

Hazard Analysis & Critical Control Point Applications to the Seafood Industry

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In the near future, federal legislation¹ may make adequate safety assurance programs mandatory for all food processors. The seafood industry should be aware of this development and be prepared for it. While seafood is no more sensitive to processing hazards than are other fresh foods, the particular methods used by seafood processors require individual attention in designing a safety assurance program that will match the industry's needs.

Whatever form seafood legislation may finally take, it will almost certainly stipulate that food processors set forth in writing the procedures they use to identify the control points in the processing operations and the hazard associated with each point. They will also be required to establish adequate control measures and an adequate monitoring plan for each point. In short, the regulation will require food processors to establish safety assurance programs based on the rational and systematic approaches of the Hazard Analysis and Critical Control Points (HACCP) concept.

This bulletin is intended to explain HACCP and to explore its applications in the seafood industry of the Pacific Northwest. Processing models are suggested for fish smoking (figure 1), cooked and picked crab processing (figure 2), and cooked and peeled shrimp processing (figure 3). Other models of processing methods are also possible.

What Is Hazard Analysis?

The hazard analysis (HA) portion of HACCP requires the processor to estimate the degree of hazard associated with each commodity produced, the intended use of the product, the modifications the processor might need to incorporate, and the possibility and extent of abuses incurred by the distributor and by the consumer.

Foods and food ingredients are grouped according to the degree of risk inherent in the product. This classification is based on scientific and epidemiological data. The Pillsbury Company, which pioneered the development of HACCP, has grouped food ingredients into five hazard categories, shown in table 1. Unfortunately, no seafood ingredients are included in this table.

Seafoods are basically protein foods that can be enjoyed by all age groups. Therefore, no seafood item would be classified as a category intended solely for infants or the elderly. Nevertheless, a seafood processor filling an institutional order for a nursing home or a hospital should be aware that the risk factor increases in people who have an impaired immune system.

Most seafoods fall into hazard categories 2 or 3 of table 1, where there is some degree of risk. Table 2 lists seafood items in decreasing order of risk.

Thermally retorted products such as canned tuna and canned smoked oysters are excluded because they are already regulated

¹The 1990 Congress adjourned before passing a mandatory seafood inspection bill. Industry leaders plan to continue efforts to write acceptable legislation.

TABLE 1. Food ingredient hazard categories in order of decreasing risk

CATEGORY	DESCRIPTION	EXAMPLE
1	Special foods intended for special populations	Infant and geriatric foods
2	a. Sensitive ingredients	Eggs, milk products
	b. Compound ingredients (30% or more sensitive)	Spray-dried shortening with more than 30% milk products
	c. Ingredients stored in a plant where sensitive ingredients are processed	Chicken fat premix stored in an egg plant
	d. New ingredients	
3	Compound ingredients (30% or less sensitive)	Spray-dried flavor with 24% nonfat dry milk
4	Ingredients of agricultural origin not previously shown to be a source of harmful microorganisms or chemicals	Wheat, starches
5	Ingredients historically free of pathogens or residues	Citric acid, sugar, salt

Adapted from Bauman (1).

under Good Manufacturing Practices Regulations, 21 CFR (Code of Federal Regulations, part 128 b) of the Federal Food, Drug and Cosmetic Act (Federal Register 3d, 2398, Jan. 24, 1973), which make safety assurance procedures mandatory for these items.

Seafood products may be divided into (1) raw seafoods, (2) processed raw foods, (3) processed foods, and (4) formulated products. Examples of raw seafoods are oysters in the shell, live crabs, and live finfish. Processed raw foods include gutted salmon, fish fillets, and shucked oysters. Processed foods include peeled shrimp and picked crab meat. Examples of formulated products are fish sticks, breaded shrimp, and seafood analogs.

Seafood products may be frozen, refrigerated, or stored at ambient temperature. While no fresh seafood should be stored at ambient temperature, some products may be exposed to ambient temperatures for varying lengths of time during processing, packaging, shipping, or market display.

Seafoods may also be consumed after cooking or without further cooking.

Discounting environmental factors and the influence of harvest and on board handling variables, neither of which can be ignored when the processor formulates an individual HACCP program, the rule of thumb is as follows: the risk increases (1) with more handling, (2) with higher storage temperature, (3) and if the product is not to be cooked further by the consumer.

TABLE 2. Seafood hazard categories in order of decreasing risk

CATEGORY	DESCRIPTION	EXAMPLE
1	Heat-processed foods usually consumed without additional cooking	Crabmeat, peeled shrimp and smoked fish
2	Nonheat-processed raw foods often consumed without additional cooking	Fish and shucked molluskan shellfish eaten raw
3	Formulated foods usually consumed after cooking	Fish sticks and breaded shrimp
4	Nonheat-processed raw foods usually consumed after cooking	Fresh or frozen fish fillets and cooked molluskan shellfish
5	Raw seafoods usually consumed after cooking	Live crustacean and molluskan shellfish

These considerations were taken into account when the hazard categories of seafoods (table 2) were developed.

Foods and their ingredients may also be assigned a classification that identifies the source of the hazard (table 3). Sources are broken into three areas and listed in order of (1) the hazard inherent in a food or ingredient, (2) the hazard that is introduced during processing, and (3) the hazard that may be introduced by consumer abuse. The + denotes the presence of a hazard, and the 0 denotes the absence of a hazard. Thus, each food can be assigned a hazard classification as shown in the third column of table 3.

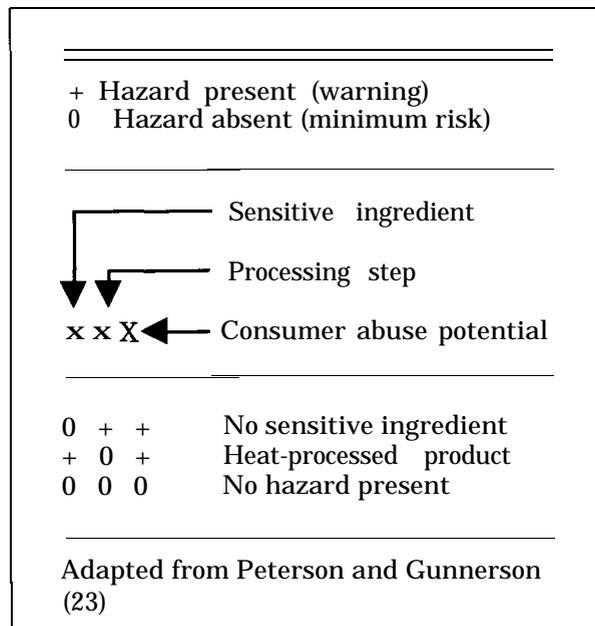
Some of the seafood products can be classified according to the hazard class assignment system as follows:

	Sensitive ingredient	Processing step	Consumer abuse potential
1. Smoked fish	+	+	+
2. Cooked and peeled shrimp	+	+	+
3. Fish stick	+	+	+
4. Salmon in round	+	0	+
5. Oyster in shell	+	0	+
6. Dried fish or jerky	+	+	0

In essence it is difficult to find any seafood product absolutely free of potential hazard as a raw material, or any that can be assumed to withstand the extreme abuse of the consumer. Even bone-dry jerky containing sufficient salt could become hazardous in extreme cases of abuse. Realistically, however, we have to determine the hazard on a relative rather than an absolute scale. The International Commission on Microbiological Specifications for Foods (ICMSF) has addressed this problem and published its seafood risk categories (26).

The assessment of hazard described above is based on concerns for public health risks. In 1987 the National Marine Fisheries Service (NMFS) launched the Model Seafood Surveillance Program (MSSP). The purpose of this program is to develop HACCP for each seafood commodity in consultation with respective industry representatives after a series of workshops. MSSP's hazard categories include seafood plant sanitation and economic fraud, along with the public health risks. Thus MSSP addresses more health hazards than does ICMSF (21).

TABLE 3. Food product hazard class assignment



What Is a Critical Control Point?

A critical control point (CCP) is defined as a point in the processing steps where the failure to effectively control a potential hazard may create an unacceptable risk. The time and temperature specified for smoking fish are examples of CCPs, and the control at these points should never fail. The CCP should be under constant control by humans or by machines, and the performance of the control step should be monitored and documented.

All other processing steps that involve the control of microorganisms are the control points (CP). Failure to control these points might not result in a definite health hazard, but it would indicate a potential risk not to be ignored. Many steps in seafood processing fall into this category. CCPs and CPs will be discussed individually in conjunction with the model HACCP for (1) smoked fish, (2) picked crab meat, and (3) peeled shrimp.

MSSP differentiates CCP and CP, although both CCP and CP contain hazards unrelated to public health. The International Commission on Microbiological Specifications of Foods introduced the concept of CCP1 and CCP2 (27). In CCP1 the control is absolute, as with heat inactivation of bacteria. In CCP2 the control is partial, for example, the removal of microorganisms from fish skin by washing. In addition, the National Food Processors Association (NFPA) proposed a system called Comprehensive System for Product Control (CSPC). Its purpose is to address the safety issues under HACCP, the nonsafety-related regulatory issues under Regulatory Compliance (RC), and the in-house quality controls issue under Quality Control (QC). Thus NFPA proposes three levels of control (9).

It is not certain at this stage which concept or system eventually will be adapted. Therefore, for the time being we will stick to CCP and CP, or the two-level control system.

Microbial Hazards of Seafoods

The microbial flora of seafood directly reflects the environment from which the fish or shellfish is extracted (15). The gill, intestine, and slime of the fish contain specific microorganisms. The mud attached to bottom fish, crab, and shrimp is another source of microorganisms. If microbial buildup is allowed to occur in the fish hold it will further add to the microbial load of seafoods.

Because the microbial quality of seafood is so dependent on its environment, the sessile shellfish is especially vulnerable to pollutants introduced into its growing waters.

The following pathogenic microorganisms are characteristically associated with seafoods. Their control should be considered critical. The important characteristics of these bacterial agents, discussed in the following section, are summarized in table 4. Table 5 lists the food pathogens and seafood items especially vulnerable to each pathogen.

In recent years, microorganisms have been recognized that are not pathogenic to "normal," healthy individuals but are

extremely virulent to certain susceptible individuals. Because of the severity of the symptoms they cause, these microorganisms are included among the pathogens described below.

1. *Clostridium botulinum*

An anaerobic, spore-forming bacterium, *Clostridium botulinum* is found in soil, sediment, fish intestines, and water (3). Seven different types of *C. botulinum*, designated from A to G, are currently recognized. Types A, B, and E are most commonly implicated in human botulism. The spores of types A and B are heat resistant and thus require heating at or above 250° F for over 15 minutes to be destroyed. Salt (NaCl) in excess of 10%, acidity below a pH of 4.6, or a temperature below 50°F will prevent the growth of types A and B.

Type E *C. botulinum* is found abundantly off the Alaska, Washington, Oregon, and northern California coasts in soils, sediments, and the intestines and gills of fish and shellfish. It is less resistant to heat than are types A and B and can be destroyed by heating at or above 180°F for over 30 minutes. Type E cannot grow in seafoods that contain salt (NaCl) in excess of 6% or acidity below pH 4.8, but it can grow and produce toxin at temperatures as low as 38° F.

Botulism poses a threat for two reasons. First, it produces one of the most potent poisons known to humans. It doesn't take

TABLE 4. Growth and heat inactivation characteristics of food poisoning bacteria important in seafood processing

Bacteria	Growth Temperature (° F)			Lowest pH for Growth	Max. NaCl (%) Tolerated	Heat Inact. (° F/min.)
	Minimum	Optimum	Maximum			
1. <i>C. botulinum</i> types A&B	50	95	118	4.6	10.0	>250/15'
type E	38	86	113	4.8	6.0	>180/30'
2. <i>Vibrio</i> spp.	41-46	95-97	108-111	5.0	9-10	>140/30'
3. <i>Salmonella</i> and <i>Shigella</i>	42	99	115	5.0	8.0	>140/30'
4. <i>S. aureus</i>	44	95	117	4.8	17.0	>145/30'
5. <i>C. perfringens</i>	59	113	122	5.0	5.0	>212/100'
6. <i>L. monocytogenes</i>	37	86-99	113	4.9	30.0	>180/30'

TABLE 5. Bacteria pathogens and the most sensitive seafoods

PATHOGEN	SENSITIVE SEAFOOD
<i>C. botulinum</i>	a. Smoked fish, including kippered and cold smoked, eaten uncooked
<i>V. parahaemolyticus</i>	a. Cooked picked crabmeat b. Frozen cooked shrimp, prawns, and lobster tail c. Fish eaten raw d. Frozen raw shrimp, prawns, and lobster tail e. Frozen raw breaded shrimp and prawns
<i>V. vulnificus</i>	a. Raw oysters
<i>Salmonella</i>	a. Freshwater fish from warm waters b. Contaminated shellfish
Viral infections, including hepatitis	a. Raw or undercooked shellfish from contaminated waters
<i>S. aureus</i>	a. Smoked fish eaten uncooked b. Frozen cooked shrimp, prawns, and lobster tails
<i>L. monocytogenes</i>	a. Cooked crab and shrimp eaten without further cooking b. Cold smoked fish eaten without further cooking

Adapted in part from ICMSF sampling plans for fish and fishery products (26).

much for this microorganism to become lethal, and a drop of pure toxin can wipe out half a million people (24). Second, an outbreak of botulism food poisoning creates a media sensation, and the resulting negative publicity drastically affects the food industry. For example, in 1982 when two men in Belgium died from eating Alaskan canned salmon, the incident directly cost the industry \$148 million and nearly ruined the canned salmon industry (28).

Our only safeguard against this microorganism is to either totally destroy it by heat or not allow it to multiply in our food. Salt, pH, and low temperature play critical roles in accomplishing the latter objective.

Botulism is caused by the action of a neurotoxin. Symptoms normally appear within 12 to 36 hours after the consumption of a food in which the organism has grown and produced toxin. The most frequently reported symptoms are generalized weakness, blurred and double vision, dry throat, and muscle paralysis, as evidenced by difficulty in swallowing, pronouncing words, and breathing. Gastrointestinal upset, nausea, vomiting, and lack of fever are the first symptoms expressed in type E botulism. If

death occurs, it usually comes 3 to 6 days after the victim ingested the toxin.

2. *Clostridium perfringens*

Although *Clostridium perfringens* is related to *C. botulinum*, it does not produce the potent neurotoxin that *C. botulinum* does. It is widely distributed in soil, and its presence in seafoods itself does not constitute a hazard. Because the organism does not grow at temperatures below 59° F, it is relatively easy to control by proper refrigeration. In fact, it does not become toxic until it has multiplied into millions.

If a seafood dish is prepared from the contaminated seafood and left unrefrigerated, the spores of this organism, which can not be destroyed by heating at 212°F for less than 100 minutes, then germinate, multiply, and produce toxin.

Because of its presence in domestic sewage, *C. perfringens* is sometimes used as an indication of fecal contamination.

The symptoms of perfringens poisoning usually appear within 6 to 22 hours. They are characterized by diarrhea and acute abdominal cramps and to a lesser degree by nausea and headache. The illness lasts about 12 to 24 hours.

3. *Staphylococcus aureus*

Staphylococcus aureus resides on human skin and in mucous membranes. Human handlers contaminate seafoods with this organism through nose and throat discharges and infected skin lesions. The organism is extremely salt tolerant and can withstand 17% NaCl. Because of its salt tolerance it can concentrate in the brine and contaminate any other seafood dipped in that brine (17). It cannot multiply at temperatures below 44° F, but the toxin it produces is heat stable and cannot be destroyed even by boiling for an hour.

Because *S. aureus* is suspected to be of human origin, its presence in food is considered evidence that the food has had excessive human handling.

Food poisoning is caused by the ingestion of preformed enterotoxin. The symptoms of staph food poisoning are nausea, vomiting, severe abdominal cramps, diarrhea, sweating, and headache. Vomiting, the most severe of the symptoms, normally occurs within 4 hours. Symptoms generally last from 24 to 48 hours, and the mortality rate is very low.

4. The *Vibrios*

The *vibrios* are marine bacteria which occur naturally in the environment. Different species may cause gastroenteritis, surface wound infections, and septicemia. The *vibrios* are more frequently found in warmer waters, increasing in number in summer months. The control of *vibrios* can be best accomplished by (1) preventing cross-contamination of cooked seafoods with raw seafoods, utensils, and surfaces; (2) properly cleaning and sanitizing all processing equipment and tables used in seafood production; (3) adequately cooking all seafoods to the proper temperature; and (4) properly handling, refrigerating, and freezing seafoods, particularly to prevent recontamination of cooked, ready-to-eat seafoods.

4a. *Vibrio parahaemolyticus*

V. parahaemolyticus is heat sensitive and can be destroyed by heating at or above 140°F for 30 minutes. It does not grow at temperatures below 41°F or at a pH below 5.0, but it can tolerate salt (NaCl) in excess of 10%. Furthermore, it can grow very rapidly, and so cross-contamination of cooked products followed by favorable incubation temperature must be avoided at all costs.

Outbreaks of gastroenteritis from *V. parahaemolyticus* are relatively new to the U.S. (the first confirmed outbreak occurred in 1971). Cooked crab stored with raw crab in the same cooler and cooked shrimp washed with the unchlorinated seawater were responsible for these outbreaks. Symptoms of gastroenteritis, in order of frequency, are watery diarrhea, abdominal cramps, nausea, vomiting, headache, fever, and chills. Incubation periods range from 4 to 96 hours, and the duration of illness ranges from several hours to 10 days.

4b. *Vibrio vulnificus*

V. vulnificus can cause serious wound infections and fatal septicemia (blood poisoning). Infection may result from eating raw or undercooked molluscan shellfish. Susceptible individuals usually have underlying chronic liver or blood-related disorders that tend to elevate the level of serum iron. The fatality rate is 67% (12).

V. vulnificus is present in the coastal waters of the Atlantic, the Pacific, and the Gulf. It has been isolated from oysters harvested from both approved and unapproved waters. Cooking will destroy this pathogen.

Concern about this microorganism has prompted the State of California to require restaurants to use a warning label for all Gulf oysters served raw (7):

WARNING:EATING RAW OYSTERS MAY CAUSE SEVERE ILLNESS AND EVEN DEATH IN PERSONS WHO HAVE LIVER DISEASE (FOR EXAMPLE ALCOHOLIC CIRRHOSIS),CANCER OR OTHER CHRONIC ILLNESSES THAT WEAKEN THE IMMUNE SYSTEM. IF YOU EAT RAW OYSTERS AND BECOME ILL, YOU SHOULD SEEK IMMEDIATE MEDICAL ATTENTION. If you are unsure if you are at risk, you should consult your physician.

4c. *Vibrio cholerae*

V. cholerae is a bacterium commonly found in warm marine environments. It may also be present in or on some fishery products. *Vibrio* enter the gastrointestinal tract of oysters and clams and can survive for over one month when shellfish are stored at 32-41°F.

V. cholerae non-01, the form more common in the U.S., causes a much milder diarrhea and gastroenteritis than that induced by classical cholera. It has caused some food-borne illnesses in humans from raw molluscan shellfish, but documented cases are relatively few. Illnesses from hepatitis A virus and *V. vulnificus* are more frequent than *V. cholerae* cases. However, *V. cholerae* incidences in seafood are on the rise since its epidemic spread from South America.

5. *Listeria monocytogenes*

Next to *C. botulinum*, the microorganism that concerns the seafood industry most is *L. monocytogenes*. *L. monocytogenes* is a common inhabitant of the intestinal tract of humans and animals. It is a hardy microorganism. Like *C. botulinum*, it can be found in soil and in fish-processing plants. It can also grow at refrigeration temperature, like *C. botulinum*, and it can survive in saturated brine, like *S. aureus*.

L. monocytogenes is extremely virulent to immunocompromised individuals, including pregnant women and unborn infants. The fatality rate for susceptible individuals is as high as 30%.

Of concern to the seafood industry is that the Food and Drug Administration (FDA) has established "zero" tolerance for *L. monocytogenes* in cooked, ready-to-eat seafoods, such as smoked fish, cooked shrimp, and picked crab meats, the three examples used in this booklet to develop model HACCP programs. Crab meats have been seized in Oregon because of the presence of *L. monocytogenes*.

A bright spot in an otherwise worrisome situation is that so far no seafood has been implicated in listeriosis, and the application of normal cleaning and sanitation practices seem to take care of the problem.

In a systematic survey of crab and shrimp processing plants in Oregon, the Oregon Department of Agriculture found *L. monocytogenes* wherever dirt and debris had accumulated—on the floor near the drain, in the floor and wall joint, on walls with peeling paint, and on the tops of processing tables. *L. monocytogenes* was also found in saturated brine and in sea gull droppings. Cooked crab meat and shrimp were contaminated with *L. monocytogenes* by contact with the dirty table top, by steam condensate dripping from the ceiling, and by aerosol generated by the high-pressure hose spray that kicked up the dirt on the floor (20).

When a stringent cleaning and sanitizing regime was enforced, the *L. monocytogenes* problem disappeared. Thus, proper application of detergents and sanitizers at regular and frequent intervals, according to the manufacturer's directions, seems to eliminate the *L. monocytogenes* problem.

Chlorine, either as chlorine dioxide or inorganic chlorine, and quaternary ammonium compound (QAC) at 200 ppm appear to be effective against *L. monocytogenes* (20).

Washing beef carcasses with a sanitizing solution to eliminate *L. monocytogenes* has met with limited success (12). However, fish may be different. According to Dr. Mel Eklund of NMFS, placing cleaned and eviscerated salmon overnight under running water that is chlorinated at 30 ppm and chilled to 38°F seems to eliminate *L. monocytogenes*.

Listeria bacteria are widespread in nature and found in soil, decaying plant material, and the intestinal tracts of animals. Humans can carry the organisms without showing symptoms of infection. While most healthy humans are resistant to the disease caused by *L. monocytogenes*, pregnant women, infants, and people with impaired immune systems (for example, people with AIDS or cancer patients undergoing chemotherapy) are at much greater

risk. This group of people has a very high mortality rate after contracting a *Listeria* infection.

L. monocytogenes is an unusual bacteria because it grows at refrigeration temperatures and high salinity. It is seen as an especially serious problem in foods which will be eaten without further cooking prior to consumption. These foods include cooked crab, cooked shrimp, and cold smoked fish.

6. *Salmonella*

Salmonella organisms originate in diseased humans or other warm-blooded animals. They can be carried in apparently healthy individuals for varying lengths of time after recovery from the disease. Seafood can be contaminated directly or through polluted water.

These heat-sensitive organisms are destroyed by temperatures at or above 140°F for over 30 minutes. They will not grow at temperatures below 42°F but will persist in either frozen or refrigerated seafoods almost indefinitely. Since a small number of these organisms could initiate the disease, the processor must employ a stringent control measure.

Salmonella causes gastrointestinal diseases resulting from the ingestion of the *Salmonella* organism; it has an incubation period of 6 to 48 hours. The symptoms of the disease, which persist for 2 to 5 days, are vomiting, diarrhea, nausea, abdominal pain, and, usually, a moderate fever. Of greatest risk are the aged, the ill, and the very young. In this group of individuals, the infection may become generalized and lead to death. The number of cases reported annually in the United States ranges from 20,000 to 40,000; mortality is about 250 people annually. However, experts estimate that 99% of the cases associated with the organism go unreported.

7. *Shigella*

Shigella species can cause a rather severe form of food-borne illness, and a relatively low number of the organisms can cause disease. The normal habitat for *Shigella* organisms is the intestinal tract of humans and other primates (they are seldom found in other animals). Their main source is people recovering from the disease.

Between 1972 and 1978, *Shigella* caused 6.5% of the known cases of food-borne illness in the U.S. The principal foods involved in these outbreaks were salads and seafoods which became contaminated during handling by infected workers. After the initial infection from a contaminated food, the disease rapidly spreads from person to person by the fecal-oral route.

Shigella is readily killed by most heat treatments used in the processing and preparation of foods and does not survive well at a pH below 4.5. Under certain conditions, however, *Shigella* can survive for extended periods in food—for example, up to 50 days in clams and shrimp.

Prevention and control require either that infected persons not be permitted to handle foods or that they practice good personal hygiene. However, routine testing of food workers is not practical or necessary. Education of food handlers, with emphasis on good personal hygiene, is the best preventive measure.

Shigellosis is a gastrointestinal disease resulting from oral ingestion of the microorganism. The incubation period is from 7 to 36 hours with symptoms characterized by diarrhea, fever, nausea, and abdominal cramps persisting for 1 to 8 days. As with salmonellosis, it is the young and the debilitated older population who are attacked with the greatest severity and frequency. One thousand to 10,000 cases are reported annually with little or no mortality. Again, however, it is estimated that only 1% of the total cases are reported every year.

8. *Yersinia enterocolitica*

Y. enterocolitica can also multiply at refrigeration temperature, and, in fact, cold temperatures favor this microorganism. Swine appear to be the major reservoir, but outbreaks have occurred from contaminated food and water such as chocolate milk, pasteurized milk, and tofu packed in spring water. Yersiniosis often mimics appendicitis in children and has been responsible for many unnecessary appendectomies.

Since cooking will readily destroy this microorganism, the cross-contamination of ready-to-eat food with animal fecal waste has been a major route of contamination.

Yersiniosis is a gastrointestinal disease characterized by diarrhea, fever, abdominal pain, and vomiting. At present in the U.S., relatively few outbreaks of yersiniosis are reported annually; the average is 2 to 3 outbreaks involving a few hundred cases.

9. Viral Hepatitis

Viral hepatitis associated with seafood is usually caused by ingestion of raw or undercooked shellfish harvested from polluted water. The hepatitis virus originates in diseased humans and not in domestic or wild animals. Although the virus is unnatural to the marine environment, it could survive in sediment for years. Besides shellfish, contaminated water used for seafood processing can spread this virus.

We do not yet have a reliable laboratory test to detect the presence of the hepatitis virus in food or in the environment. However, routine detection may soon become a reality with the advent of polymerase chain reaction technology.

10. Others

In recent years, *Escherichia coli* (0157:H7) has been implicated in food poisoning outbreaks, and the public has wondered about the relationship between this bacterium and the garden variety *E. coli* that is found in the intestinal tract of humans and warm-blooded animals. In fact, microorganisms often acquire new traits, such as resistance to antibiotics. *E. coli* (0157:H7) is one such microorganism. However, it causes severe hemorrhagic colitis that resembles a symptom of shigellosis.

Fishermen are familiar with so-called "fish finger," caused by a microorganism named *Erysipelothrix rhusiopathiae*. It is an acute but self-limiting skin infection. It produces nonsupportive, purplish red lesions on the hand and fingers. The lesions cause burning and itching sensations, but no pain. The infection is

localized and clears up in a few days without treatment. An interesting coincidence is that microbiologically *Erysipelothrix* is closely related to *Listeria*.

According to the Center for Disease Control, the most common seafood-borne illness reported in the U.S. is ciguatera, or "reef fish poisoning," resulting from the ingestion of certain tropical fish that have accumulated toxic plankton. Toxic fish cannot be differentiated from normal ones, but fishermen usually avoid certain reefs and larger fish that tend to accumulate more toxins. The next most common seafood-borne illness is scombroid fish poisoning, caused by microbial conversion of histidine to histamine in scombroid fish species. Histamine causes typical allergylike symptoms and produces skin rashes.

Nematodes, or "herring worms," cause eosinophilic enteritis when a person eats lightly pickled "green herring." Tapeworm infection becomes a problem when raw, unfrozen salmon is eaten as "sushi."

Table 6 lists the appropriate control measures for these pathogens, based mainly on the United Nations Food and Agriculture Organization (FAO) booklet *Fish and Shellfish Hygiene* (6). The tables have been modified to accommodate the specific needs of the Pacific Northwest seafood industry.

Model HACCP System

The HACCP system is not confined to microbiological monitoring. Seafood processors need to optimize (and, when appropriate, record) the layout and construction of the processing plant. They also need to monitor brine strength, temperature, and the operations of processing machinery, refrigeration systems, conveyors, and chlorination systems.

Sometimes, microbial testing may be needed to monitor the proper performance of procedures and the functions of equipment. For example, the microbial load of the conveyer belt should be known before managers establish a proper cleanup schedule. On the other hand, the microbial control measure may not require microbial testing. For example, proper control of cooking time and temperature during smoking-a control step to ensure safety from *C. botulinum* in a fish-smoking operation - will eliminate the need to test for *C. botulinum*.

TABLE 6. Control measures against seafood pathogens

PATHOGEN	CONTROL MEASURES
<i>C. botulinum</i>	<ul style="list-style-type: none"> a. Correct processing b. Cooking just prior to eating food
<i>Vibrio</i> spp.	<ul style="list-style-type: none"> a. Sanitary handling and processing b. Adequate refrigeration or freezing c. Cooking just prior to eating food
<i>Salmonella</i>	<ul style="list-style-type: none"> a. Proper sewage disposal b. Sanitary handling and processing c. Adequate cooking d. Prohibit seafood harvesting from the polluted waters
Viral infections, including hepatitis	<ul style="list-style-type: none"> a. Proper sewage disposal b. Adequate cooking c. Prohibit seafood harvesting from the polluted waters
<i>S. aureus</i>	<ul style="list-style-type: none"> a. Sanitary handling and processing b. Prohibit person suffering from cold or open infected wound from handling food c. Frequent brine change or adapt spray or injection system
<i>C. perfringens</i>	<ul style="list-style-type: none"> a. Rapid cooling of food after cooking
<i>L. monocytogenes</i>	<ul style="list-style-type: none"> a. Decontamination of raw materials b. Sanitary handling and processing c. Adequate cooking d. Preventing cross-contamination from raw to cooked products
Adapted from FAO, <i>Fish and Shellfish Hygiene</i> (6).	

Part 128, Title 21, of the code of federal regulations (*Federal Register* 34:6977, April 26, 1969) spells out sanitation regulations for the manufacturing, processing, packing, and handling of human food. These regulations cover specifications for plant and grounds, equipment and utensils, and sanitary facilities and controls, including water supply, sanitary operations, and processing controls. Sanitation recommendations in more readable form can be found in *Fisheries Facts-8*, published by J.P. Lane (13), and *Sanitation Guidelines for the Breaded Shrimp Industry*, by J.D. Clem and S. Garrett (2).

Regulations that would have specifically governed smoked and smoke-flavored fish were spelled out in *Federal Register* 35:17401, Nov. 13, 1970. However, these regulations have not been enforced since the industry proved in court that it could not produce salable smoked fish with a heating requirement of 180°F. At this writing (August 1991), a new regulation is being reviewed internally by the FDA. It is expected to be available soon for industry review and comment. The new regulation is said to be very similar to the model GMP (good manufacturing practice) adapted in June 1991 by the Association of Food and Drug Officials and that adapted by New York State on April 16, 1990. The New York regulation calls for (1) a "competent process authority" to review fish-smoking procedures, (2) a prohibition against processing any uneviscerated fish, (3) minimum processing at 145°F for 30 minutes, and (4) strict adherence to 38°F storage for raw fish as well as for the finished products (8). The HACCP program described here will aid processors in producing safe, wholesome smoked fish, as well as in meeting the intent of these regulations.

Fish smoking is a single-product process. The component is fish; the product is smoked fish. Smoked fish is in seafood hazard category 1 (table 2) because of its potential hazard of *C. botulinum* and *L. monocytogenes*. The major components of the critical control points are (1) decontamination of raw fish, (2) the smoking temperatures and time, (3) the water phase salt (WPS)² content of the smoked fish, and (4) the storage temperature of the smoked fish.

Regulations may permit only one hot smoking process. For example, the recommended regulation is that fish must be smoked at or above 145°F for not less than 30 minutes, must contain a WPS level in excess of 3.5%, and must be stored at or below 38°F.

The smoking process diagram is shown in figure. 1. Instructions for the control measures for four CCPs (soaking, brining, smoking, and storing the finished product) are given in the following section.

²WPS (water phase salt) =

$$\frac{\% \text{ salt in finished product}}{\% \text{ salt} + \% \text{ moisture in finished product}} \times 100$$

Critical Control Points

A. Soaking

- Run chlorinated cold water over eviscerated and cleaned fish.
- Best results are obtained with 30 ppm chlorine residual, water temperature of 38°F or below, and overnight soaking.
- For specific recommendations, contact NMFS, 2725 Montlake Blvd. E., Seattle, WA 95112; (206) 442-7746, FAX (206) 553-4304.

B. Brining

- Prepare brine in sufficient strength so that the brine level of fish will reach the desired level within 12 hours at 38°F. More specifically, measure and record the amount of salt added, the volume of water, the salimeter reading, and the temperature of the brine.
- A guide on brine preparation (10) is available from Oregon Sea Grant, Oregon State University, Administrative Services Building 402, Corvallis, OR 97331-2134, or phone (503) 737-2716.
- You must experimentally determine the relationship between the brine concentration and the final WPS of the smoked fish.

C. Smoking

- Impending regulations may specify that the internal temperature of fish and the oven temperature during smoking be continually monitored and recorded.
- The recommended smoking process of not lower than 145°F for not less than 30 minutes is based on the coldest part of the fish in the oven. Analyze at least a sample from each oven load for water phase salt (WPS) level, and record the results.

D. Storing

- Keep the smoked fish below 38°F and continually monitor the storage temperature.

Other Control Points

a. Raw Fish

- Examine the fish for freshness and wholesomeness.
- Keep below 38°F all eviscerated fish or fish in the round not being used immediately.

b. Frozen Fish

- Check the fish for wholesomeness.
- Keep frozen fish frozen until use. Defrost it at or below 45°F.

c. Eviscerating, Cleaning, and Rinsing with Fresh Water

- Cleanly remove the entire gut content and thoroughly rinse the fish, especially the gut cavity, with approved fresh water.

d. Draining

- Drain excess water at or below 45°F for no longer than 2 hours.

e. Rinsing in Fresh Water after Brining

- Rinse to prevent salt crystallization on the skin of smoked fish and drain to facilitate proper drying in oven.

f. Cooling Smoked Fish

- Cool the smoked fish to 50°F or below within 3 hours and, subsequently, cool the fish to 38°F or below within 12 hours after smoking.

g. Packaging

- Label the package with the name and location of the plant, the date of packaging, and the oven load. Keep records to provide positive identification.

See Lane (13) and Clem and Garrett (2) for plant and equipment cleaning procedures.

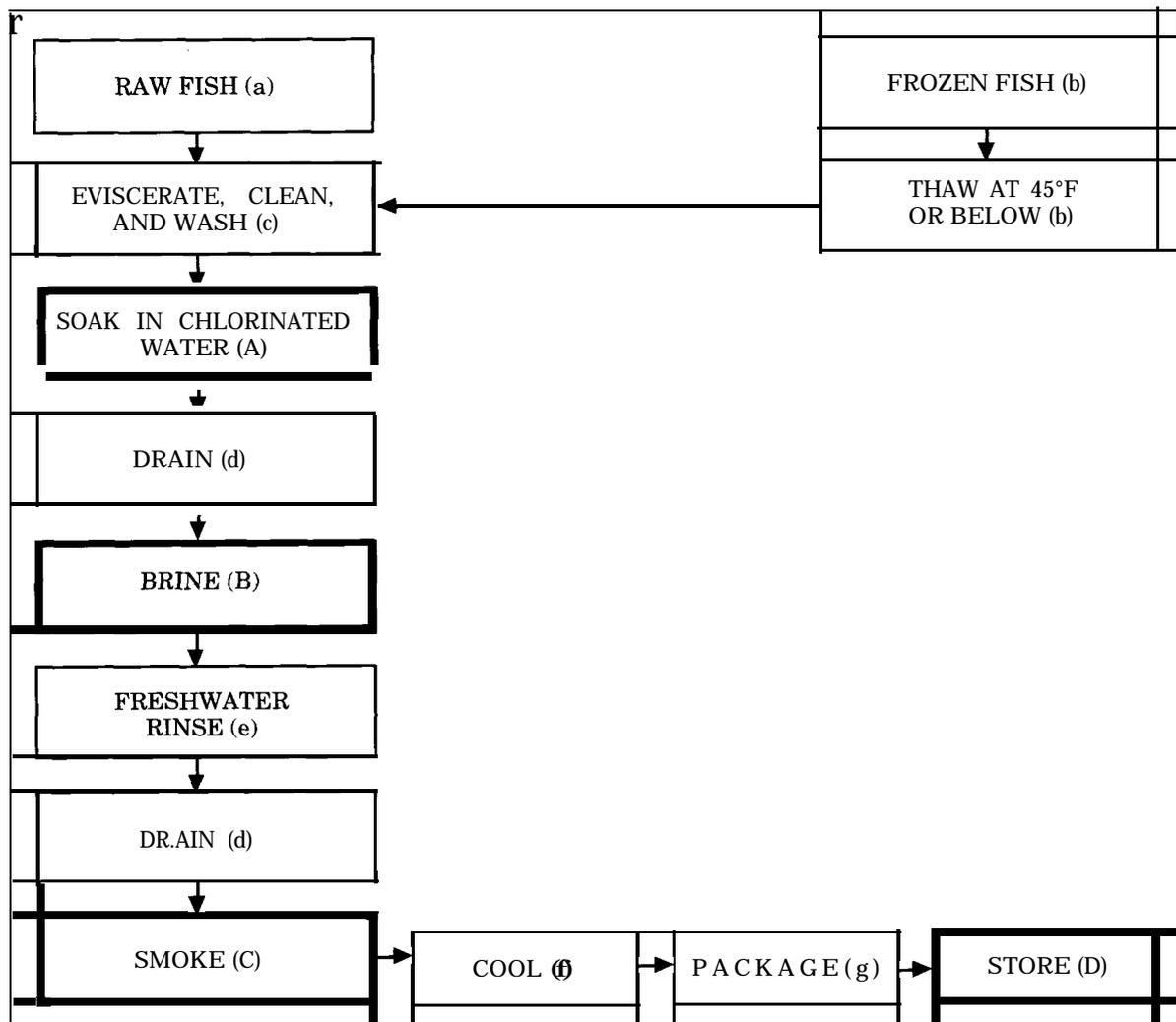


FIGURE 1. Fish-smoking process. Critical control points are in bold boxes. See text for control measures.

HACCP for Dungeness Crab Processing

Cooked and picked Dungeness crab meat belongs to the seafood hazard category 1 (table 2). Crabs are extracted from an environment known to harbor *C. botulinum* spores, and the marine environment has to be assumed to contain *V. parahaemolyticus*. *Listeria monocytogenes* is known to be present in crab-processing plants (20). Crab processing requires excessive human handling, which increases the opportunity for contamination of the finished product with bacteria of the raw crab and those from the human handlers (*S. aureus*). In addition, the picked crab meat is usually consumed without further cooking.

When landed, crab is alive. The flesh of the living animal is theoretically sterile; therefore, processors start out with a raw product of microbiologically ideal quality. Processors have full control over the microbial quality of the crab meat that leaves their plants.

The keys to proper crab processing are (1) to avoid cross-contaminating the picked crab meat with the raw crabs, (2) to minimize contamination from the processing environment, and (3) to promptly refrigerate the picked crab meat at temperatures below 38°F.

The crab-processing diagram is shown in figure 2, and the control measures for CCP and CP are as follows.

Critical Control Points

A. Picking

- Make sure the picking area is physically separated from other processing areas, especially from raw crabs, crab cookers, and processing areas for raw fish and shellfish.
- Clean and sanitize the picking tables with 50 ppm³ chlorine at each shift change.
- Ensure that pickers wear clean clothes, apron, head cover, and gloves. Clean and sanitize their aprons with 200 ppm chlorine at each shift change.
- Pick cooked and cooled crab within an hour of cooking. Never pile up on the picking table more cooked crabs than can be picked in an hour.
- Do not allow pickers to handle raw crabs.

B. Brining

- Prepare fresh and chilled brine at each break or every 2 hours of operation (halotolerant *L. monocytogenes* and *S. aureus* are known to be concentrated in old brine).

³The latest information shows that *L. monocytogenes* forms microcolonies on stainless steel and covers itself in biofilms. Five minutes exposure to 200 ppm chlorine is needed to destroy it. QAC at 200 ppm is equally effective, and, because it leaves a protective film, it is the sanitizer of choice for tabletops at the end of the working day. QAC at 1000 ppm may be used to sanitize walls and floors. Rinsing is not necessary if 200 ppm is not exceeded for chlorine or QAC. Iodophor used at the maximum concentration of 25 ppm is not as effective.

C. Storing

- Store packaged crab meat at temperatures below 38°F at all times or quick-freeze them.

Other Control Points

a. Live Crab

- To prevent active crabs from damaging each other, place the live crabs at 45°F for 12 hours before handling.

b. Butchering and Cleaning

- Check the condition and cleanliness of the brush. It should be washed and sanitized at the end of each shift or every 2 hours.
- Remove carapace cleanly.
- Cut the crabs in halves.
- Brush off intestinal content as completely as possible.
- Wash and rinse the halves in running water or with spray.

c. Cooking

- Check the water temperature at 2-hour intervals for the continuous cooker (before each load is added for the batch system).
- Cook the crab at 212°F for at least 15 minutes.
- Air-cool the cooked crab for an hour in an isolated location removed from raw crabs and heavy traffic.
- NEVER HANDLE COOKED CRAB WITH UTENSILS AND BASKETS USED FOR HANDLING RAW CRABS.
- Cooked crabs should not be handled by those who handle raw crabs.
- Do not cook more crabs than the pickers can handle in an hour after cooking.

d. Rinsing with Fresh Water

- Rinse off the brine in fresh, potable water spray within minutes of brining.

e. Packaging

- Clean and sanitize the packaging table with 200 ppm chlorine at each break.
- Package picked crab within 10 minutes.
- Chill the packaged crab immediately to temperatures below 38°F.
- Package the crab so that the package can not be mis-handled. Each package should display the warning, "store below 38°F."

See Lane (8) and Clem and Garrett (2) for plant and equipment cleaning procedures.

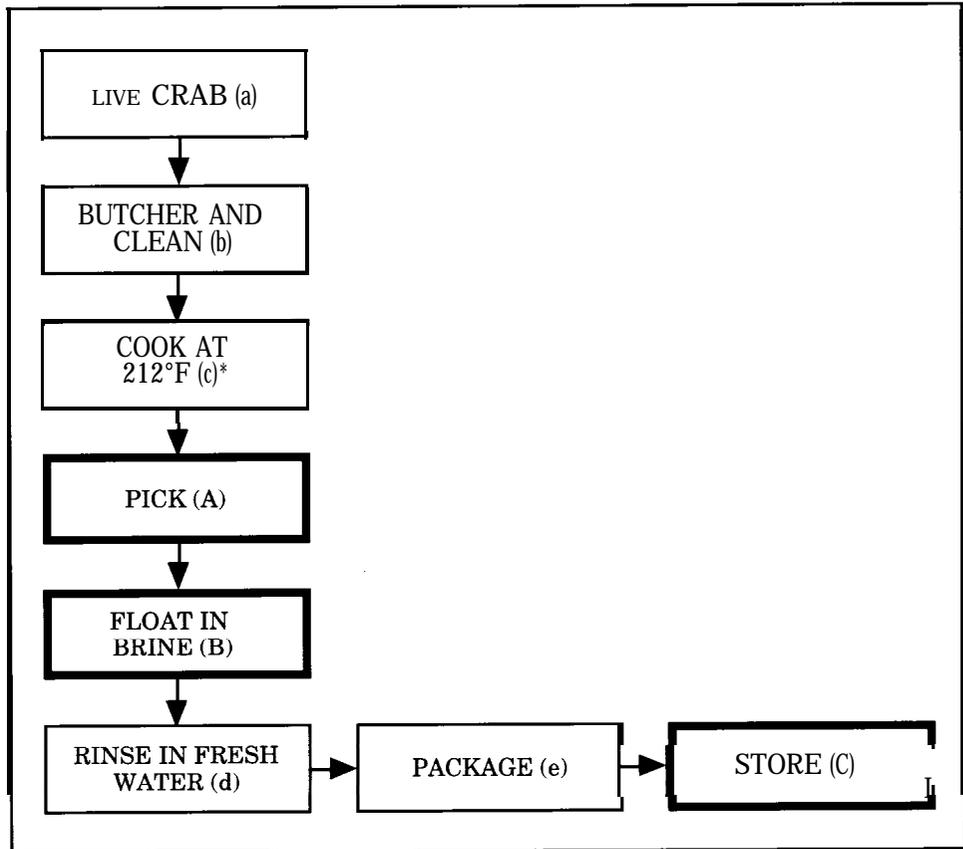


FIGURE 2. Processing of cooked and picked crab . Critical control points are in bold boxes. See text for control measures.

*Industry representatives at the MSSP workshop considered the cooking step critical for inactivating microorganisms and preventing blueing. Cooking, followed by cooling and chilling with water, was thought to be critical because of the concern for water quality (22).

Cooked and peeled shrimp belong to the seafood hazard category 1 (table 2). Pacific shrimp comes from the same environment as the Dungeness crab. Therefore, *C. botulinum* hazard cannot be discounted. Shrimp, in contrast to Dungeness crab, is harvested generally during the warmer months, and this increases the risk of *V. parahaemolyticus* contamination. The mechanical peeler has largely replaced hand picking and has reduced the chance for human contamination. However, it has increased the chance for equipment-related contamination.

The condition in which shrimp is received at the plant can vary depending on the age of the shrimp out of water, handling practices on board ship, and the degree and care in icing.

Control of raw material and the proper care and sanitization of the processing equipment are even more critical for shrimp than for the crab because of seasonal and handling factors. The key to sound shrimp processing is (1) to avoid contaminating the picked shrimp with the raw shrimp, (2) to eliminate the microbial buildup in and on the processing machinery, and 3) to promptly refrigerate the peeled shrimp to below 38°F. Quick-freezing is preferable to refrigeration.

Shrimp-peeling steps and the control measures for CCP and CP are shown in figure 3 and discussed in the following section.

Critical Control Points

A. Injecting with Brine

- Brine is used to flavor the shrimp. The flavoring process can best be carried out by injecting brine in the finished product. The brine tank quickly accumulates bacteria; thus, it serves as an inoculation tank for *V. parahaemolyticus*, *L. monocytogenes*, *S. aureus*, and other undesirable microorganisms.

B. Storing

- Chill the packaged shrimp to below 38°F within 10 minutes after packaging.
- Never expose the peeled shrimp to temperatures above 38°F. Quick-freezing is preferable to refrigeration.

Other Control Points

a. Iced Shrimp

- Be sure that the shrimp has been well iced and that its temperature at any point does not exceed 40°F.
- De-ice the shrimp. Do not de-ice and re-ice.

b. De-icing and Washing

- De-ice the shrimp just prior to peeling by immersing it in potable tap water. Wash the shrimp as thoroughly as possible before cooking.

c. Treating with Phosphate

- Soak shrimp in 0.5 to 2.0% condensed phosphate for up to 30 minutes at 32°F.

- Specific recommendations for this process (4) are available from OSU Seafoods Laboratory, Astoria, OR 97103; phone (503) 325-4531; FAX (503) 325-2753.
- d. Machine Peeling
- Clean and sanitize peelers and transport ducts with 50 ppm chlorine at each break or every 2 hours of operation.
 - Inspect peelers and ducts every 10 minutes during operation to ensure that no peeled shrimp accumulates on the line.
- e. Washing
- Wash the peeled shrimp in a sufficient quantity of fresh water.
- f. Inspecting
- Wear clean clothes, aprons, and head cover. Carry out the inspection along the conveyer belt with the running water. If a table is used, clean and sanitize the table top with 200 ppm chlorine at each break or every 2 hours of operation.
- g. Packaging
- Clean and sanitize the packaging table with 200 ppm chlorine at each break or every 2 hours of operation.
 - Package the peeled shrimp within 10 minutes of peeling.

See Lane (13) and Clem and Garrett (2) for plant and equipment cleaning procedures.

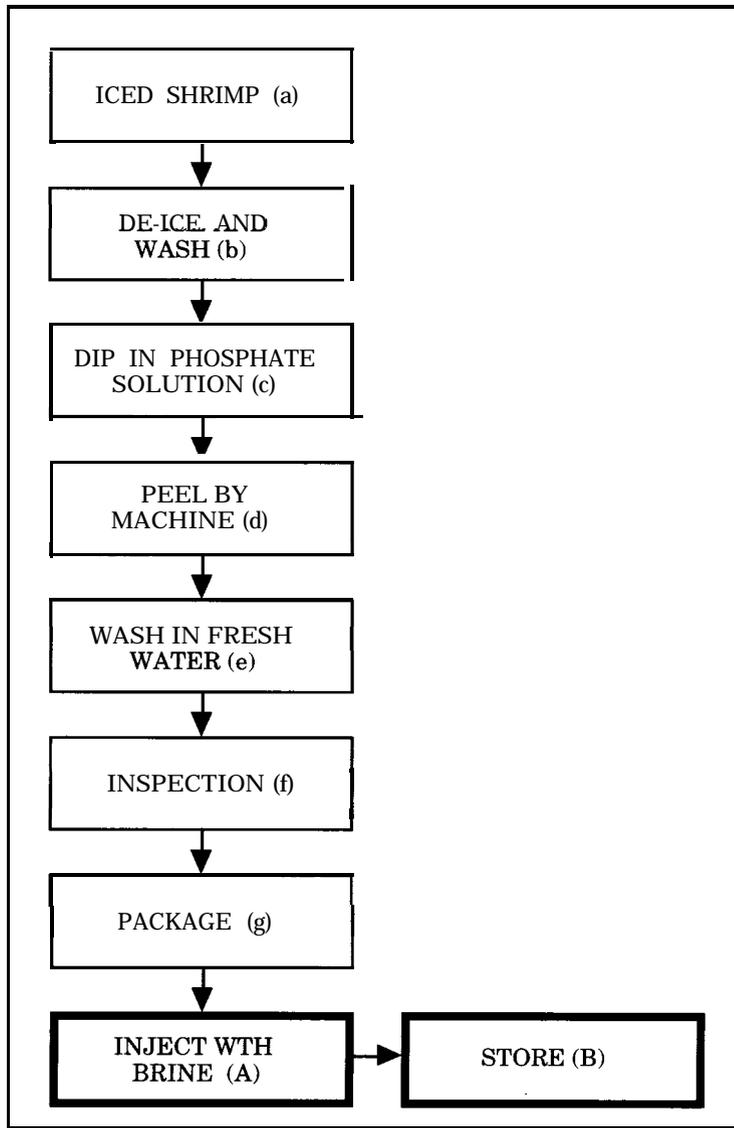


FIGURE 3. Processing of cooked and peeled shrimp. Critical control points are in bold boxes. See text for control measures.

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