Microbiological Evaluation of Cold-Water Shrimp (*Pandalus borealis*)

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A bacteriological survey of the Maine shrimp industry was conducted to investigate the conditions associated with the production of frozen, raw, peeled shrimp. In-plant samples and finished product units were collected from seven plants. The most probable number of *Escherichia coli*, coliforms, and coagulase-positive staphylococci, as well as aerobic plate counts (APC), were determined. Freshly harvested shrimp collected from fishing vessels had an APC geometric mean of 510/g, and *E. coli*, coliforms, and coagulase-positive staphylococci were absent. Subsequent storage and insanitary practices during processing increased the APC and introduced coliforms. However, the low air temperatures (18 to 45 F) in the plants and the large volumes of cold water (34 F) used during processing inhibited significant bacterial build up in the finished product.

The presence of cold-water shrimp (*Pandalus borealis*) along the coast of Maine has been known to New England fishermen since the early 1900's. However, only in the past five years has the commercial value of this seafood commodity been explored.

In 1967 the Bureau of Commercial Fisheries reported that 3.1 million pounds of shrimp had been landed in Maine. In the 1972 season (December to April), 18.6 million pounds of shrimp were landed (3).

This survey was made to investigate the sanitary conditions and the bacteriological quality of raw, peeled shrimp during production. Shrimp processed during this investigation were received from locally operated fishing vessels harvesting their catches in the Gulf of Maine, generally within 15 miles of the coast. Shrimp catches were returned to the processing plants within 12 h after harvesting.

**MATERIALS AND METHODS**

**Collection of samples.** Gulf of Maine shrimp (*P. borealis*) are usually unloaded from the fishing vessels at the dockside plants by a canvas or wire bucket hoist system. A conveyor system transfers the shrimp to storage bins (2,000- to 10,000-lb capacity) filled with cold water, or they are iced for overnight storage. The next morning the water is drained from the storage bins, and the shrimp are moved by a conveyor system to automatic peeling machines. (In a hand-peeling operation, the shrimp are placed in metal buckets and carried into a processing room for peeling.)

After peeling, the shrimp meats fall into a water flume leading to a series of washer mechanisms that remove the remaining shell from the meats. A final inspection precedes the packing and weighing operation. The finished product is then packed in bulk consumer-size packages and frozen. Shrimp meats are also processed for instant quick freeze (IQF) in individual, frozen pieces and packaged before freezer storage. Line samples of raw, unpeeled shrimp, line samples taken during various stages of processing, and samples of the finished, raw shrimp meats were collected aseptically. Immediately after collection, the samples were placed in the firm's freezer. When the inspection was finished, the samples were transported under dry ice to the laboratory. In general, analysis of the samples was begun two weeks from the date of collection.

In this investigation, a total of 121 finished product samples and 135 line samples were collected from seven shrimp meat processing plants.

Sanitation was judged by observing cleanliness, equipment construction materials, cleanliness of building, employee sanitation, and hygienic practices in conjunction with time-temperature abuse of the product. Four of the seven plants were graded as poor for sanitation on the basis of these criteria. The remaining three plants were graded as marginal, for in certain operations they still used practices that were considered objectionable and in need of improvement.

**Analytical procedures.** The methods of the Association of Official Analytical Chemists (1) were used to determine the aerobic plate count (APC) and the most probable number (MPN) of coliforms, *E. coli*, and coagulase-positive staphylococci.

**RESULTS AND DISCUSSION**

**Raw shrimp.** Eight samples of freshly harvested, unpeeled Gulf of Maine shrimp were
collected from returning fishing vessels before they were unloaded. Coliforms, E. coli, and coagulase-positive staphylococci were not found. Most of the reports on the microbiological flora of freshly caught shrimp indicate the absence of coliform bacteria. Gulf Coast shrimp, Pacific shrimp, and fresh pond shrimp were examined by Williams et al. (10, 11), Harrison and Lee (6), and Vanderzant et al. (8), respectively. Coliform bacteria were generally absent, although Green (5) found bacteria of the E. coli-Aerobacter aerogenes group in half of all samples of freshly netted shrimp from the coast of Louisiana; E. coli was isolated from one sample.

The APC of freshly harvested Gulf of Maine shrimp ranged from <100 to 1,600/g, with a geometric mean of 510/g. These data are comparatively lower than data reported on shrimp harvested in other areas of the United States. In Gulf of Mexico shrimp, Green (4) reported an APC of 42,000/g and Vanderzant et al. (9) found an APC of 210,000/g. Harrison and Lee (6) reported on Pacific shrimp and found an APC ranging from 300,000 to 1,300,000/g.

Storage. Plants operating under poor sanitary conditions provided numerous avenues for bacterial contamination of the finished product, chiefly the extremely poor storage conditions of raw shrimp between time of receipt from fishing vessels and entry into the processing equipment. Results of samples of unpeeled shrimp collected from storage bins of plants classified as having poor sanitation (group X) showed an APC of 95,000/g (Table 1). Samples collected from storage bins of firms classified as having marginal sanitation (group Y) had an APC of 2,500/g.

Unsanitary conditions in group X included the unloading of shrimp from the holds of fishing vessels by canvas buckets heavily encrusted with organic material. Shrimp were spilled from these overfilled buckets onto the loading dock, which was frequented by animals and birds. The shrimp were shoveled from the dock onto the conveyor system leading to poorly constructed storage bins with wooden side walls, pitted concrete floors, and negligible drainage. Shrimp collected from this bin after 12 h of overnight storage had an APC of 360,000/g and an average MPN of 460 coliforms/g. E. coli ranged from 3.6 to 7.2/g.

In contrast, group Y stored its shrimp in clean, stainless-steel holding bins or plastic tubs. Ice was added, and the shrimp were held near 32 F overnight. Samples collected the next morning showed an APC of 220/g and no coliforms or staphylococci.

Peeling. Shrimp were gravity fed from the openings at the base of the holding bins into stainless-steel troughs where rapidly flowing water (city water or chlorinated sea water) carries the shrimp to an inclined conveyor. Water temperatures averaged 34 F. Group X plants showed a reduction in APC from 110,000/g before entering the peeling operation to 2,700/g after peeling. Coliform MPN averaged 12/g and E. coli MPN averaged 10/g; no staphylococci were found. This reduction in counts, except for E. coli, could be attributed to the washing effects the shrimp received while being flumed from the bins to the peelers. Large volumes of cold water were used in the automatic peeling equipment.

Plants in group Y, which included the two hand-peeling operations investigated, surprisingly showed a reduction in counts. The APC was 1,700/g before peeling and 93/g after peeling. The small volume of shrimp processed (in comparison with mechanical peelers) appeared to lend itself to better sanitary control than did production lines.

Washing. In the mechanical peeling operations, shrimp meats were washed by passing through potable water in a series of mechanical washers. In hand-peeling operations, the shrimp were washed in a colander with tap water. Shrimp were found to be free of coliforms and staphylococci; the average APC was 550/g.

Sorting-weighing. These processing steps are continuous in plants that process shrimp meats in bulk consumer-size packages. In the

| Table 1. Results of analyses of raw shrimp collected from shrimp plant holding bins* |
|-----------------------------------------------|
| Plant                      | Sanitary conditions | Samples examined (no.) | Aerobic plate count/g |       |
| Group X (C, D, F, G)       | Poor               | 15                    | 1,400-750,000         | 95,000 |
| Group Y (A, B, E)          | Marginal           | 9                     | 100-16,000            | 2,600  |

*No coagulase-positive staphylococci were found. E. coli MPN avg/g for plant C was 1.2; all other plants were negative. Coliforms MPN avg/g for plant C was 460 and for plant G, 0.19; all other plants were negative.
IQF process, the weighing is interposed by employees sorting each piece of shrimp meat on a vibrating conveyor belt that moves through a −350 F freezer tunnel for 5 to 7 min. Plants in group X used equipment that was not cleaned before use, or else a combination of insanitary equipment and poor sanitary practices by employees at the sorting lines contributed to the increased APC. Samples collected during and after this IQF operation showed an APC of 47,000/g, a coliform average of 8.8/g, and no E. coli or staphylococci.

Similar insanitary conditions were found in group Y plants. Sanitary control was good until the shrimp meats were weighed into consumer packages before freezing. Employees handling the product with insanitary hands at this point did not significantly increase the total bacterial counts, but they did influence the microbial quality. Coagulase-positive staphylococci ranging from 3.6 to 9.1/g first appeared in the product after insanitary handling. Comparative studies on raw, breaded shrimp by Surkiewicz et al. (7), on cooked shrimp by Harrison and Lee (6), and on raw, iced shrimp by Carroll et al. (2) reported that the bacterial content of the finished product was a reflection of the sanitary conditions in the plant.

**Finished product.** Table 2 reports the results of analysis for in-line and finished product samples for the two plant groups. In this survey we examined 121 finished product samples of frozen shrimp meats. The APC ranged from 850/g in marginally sanitary plants (group Y) to 8,900/g in poor sanitation plants (group X). Coagulase-positive staphylococci were isolated from 12 (10%) of the finished product samples. (A majority of the isolations were from plants that abused the product during the sorting operation.) Of the samples examined, 47 (39%) contained coliforms. Group Y plants had an average coliform count of 5.2/g, in comparison with 7.6/g for group X plants. About 3.6/g of E. coli was found in 3 (<1%) of the samples.

In spite of poor sanitary conditions and various avenues for bacterial contamination, significant bacterial build-up after the shrimp were peeled was inhibited by the use of copious amounts of extremely cold water throughout the equipment and by the rather cold air temperatures in all processing areas except the packaging room. The average water temperatures (potable city water or chlorinated sea water) were 34 F, and the air temperature of the storage area averaged 42 F (18 to 45 F). Temperatures of shrimp stored as raw material generally did not vary more than a few degrees from the air temperature. The shrimp were subjected to short periods of warm-air temperatures (45 to 70 F) only when they entered the peeling and packaging areas. However, most temperature readings at the processing lines and at the end of the packaging operations were less than 50 F. Low air and water temperatures, in combination with average shrimp processing time (time from raw-material storage bins to freezer) of less than two h, precluded any significant bacterial build-up in the finished product.

This survey revealed that cold-water shrimp (*Pandalus borealis*) contain very low APC. Storage conditions prior to peeling expose the shrimp to opportunities for bacterial contamination that include sanitary index bacteria of the *E. coli*-*A. aerogenes* group. Peeling and washing steps reduced the number of bacteria to a level comparable to that existing when the

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**Table 2. Results of analyses of raw shrimp collected at plants**

| Plant* | Sanitary conditions | Type of sample | Samples (no.) | Coliforms (MPN avg/g) | Aerobic plate count/g |
|--------|---------------------|----------------|---------------|-----------------------|----------------------|
|        |                     |                |               |                       | Range                | Geometric mean      |
| Group X (C, D, F, G) | Poor                | In-line        | 89            | 31.8                  | <100–2,100,000       | 8,900               |
|        |                     | Finished product | 80            | 7.6                   | 800–240,000          | 17,000              |
| Group Y (A, B, E)  | Marginal            | In-line        | 46            | 1.0                   | <100–16,000          | 660                 |
|        |                     | Finished product | 41            | 5.2                   | <100–4,800          | 850                 |

* E. coli MPN avg/g was negative except for plant B (0.7 for finished product samples); plant C, in-line sample MPN avg/g of 1.5 and finished product samples MPN avg/g of 0.2; and plant D (in-line samples, MPN avg/g of 4.2). Coagulase-positive staphylococci MPN avg/g was negative except for plant B (2.5 for finished product samples); plant D (0.2 for finished product samples); and plant E (2.2 for finished product samples).

* All plants used mechanical peelers except A and E, which used hand-peeling procedures.

*IQF* shrimp.
shrimp were first harvested. However, human handling of shrimp meats during sorting and weighing increased the bacterial counts, and this handling can introduce organisms, namely, coagulase-positive staphylococci, that have public health significance.

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