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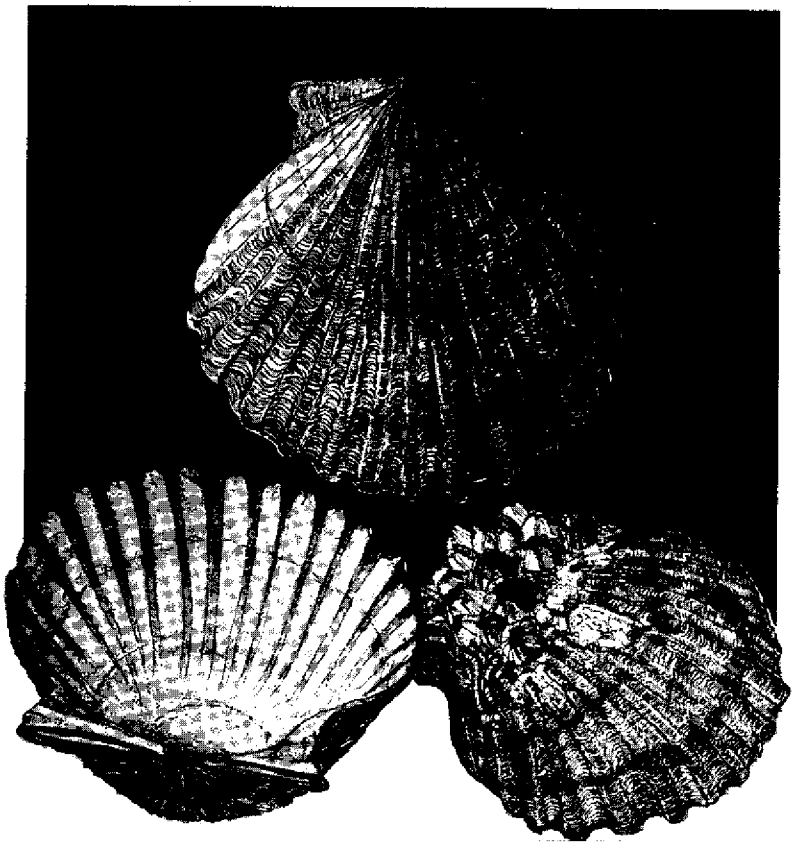

Gulf & South Atlantic Fisheries Development Foundation, Inc.

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QUALITY CONTROL IN CALICO SCALLOP PRODUCTION

SUMMARY

Based on industry and regulatory concerns this study was initiated to describe problems and opportunities in quality control in production, processing and storage of calico scallops, Argopecten gibbus. The work was deemed necessary as a consequence of the recent, rapid increases in annual production which have escalated 5 to 8 fold since 1980 with 1984 production expected to exceed 28 million pounds with a dockside value over $35 million. The intent was to focus on problems and establish guidelines and education through development of an operations manual and workshops with emphasis on general and specific good manufacturing practices (GMP's). This descriptive work has provided the following observations:

HARVEST

1. For the processing firms involved during this period of study (Oct. 1983-Sept. 1984), the average daily production per vessel ranged from 300 to 500 gallons and catches could exceed 600 to 900 gallons. This production interprets to processing capabilities of 3000 to 9000 gallons per day depending on the size of the processing facility, number of processing lines, and processing efficiency. More precise interpretation for production and processing was not possible from existing data and could imply errors.

2. The fishing schedule and methods are arranged to assure an economical harvest yet prevent product abuse. Summer fishing time is shorter and tarps are used to protect the catch from sunlight and rain.

3. Normal deck loading methods and time did not cause excessive thermal abuse during October through June. The landed product can

be expected to contain 10^3 to 10^4 microorganisms/gram of meats. Higher counts were a consequence of excessive delays in unloading at the dock, heavy rainfalls, and washing the catch with water taken from the port.

4. Better methods are needed to access the quality of the scallops prior to processing. The vessel remains the most variable operational aspect influencing product quality.

Processing

1. In general, processing of calico scallops appears above average for most common seafood processing operations and there are no major quality or sanitation problems. Improved manufacturing practices can be resolved with additional management and education.

2. Specific problem areas include:
   -continuous policing grounds and equipment about the plant to present development of spoilage odors and attraction of insects and pests.
   -modification of shucking equipment and associated facilities to allow easier access for more frequent cleaning.
   -refrigeration of water sprays to evisceration table.
   -modification of chill tank operations to assure clean water temperatures below 40°F.
   -improved plant ventilation for temperature control and worker comfort.
   -more attention on general GMP's (good manufacturing practices).

MICROBIAL ASSESSMENT

1. Microflora typical of fresh shellfish were recovered from fresh calico scallops harvested during October through June. A consistently higher proportion of gram-negative bacteria were noted in scallops after emerging from the chill tanks.

2. Processing generally elevated the microbial counts (APC's) approximately 10 fold higher than on dockside product. Processed calico scallops had an immediate bacterial load (APC's, 20°C) of approximately 10^4 to 10^5 microorganisms/gram of meats.

3. There was no apparent influence of processing time per vessel or amount of consecutively processed product on the bacterial counts of finished scallops. The processing mode and methods appear to be functioning with an established bacterial load for the operating conditions.

4. Chill tank waters and the shucking process and/or flume waters from the shucker are a probable area for fecal coliforms and *E. coli* contamination. Any original source was not detected in the plants, but occasionally occurrence was noted on the deck loaded harvest prior to processing.

5. No Staphylococcus aureus, Salmonella, or Vibrio (parahaemolyticus, cholera, or vulnificus) were recovered from any processing points.

REFRIGERATED STORAGE

1. Mechanically shucked calico scallops can be expected to have an acceptable shelflife of 13 to 17 days in 1.7°C (35°F) storage. In these conditions the meat approaches a class B condition by day 9 and a borderline class C condition (unacceptable) on the 17th day.

2. Aeorbic plate counts (20° and 7°C) inexcess of 10^7 microorganisms/ gram could represent the objectionable level for calico scallop meats.

3. Sensory assessments, primarily odor, remain the most reliable methods to judge calico scallop meat quality and spoilage.

4. Muscle pH and the resazurin dye reduction tests were not reliabe indicators of product quality.

PRODUCT YIELDS AND COMPOSITION

1. A 53.4 percent decreased meat count within 60 days (Oct.-Dec.) indicates the dynamic growth rate for calico scallops.

2. Meat yield from whole scallops ranged from 5% to 8%.

3. Meat counts increased during processing and storage indicating the individual meats decreased in size and/or weight. The increased count varied such that processed meat counts should not be used to predict or regulate fisheries management.

PARASITES

1. Occurrence of larval encysted, Sulcascaris sulcata in calico scallop adducter muscles was usually in excess of the FDA's temporary action level of 20% infestation.

2. Approximately 45% of the external parasites present were able to survive processing and one days refrigerated storage. Thus a 20% parasite occurrence could represent 9% live occurrence.

3. No alternate methods (i.e., fishing methods and locations, hand culling, or extra evisceration) seem pausible or practical for removing the encysted parasites. Altered processing methods were detrimental influences on product quality.

4. Most attempts to kill the parasites for aesthetic reasons have proven useless and/or impractical (i.e., typical refrigeration, fresh water, bisulfite solutions, sonication, or steam tunnels).

5. Parasite survival was decreased by super chill temperatures (-1.0°C; 30.2°F), and eliminated by frozen storage.

6. Microwave heat treatments to provide a meat temperature of at least 45°C (113°F) for 15 seconds appears to offer some promise in killing encysted parasties without altering meat quality.

7. Exposure to temperatures of 35°C (95°F) or above provided an immediate, total parasite kill. Also, the parasites cannot survive exposure to gastric juice typical for human digestion. Thus there appears to be little possibility that larval Sulcascaris sulcata poses any threat to human health.

QUALITY CONTROL IN CALICO SCALLOP PRODUCTION

INTRODUCTION

Recent, rapid growth in the calico scallop industry has attracted regulatory and industry concern for quality control during production, processing and distribution. Prior production was primarily processed by a limited number of experienced firms in Florida and North Carolina which had evolved from sporadic developments initiated during the early 1960's (1, 2, 3). This limited participation in the fishery had allowed some degree of "self-regulation" for various quality attributes, including meat size (count per pound),but in 1981 the regional production escalated to in excess of 15.1 million pounds (Figure 1). The 1984 production is expected to exceed 28 million pounds (Table 1). This increase is in part, a result of additional participation in the fishery, increased fishing effort, and improved processing capability relative to shucking rate and meat size. The calico scallop fishery has proven to be an attractive alternative for southern fishing vessels competing with increasing fuel cost to harvest the limited supply of shrimp. Likewise, the successful expansion of the fishery is a positive reflection on resource potential and market demand for this particular scallop. When calculated at a conservative 1983 average of $10 per gallon of shucked meats, the estimated 1984 dockside value of this fishery may exceed $35 million. The corresponding 1984 wholesale value could exceed $70 million. These values are quite impressive when realizing the majority of calico

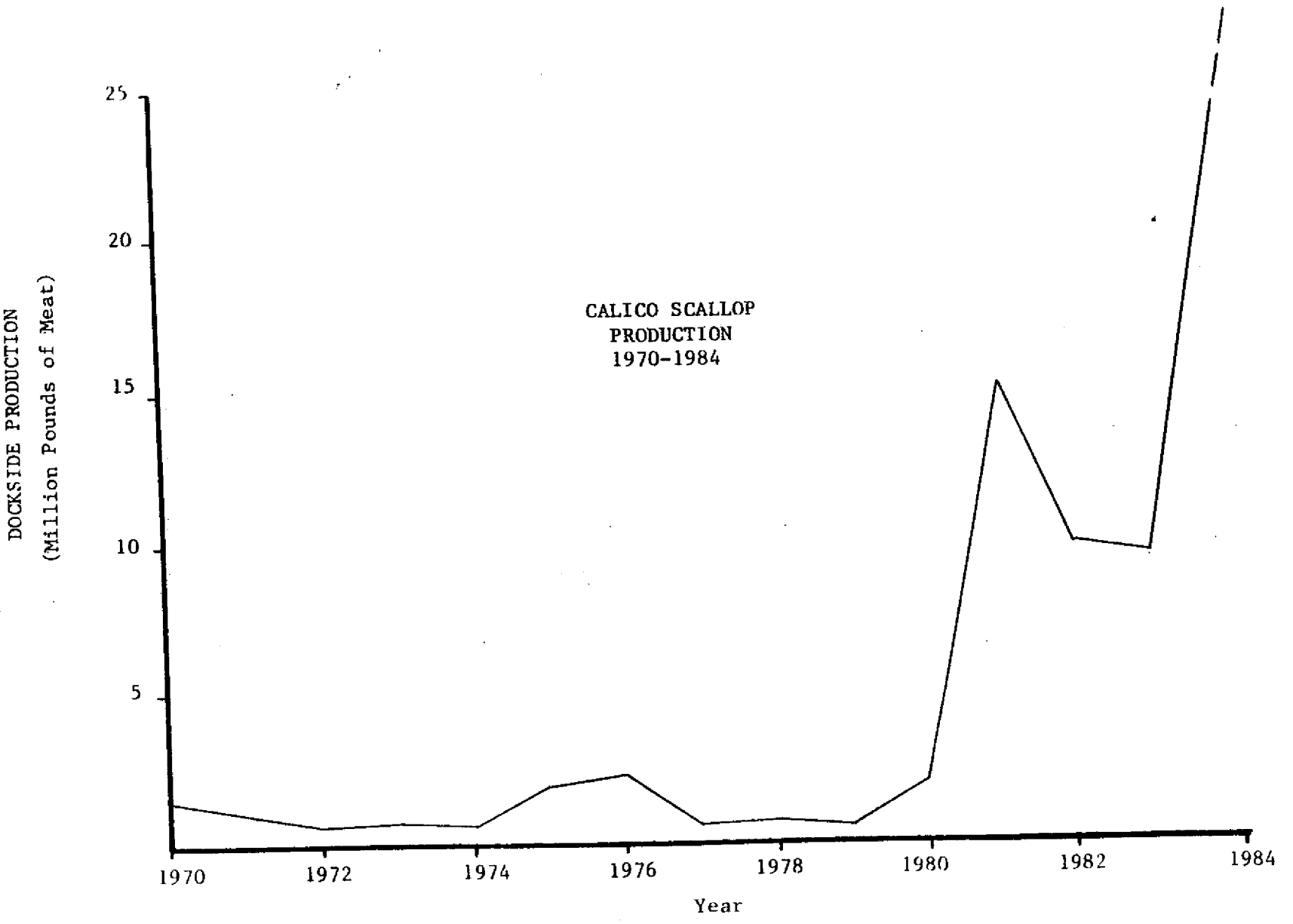

Figure 1. Production of calico scallops during the last decade. (Source: National Marine Fisheries Service Fisheries of the United States, from Current Fishery Statistics reports in 1971 through 1983 and preliminary supplements from U.S. Department Commerce, National Fisheries Service Statistical Branch - Miami).

Table 1. Dockside landings for calico scallops as recorded by the National Marine Fisheries Service since 1980. Over 95 percent of the reported production was landed in Florida.

CALICO SCALLOP PRODUCTION
(pounds edible meats)

	1980	'81	'82	'83*	'84*
Jan	11,392	627,207	825,622	1,056,000	2,583,000
Feb	37,608	575,515	1,048,187	512,000	2,340,000
Mar	66,512	466,328	1,253,135	498,000	2,435,000
Apr	106,096	898,281	913,325	721,000	2,727,000
May	235,155	1,104,461	1,104,713	262,000	3,082,000
Jun	290,000	1,265,313	1,282,832	232,000	4,041,000
Jul	159,960	1,455,569	810,855	113,000	**3,262,000
Aug	163,840	2,154,077	1,016,666	130,000	**3,551,000
Sept	283,328	2,186,604	737,035	685,000	
Oct	535,216	1,873,396	660,653	1,603,000	
Nov	397,656	1,510,971	585,005	1,834,000	
Dec	277,600	1.053,134	605,146	1,816,000	
Total	2,582,471	15,170,881	10,843,204	9,462,000	***28,406,000

* 1983-84 production rounded to nearest thousands.
** Preliminary figures, any changes will only include additional pounds.
*** Projected annual production assumes monthly productions of 1.0 million pounds/month during September through December 1984.

scallop production is concentrated along one 200 mile coastal sector of northeast Florida.

Consequences of this rapid growth were many newcomers to both regulations and operations of calico scallop production, as well as more intense market competition. In some instances product quality has suffered. Pertinent State and Federal regulatory agencies have received complaints on product decomposition, presence of parasites, and mislabeling (confusing bay and calico scallops). The regulatory and industry concern culminated in an Industry/Regulatory Forum conducted by the Florida Sea Grant Marine Extension Program on December 2, 1982 in Cocoa, Florida. The primary objective of this meeting was to discuss prevailing conditions and exchange pertinent information to improve the regulatory mode and encourage a more quality conscious attitude. Quality was identified as the most important attribute to assure the economic welfare of this relatively new fishery. Discussion for quality concerns ranged from time-temperature abuse aboard the fishing vessels to water use in terms of both quantity and contact time during processing. The meeting attendance included representatives from the Florida Departments of Agriculture and Consumer Services, Natural Resources, and Health and Rehabilitative Services, academic interests, industry (vessel and plant reps.), and respective trade associations and the Gulf and S. Atlantic Fisheries Foundation. Recommendations for further action included:

1. Provide better definition and guidelines to prevent product decomposition
2. Provide an up-to-date scallop production quality control manual and workshop for the user groups.

One specific quality concern was the presence of parasites in the scallop meats. The occurrence of parasites on scallops is not a new phenomena, but in Fall, 1981 the U.S. Food and Drug Administration (FDA) recommended a temporary action level of 20 percent parasites permissible in calico scallops (Basis: one percent equals one parasite per one scallop meat per one hundred scallop meats). Subsequent inspections have alarmed the industry, altered fishing activity, stifled some wholesale transactions and, in at least one case, forced the destruction of 13,000 pounds of processed meats with a 1982 wholesale value ($20/gallon) in excess of 32 thousand dollars. Although industry is debating this regulation, the 20 percent level remains enforceable until further evidence is developed to support regulatory modification. Changes must consider the value perception and health of consumers, and the practical options for industry.

In addition to overall product quality and the specific parasite problem, the industry has integrated their production data with the South Atlantic and Gulf of Mexico Fishery Management Councils' efforts to develop a calico scallop Fishery Management Plan (FMP). The Councils have considered size limits by count (scallop meats per pound) which could influence the mode of operation and value of the fishery. Currently the question of an applicable size limit remains unanswered. If a size limit is deemed necessary it would be best implemented at the vessel level, but economic predictions used to select size limits must include market values after processing. A better understanding of any size differential between landed count and processed count is necessary to assure accurate predictions. Thus a

comprehensive assessment of calico scallop production not only has implications of economic security through quality control and prevention of parasite problems, but also could provide information relative to management of the fishery.

Thus a cooperative Industry - Foundation - Sea Grant project was initiated to assess the various aspects of harvest, processing and storage which influence quality control in calico scallop production. Specific objectives included:

1. Establish guidelines for product quality standards and grades, and provide better definition of project spoilage or decomposition.
2. Demonstrate the feasibility of product reclamation and parasite survival for infested product.
3. Write a current industry operations manual to encourage quality control.
4. Conduct a final industry/regulatory workshop to transfer the results of this project.

The project began in May 1983 and incorporated further assistance from the National Marine Fisheries Service Laboratory - Charleston, S.C. to address product quality during truck transport of shellstock.

BACKGROUND

FISHERY AND PROCESSING

The development of the calico scallop (Argopecten gibbus) fishery in the Gulf and South Atlantic region of the United States has been adequately reviewed in previous publications (2,3,6-9) and fishery management documents (1). Compared to the established regional fisheries for shrimp, blue crab, and certain traditional fish, calico scallop production is relatively a new emerging fishery. Although landings have been recorded since 1959 (3-5), production was sporadic until the 1970's and has significantly increased since 1981 (Figure 1). Overall this industry has evolved 24 years from the initial processing, but in terms of current production rates and volumes per plant this industry is less than 10 years old.

Currently there are 6 established firms actively processing along the east coast of Florida, and at least one active firm in Georgia (Table 2). Inactive plants with processing capability are based in North Carolina and the panhandle region of Florida. Activity of these latent plants is usually dependent on sporadic occurrence of commercial quantities of calico scallops in adjacent waters. Recent production and economic success has stirred interest for addition of new processing facilities, but the only evident construction is expansion of some existing firms. Attempts to construct processing facilities on vessels continue, yet have not been proven to be practical or economically competitive with land based operations.

Table 2. Calico scallop processing firms active as of September 1984.

FLORIDA

Canaveral Seafood
70 South Banana River Dr.
Merritt Island, FL 32952

Frost Seafood
142 Riberia St.
St. Augustine, FL 32084

Homer Smith Seafood Co.
P.O Box 1606
Green Cove Springs, FL 32043

Ponce Seafood
Div. Cape Seafood, Inc.
730 Scallop Dr.
Port Canaveral, FL 32920

Southern Seafood
750 Scallop Dr.
Port Canaveral, FL 32920

St. Augustine Trawlers, Inc.
P.O. Box 40
St. Augustine, FL 32084

GEORGIA

Calico Seafood
P.O. Box 1096
Darian, GA 31305

The major center of production remains in Port Canaveral, Florida. Firms based in the Port are traditional, large and located in close proximity to the major calico scallop beds. Plant location is important since processing depends on daily landings from vessels specifically equipped to harvest scallops. The vessels have wooden, metal (steel or aluminum) or fiberglass hulls ranging from 50 to 90 feet in length. Thus the calico scallop fishery has proven to be a viable alternative for shrimp vessels.

The primary harvest gear is a modified shrimp trawl with "tickler chains" placed on the footrope for agitation (1). Depending on vessel size, this gear can be fished in single or dual fashion (two trawls simultaneously from one vessel). The catch is deck loaded and covered with a tarp to provide protection from sun and rain. When returned to dock the catch is unloaded with an hydraulic-crane ("knuckle boom") equipped with a special open-hinged scoop. After running through a series of hoopers with rollers and washers the culled and cleaned shellstock (i.e., calico scallops with shell, meat and viscera intact) enters the processing plant.

The common method of processing depends on a steam shucking and roller evisceration technique which yields cleaned, raw meats (Figure 2). All established firms use the same basic processing concepts with slight modifications and innovations to suit their plant size or processing scheme. The finished product is most commonly packaged in plastic gallon containers, but use of smaller containers (pints) and bulk packs have been initiated to suit special interests and requests. Approximately 90 percent of the production has been sold as

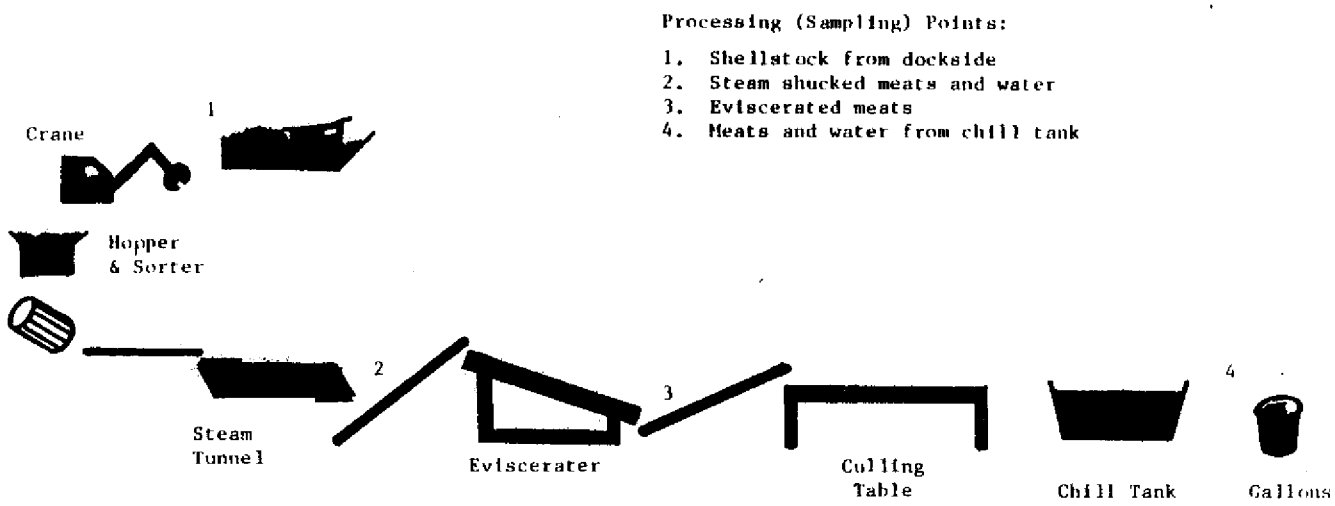

Figure 2. Illustration of processing operations and processing points used for sampling throughout the study.

fresh, refrigerated product in the New York area (1), but recent production has forced market ventures about the nation including the west coast and some international efforts, primarily Canada.

QUALITY CONTROL

Studies to monitor quality control in scallop production are limited and differ among the variety of scallop species and respective handling methods. Most reported work has focused on describing spoilage and shelflife of the shucked meats (10-22). Interpretation and comparison of the reports is complicated by the differences in experimental designs, but in general the fresh shelflife of most hand or mechanically shucked scallop meats stored at 0° to 5°C (32° to 41°F) will range from 9 to 18 days. This generalization is based on shelflife defined as the limit in days for acceptability. Differences

in fresh shelflife were more evident due to processing conditions, packaging and storage temperature rather than between various species. Scallop species investigated include domestically produced Bay Scallops (Aequipecten irradians; 11, 12, 17, 19) Calico Scallops (Argopecten gibbus; (10, 11, 12, 17, 19, 22), Atlantic Sea Scallops (Placopecten magellanicus; 13, 15, 16, 18) and Pacific Sea or Weathervane Scallops (Patinopecten caurinus; (14,) and foreign varieties from England (Greats - Pecten maximus and Queens - Chlamys opercularis ;43) and Australia (Pecten alba; 20, 21).

Attempts to prolong fresh shelflife have yet to provide any successful, safe applications. Australian scallops pre-treated with 0.1% potassium sorbate and vacuum packaged in barrier bags stored at 4°C (39°F) had a fresh shelflife of 28 days, but the potential for undetectable growth of Clostridium botulinum type E in the vacuum packaging is a possibility which requires further investigation (20). Likewise, the use of a 30 second pre-dip of calico scallop meats in 1.0% sodium bisulfite provided a fresh shelflife of 25 days for storage in plastic containers packed in ice (22), but the use of sulfiting agents is currently under close scrutinization by the U.S. Food and Drug Administration (FDA) and there is no recognized use or prior sanction for use of sulfites to prolong the shelflife of scallops. Recognizing the current regulatory concerns and the potentially high concentration of sulfite residues on scallop, which reportly absorb water (19), approved use of sulfites to treat fresh scallops is unlikely and if approved it would have to be declared in labeling as an added ingredient.

Attempts to develop quality indices or tests to judge fresh scallop quality have included chemical tests for volatile acids and

bases, pH, salt-soluble proteins, adenine nucleotides, and octopine (11, 14-16). Some of these tests can distinguish fresh from spoiled or decomposed scallops, but they could not adequately monitor progressive changes in quality and were not assessed using mechanically processed meats. Marginal success was reported for the use of hypoxanthine (15, 18), resazurin (17, phosporylated sugars (14) and picric acid turbidity (10) as chemical indices for scallop quality, but these reports recommend further investigations.

More recent work with calico scallops suggest trimethylamine (TMA) analysis could be used to differentiate quality in fresh meats, but any major distinction in results was not evident until beyond 11 days iced storage or well into advanced spoilage for untreated scallops (22). Use of TMA as an indicator of advanced spoilage was also noted in previous work with hand-shucked calico scallops (10). The recent work with mechanically processed calico scallops indicated the best judgement for meat quality was sensory analysis with distinct aroma scores (i.e., briny, post-room, and putrid odors) and overall acceptability as the most reliable indicators (22).

Sensory assessments have been the most useful and practical method to monitor scallop quality (10, 13, 16, 22), but they typically only rate product acceptance and provide no description of spoilage. As previously noted, acceptable storage life of fresh scallop meats, refrigerated and/or in ice, is rated at 9 to 18 days with warnings of a possible toughening of cooked texture during prolonged storage (14, 18). Likewise, scallops tend to absorb water which alters favorable texture, and increases drip loss and cook loss (14, 18, 19). Attempts to correlate sensory assessments with objective test methods have been unsuccessful (18).

Similarly, the use of total microbiological counts to monitor scallop quality is questionable. Varga and Blackwood (13) concluded bacteria counts are not useful as indicators for meat quality from Atlantic sea scallops. Despite initial total bacterial counts ranging from $8X10^4$ to $3X10^7$ bacteria/gram for fresh meats, panel scores were considered the best indices of quality for bay and calico scallops (10-12, 17). Prior conversation with Florida Department of Agriculture and Consumer Services indicated the State authorities rely more on organoleptic assessments than microbial counts to monitor food quality in processing (23).

In efforts to assist the calico scallop industry in addressing problems with spoilage and sanitation the National Marine Fisheries Service (24) and North Carolina State University (12) prepared manuals of instructions on quality control. These manuals are primarily common sense guidelines which exemplify FDA's Good Manufacturing Practices (GMP's). Both manuals are useful but they were produced prior to 1970 when calico scallop production was low relative to current production. Further supplements for these manuals are necessary to address the current methods and volumes of production.

PARASITES

No quality control studies have addressed the concern for parasites in calico scallops. The primary parasite in question is the nematode, Sulcascaris sulcata. The most recent regulatory concern for these nematodes in calico scallops surfaced in Florida as a consequence of industry allegations. Regulatory response interpreted occurrence as "excessive levels of nematodes" when actual existing or background levels were unknown. In Fall 1981 the U.S. FDA recommended

a 20% action level (Basis: one percent infestation equals one nematode cyst per one adductor muscle per 100 individual muscles or shucked meats). This level was based in reference to the similar defect action level for tullibees, ciscos and other freshwater fish (25).

The occurrence of this nematode and/or similar forms is not a new phenomena or recent infestation. Occurrence was intitially documented in scallops (Pecten sp) from North Carolina in 1930 (26). The same nematode was later reported from calico scallops in Florida (27). During 1970 and 1971 infestation levels in samples of Florida calico scallops exceeded 38% (28). More recent work in Florida has cited occurrence ranging from 28 to 68% with a mean of 45.5% (29).

This nematode is not unique to calico scallops, and similar indistinguishable forms have been reported from a variety of mollusk (28, 30), including commercial varieties of surf clams (31-33) and bay scallops (34, 35). To date five scallop species have been implicated with potential infestation with this nematode:

Domestic Species;

Argopecten irradians

Argopecten gibbus

Foreign, Australian Species (Reference 36)

Anachlamys leopardus

Amusium balloti

Chlamys asperrimus

Levels of S. sulcata infestation have been reported in samples of Virginia surf clams, Australian Queenland scallops and Florida calico scallops as high as 78, 64 and 38%, respectively (32, 36, 28).Attempts to correlate infestation levels with scallop size, harvest location,

and season have been questionable. Extensive field sampling in Florida could not distinquish any level of infestation relative to calico scallop size or latitudinal location of harvest (29).

Fortunately studies conducted by the U.S. FDA have indicated this parasite should not pose a major health concern (37). Citation of FDA work indicated S. sulcata would not survive normal human body temperatures or 37°C (28), yet FDA investigators recommend a cook temperature of 60°C for 1 minute to kill all anisakine larvae (38). Although the larval nematodes tend to survive normal refrigeration, they perish after 24 hours frozen (-20°C) storage (38).

Realizing the primary concern is the potential for an unpleasant consumer experience, a series of tests were conducted to measure consumer perception of the nematodes in raw and cooked scallops (39). In paried comparison tests using over 1,500 consumers, the consumer perception of nematodes in raw calico scallops (scored as detection of blemishs, dots, spots, specks, blotches, etc.) never exceeded 1.3% detection at infestation levels of 0% to 40%. At 50% and 75% infestation, detection increased to 4.7% and 8.5%, respectively.

Attempts to remove the parasytic cyst during processing with water soaks, heat, extra evisceration time, etc. have been unsuccessful. Likewise, fishing different scallop beds by latitude, depth, shell size and/or season have not indicated any methods to avoid infestation in calico scallops.

CONCLUSION

This review indicates limited work and a need to better describe the quality attributes of calico scallop production, processing and distribution. Although specific studies for calico scallop production

in North Carolina and informal guidelines issued by the National Marine Fisheries Service have provided useful quality control manuals (12, 24), this work is not current with the present mode and volume of calico scallop production. During the 1970's the major production of calico scallops shifted to the eastern coast of Florida. In the last four years annual production has increased 5 to 8 fold and shucking capability has been adjusted to handle higher count scallops. There are no published guidelines for quality control during harvest, especially in the warmer, subtropical climates. In particular, there are no guidelines to address parasite problems. Thus, current regulatory and industry concerns for quality control in calico scallop production require further investigation.

METHODS

The basic study approach was to provide a microbial, chemical and organoleptic description of calico scallop production from actual harvest and processing through simulated storage. In most cases, sampling for microbial, chemical and organoleptic analyses was conducted simultaneously from the same batches (same vessel or harvest as landed and processed). The results per month can be compared relative to the same vessel and firms sampled. Specific attention focused on the occurrence, survival and potential eradication of the nematode, Sulcascaris sulcata. This descriptive work could then be used to outline recommendations and operational guidelines to enhance the quality and safety of the final product. Actual field work on the vessels and in the processing plants occurred during October 1983 through August 1984 to assure a continuous assessment through seasons. All data is based on the established 1983-84 production in Port Canaveral, Florida.

DESCRIBING HARVEST AND PROCESSING

A predetermined sampling scheme was used to observe and collect data from selected processing points from the moment of harvest through processing and storage for scallops produced by a single vessel (Figure 2). Time-temperature regimes were recorded at each processing point. Temperatures within the deck loaded harvest were recorded with an Omega 2165 digital thermometer equipped with T type wire thermal probes placed at varying depths within the pile. On return to the plant, processing temperatures were recorded as the product proceeded through actual, full scale operations.

Scallop shell and meat sizes and weights were recorded at processing points to determine processing yields. Length and width of the final processed meat were measured with vernier calipers. Gallon samples of the final product were iced in coolers for transport (3 hours) to the University of Florida for simulated storage. Storage included frozen (-34°C, -30°F) and fresh (1.7°C and 7.2°C; 35°F and 45°F) in the original thick plastic gallon containers or repacked in barrier film bags to provide reduced sample sizes packed under conditions similar to that in original plastic gallons.

MICROBIAL ASSESSMENT

Samples for microbial analyses were taken from the predetermined processing points (Figure 2). Hand-shucked samples from shellstock on the vessel and at the dockside included the meats (whole adductor muscle) with attached viscera. Samples after steam shucking were analyzed with remaining viscera attached, but all further processing samples only included meats. Samples (20-30g) prepared on the vessel or in the plant were placed in Whirl-pak bags and massaged for 60 seconds with sterile Butterfield's diluent (30 ml) then plated for aeorbic plate counts at 20 to 25°C. Parallel and additional microbial analyses were conducted within 12 hours of collection. These latter samples (25g) were blended with sterile Butterfield's diluent (225 ml) for further analyses. All further analyses conformed to the Bacteriological Analytical Manual for Foods, BAM (40) with the exception of the surface plating technique for Aeorbic Plate Counts

(APC) with incubations at 35°C for 48 hours, 20°C for 5 days and 7°C for 10 days. In addition, the plate count agar was supplemented with 0.5% NaCL.

All samples were also examined for Salmonella and Staphylococcus (41). Vibrio sp. were determined in October and June sampling using the MPN protocol. Vibrio sp. were determined by transferring 1 ml aliquots of the sample homogenate into tubes of alkaline peptone water (1% peptone, pH 8.4) to obtain a 3-tube MPN series. After incubation for 8 to 10 hours at 37°C, positive or turbid alkaline peptone tubes were streaked onto TCBS agar (Difco) plates for isolation of colonies. TCBS agar plates were incubated for 24 hours at 37°C and morphologically typical colonies of Vibrio sp. were isolated and identified using standard biochemical tests and API-20E biochemical test strips (Analytab Products, Plainview, NY).

Anaerobic plate counts were performed to enumerate facultative and anaerobic microflora in scallops stored under low oxygen conditions (i. e., sealed plastic gallons or barrier bags), during refrigerated storage. For anaerobic plate counts, 1 ml aliquots of appropriate dilutions of the sample homogenate were plated with anaerobic agar (Difco) using the pour plate technique. Plates were incubated anaerobically in a Gas Pak^{R} system (BBL, Cockeysville, MD) for 5 days at 20°C.

Representative isolates were taken for taxonomic characterization from APC's (25°C) initiated on site. The number of selected isolates equalled the square root of the colony number on the countable plates. Bacterial isolates were identified using standard methods and criteria in Bergey's Manual of Determinative Bacteriology (42).

CHEMICAL ASSESSMENT

Proximate composition and pH of the meats were determined for scallop meats from the predetermined sampling scheme (Figure 2). Protein, moisture and fat was analyzed by standard procedures (43), and pH was monitored with a Fisher Accumet 640 in the field and Corning 130 meter in the lab. The pH readings were taken with a surface contact combination electrode. Attempts to monitor changes in the muscle glycogen content (44) proved inconsistent and were discontinued. Resazurin analysis (17) was performed on samples stored at 1.7 and 7.2°C (35° and 45°F) for 17 days.

ORGANOLEPTIC ASSESSMENTS

Sensory assessments of refrigerated meats were performed with informal evaluations and with a structured panel evaluation. The informal evaluations (2 to 3 experienced investigators) recorded daily responses to raw samples. The panel evaluated cooked samples (broiled 8 minutes or until done) presented in paried comparisons. One sample was always from a prefrozen (-34°C; -30°F) control and the variable samples were from selected days storage (1, 5, 9, 13 and 17 days) at 9.7° and 7.2°C (35° and 45°F). The frozen and refrigerated samples were always taken from the same initial batch of fresh shucked scallops. The panelists were instructed to note any differences in appearance, odor, texture, flavor and general acceptability.

OCCURRENCE OF PARASITES

Percent occurrence and percent survival within occurrence (survivability) was monitored for parasitized meats (at least one

externally visible cyst per adductor muscle) separated from the total meats sampled from the predetermined processing points (Figure 2). Parasites were teased from cysts with forceps and needles. Parasites were considered alive if they responded to slight agitation after 1 hour in Earl's solution. The survival response was similar in fluids drained (weepage) from the shucked meats.

Attempts to decrease the percent occurrence included additional passes across the eviscerater, hand-sorting, freshwater soaks (1.7°C 35°F) and direct heat treatment. Attempts to decrease percent survival included iced storage, refrigeration (1.7°C; 35°F), super-chill (-2.2°C; 28°F), frozen storage (-17.8° and -34°C; 0° and -30°F), freshwater soaks (1.7°C; 35°F), exposure (12 hours) to 0.25 and 0.50% bisulfite solutions, sonication, and heat treatments (steam and micro-wave). Description of attempts will be explained with results.

RESULTS AND DISCUSSION

HARVEST

Harvest of calico scallops involved bottom trawls pulled across established beds primarily located along the central east coast of Florida. The trawls were arranged singularly or as dual trawls, one from each side of the vessel. The common vessel was a modified shrimp trawler, 60 to 70 feet. Modifications included aft deck alterations for open space and durability, rigging to unload trawls directly on the deck, and graded scuppers to retain scallops but drain deck water. Deck loading allowed ample production per vessel which for the larger vessels during maximum production can exceed catches yielding more than 600 to 900 gallons of meats per trip. A typical catch per vessel per trip was 300 to 500 gallons.

Likewise, deck loading facilitates unloading. Mobile dockside cranes equipped with hydraulic "knuckle-booms" and scoops can unload full vessels within 2 hours. This scheme of unloading is an essential key to the continuous, mechanized shucking operation. Thus one shucking facility could handle 12 or more vessels per day or typically produce 3000 to 7000 gallons per day. Plant production rates during this study ranged from 3000 to 9000 gallons day.

In attempt to minimize the exposure of the catch, processors try to regulate vessel turn-around time (total hours from departure, while trawling, and during return to dock) to less than 18 to 24 hours (Table 3). Shorter turn-arounds are enforced during the warmer season. This schedule can allow from 8 to 10 hours of actual trawling

Table 3. Daily schedule for trawl production of calico scallops.

Activity	Time (hours) Average	Range
Out (port to fishing location)	4-6	2-10
Fishing (total trawling time)	8-10	4-14
In (fishing location to port)	4-6	2-10
Dockside (includes unloading)	2-3	2-6
Combined	18-24	

which is necessary to produce an economical catch. Unpredicatable weather and vessel breakdowns can disrupt the schedule such that management may have to judge acceptance of the catch. Decisions are usually based on appearance and shuck performance. "Green" or fresh, lively scallops are more difficult to shuck, and morbid scallops with soft meats indicate poor quality. Also the degree of encrustation from barnacles on the scallop shells can insulate the meats thus requiring more heat treatment to effect proper shucking. In these situations more reliable and immediate management criteria are needed.

Total time for scallops on the deck can range from 12 to 18 hours. During October, February and June this storage time on deck did not cause excessive thermal abuse (Table 4) and the catch, from top to bottom of the compiled harvest, remained alive or showed no sensory signs of initial spoilage. This was true for samples which

Table 4. Temperatures within a typical deck load of calico scallops accumulated during a daily harvest. Temperatures were continuously recorded from wire probes placed throughout the catch piled on the deck. Temperature readings in the pile are averaged for three probes per depth.

Ambient Conditions	Location of thermal probe (feet above deck)	Temperature(°F) Initial	Final	Duration (hours)
October:	Top (> 6')	78.6	78.4	5.5
Air (76-82°F)	Middle (2-4')	78.0	81.0	9.5
Water (75°F)*	Bottom (0')	78.0	81.5	13.0
February:	Top	70.0	70.0	3.0
Air (70-75°F)	Middle	70.5	70.2	9.0
Water (72°F)*	Bottom	71.5	71.3	12.0
June:	Top	77.4	77.3	5.0
Air (85-88°F)	Middle	76.2	79.8	12.0
Water (79°F)*	Bottom	76.2	79.3	14.0

*Surface water temperature at harvest.

had been exposed to 78-81.5°F deck temperatures for 13 hours. Microbial results support the observed product conditions, but indicate vessel product abuse can occur (Table 5). In general the landed product can be expected to contain 10^3 to 10^4 microorganisms/gram (APC, 20°C) of meats and viscera. There was no discernible distribution of bacterial counts relative position of the scallop samples in the pile of scallops harvested. In two instances the dockside microbial loads exceeded 10^5 microorganisms/gram (APC, 20°C) with corresponding high counts at 7°C incubation indicative of psychrotropic spoilage bacteria. One situation was traced to a vessel breakdown during a major rainstorm, the other was thought to result from dockside washing of the catch with water pumped from the port. In these conditions no immediate adverse sensory attributes were noted.

Table 5. Microbial analyses (APC-aerobic plate counts, microorganisms/gram) for whole scallops, meat and viscera taken immediately from the water and after deck storage and unloading at the dock. APC's (25°C) represent analyses run at sampling location, while other analysis (35°, 20°,and 7°C) were conducted in the lab. Counts listed represent geometric means for at least three samples.

		IMMEDIATE HARVEST				LANDED,DOCKSIDE			
		APC, °C				APC, °C			
Month	Vessels*	35°	25°	20°	7°	35°	25°	20°	7°
Oct.	A t		$2.0X10^2$			$1.3X10^3$	$3.9X10^2$	$1.5X10^3$	$(2.7X10^1)$**2
	m		$2.8X10^2$			$1.3X10^2$	$6.2X10^2$	$5.4X10^2$	$(1.0X10^1)$
	b		$1.0X10^2$			$1.8X10^4$	$5.4X10^3$	$1.9X10^4$	$(1.0X10^1)$
Nov.	B					$4.2X10^3$		$2.4X10^3$	$4.0X10^1$
	C					$3.8X10^3$		$6.3X10^3$	$4.9X10^2$
	D					$7.7X10^3$		$5.2X10^4$	$(1.0X10^0)$
	E					$3.2X10^3$		$5.5X10^3$	$(2.8X10^0)$
	F					$3.6X10^3$		$6.7X10^3$	$(9.1X10^1)$
Dec.	G					$1.1X10^5$		$1.6X10^5$	$1.0X10^4$
Feb.	G t	$1.0X10^2$	$2.7X10^3$	$1.4X10^3$	$1.1X10^3$	$1.1X10^3$	$2.4X10^3$	$8.0X10^3$	$2.9X10^3$
	m	$1.5X10^2$	$1.7X10^3$	$1.4X10^3$	$3.8X10^3$				
	b	$2.2X10^2$	$1.4X10^3$	$2.5X10^3$	$7.1X10^2$	$3.0X10^4$	$3.0X10^4$	$1.1X10^5$	$6.6X10^4$
Jun.	I t		$1.0X10^3$			$1.1X10^3$	$1.0X10^4$	$1.8X10^3$	$1.9X10^2$
	b		$1.3X10^3$			$4.8X10^3$	$6.2X10^4$	$7.0X10^4$	$2.3X10^3$

* Different vessels are denoted by capital letters. The smaller case letters, t, m, and b denote sample locations within an accumulated catch of scallops (i.e., top, middle and bottom of the compiled catch, respectively).

** Counts listed in parenthesis denote estimates per gram.

Prior to unloading and processing the catch a sensory assessment and initial mechanized shucking performance will indicate the condition of the scallops. A "green" scallop which is lively and still demonstrating an active, strong contractile response is more difficult to shuck. Condition of the scallops will depend on total deck time, ambient temperature, rainfall, etc. When necessary a freshwater prerinse is used to weaken the scallops. This process is effective in a short period of time (less than 30 minute rinse). Fresh, clean water is available for this process, but occasional use of deck hoses and port water can be detrimental and is strongly discouraged.

After unloading, the scallops travel through a series of hoppers, sorters and conveyors which cull, size and provide further rinsing of the desired scallops. The typical harvest is well over 90% whole scallops by weight. Incidental harvest includes an assortment of bottom dwelling invertebrates and a few small fish. This culling arrangement is routine and necessary, but it can contribute to off-odors about the plant. The culled wastes and drippings which fall about the conveyors can accumulate, decompose and cause objectionable odors. Similar consequence can occur around and on any outside equipment including the trucks used to haul wastes from the plant. Careful, continuous policing of the plant grounds, equipment, and trucks is essential to prevent odors. Fresh, shucked scallops should not cause objectionable odors. Any complaints of odors from a scallop processing plant can usually to traced to poor grounds keeping and negligent maintenance of equipment and trucks.

PROCESSING

Actual processing begins with a thermal shock tank to dislodge the meat and viscera from the shell. Tanks of variable designs use steam and some form of agitation or vibration which separate the meats and viscera into a water flume for delivery to the unique evisceration apparatus. (Note: Some firms, not used in this study, employ flotation tanks between shucking and evisceration to separate out heavier shell fragments by bouyancy difference in salt brines). Evisceration employs a series of parallel rollers which continually move to and fro to pinch the soft, stringy viscera from the firmer, cylindrical meats. Acceptable meats pass down the inclined rollers into a water flume/conveyor for distribution to a culling table for hand sorting to remove discolored meats and to return poorly eviscerated meats for reeviseration. After culling, the meats are flumed to a chill tank as a final rinse and chill prior to packaging and storage. The entire automated processing operation requires approximately 3 to 5 minutes from the time one whole scallop enters the steam shucker until the chilled meat is packed in gallon containers.

The primary concerns for product quality during processing involve time-temperature considerations and sanitation (Table 6). The processing times through all segments of the operation are most efficient and require no major changes for improvement. The influence of ambient temperature is evident, especially during warmer months. Elevated room temperatures during the summer months suggest the need for better ventilation and air conditioning for plant sanitation and worker comfort. High ambient temperatures also caused elevated

Table 6. Recorded temperatures (°F) encountered by the product during continuous mechanized processing of calico scallops. Recordings taken from three separate firms.

Month	Ambient Outside Air	Shucking Room	Flume water after Shucking	Eviscerator Water	Culling Room	Chill Tank Water
Oct.	79	90-94	86-125	79	82-84	42-53
Nov	65	------	--------	75	72	38-40
Dec.	78	90-92	100	78	78	42-45
Feb.	68	86-88	91	75	84	38-40
June	85	99	99	78	85-90	38-40

temperatures encountered in the chill tanks. Proper loading rates, frequent water changes, insulation, and additional refrigeration were recommended to address this concern. Although each firm has a dictated operating schedule and procedures, generally the chill tanks were not adequately monitored for temperature, salinity, or cleanliness. Temperatures in excess of 40°F were common, initial brine strengths ranged from 0 to 4%, and periodic changes in water lapsed. The economic incentive for altering the chill tank operation is evident in the extended shelf-life of properly chilled product prior to packaging and storing. Time from packaging to storage in ice and refrigeration was less than 20 to 30 minutes.

Sanitation while processing and during periodic clean-ups is fair, and typical for similar seafood process settings, but it could be improved. Signs of slime on conveyor belts, dirty tanks, improper storage and handling of packaging materials, open doors and windows, damp walls and ceilings, improper lighting, etc. indicate need for general education and improved management. The recommended approach will include assignment of quality control managers, routine clean-up schedules, proper clean-up procedures and equipment, and establishing a recorded self-inspection program which can include simple microbial profiles.

In general, the production and processing of calico scallops appears above average for most common seafood processing operations and there are no major quality or sanitation problems. Proper chill tank operations require minor attention, and general manufacturing

practices (GMP's) can be further improved with additional education and management. Likewise, general housekeeping about the plant should be encouraged to curb odors and avert attraction of pests.

The most variable aspect of production is the vessel. Processors are aware of this situation and attempt to dictate a fishing schedule which minimizes deck time for the harvest. In situations and seasons of rainfall and warm temperatures this schedule is altered and tarp covers are used to protect the catch. Improved methods for immediate dockside assessment of quality would be useful in times of questionable quality.

MICROBIAL ASSESSMENTS FOR SCALLOPS

The microflora characterized from aerobic plate count (20°C) analyses of scallops collected October, February and June are presented in Tables 7-9, respectively. During all harvesting periods, a heterogenous distribution of microflora typical of fresh shellfish prior to extended refrigerated storage was observed for scallops sampled at various stages of harvesting and processing. Few consistent differences in the taxonomic distribution of microflora were observed between scallops collected at sequential stages of harvesting and processing prior to exposure in the chill tanks. A consistently high proportion of gram-negative bacteria was noted in scallops after emerging from chill tanks.

For October samples, gram-positive genera comprised 60-65% of the microflora in samples collected at sea and dockside with Staphylococcus, Corynebacterium and Micrococcus being recovered most

Table 7. Taxonomic profile of microflora recovered from scallops collected in October*.

Genera	Immediate Harvest	Dockside	Mech. Shucked	After Evisceration	After Chill Tank
Gram Positive:					
Aerococcus	6	---	12	5	3
Bacillus	2	6	2	8	---
Cornebacterium	5	10	---	3	4
Micrococcus	6	5	4	---	2
Staphylococcus	17	1	1	---	---
Gram Negative:					
Acinetobacter	---	4	1	5	---
Aeromonas	1	4	1	---	---
Enterobacter cloacae	2	1	---	---	---
Enterobactes aerogenes	---	---	---	3	---
Escherichia coli	---	---	---	---	3
Flavobacterium	10	---	2	2	7
Klebsiella	4	---	---	---	---
Moraxella	8	3	1	---	---
Pseudomonas	---	---	---	---	4
Totals	61	34	24	26	23

* Values represent number of isolates characterized from APC (25°C) plates initiated at a given location or processing point

Table 8 Taxonomic profile of microflora recovered from scallops collected in February.*

Genera	Immediate Harvest	Dockside	After Chill Tank
Gram Positive:			
Aerococcus	5	4	---
Bacillus	10	11	1
Corynebacterium	4	4	---
Locatobacillus	---	---	1
Micrococcus	1	2	1
Staphylococcus	8	---	13
Gram Negative:			
Acinetobacter	2	2	17
Aeromonas	---	2	2
Alcaligencs	1	2	---
Erwinia herbicola	2	---	---
Escherichia coli	---	1	---
Flavobacterium	6	4	10
Klebsiella	---	---	2
Moraxella	10	9	2
Proteus	---	---	7
Pseudomonas	9	7	4
Serratia	4	2	---
Others:			
Yeasts	3	1	---
Totals	65	51	60

* Values represent number of isolates characterized from APC (25°C) plates initiated at a given location.

Table 9. Taxonomic profile of microflora recovered from scallops collected in June 1984*.

Genera	Immediate Harvest	Dockside	After Chill Tank
Gram Positive:			
Bacillus	4	5	2
Cornebacterium	1	-	5
Micrococcus	2	3	3
Staphylococcus	3	-	3
Gram Negative:			
Acinetobacter	-	-	7
Aeromonas	3	4	4
Citrobacter freundii	-	-	3
Enterobactes aerogenes	-	3	-
Erwinia herbicola	1	5	-
Flavobacterium	1	-	12
Moraxella	2	5	6
Proteus	-	-	-
Pseudomonas	-	2	-
Other:			
Yeasts	7	21	-
Totals	24	48	46

* Values represent number of isolates characterized from APC (25°C) plates initiated at a given location.

frequently. Predominant gram-negative isolates included Moraxella and Flavobacterium. The proportion of gram-positive to gram-negative isolates was 80:20 after steam-shucking but was approximately 60:40 following evisceration. The ratio of gram-positive to gram-negative isolates was 40:60 in finished scallops emerging from the chill tanks although the types of microflora recovered were similar to those recovered in preceeding processing stages with the exception of Pseudomonas sp. recovered in finished scallops. These results may be attributed to greater survival and/or proliferation of psychrotrophic gram-negative bacteria in the low temperature conditions of the chill tanks.

Gram-negative bacteria comprised a higher proportion of the microflora recovered from scallops collected in February as compared to October. These data may reflect a seasonal shift to a more psychrotrophic indigenous microflora due to the lower ambient water temperatures. Gram-positive organisms accounted for approximately 40% of the isolates recovered from scallops collected at sea and dockside and were predominated by Bacillus sp., Aerococcus sp. and Corynebacterium sp.. Predominate gram-negative bacteria included Moraxella, Pseudomonas and Flavobacterium. Yeasts were also recovered from scallops prior to processing. As observed in October, a large increase in the proportion of gram-negative isolates was noted in scallops after exposure to chill tanks with over 70% of the microflora being gram-negative bacteria. Predominant gram-negative genera recovered from finished scallops included Acinetobacter and Flavobacterium. Acinetobacter and Moraxella are closely related

genera which along with the Pseudomonas are common psychrotrophic spoilage type bacteria commonly encountered in many fresh seafoods and other meats.

The microflora recovered from scallops collected at sea in June was comprised of approximately 40% gram-positive bacteria, 30% gram-negative bacteria and 30% yeasts. Gram-positive bacteria, gram-negative bacteria and yeasts accounted for approximately 20, 40 and 40%, respectively, of the microflora recovered from dockside samples. Gram-positive genera recovered from scallops before processing were similar to those observed in October and February determinations while predominant gram-negatives in June included Moraxella, Aeromonas and Erwinia. The recovery of large proportions of yeasts in scallops prior to processing may relect fluctuations in the normal microflora of the marine environment from which the samples were harvested and/or sanitation of the respective vessel. It should be noted that yeasts are not considered significant spoilage microogranisms in fresh seafoods during refrigerated storage and that yeasts were not recovered from sallops after chill tank exposure. A large increase in proportion of gram-negative isolates was observed again in finished scallops taken from chill tanks with over 70% of the microflora being gram-negative. Predominant genera recovered from finished scallops in June included Flavobacterium, Acinetobacter and Moraxella.

MICROBIAL ASSESSMENT FOR PROCESSING

Processing generally elevated the microbial counts (APC) as compared to dockside counts (Table 10). The increases do not denote any

Table 10. Aerobic plate counts (microorganisms/gram) for calico scallop meats sampled during processing. The listed geometric means represent three to six samples depending on month, and all samples per month came from one vessel through processing.

Month	*Firms Unidentified	Process	Aerobic Plate Counts (°C) 35°	20°	7°
			organisms/gram		
Oct.	I	MS	$1.4X10^5$	$1.4X10^5$	$(1.5X10^2)$
		E	$7.9X10^4$	$7.1X10^4$	$5.8X10^2$
		CT	$3.2X10^5$	$4.0X10^5$	$1.2X10^5$
Nov.**	II	MS	$4.5X10^6$	$2.8X10^6$	$1.1X10^6$
		E	$2.8X10^5$	$3.0X10^5$	$1.0X10^2$
		CT	$5.3X10^5$	$4.2X10^5$	$6.0X10^3$
	III	MS	$3.7X10^3$	$3.2X10^3$	$(3.8X10^1)$
		E	$1.8X10^3$	$1.5X10^3$	$(2.5X10^1)$
		CT	$1.2X10^4$	$1.1X10^4$	$(2.3X10^2)$
Dec.	IV	MS	$1.0X10^5$	$9.4X10^4$	$2.8X10^3$
		E	$6.0X10^4$	$5.7X10^4$	$6.0X10^3$
		CT	$1.0X10^4$	$1.3Xa0^5$	$1.3X10^4$
Feb.	V	CT	$6.5X10^5$	$3.6X10^5$	$3.8X10^5$
Mar.	VI	CT+1 day	$9.5X10^4$	$9.0X10^4$	$2.1X10^4$
Jun.***	VII	MS	$4.8X10^5$	$8.0X10^4$	$2.8X10^4$
		E	$3.8X10^5$	$3.4X10^5$	$5.3X10^3$
		CT	$3.0X10^5$	$3.8X10^5$	$5.3X10^3$
Aug.	VIII	CT+1 day	$4.7X10^4$	$6.2X10^4$	$6.2X10^2$

* Three firms were assessed, each at least twice. Letters, MS, E, and CT denote samples taken after mechanical shucking, evisceration, and soak in chill tank, respectively.

** November data represents means across four separate vessels landing product consecutively (see Table 12).

*** June data represents means for two sets of samples taken as a vessel was initially (top) and finally (bottom) unloaded and processed (see Table 11).

major problems and reflect similar situations common in most seafood processing operations. The monthly results tend to reflect higher consistent counts at processing points during June, but the variable counts at 7°C were thought to be related to vessel conditions, duration of harvest, and/or operation of the chill tank.

In comparison, the dockside counts indicate the mechanical-steam shucking process elevates the mean APC's (35, 20, 7°C) approximately 10 fold higher than on dockside product (the monthly results in Table 10 correspond with the respective dockside results in Table 5). Although the shucking process utilizes pressurized steam in tunnels or tanks, the actual temperature of the scallop meat should remain below 140°F. Higher temperatures would be evidenced by a cooked or partially cooked appearance on the surface of the meats. This meat temperature in combination with post-shuck flume temperatures of 90° to 125°F (Table 6) would promote some bacterial growth. Likewise, the construction and operation of the shuckers warrants further attention for periodic clean-up to prevent bacterial accumulation about the tunnels which may contaminate scallop meats.

Bacterial counts tend to decrease during evisceration due to the rinsing and dilution influence of the high pressure water sprays which cleanse and 'lubricate' the eviscerator rollers. Decreasing the temperature of the sprays could impart some advantages.

Although the chill tank could decrease the eviscerated product temperature from 78-79°F to 38-40°F, the water in the tanks generally 'innoculated' the meats prior to packaging. In one instance when tank water temperature was at 53°F the APC's (7°C) on the scallop meats

increased 200 fold after the brief soak (1 to 2 minutes) in the chill tank. Interestingly, there was no apparent influence of processing time or amount of consecutively processed product on the bacterial counts of finished scallops encountered during one month of split sampling. Samples taken for bacterial analysis at the beginning (top) and end (bottom) of processing one vessel's catch in June generally yielded similar results (Table 11). However, for scallops emerging from the mechanical shucker, samples taken at the beginning (top) had higher counts (40-100 fold) than those taken at the end (bottom) of processing per vessel indicating a decrease of bacterial contamination via the shucker and/or shucker flume water as processing progressed. Apparently, down time between processing catches from individual vessels allows bacterial growth within the line of shucking equipment and associated flume waters. There was no discernible pattern in bacterial analyses for samples taken during four consecutively processed catches (Table 12). No routine clean-up or altered procedures occurred between processing each vessel's catch. Thus the processing mode and methods were operating with an established bacterial load for the operating conditions.

Microbial analyses indicate the chill tank waters and shucking process and/or flume water from the shucker are a probable source of fecal coliform and E. coli contamination (Table 13). Although fecal coliforms and E. coli were recovered sporadically on dockside hand-shucked meats these organisms could proliferate slightly during processing and provide a source for accumulation on equipment in the processing operation. The presence of psychrotrophic (APC, 7°C) as well

Table 11. Aerobic plate counts (microorganisms/grams of meat or ml of water) for calico scallop samples taken at dockside through processing for one vessel unloaded in June. Samples were taken at the beginning (top of the harvest or last caught) and end (bottom of the harvest or first caught) of the unloading and processing operations. Listed geometric means represent three samples

Sample Location		Aerobic Plate Counts (°C) 35°	25°	20°	7°
Dockside Shellstock	top	$1.1X10^3$	$1.0X10^4$	$1.8X10^3$	$1.9X10^2$
	bottom	$4.8X10^4$	$6.2X10^4$	$7.0X10^4$	$2.3X10^3$
Mech. Shucked	top	$9.8X10^5$	-----	$1.4X10^6$	$5.4X10^4$
	bottom	$1.8X10^4$	-----	$1.8X10^4$	$1.3X10^3$
Eviscer.	top	$4.9X0^5$	-----	$4.4X10^5$	$3.0X10^4$
	bottom	$2.6X10^5$	-----	$2.4X10^5$	$2.8X10^4$
Chill Tank	top	$3.1X10^5$	-----	$3.7X10^5$	$6.5X10^3$
	bottom	$3.0X10^5$	-----	$3.9X10^5$	$4.2X10^3$
Chill Tank Water	top	$9.4X10^5$	-----	$7.9X10^5$	$1.5X10^4$
	bottom	$7.9X10^5$	-----	$1.0X10^6$	$1.0X10^4$
Shucker Flume Water	top and bottom	$1.8X10^5$	-----	$1.4X10^5$	$3.5X10^3$

Table 12. Aerobic plate counts (microorganisms/gram of meats or ml of water) for calico scallop samples and chill tank water taken during the unloading and processing of four separate vessels handled consecutively at one processing firm in November. The listed geometric means represent three samples.

Sample Location	Vessel	Aerobic Plate Counts (°C) 35°	20°	7°
Dockside Shellstock	1	$3.7X10^3$	$6.3X10^3$	$3.9X10^2$
	2	$7.7X10^3$	$5.2X10^4$	$1.0X10^0$
	3	$3.2X10^3$	$5.5X10^4$	$2.8X10^0$
	4	$3.6X10^3$	$6.7X10^3$	$9.1X10^1$
Mechanically Shucked	1	$2.9X10^4$	$2.3X10^4$	$1.5X10^2$
	2	$2.6X10^3$	$2.1X10^3$	$1.0X10^1$
	3	$1.8X10^3$	$2.0X10^3$	$1.0X10^1$
	4	$2.1X10^3$	$1.7X10^3$	$9.3X10^1$
Eviscerated	1	$6.1X10^3$	$3.3X10^3$	$1.5X10^2$
	2	$3.5X10^3$	$2.1X10^3$	$1.0X10^1$
	3	$9.1X10^2$	$2.0X10^3$	$1.0X10^1$
	4	$1.3X10^3$	$1.5X10^3$	$2.2X10^1$
Chill Tank	1	$1.5X10^4$	$1.4X10^4$	$7.8X10^2$
	2	$1.1X10^4$	$1.1X10^4$	$3.0X10^2$
	3	$1.0X10^4$	$1.4X10^4$	$1.0X10^2$
	4	$1.2X10^4$	$7.9X10^3$	$2.2X10^2$
Chill Tank Water	1	$7.0X10^2$	$1.1X10^2$	$5.4X10^0$
	2	$1.3X10^5$	$1.1X10^5$	$2.0X10^3$
	3	$1.1X10^5$	$8.0X10^4$	$2.0X10^3$
	4	$1.4X10^5$	$9.4X10^4$	$2.8X10^3$

Table 13: Summary of fecal coliform (FC) and E. coli (EC) data (units: MPN's/g meats or MPN's/ml water) taken for scallops processed from one vessel per month. Values for processed scallop meats and dockside meats plus viscera represent the goemetric mean for at least three samples. Number of samples for geometric means for water samples are identified in parenthesis.

Sample Location	Results/Month, 1983-84											
	Oct. (A)*		Nov. (B)**		(C)		Dec. (D)		Feb. (E)		Jun. (F)	
	FC	EC	FC	EC	FC	EC	FC	EC	FC	EC	FC	EC
Dockside Vessel: t***	4.5	NR										
m	1.5	NR	NR	NR	3.6	3.6	1.9	1.9	NR	NR	NR	NR
b	1.5	NR							NR	NR	1.9	1.5
	NR	NR							NR	NR		
After Shuck	2.1	2.1	NR	NR	>1100	>1100	230	230			2.3	2.3
After Evisc.	NR	NR	NR	NR	3.6	3.6	11	11			NR	NR
Chill Tank	10.0	4.4	NR	NR	NR	NR	38	38	NR	NR	NR	NR
Chill Tank Water	40 (3)	2.5	NR (4)	NR	2.3 (1)	2.3	4.3 (4)	3.4			t7.5 b9.3 (1)	0.4 NR
Flume Water from Shucker							>110 (1)	>110			9.3 (1)	9.3

*Letters (A) thru (F) denote unidentified, individual scallop firms. Three firms were involved.
**November data (B) represent means for samples from 4 separate vessels unloaded consecutively.
***Small letters t, m, and b denote top, middle and bottom samples from same vessel.

as coliform bacteria in the chill tank could have an impact on the subsequent quality and refrigerated shelf-life of the scallops. Additional efforts are needed to reduce their accumulation. More frequent (6 hours) drainage and proper cleaning of the chill tanks should be encouraged, and additional insulation and refrigeration should be considered to maintain lower operating temperatures. As previously mentioned, attention should be given to cleaning shuckers and assoicated plumbing including flume water to prevent bacterial accumulation. The high temperatures in this equipment would provide a selective environment for growth and/or accumulation of coliform bacteria.

The persistence of fecal coliforms and E. coli on meats and in processing waters was unanticipated. The only identified source was the incoming raw materials. Careful evaluations eliminated the water supply as a probable source in one plant. Obvious cross-contamination with sewage was not evident, but detailed bacterial assessments would be necessary to rule out any possbile hidden leaks, siphons, etc. Warm, damp and improperly sanitized conditions appeared to enhance proliferation on the product as well as in the processing effluents and/or fluming waters. Realizing the product is initially harvested essentially free of fecal coliforms or fecal contamination, from deep (10-15 fathom) ocean waters (3.4-3.5% salt), the presence of fecal coliforms and E. coli in processed scallops warrants thorough sanitation procedures in the plant and on the vessels before and after harvest. In-line chlorination or ozonation for processing and/or flume waters, frequent and proper cleaning/sanitizing procedures, and

generally improved manufacturing practices should diminish coliform and E. coli counts on the facilities and product.

Overall the microbial assessments have not indicated any major concerns detrimental to product quality or safety during scallop processing. No Staphylococcus aureus nor Salmonella have been recovered from any processing point (Figure 2) during any month of sampling. Vibrio sp. analyses run on a full compliment of samples in October, and on dockside and chill tank samples in June recovered no V. parahaemolyticus, V. cholera, or V. vulnificus.

REFRIGERATED STORAGE

Refrigerated storage in barrier bags (no vacuum) suggest aerobic plate counts (24° and 7°C) in excess of 10^7 microorganisms/gram of shucked meats represents the objectionable level for calico scallops (Table 14 and 15). Sensory judgements for raw scallops were based on a simple tri-level scale indicating two levels of quality and eventual spoilage. As noted in previous storage studies with various scallops (10, 20, 22), progressive changes in the meat odors from a pleasant fresh shellfish/scallop aroma, to noticeable off-odors, and finally putrid smells is the most distinct sensory perception by which to judge scallop freshness/quality. Changes in appearance and meat color were limited with the most distinct change being from a damp, firm product to slimy, sticky meats with accummulated weepage at the time of noticeable spoilage. Based on these results mechanically shucked calico scallops continually stored at 1.7°C (35°F) can be expected to have a 13 to 17 day maximum refrigerated shelflife. In these conditions the meats approach a class B condition by day 9 and were usually

Table 14. Aerobic plate counts (APC; microorgansims/g) for processed calico scallop meats initially packed in plastic gallon containers then repacked in small (pint) barrier bags for refrigerated storage studies at 1.7° and 7.2°C (35° and 45°F). Listed geometric means represent three samples.

Month	Storage Time(Days)	Storage Temp	APC, (°C) 35°	20°	7°	Storage Temp(°C)	APC (°C) 35°	20°	7°
Feb.	1	1.7°C	$4.7X10^5$	$4.7X10^5$	$1.1X10^4$	7.2°C	$4.5X10^5$	$4.9X10^5$	$1.2X10^4$
	5		$2.1X10^5$	$2.2X10^5$	$1.9X10^4$		$9.3X10^5$	$8.4X10^5$	$7.9X10^5$
	9		$4.2X10^5$	$5.5X10^5$	$2.4X10^5$		$1.8X10^7$	$1.9X10^7$	$1.3X10^7$
	13		$2.5X10^6$	$2.6X10^6$	$3.1X10^6$		$8.9X10^7$	$1.2X10^8$	$1.0X10^8$
	17		$7.3,10^6$	$7.2X10^6$	$7.6X10^6$		$2.5X10^8$	$2.8X10^8$	$2.0X10^8$
Mar.	1	1.7°C	$2.5X10^4$	$9.0X10^4$	$2.1X10^4$	7.2°C	$1.6X10^5$	$1.5X10^5$	$4.8X10^4$
	5		$1.7X10^5$	$2.1X10^5$	$1.3X10^5$		$5.1X10^6$	$9.7X10^6$	$7.5X10^6$
	9		$4.4X10^6$	$4.6X10^6$	$5.2X10^6$		$1.0X10^8$	$1.9X10^6$	$1.4X10^8$
	13		$1.1X10^7$	$2.0X10^7$	$1.8X10^7$		$1.5X10^8$	$3.9X10^8$	$3.3X10^8$
	17		$1.1X10^8$	$2.1X10^8$	$1.8X10^8$		$8.0X10^7$	$3.9X10^8$	$2.8X10^8$
Jun.	1	1.7°C	$2.5X10^5$	$2.6X10^5$	$5.7X10^3$	7.2°C	$4.0X10^5$	$5.0X10^5$	$2.4X10^3$
	5		$1.6X10^5$	$2.5X10^5$	$2.5X10^4$		$2.4X10^5$	$3.2X10^5$	$1.8X10^5$
	9		$3.6X10^5$	$4.3X10^5$	$1.2X10^5$		$1.3X10^7$	$1.5X10^7$	$1.3X10^7$
	13		$5.3X10^5$	$4.0X10^5$	$5.3X10^5$		$1.2X10^8$	$1.2X10^8$	$1.0X10^8$
	17		$1.5X10^6$	$2.5X10^6$	$2.0X10^6$		$6.9X10^7$	$9.4X10^7$	$8.4X10^7$
Aug.	1	1.7°C	$6.1X10^4$	$7.5X10^4$	$5.1X10^2$	7.2°C	$4.7X10^4$	$6.2X10^4$	$6.2X10^2$
	5		$3.9X10^4$	$6.7X10^4$	$2.9X10^3$		$7.1X10^5$	$7.9X10^5$	$3.8X10^5$
	9		$3.5X10^5$	$3.9X10^5$	$3.2X10^5$		$9.7X10^6$	$1.1X10^7$	$1.0X10^7$
	13		$1.7X10^6$	$2.0X10^6$	$1.9X10^6$		$1.0X10^8$	$1.1X10^8$	$1.2X10^8$
	17		$3.2X10^7$	$3.0X10^7$	$3.4X10^7$		$1.1X10^8$	$1.5X10^8$	$1.0X10^8$

Table 15. Range for bacterial counts (APC, 20°C) and general organoleptic evaluations for odor from raw calico scallops packed in plastic gallons stored at 1.7° and 7.2°C (35° and 45°F) for 17 days. Bacteria counts represent the range for geometric means per monthly samplings of processed meat produced during February through August.

Days Storage	1.7°C (35°F) Storage (APC, 20°C)	Odor Rating*	7.2°C (45°F) Storage (APC, 20°C)	Odor Rating
1	$7.5X10^4$ to $4.7X10^5$	A	$6.2XC10^4$ to $5.0X10^5$	A
5	$6.7X10^4$ to $2.5X10^5$	A	$3.2X10^5$ to $9.7X10^6$	(A)B
9	$3.8X10^5$ to $4.6X10^6$	(A)B	$1.1X10^7$ to $1.9X10^8$	B
13	$4.0X10^5$ to $2.0X10^7$	B	$1.1X10^8$ to $3.8X10^8$	(B)C
17	$2.5X10^6$ to $2.1X10^8$	(B)C	$9.5X10^7$ to $3.9X10^8$	C

* Odor Rating
- A - Acceptable odor, pleasant, fresh shellfish/scallop aroma.
- B - Acceptable, but noticeable off-odors, old, stale odors.
- C - Unacceptable, distinct off-odors, putrid.
- (A)B - predominately 'B', but could be 'A' depending on sample.
- (B)C - predominately 'C', but could be 'B' depending on sample.

in borderline class C condition or unacceptable on the 17th day. A graphic presentation of the bacterial results (APC's, 7°C) further substantiates the expected shelflife and questionable meat quality with counts in excess of 10^7 microorganisms/gram (Figure 3).

Higher storage temperatures or fluctuating temperatures would diminish shelflife as noted for the pyschrotrophic (spoilage bacteria) counts (APC, 7°C) for meats stored at 7.2°C (45°F) (Figure 3). Lower storage temperatures could extend shelflife as reported for calico scallop stored at 0 to 1.1°C (32° to 34°F) for 15 to 18 days (12). Overall the current refrigerated shelflife of calico scallops is similar to that reported in previous studies, including other scallop species (Table 16)

After one day of storage at 1.7° or 7.2°C (35° or 45°F) anaerobic plate counts (20°C) (Table 17) on scallops during February and June were approximately 40% of corresponding aerobic plate counts during March and August. Increases in anaerobic counts (20°) were generally much greater than corresponding increase in APC's 20°C over the first 5 and 9 days of storage at 1.7°C and 7.2°C respectively. Anaerobic counts approximated corresponding APC's (20°C) within 9 to 13 days and 5 days at 1.7 and 7.2°C, respectively, after which parallel increases in anaerobic and aerobic counts were observed throughout the remaining storage period. These results suggest a predominantly facultatively anaerobic microflora developing on scallops stored at either 1.7 or 7.2°C since such organisms generally are detected by both aerobic and anaerobic analyses and are indicative of the conditions under which the scallops were stored. Thus the anaerobic plate counts (20°C)

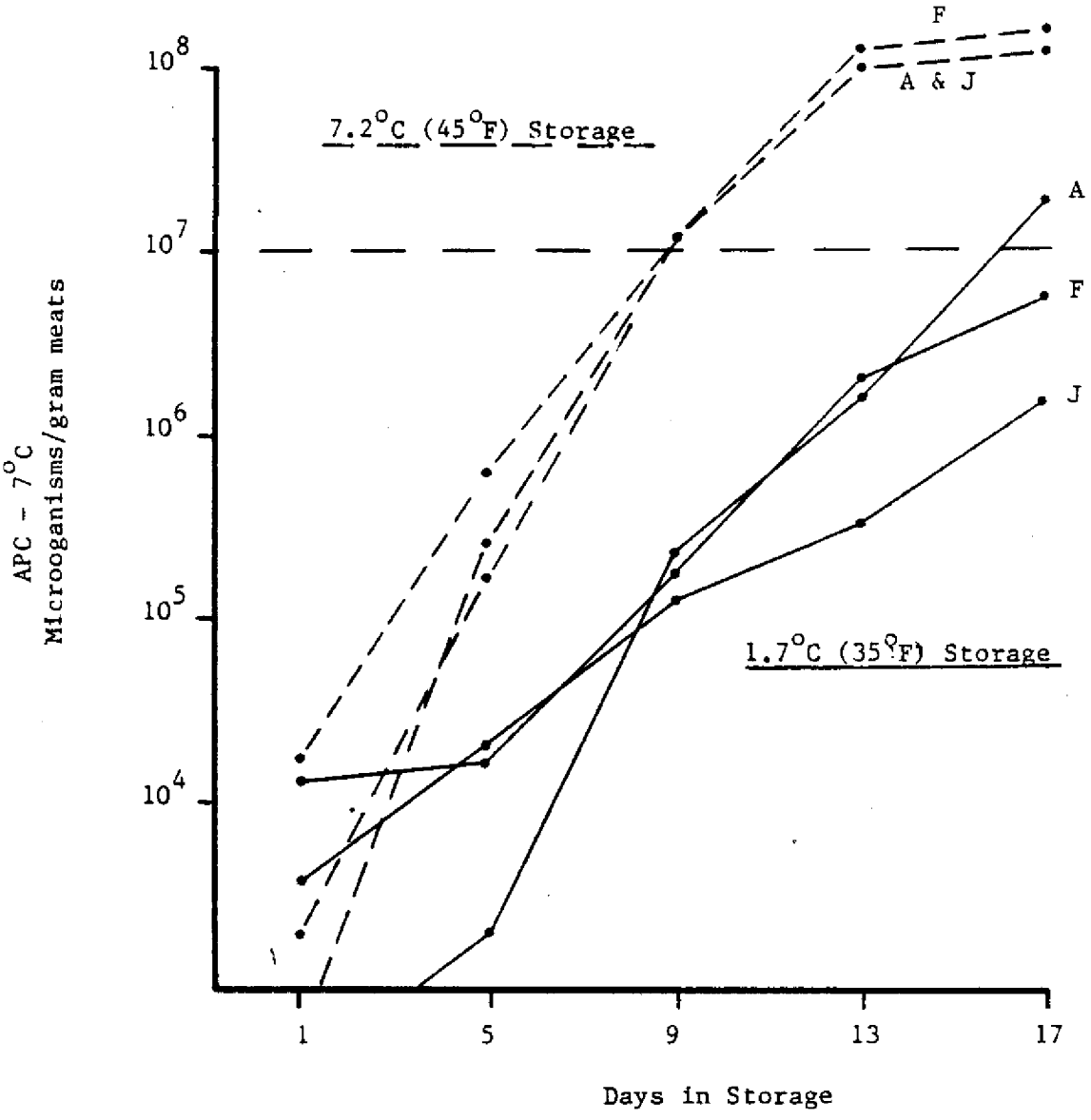

Figure 3. Aerobic plate counts (7°C) for calico scallop meat stored for 17 days in 7.2°C (45°F) and 1.7°C (35°F) refrigeration. Letter A, F, J denote comparative monthly samples for August, February and June, respectively.

Table 16. Comparison of reported refrigerated shelflife for various types of scallops. The calico scallop are the only mechanically shucked scallop.

Type of Scallops*	Storage Temperature	Conditions	Total Days Shelflife	Reference No.
Calico	37.4F (3°C)	n.s**	5-11	17
Calico	37.4F (3°C)	n.s.	13	19
Calico	35.0°F(1.7°C)	barrier bag	13-17	present
	45.0°F(7.2°C)	barrier bag	9-13	present
Calico	32-34°F	n.s	15-18	12
Calico	Iced	cloth bag	12	10
	Iced	poly bag	9	10
Calico	Iced	plastic tub	12	22
Bay	Iced	n.s	10	11
	37.4°F(3°C)	n.s	9	11
Sea	Iced	n.s	10-12	13
Weathervine	32°F(0°C)	glass jar	10	14
English	Iced	n.s	9	45
Australian	39.2°F(4°C)	poly bag	6-9	20
	39.2°F(4°C)	vacuum bag	6-9	20

* Type of scallop species; Calicos (Argopecten gibbus); Bay (Argopecten irradians); Seas (Placopecten magellanicus); Weathervanes (Patinopecten caurinus); English varieties (Pecten maximus and Chlamys operecularis); and Australian scallops (Pecten alba).

** n.s. denotes conditions "not specified", but in most reports the packaging was typical commercial units (i.e., boxes, bags, or plastic tubs).

Table 17. Anaerobic plate counts (20°C) for processed calico scallop meats initially packed in plastic gallon containers then repacked in small (pint) barrier bags for refrigerated storage studies at 1.7° and 7.2°C (35° and 45°F). Listed geometric means represent three samples.

Month	Storage Time (Days)	Storage Temp.	Anaerobic Counts (20°C)	Storage Temp.	Anaerobic Counts (20°C)
Feb.	1	1.7°C	$6.1X10^3$	7.2°C	$8.7X10^3$
	5		$1.1X10^4$		$1.1X10^6$
	9		$1.9X10^5$		$1.5X10^7$
	13		$2.0X10^6$		$1.1X10^8$
	17		$7.1X10^6$		$1.9X10^8$
Mar.	1	1.7°C	$3.7X10^4$	7.2°C	$6.2X10^4$
	5		$1.1X10^5$		$8.1X10^6$
	9		$3.5X10^6$		$1.6X10^8$
	13		$2.5X10^7$		$3.3X10^8$
	17		$1.3X10^6$		$8.7X10^7$
Jun.	1	1.7°C	$8.0X10^3$	7.2°C	$1.1X10^4$
	5		$2.7X10^4$		$1.8X10^5$
	9		$7.0X10^4$		$1.1X10^7$
	13		$8.8X10^5$		$1.0X10^8$
	17		$1.3X10^6$		$8.7X10^7$
Aug.	1	1.7°C	$3.2X10^4$	7.2°C	$1.9X10^4$
	5		$2.0X10^4$		$5.3X10^5$
	9		$2.9X10^5$		$1.2X10^7$
	13		$1.8X10^6$		$1.0X10^8$
	17		$3.3X10^7$		$1.2X10^8$

reflected the development of psychrotrophic, facultatively anaerobic microorganisms which would be primarily responsible for loss of microbial quality during refrigerated storage of scallops under low O_2 tension conditions encountered in barrier bags or sealed gallon containers.

Attempts to monitor pH on the surface of the meats did not indicate any discernible pattern during immediate processing or during storage time on the vessel and subsequent to processing. Repeated samples taken from harvests and corresponding processing of four separate catches during October through December indicated the raw, alive (pre-rigor) meats had an average surface pH of 6.59 $\pm$ 0.20 (n=12) and the shucked meats from the chill tank had a corresponding pH of 6.48 $\pm$ 0.15 (n=12). Likewise, surface pH on the meats stored for 1 to 17 days at 35° and 45°F (1.7° and 7.2°C) showed no discernible pattern to denote progressive spoilage (Table 18). These results are similar to previous reports indicating poor reliance on muscle pH as an indicator for calico scallop quality or progressive spoilage (10, 19, 22).

Likewise, the use of a simple resazurin dye reduction test to measure bacterial loads and indirectly assess calico scallop quality was not reliable. Based on the published guidelines (12) a resazurin dye reduction time greater than 2 hours (120 minutes) indicates superior quality and reduction times less than 1 hour (60 minutes) indicates questionable quality. Although the average dye reduction times for resazurin tests with calico scallops stored at 1.7° and 7.2°C (35° and 45°F) followed a discernible decreasing pattern, the

Table 18. Mean surface pH for mechanically sucked calico scallop meats stored in refrigeration, 1.7°C (35°F) and 7.2°C (45°) for 17 days. Mean values represent averages for 9 separate readings.

Days Storage	Surface pH; Average (Std. devaiation) 35°F	45°F
1	6.57 (.03)	6.53 (.03)
5	6.42 (.00)	6.22 (.01)
9	6.29 (.05)	6.34 (.13)
13	6.30 (.05)	6.58 (.09)
17	6.40 (.05)	6.45 (.12)

results per sample (or per monthly samples) were too variable to predict meat quality (Table 19). Questionable and unacceptable meat quality as denoted by general odor ratings (BC-questionable and C-unacceptable) correspond to average reduction times ranging from 25 to 195 minutes for scallops stored at 1.7°C (35°F), and 20 to 82 minutes for the same stored at 7.2°C (45°F). The standard deviation of the means from six analyses per monthly samples was higher at the lower storage temperature, 1.7°C (35°F). The variable response is most likely due to differences in microbial count and flora, and methodology. Further work could refine the methodology, but the resazurin test could only be used in support of more reliable, sensory techniques.

Table 19. Resazurin tests as a measure of the microbial loads and quality (odor ratings) for refrigerated calico scallops. Listed means and standard deviations (±) are results from six samples per storage day per month.

	Resazurin Reduction Time Minutes +(Std. dev)						
	35°F(1.7°C) Storage				45°F(7.2°C) Storage		
Days Storage	Odor * Rating	Mar	Jun	Aug	Odor Rating	Mar	Jun	Aug
1	A	260±20	142±110	190±120	A	185±47	175±75	170±40
5	A	205±29	195±21	325±43	AB	85±35	160±8	140±47
9	AB	135±54	245±35	95±42	B	20±8	79±14	90±26
13	B	115±54	210±37	95±42	BC	20±8	60±17	75±30
17	BC	25±27	195±104	95±20	C	23±11	82±8	75±30

* Odor rating: A-acceptable, B-acceptable with some off-odors, and C-unacceptable off-odors.

PRODUCT YIELDS AND COMPOSITION

Product yields and basic chemical composition were monitored per month to note any seasonal effect and the influence of processing. As expected the scallop shell size increased during fall (Table 20), and the meat count showed a corresponding decrease (Table 21). From October to December the meat count decreased 53.4 percent indicating the dramtic growth rate associated with this shellfish. Thus in less than 60 days the product yield, measured as counts per pound, had more than doubled.

The processed meat yield was variable ranging from 5% to 8% of the original whole, shell-on scallop weight. When processed the meat counts increased indicating the individual meats decreased in size and/or weight (Table 21). The meat counts increased 20%, 9.4% and

Table 20. Shell dimensions encountered in sampling the harvest of calico scallops during 1983. Data per month represents 150 scallops randomly taken from one vessel.

	*Shell Dimensions (mm), Average (std. deviation)		
Month	Width	Length	Depth
Oct.	40.6 (2.6)	39.3 (2.2)	21.0 (1.5)
Nov.	46.5 (2.9)	44.9 (2.5)	24.1 (1.4)
Dec.	53.5 (3.3)	50.5 (2.8)	27.6 (1.8)

* Width is the distance between lateral sides on the edge of the shells; length is the distance between connecting base of the shells to the front edge of the shells; and depth is the distance between the convex surfaces of each shell half.

Table 22. Proximate protein and moisture content in calico scallop meats during processing. Data represents analyses (triplicates) of six samples from one vessel or harvest through processing.

Month	Proximate Composition (%), Avg. (Std. dev.)				
	Hand Shucked	Mech. Shucked	After Evisceration	After Chill Tank	Storage (35°F) 1 to 2 days
	---------- Protein ----------				
Oct.	17.0(0.1)	15.7(0.4)	17.5(0.3)	17.6(0.1)	17.7(0.3)
Nov.	--------	16.6(0.1)	17.0(0.4)	17.8(0.2)	---------
	---------- Moisture ----------				
Oct.	74.6(5.3)	79.7(0.6)	79.9(9.4)	79.1(0.3)	78.2(9.4)
Nov.	--------	81.4(0.5)	80.4(0.6)	79.8(0.7)	---------
Dec.	82.8(0.2)	---------	81.7(0.3)	81.9(0.2)	---------
Feb.	---------	---------	---------	---------	79.2(0.3)
Mar.	---------	---------	---------	---------	80.7(0.5)

Table 21. Product yields during processing of calico scallops during 1983-84. Data per process category represents 6 random samples per one vessel with 25 meats per sample.

	Meat Counts Per Pound; Average (Std. Deviation)			
Month	Hand Shucked	Mech. Shucked	After Evisceration	After Chill Tank
Oct.	247 (13)	264 (11)	303 (19)	317 (12)
Nov.	--------	244 (27)	235 (39)	267 (38)
Dec.	115 (5)	--------	159 (9)	136 (6)
Feb.	134 (7)	--------	144 (12)	162 (9)

3.4% after mechanical shucking through the chill tank treatment for respective samples taken during October, November, and March. The apparent weight loss was partially due to moisture loss during processing (Table 22). These results do not agree with reports of water uptake by raw calico scallop meats soaked in water and salt solutions (19). Variation in apparent weight loss would be influenced by the initial condition or quality of the meats and the initial proximate composition. The nutrient composition of calico scallops has been reported to vary significantly by season and harvest location as a consequence of environmental factors. The average monthly moisture contents for hand shucked calico scallop meats ranged from 76.1% to 81.9% within one year from one harvest location in North Carolina (46). The average proximate compositions for calico scallops (Table 22) are similar to previous reports and are similar to the compositon for bay and sea scallops (Table 23)

Meat counts also increased during refrigerated storage and the increase was more pronounced at the higher storage temperature (Table 24). Again the probable cause was moisture loss or weight loss, evi-

Table 23. Proximate composition (%) for raw scallop meats

Scallop	Moisture	Protein	Fat	Ash	Calories
Calico (*Argopecten gibbus*)	79*	1.61	0.6	1.5	
	77.8-82.1**	15.4-16.9	02.-1.0	1.4-1.8	79
Bay (*Argopecten irradians*)	80.2	14.8	0.6	1.5	
	78.0-82.9	13.7-16.0	0.3-1.5	1.3-1.7	76
Sea (*Placopecten magellanicus*)	77.8	17.4	0.6	1.6	
	74.6-80.4	15.2-20.1	1.3-1.8		85

* Means and ** Range for reported figures.
*** Calories per 100 grams meat.
Source: Sidewell, V. D. 1981. Chemical and nutritional compositon of finfishes, whales, crustaceans, mollusks, and their products. U.S. Dept. Commerce, National Marine Fisheries Service, NOAA Technical Memoradum NMFS F/SEC-11. 432pp.

Table 24. Mean raw meat counts for calico scallops mechanically shucked and packed in gallon containers stored at 1.7°C (35°F) and 7.2°C (45°F) for 17 days. Means represent the average of 3 samples per storage day and temperature, and all samples came from the same vessel harvest in March.

Days Storage	Raw Meat Counts (total meats/pound) 35°F Storage	45°F Storage
1	139	135
5	139	158
9	140	147
13	144	155
17	142	156

dent as accumulative weepage in the bottom of the containers. The weepage fluid was a "milky" colored liquid typical for drip loss containing soluble proteins. During prolonged refrigeration weepage was more evident at the higher storage temperature, 7.2°C (45°F) which resulted in a 14.8% increased meat count after 13 days storage.

Thus, recognizing the variable increase in raw scallop meat counts during processing and storage, any attempts to establish fishery management plans relative to meat size limits must consider harvest size by sampling prior to processing. Attempts to apply a correction factor for meat counts after processing and storage would be complicated by size and/or weight variations due to environmental factors, harvest location and season, initial condition or quality of the meats, processing conditions, and storage to time and temperatures. These factors will vary per season, per vessel, and per processing firm, thus prventing use of processed meats to predict and regulate fisheries management.

OCCURRENCE AND SURVIVABILITY OF PARASITES

The encysted parasites, Sulcascaris sulcata, visible on the surface of the raw meats, were present in all harvests throughout the duration of the study. Percent surface occurrence ranged from 14% to 40% with no discernible pattern in occurrence relative to season, scallop size, or harvest location. Results for percent occurrence in the harvest are currently undergoing further investigation to appear in later reports (47)

The occurrence of parasites was often in excess of FDA's temporary 20% action level for adulterated product. Attempts to avoid harvesting scallops with high levels of infestation proved futile and impractical. Occurrence could not be predicted by fishing depth, bottom type, location, scallop size, or season. Fishing efforts substantiate previous reports on futility in trying to avoid occurrence (29). Likewise, attempts to remove the infested scallops by hand slowed the culling procedure. Hand culling is totally impractical realizing meat counts can range in excess of 250 meats per pound, parasites are difficult to detect, internal parasites are not visible and the culling rate must match the production rate of the mechanized shucking/evisceration equipment. A slow culling rate causes product accumulation and backups which expose the meats to potential contamination and thermal abuse. Further sorting prior to packaging was also impractical and enhanced thermal and microbial abuse.

Additional processing on the evisceration apparatus was investigated in an effort to remove parasites while processing. The thought was to use the abrasive action of the rubber coated evisceration rollers to grind the parasites from the surface. After three runs for the same scallop meats (10 gallons) passed across the same eviscerator, the viable parasite counts still remained as initially recorded. The additional process could not remove parasites internally viable within the individual scallop meats. Scallop meats with an initial meat count of 136±6 (n=250) increased in counts to 144±7 and 155±6 after a second and third pass over the eviscerating table, respectively. Thus extra evisceration caused 5.9% and 14.0% increase in meat count and the surface of the extra processed meats was soft and fragmented. The result of extra evisceration resulted in lower yields, inferior product quality and presistent parasites. Thus no alternate methods for processing seem plausible or practical for removing the parasites to decrease percent occurrence without detrimental influences on product quality.

Recognizing calico scallop parasite infestations often exceed 20% and processing cannot decrease percent occurrence, attempts focused on killing the larval nematodes to minimize aesthetic problems. An initial study monitored survival of the parasites during typical processing. After the various processing stages, at least 20 individual larval parasites were dissected and placed in either Earl's solution or saline solution at room temperature, 68-70°F. Parasites were considered to be displaying a live response if they moved while soaking and being agitated within 1 hour in the solution. The survival of the

larval parasites was determined using scallop meats of shellstock immediately upon ship arrival at dockside, after steam shucking, after evisceration by rollers, immediately after cooling to 5°C (40°F), and after 1 day storage at 5°C. Approximately 45% of the external parasites present were able to survive complete processing and refrigerated storage for one day (Table 25). Thus the calculated percent live parasite occurrence for this one harvest exceeded 17%. Further sampling from additional vessels and during October through August indicated the percent survivability for parasites present ranged from 40% to 60%. Thus the possible percent live parasite occurrence for processed meats during this study was calculated to range from 5.6% to 24% (% occur- rence X range in % survivability).

Additional cooling and freezing during storage of processed meats could decrease the parasite survivability (Table 26). Refrigerated storage from 1.7°C (35°F) to 0°C (32°F) could depress survivability but the results varied depending on the initial condition of the scallops and parasites. Variability in survival was evident for the results for separate harvests stored for 45, 70 and 168 hours. In trials, for encysted parasites exposed to 0°C (32°F) for 70 hours, survivability reached 20%. Thus recognizing fresh calico scallops can be distributed to markets and consumers within less than 72 hours after processing, parasite survival is possible on raw refrigerated meats. Although prolonged super chilling (-1.0°C; 30.2°F) provided more kill than typical refrigeration temperatures, frozen storage (-3° or -30°C) provides the only complete kill of all parasites on the meats.

Table 25. Occurrence and survival of larval parasites, Sulcascaris sulcata encysted on raw calico scallop meats during harvest and processing from one vessel.

Stage of Processing	% Total Occurrence* per 100 meats	% Survivability** per 20 parasites	%Live Parasite*** Occurrence
Shellstock	38	60	22.8
Steam-Shucked	36	40	14.4
Eviscerated	37	25	9.3
Cooled (5°C) (immediate)	39	45	17.6
(One day)	38	45	17.1

*% Total Occurrence accounts for all meats with at least one visible, external cyst.

**% Survivability accounts for all parasite nematodes displaying an alive response. Sample size included 20 parasitized meats.

***% Live Parasite Occurrence = % Occurrence X % Survivability

Table 26. Affects of additional cooling and freezing on survivability of parasites, S. sulcata on raw calico scallop meats.

Storage Temp. °C	Storage Temp. °F	Exposure* Hours	Number Meats with Parasites	No. Parasite Surviving	Percent Survivability
1.7	35.1	45	37	1	3
1.7	35.1	70	20	13	65
1.7	35.1	68	31	2	7
1.7	33.8	12	30	17	57
0**	32.0	45	39	1	3
0	32.0	70	15	3	20
0	32.0	168	38	0	0
-1.0***	30.2	13	30	10	33
-1.0	30.2	45	34	0	0
-1.0	30.2	70	19	2	11
-3.0	26.0	45	29	0	0
-30.0	-22.0	70	21	0	0

* Exposure trials for 45, 70 and 168 hours include two separate harvests.
** Iced Storage
*** Super chilled product, remained unfrozen.

Parasite survivability was also depressed by elevated temperatures in excess of 30°C (86°F) (Table 27). These results were determined for live parasites dissected from the meats and subjected to temperatures elevated above normal processing conditions. Temperatures of 35°C (95°F) or above provided an immediate, total kill. Thus it is doubtful that parasites, even if eaten as part of uncooked scallop meats, can survive a human body temperature of 98.6°F (37.5°C). Although this is a promising result, normal heating procedures (at least for short durations) which may allow the internal meat temperature to reach 95°F thereby killing all the nematodes, may heat the exterior of the meats above 100°F (43°C) thus initiating cook and affecting meat quality.

Although it is clear that the nematodes cannot survive human body temperatures, other experiments were performed to determine the effects of mammalian digestive juices upon the survivability of the nematodes. Nematodes were dissected from scallop meats and force-fed to white mice by holding the mouths open and forcing the living, whole parasite down the esophagus into the stomach. The mice were then sacrificed at various time intervals to determine the presence of parasites in the stomachs. Parasites were also directly exposed to gastric juices extracted from the stomachs of mice. The results of the digestive experiments are shown in Table 28. In no instance was it possible to find the presence of the nematodes. Even after only 15 min. in the stomach the parasites were apparently digested. In the extracted gastric juices parasites began to dissolve in only 5 minutes and within 15 min. discernible parasites could not be detected. Thus, there appears to be little possibility that larval Sulcascaris sulcata poses a threat to human health.

Table 27. Survivability of live parasites (20) dissected from calico scallop meats, suspended in Earl's solution, then exposed to temperatures elevated by water bath treatment.

Temperature of Bath °C	°F	No. Alive After 1 hr. Exposure	% Survivability
10	50	20	100
15	59	20	100
20	68	15	75
25	77	12	60
30	86	5	25
35	95	0	0
40	104	0	0

Table 28. Effects of mouse ingestion and digestive juices on survivability of nematodes, S. sulcata on calico scallops.

Number of Mice	No. Nematodes Feed/Mouse	"Digestion" Time (mins)	No. Nematodes Recorded
10	20	60	0
10	20	30	0
10	20	15	0
10*	20	15	0

Further attempts to kill parasites with heat included an innovative steam tunnel installed after evisceration and prior to the chill tank. The tunnel specifications were designed by a participating scallop firm requesting equipment confidentiality. The tunnel was operating at an internal temperature of 49°C (120°F). Eviscerated scallops with an external temperature of 26.6°C (80°F) entered the tunnel for a residence (exposure) time of 10 to 20 seconds. Although the steam tunnel imparted additional parasite mortality (Table 29), the steam treated meats had a noticeably softer, fragmented texture which was detrimental to final production quality. Subsequent storage at 1.7°F (35°F) indicated the steam treated meats spoiled more rapidly than nonsteam treated meats. The steam tunnel was declared partially effective but detrimental to meat quality. The experimental tunnel was removed from the processing operation.

Further heat applications were performed using a conventional microwave oven in an attempt to rapidly elevate both the external and internal meat temperature sufficiently to destroy the nematodes but not significantly affect meat quality. In these experiments meats containing at least one parasite were exposed to high and low settings of the microwave oven for various periods of time after which the parasites were dissected and their survivability assessed. As in the previous experiments, external and internal meat temperature had to exceed 30°C (86°F) in order to significantly affect the parasite survivability (Table 30). Length of exposure as well as degree of exposure also affected survivabiltiy with a low microwave setting for 60 sec. or a high setting for 15 sec. necessary to kill greater than

Table 29. Survivability of nematodes following heat treatment in a steam tunnel 49°C (120°F). Averages represent results from three separate vessels identified as A-C. All vessels landed the same day in December.

Vessel	Stage of Processing	% Total Occurrence per 100 meats	No. Parasites Alive	Percent Survivability
A	eviscerated*	22	9	41
	steam treat.	17	3	18
B	eviscerated	12	2	17
	steam treat.	13	2	15
C	eviscerated	18	7	39
	steam treat.	17	4	24
Average	eviscerated	17	6	35
	steam treat.	15	3	20

* Separate samples (100 meats) were taken immediately after evisceration and after steam tunnel treatment.

Table 30. Survivability of parsasites, S. sulcata after microwave heat treatments. All scallops treated came from the same original harvest through typical processing. Initial infestation level was 27%.

Energy Setting/Time(Sec.)	Resutling Meat Temp. °C (O)	(I)	No. Parasitzed Meats Treated	Percent Survivability
Control (no treatment; iced)				
Low/30	29	28	10	60
LoW/30	29	28	10	40
Low/30	30	28	10	50
Low/60	45	43	10	0
Low/60	45-50	41-42	10	0
Low/60	40-50	40	10	10
High/15	41.5		5	20

* (O) = outside meat temperature; (I) internal meat temperature.

90% of the parasites. Ice treament following microwave application was deemed necessary for good manufacturing practice, but the cold temperature stopped residual heating and enhanced parasite survival (Table 31). Thus the microwave technique appears to offer some promise. Meat quality did not appear to be affected by the high setting/short time microwave treatment. If the technique were applied to the commercial operation, careful monitoring would have to be employed to ensure that meat temperatures reached 40°C for a least 60 sec. or 45°C for 15 sec. Continuous treatment of microwave units for commercial in-line application are available and may be applicable to continuous processing schedules.

Scallop meats were also exposed to a series of "soaks" to determine if the parasites could be killed by disrupting their osmotic balance. Scallop meats containing surface parasites were placed in two concentrations of sodium bisulfite for 12 hrs. after which time the survivability of the nematodes was determined. Many of the parasites appeared to tolerate concentrations ranging from 0% (fresh water) to 0.05% bisulfite (Table 32). In fact, the parasites from scallops in the higher concentration appeared to be stimulated ("hatched" and crawling on the meats). The bisulfite soaked meats retained their color and odor, but they were swollen and soft. Survivability and detrimental product quality precluded continued use of soaks to kill parasites. Likewise, the prevailing regulatory concerns for use for sulfiting agents in foods would probably eliminate such treatments.

Finally one of the newer techniques in food processing is sonication. A Bronson E-module ultrasonic generator was utilized to deter-

Table 31. Survivability of parasites, S. sulcata after microwave treatments and subsequent ice treatment. All scallops came from the same original harvest through typical processing. Initial infestation was 18%.

Energy Setting/Time(Sec.)	Resutling Meat Temp (°C)	Ice Treatment No.* P-meats	Ice Treatment Surviv.** (%)	No Ice Treat. No. P-meats	No Ice Treat. Surviv (%)
High/15	45	11	0	12	0
		12	0	13	0
		9	11	12	0
Low/60	43	13	7	8	0
		10	10	8	0
		8	0	13	0

*No. P-meats - number of parasitized meats treated
**Surviv. - % Survivability

Table 32. The effect of sodium bisulfite "soaking" on the survivability of nematodes.

Bisulfite Concentration (%)	No. Parasitized Meats treated	Percent Survivability
0	20	40
.25	20	40
.50	20	40

mine the effects of sonication on parasite survival. The generator was attached to a 6 inch circular metal water jacket surrounding a central plastic tube (one inch diameter). The plastic tube could be filled with the material to receive sonication and the sonication was transmitted from the generator through the water surrounding the tube. Water temperature in the jacket was circulated through refrigeration to control temperature. The sonication destroyed all dissected parasites suspended in the plastic tube of water, but the parasites within cysts on the scallop meat survived the same application (Table 33). Survival precluded continued use of sonication.

Thus, it appears that physical removal of the parasite is not possible and destruction of the parasite is difficult although it may be possible with alterations in the present processing and handling techniques. However, even without these changes to kill the parasite, the evidence from this study further substantiates the fact that the neamatodes are killed by human body temperatures and are easily dissolved by digestive juices.

Table 33. The effects of sonication on survival of parasites, S. sulcata from meats of calico scallops.

Vibration Time	Water Temp. (C) initial	final	No Parasitized Meats Treated	Survivability %
60 (meat)	24	27	5	100
120 (meat)	24	28	3	100
60 (dissected parasites)	24	27	3	0

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