td>81.63 b</td>
<td>78.30 ab</td>
</tr>
<tr>
<td>pH 7.0</td>
<td>84.77 ab</td>
<td>79.20 a</td>
</tr>
<tr>
<td>pH 8.0</td>
<td>85.47 a</td>
<td>79.23 a</td>
</tr>
<tr>
<td>pH 9.0</td>
<td>86.60 a</td>
<td>79.77 a</td>
</tr>
<tr>
<td>pH 10.0</td>
<td>86.30 a</td>
<td>78.67 a</td>
</tr>
<tr>
<td>Tap water</td>
<td>78.63 b</td>
<td>77.13 b</td>
</tr>
<tr>
<td>Unwashed</td>
<td>71.87 c</td>
<td>N/A</td>
</tr>
<tr>
<td>Overall Mean</td>
<td>82.07</td>
<td>78.54</td>
</tr>
<tr>
<td>CV (%)</td>
<td>2.24</td>
<td>1.14</td>
</tr>
<tr>
<td>SEM</td>
<td>3.37</td>
<td>0.80</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>3.22</td>
<td>1.57</td>
</tr>
</tbody>
</table>

abc - Means within columns not followed by a common letter differ (P<0.05).
N/A - Data not available
CV - Coefficient of Variability
SEM - Standard error of the mean
LSD - Least significant differences at 5% level of probability.
Table 3. Mean Hunter “L”, “a”, hue, and AE color values of menhaden mince as affected by different washing treatments.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>L</th>
<th>a</th>
<th>Hue$^1$</th>
<th>ΔE$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH 5.0</td>
<td>51.92 a</td>
<td>0.11 bc</td>
<td>89.70 a</td>
<td>39.35 b</td>
</tr>
<tr>
<td>pH 6.0</td>
<td>51.70 a</td>
<td>0.33 bc</td>
<td>88.61 a</td>
<td>39.59 b</td>
</tr>
<tr>
<td>pH 7.0</td>
<td>51.44 a</td>
<td>0.16 bc</td>
<td>89.53 a</td>
<td>39.73 b</td>
</tr>
<tr>
<td>pH 8.0</td>
<td>52.98 a</td>
<td>0.28 bc</td>
<td>88.42 a</td>
<td>38.15 b</td>
</tr>
<tr>
<td>pH 9.0</td>
<td>53.27 a</td>
<td>-0.06 c</td>
<td>90.68 a</td>
<td>37.97 b</td>
</tr>
<tr>
<td>pH 10.0</td>
<td>51.95 a</td>
<td>0.13 bc</td>
<td>89.86 a</td>
<td>39.22 b</td>
</tr>
<tr>
<td>Tap Water</td>
<td>51.28 a</td>
<td>0.72 b</td>
<td>86.97 a</td>
<td>40.04 b</td>
</tr>
<tr>
<td>Unwashed</td>
<td>41.41 b</td>
<td>4.49 a</td>
<td>68.74 b</td>
<td>49.97 a</td>
</tr>
</tbody>
</table>

Overall Mean 50.74 0.77 86.56 40.50

<table>
<thead>
<tr>
<th>cv (%)</th>
<th>SEM</th>
<th>LSD (0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.18</td>
<td>2.60</td>
<td>2.82</td>
</tr>
<tr>
<td>54.27</td>
<td>0.19</td>
<td>0.76</td>
</tr>
<tr>
<td>2.55</td>
<td>4.86</td>
<td>3.86</td>
</tr>
<tr>
<td>3.87</td>
<td>2.46</td>
<td>2.75</td>
</tr>
</tbody>
</table>

$^1$Hue = Tan$^{-1}$(b/a)
$^2$ΔE = Total color difference = [(L-L$_0$)$^2$ + (a-a$_0$)$^2$ + (b-b$_0$)$^2$]$^{1/2}$

abc - Means within columns not followed by a common letter differ (P < 0.05).
CV - Coefficient of Variability
SEM - Standard error of the mean
LSD - Least significant differences at 5% level of probability.
side). These adjustments are essential to control the quantity of dark muscle incorporated as well as skin, bone and scale.

CONCLUSIONS

Washing with tap water or pH-buffered water (acid or alkaline) resulted in a lighter (P<0.05) color mince than unwashed product. However, there were no differences (P>0.05) in washing treatment on color of mince and gel made from menhaden. There was no effect (P>0.05) of washing treatment on carotenoids or TBARs, but there were (P<0.05) on hematin and carbonyl values of the mince.

ACKNOWLEDGMENTS

The authors would like to thank Mrs. Sabrina Hunt for her aid in typing and editing.

REFERENCES


