Present Status and Perspective on the Implementation of HACCP in Japanese Fish Processing Industries

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Abstract

The HACCP philosophy is gaining momentum with industry and regulators alike as the best approach to assuring the highest degree of food safety. This is exemplified by the numerous publications and courses on this subject in recent years as well as examples of successful application by industry and the efforts of committees such as the NACMCF. The HACCP philosophy is also gaining worldwide acceptance, as shown by the recent activities of the Codex Alimentarius Commission's Food Hygiene Committee.

HACCP is a common-sense philosophy that can be applied to food systems ranging from the simple to the complex. Applying the principles as described in this paper demonstrates that the process, while requiring careful thought, is not unattainable. Joining HACCP with another related management philosophy which is growing in popularity - Total Quality Management (TQM) - can provide a formidable combination for competitive advantage.

Recently, owing to the shortage of labor, a high Yen exchange rate and the diversification of consumer's needs, the industrial structure of Japan has markedly changed, resulting in a rapid expansion of import of foods and raw materials. In 1990, 54% (on the calorie base) of the total food supply of Japan was imported, while in 1994, the figure has reached as high as 63%. In recent years, due to the rapid increase in the surplus of payment from international trade, the Japanese government has been strongly requested by its trade partners to harmonize with international regulations, together with the easing of internal legal restrictions and regulations. On April 1, 1995, the Ministry of Health and Welfare and the Ministry of Agriculture, Forestry and Fisheries decided to change the date-indication system for food products from the "date of manufacture" to "use by date" or shelf life.

In order to harmonize with international food regulations, the Ministry of Health and Welfare presented a revised plan in the Food Sanitation Law and Nutritional Improvement Law to the Diet for discussion, and the proposed bills were carried through the Diet on May 24, 1995; the new acts came into force on May 24, 1996. Among the revisions to the Food Sanitation Law, articles relating to the improvement and enforcement of a self-imposed sanitary control system to secure food safety are involved, in which the approval system for manufacturing foods through "Comprehensive Sanitation Controlled Manufacturing" is included. This new system has been derived from the HACCP concept. However, its implementation is different from other countries, as it is applied voluntarily in Japan.

In July 1, 1994, the Product Liability Law, so-called PL-Law was enacted in Japan and came into force on July 1, 1995. As to the safety problem of a product, the food industry would be one of the most seriously involved groups among various industries in Japan by the enforcement of the PL-Law. In general, for industry to cope with the PL-Law, there would be two measures, viz., PL-prevention and PL-defense against legal proceedings.

Recently, food industries in Japan are much interested in the HACCP system as a counter- measure against the PL-Law.

The Hazard Analysis and Critical Control Point (HACCP) concept has been gaining momentum in recent years as the best approach to assuring food safety at every stage of the food chain. The HACCP approach has already been adopted in the regulations to control quality and safety of seafoods and other food items in EU countries and the U.S.A.; their influence is felt in the international food trade, especially fishery products. In 1994, the Bureau of Food Distribution, Ministry of Agriculture, Forestry and Fisheries started a new project called "Comprehensive Control System for Improving Food Safety" aiming to establish a model HACCP plan applicable to medium-sized and regional producers and even to small family-operated plants in Japan.

An expert committee was organized under the Japan Food Industry Center to establish a generic model HACCP plan for pre-cooked frozen foods. In 1994, 6 items of pre-cooked frozen foods were selected, viz hamburger, macaroni au gratin, potato-croquette, creamy-croquette, "*shaw mai*"(Chinese dish) and "*gyo-za*"(Chinese dish). In September 1995, a guidebook for developing HACCP plans for the aforementioned frozen pre-cooked foods was published by the Japan Food Industry Center.

In 1995, the Ministry of Health and Welfare

organised a team to investigate the application of "Comprehensive Sanitation Controlled Manufacturing System" targeting at meat and dairy products. The generic model HACCP plans for the aforementioned foods will be published in the near future.

In the middle of March 1995, a team came to Japan from the EU to investigate the actual status of fish processing plants. When they visited a scallop shucking plant in the Aomori Prefecture where frozen scallop ligaments (adductor muscles) were produced, they found several defects in the hygiene conditions of the plant. Consequently, due to defects prescribed in the "Council Directive of EC, 1991", the export of all fishery products from Japan to European countries was suspended. After repeated negotiations by the Ministry of Health and Welfare and the Fisheries Agency of Japan with the authorities of the EU, the export of seafoods except frozen scallop ligaments resumed at the end of 1995. In 1991, the EC (currently EU) enforced HACCP-based regulations for fish and fishery products including imported fish and fishery products. Moreover, on December 18, 1995 the US-FDA announced the new regulation of "Procedures for the Safe and Sanitary Processing and Importing of Fish and Fishery Products", commonly called "Seafood HACCP Regulation" which will be enforced on December 18, 1997.

In accordance with the international trend of HACCP implementation, the Fisheries Agency has decided to adopt the HACCP concept in fish processing plants in order to promote the correct hygienic handling of fresh and processed fishery products at all stages of production. A new project has begun for developing generic models for HACCP to secure safe products of high quality. In the current project, some 15 items of fresh and processed fishery products are included. In 1995, three items of fishery products, frozen scallop ligaments (adductor muscles, to be eaten raw), frozen mechanically minced fish meat (surimi), and frozen fish fillets (mackerel, eaten after cooking) have been selected. After intensive investigation, the expert committee published a guidebook for each product to develop its HACCP plan. The purpose is to present a detailed approach to developing HACCP plans for individual food items, and these guides should not only be useful to fish processors, but be also particularly helpful to the smaller processor attempting to develop a HACCP plan for his facility.

In 1994, the Japan Society for Research of Food Protection organized the following two divisions, the technology for control of food micro-organisms, and the HACCP divisions. The latter division has already conducted three workshops on the implementation of HACCP, in 1994, 1995 and 1996, to enlighten researchers and technologists working at food laboratories and various food factories in Japan. In addition, the HACCP division is now preparing guidebooks for developing HACCP plans to address the safety concerns of various food products, in which several types of fish paste products, *kamaboko* in Japanese, and 5 kinds of cooked, ready-to-eat chilled foods are included. These will appear in the series of "Advances in Food Protection Research" published by our Society in the near future.

Appendix

(REFERENCE MATERIAL FOR HACCP IMPLEMENTATION)

Basic Knowledge to Establish HACCP Plan with Special Reference to the Hazard Analysis of Fish and Shellfish

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Introduction

Traditionally, the means of preventing foodborne illness have been by inspection and surveillance of final products. The distribution of dangerous contaminants in foods is sporadic and the accuracy and precision of analytical procedures, particularly the microbiological monitoring of foods, are relatively low. Consequently, sample examinations will only exceptionally reveal deficiencies, thus making negative results almost worthless.

Microbiological examination of final products has been and is still carried out in large numbers as a means to provide safety. The results are evaluated against microbiological criteria, which may have either mandatory or voluntary status. The currently used microbiological criteria apply to fish and fishery products by the members of the European Union (EU) together with Canada, Japan and the U.S.A. The tests required are listed in Table 1. Therefore, it can be stated that current practices for providing safety, or assurance of safety, and normal shelf life of fish products by microbiological end-product testing, are costly but of very limited value. Point-of-entry testing of fish products must generally be considered as an inefficient means of retrospective assessment of processing, transport and storage conditions.

Hazard Analysis Critical Control Point System Adopted by the Codex Alimentarius Commission, and its Application

The Hazard Analysis Critical Control Point (HACCP) system, which is science-based and systematic, identifies specific hazards and measures for their control to ensure the safety of food. HACCP is a tool to assess hazards and establish control systems that focus on prevention rather than relying mainly on end-product testing.

The HACCP system, which was first outlined in 1971 in the U.S.A. (APHA, 1984) has now been widely accepted internationally, and in 1993 FAO/WHO, the Codex Alimentarius Commission (CAC) published the "Guidelines for the Application of Hazard Analysis Critical Control Point (HACCP) System".

1. *HACCP Principles*

The HACCP system consists of the following seven principles:

a. Conduct a hazard analysis.
b. Determine Critical Control Points (CCPs).
c. Establish critical limits for CCPs.
d. Establish a system to monitor and control CCPs.
e. Establish corrective action to be taken when monitoring indicates that a particular CCP is not under control.
f. Establish methods for verification to confirm that the HACCP system is working effectively.
g. Establish documentation concerning all procedures and records appropriate to these principles and their application.

2. *Logical Sequence for Application of HACCP*

It is possible to implement the 7 principles of HACCP in 12 separate steps according to the Codex document:

a. Assemble a HACCP team.
b. Describe the product.
c. Identify its intended use.
d. Construct a flow diagram.
e. On-site verification of flow diagram.
f. List all potential hazards associated with each step, conduct hazard analysis, and consider any measures to control identified hazards (Principle 1).
g. Determine CCPs (apply the decision tree) (Principle 2).
h. Establish critical limit for each CCP (Principle 3).
i. Establish a monitoring system for each CCP (Principle 4).
j. Establish corrective action for deviation that may occur (Principle 5).
k. Establish verification procedures (Principle 6).
l. Establish record keeping and documentation (Principle 7).

Factors Contributing to Foodborne Disease Outbreaks

1. *Improper Storage/Holding Temperatures*

Foodborne disease organisms will grow in foods held at temperatures between 5°C and 55°C; most pathogenic bacteria grow very rapidly at temperatures between 25°C and 40°C.

2. *Inadequate Cooking*

Inadequate cooking represents a hazard since cooking is relied upon to destroy many foodborne disease organisms and toxins.

- Undercooked food — poultry, hamburger, fish products, etc.
- Improperly processed food — botulism from canned food.

3. *Poor Personal Hygiene*

Many foodborne disease organisms are transferred by the faecal-oral route — viruses (hepatitis A, Norwalk), *Shigella.*

Infected food handlers with poor personal hygiene transfer organisms to food — *S. aureus*, viruses, *Shigella.*

4. *Cross-contamination*

Foodborne pathogens can be transferred from raw product to utensils and equipment, which, if then used for cooked or other ready-to-eat foods, can in turn transfer pathogens which may lead to illness.

Cutting boards, slicers, mixers and grinders with hard-to-clean surfaces are particularly problems.

Utensils and equipment used in the preparation of raw products should never be used for cooked products.

5. *Improper Reheating*

6. *Poor Storage Practices*

Cross contamination may occur when cooked products are stored with raw products or materials in the same refrigerator and when chemicals and foods are stored together.

Microbiological Hazards Relating to Fish and Fishery Products

1. *Identification of Microbiological Hazard Relating to Seafoods*

Seafood hazard categories in order of decreasing safety risk are as follows :

a. Eating of raw fish and shellfish: Japan has a tradition for eating raw fish and shellfish (sashimi and sushi).
b. Molluscs, including fresh and frozen mussels, clams, oysters in shell or shucked. Often eaten with no additional cooking.
c. Lightly-preserved fish and shellfish products (ie. NaCl < 6%(w/w) in waterphase, pH > 5.0). This group includes salted, marinated, cold smoked and gravid fish and shellfish eaten without cooking.
d. Heat-processed (pasteurized, cooked, hot smoked) fish products, molluscs (including squid, octopus and scallop) and crustaceans (crabs, lobsters and shrimps).Some products are eaten with no additional cooking.
e. Heat-processed fish and shellfish (sterilized, packed in sealed containers). Often eaten with no additional cooking.
f. Semi-processed fish and shellfish (ie. NaCl > 6%(w/w) in water phase, pH < 5.0), preservatives (sorbate, benzoate and NO_2) may be added, although the use of sorbate and benzoate in these products is prohibited in Japan. This group includes salted and/or marinated fish and fish egg products (eg. salted Alaska pollock roe, salmon eggs and caviar) and molluscs including squid, octopus and bivalves eaten after or without cooking.
g. Dried, salt-dried and smoked-dried fish and shellfish. Usually eaten after cooking.
h. Fresh and frozen fish and crustaceans. Usually eaten after cooking.

2. *Biological Risk Factors Affecting the Safety of Fresh and Frozen Fish and Shellfish*

Foodborne disease organisms which represent health hazards have been arbitrarily divided into four groups (ICMSF, 1986; NAS/NRC, 1985) as follows:

Severe; direct health hazards.
- Moderate; direct hazards with potentially extensive spread.
- Moderate; indirect hazards with limited spread.
- Low; indirect hazards, or microbes that serve as indicators of a potential for a more severe hazard or condition.

Table 2 provides the classification of the most common foodborne disease agents.

Table 3 provides the classification for some of the most common foodborne disease agents relating to fresh and frozen fish and shellfish.

Prevention of Food-borne Microbial Diseases

General principles :

1. *Prevent Contamination of Foods*

a. The use of good personal hygiene practice.
b. Avoid cross-contamination between raw foods and cooked and read-to-eat foods.
c. Thoroughly clean and sanitize utensils and work surfaces used for raw foods.
d. Equipment and utensils should be clean and made from appropriate materials to avoid contamination from toxic materials.

2. *Destruction of Foodborne Disease Agents*

a. Many foodborne disease organisms will be destroyed by proper cooking.
b. Freezing can be used to destroy parasites in fish and meat, but it has little effect on bacterial pathogens in foods.
c. Use of acids and preservatives.
d. Irradiation of foods to kill pathogenic micro-organisms - radicidation (to kill non-spore forming pathogenic micro-organisms such as *Salmonellae* and *Staphylococcus*) and radappertization (to destroy spore-formers such as *Clostridium botulinum*).

3. *Prevention of Multiplication of Foodborne Disease Organisms*

a. Food poisoning organisms must multiply to large numbers before they can cause disease: eg. *S. aureus* — $10^5 \sim 10^6$ to produce enough toxins to cause disease, and *C. perfringens*, *V. parahaemolyticus* — 10^6/g.
b. Infectious disease — cause infection with minute quantities of an organism: e.g. *S. typhi* and *V. cholerae* cause infection with the order as low as $10^1 \sim 10^3$/g.
c. Freezing generally prevents growth of all foodborne disease organisms.
d. Proper refrigeration temperature (< 4°C) will prevent multiplication of most foodborne disease organisms, although *Y. enterocolitica* can grow at temperatures as low as -2°C.
e. To lower the temperature of foods rapidly: 60°C to 4°C ("dangerous zone" for microbial growth) in 4 hours.
f. Decreasing the pH and/or the water activity (Aw) of a food can prevent or slow down the growth of foodborne pathogens.
g. Holding foods at elevated temperatures (> 60°C; 140°F).

Destruction of Pathogens and Spoilage Bacteria by Pasteurization of Seafoods

Clostridium botulinum is the organism of concern in many canned products, and their number in most foods is usually very low; an average of less than one per container is assumed (Stumbo, 1973). On the other hand, if high numbers are expected, or if a more heat-resistant organism is targeted, then a suitable process is recommended. No target organism has been identified for the pasteurization of crabmeat and the process is based on historical data that gave the desired shelf life; a *z*-value of 8.9°C was picked arbitrarily in the absence of a specific target organism. Within the range of normal crabmeat pasteurization temperatures, F-value calculations based on $z = 8.9$°C produce a reasonable and safe conservative process (Ward *et al.*, 1984).

Fortunately, pasteurization provides a very large safety factor for the destruction of type E, the type most commonly associated with marine environments. Innoculated crabmeat, given a typical commercial process, achieved at least an 8 - D reduction of *Clostridium botulinum* type E spores (Cockey & Tatro, 1974). Other researchers have determined D_{85} values of 0.2 - 0.32 min in a variety of heating media. Based on these findings, a process of F = 31 min (reference temperature: 85°C, $z = 8.9$°C) should provide at least a 96 - D process for *C. botulinum*, type E.

However, other types of psychrotrophic, non-proteolytic *C. botulinum* are more heat resistant. Non-proteolytic type B is reported to have D-value of 0.45 - 14.33 min. A 31 min F-value provides a 2.4 - D process for the most heat-resistant strain of this organism. Type F is reported to have similar heat resistance. Numerous researchers have explored this area (Cockey & Chai, 1991; Simunovic *et al.*, 1985; Lynt *et al.*, 1982, 1977; Eklund, 1992; Stumbo, 1973).

Most spoilage micro-organisms and pathogens are heat sensitive and can be destroyed by low to moderate heat. The heat resistance of various bacteria and bacterial spores are summarized in Table 4.

The D-values and F-values of non-spore forming pathogens and spoilage organisms were calculated from heat resistance data in the literature (Rippen & Hackney, 1992) with milk being the most common heating medium are shown in Table 5.

As can be seen in Table 5, crabmeat's ready-to-eat status has made the control of *Listeria monocytogenes* in these products a high priority to the US-FDA (Hooker *et al.*, 1991). Although *L. monocytogenes* exhibits greater heat resistance in crabmeat than in fluid milk products, D-values reported by Harrison and Huang (1990), showed it is eliminated by pasteurization as prescribed for fresh-cooked seafoods and of milder thermal processes targeting vegetative pathogens in products destined for frozen distribution. These applications are likely to become more important in the 1990s as safety concerns predominate.

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Table 1. Microbiological tests included in the Microbiological Standards and Regulations of some European countries, Japan and USA (FAO, 1989)[b].
(Note: Belgium, Canada, Denmark, Germany, Ireland and Portugal have no microbiological standards for fish and fish products.)

	Italy	France	Luxembourg	Netherlands	United Kingdom	Spain	USA	Japan
Raw fish, fillets, fresh/frozen		1,2,7,10,11[a]	1,3,7,10,11			1,2,5,6,7,10		1,2 or 6
Semi-preserved fish products								
Pasteurized		1,2,7,10,11						
non-pasteurized		1,2,7,10,11						
Smoked salmon		1,2,7,11						
Crustacean								
raw		1,2,7,11	1,3,7,11				1,6,10	
cooked		1,2,7,11	1,3,7,11		1,6,7,10			
cooked and peeled		1,3,7,10,11	1,3,7,10,11	7,10				
Molluscs								
live	6,7	3,4,7	3,4,7					
raw	6,7			6,7		1,6,7		1,6
pre-cooked	6,7	1,3,7,10,11	1,3,7,10,11			1,7,8,9,10		

[a] The figures refer to tests for:
1. Aerobic plate count (APC); 2. Coliforms; 3. Faecal coliforms; 4. Faecal streptococci; 5. Enterococci; 6. *E. coli*;
7. *Salmonella*; 8. *Shigella* spp.; 9. Total enterobacteriaceae; 10. *Staphylococcus aureus*; 11. Anaerobic sulfite reducing bacteria.

[b] Referred and adopted from H.H. Huss, International J. of Food Microbiol, 15: 33-44 (1992)

Table 2. Classification of foodborne disease agents[a].

- ♦ Severe; Direct Health Hazards:
  - *Clostridium botulinum*
  - *Shigella dysenteriae*
  - *Listeria monocytogenes*
  - *Escherichia coli 0157:H7* (enterohemorrhagic)
  - *Salmonella typhi*
  - *Salmonella paratyphi A & B*
  - *Brucella abortus; Brucella suis*
  - *Mycobacterium bovis*
  - *Vibrio vulnificus*
  - Hepatitis A virus
  - Fish and Shellfish toxins
  - Certain Mycotoxins (aflatoxin)
- ♦ Moderate; Direct Hazards with Potentially Extensive Spread:
  - *Salmonella* spp.
  - pathogenic *Escherichia coli* (e.g. enterotoxigenic)
  - *Streptococcus pyogenes*
  - *Shigella* spp.
- ♦ Moderate; Indirect Hazards with Limited Spread:
  - *Staphylococcus aureus*
  - *Clostridium perfringens*
  - *Bacillus cereus*
  - *Vibrio parahaemolyticus*
  - *Coxiella burnetii*
  - *Yersinia enterocolitica*
  - *Campylobacter fetus*
  - *Trichinella spiralis*
  - histamine (from microbial decomposition of scombroid fish)

[a] Adapted from ICMSF, 1986

Table 3. Biological risk factors relating to fresh and frozen fish and shellfish.

Organisms/component of concern	Hazard		Severity	Risk
	Contamination	Growth		
Pathogenic bacteria:				
a) Normally found in aquatic environment				
Clostridium botulinim	—	+	high	low
Vibrio cholerae	—	+	high	low/N.R.[a]
V. parahaemolyticus	+	+	moderate	high/N.R.[a]
NAG *Vibrio*	—	+	moderate	low/N.R.[a]
Listeria monocytogenes	—	+	moderate	low/N.R.[a]
Aeromonas hydrophila	—	+	moderate	low/N.R.[a]
b) From animal/human, reservior				
Salmonella	(+)[b]	+	high	high
E. coli(e.g. enteropathogenic)	(+)[b]	+	moderate	high
Shigella	(+)[b]	+	high	low
S. aureus	(+)[b]	+	moderate	high
Producer of biogenic amines (histamine)				
Morganella morganii	—	+	moderate	high
Photobacterium histaminum	+	+	moderate	high
P. phosphoreum (psychrophilic)	+	+	moderate	high
Spoilage bacteria				
Pseudomonas spp.	+	+	low	high
Flavobacterium spp.	+	+	low	high
Achromobacter spp.	+	+	low	high
Moraxella spp.	+	+	low	high
Serratia spp.	+	+	low	high
Parasites				
Anisakis larva	+	—	low	low/N.R.[a]
Tapeworm (*Diphyllobothrium latum*)	+	—	low	low/N.R.[a]
Distoma hepaticum (*Clonorchis cinensis*)	+	—	low	low/N.R.[a]
Paragonimus (*P. westermanii*)	+	—	low	low/N.R.[a]
Biotoxins				
Ciguatoxin	+	—	high	high/N.R.[c]
Saxitoxins	+	—	high	high/N.R.[c]
Dinophysis toxins	+	—	high	high/N.R.[c]
Viruses				
Hepatitis virus A	+	—	high	high/N.R.[c]
Norwalk virus	+	—	high	high/N.R.[c]
Rotavirus	+	—	high	high/N.R.[c]

[a] N.R., no risk, provided the fish is cooked before consumption.
[b] Depending on fishing area and local conditions.
[c] Depending on fishing area and season.

Table 4. Heat resistance of bacteria and bacterial spores.

Bacteria species	D-value (min)	
Brucella spp.	at 65.5°C	0.1 - 0.2[1]
Salmonella Senftenberg 775W	at 65.5°C	0.8 - 1.0[1]
Salmonella spp.	at 65.5°C	0.02 - 0.25[1]
Staphylococcus aureus	at 65.5°C	0.2 - 2.0[1]
Yeasts and molds and spoilage bacteria	at 65.5°C	0.5 - 3.0[1]
Spores of mesophilic aerobes		
Bacillus cereus	100°C	5.0[2]
Bacillus subtilis	100°C	11.0[2]
Bacillus polymyxa	100°C	0.1 - 0.5[2]
Spores of mesophilic anaerobes		
Clostridium butyricum	100°C	0.1 - 0.5[2]
Clostridium perfringens	100°C	0.3 - 20.0[2]
Clostridium botulinum		
Type A and type B proteolytic strains	100°C	50.0[2]
Type E and non-proteolytic types B and F	80°C	ca. 1.0[2]
Spores of thermophilic aerobes		
Bacillus coagulans	120°C	0.1[2]
Bacillus stearothermophilus	120°C	4.0 - 5.0[2]
Spores of thermophilic anaerobes		
Clostridium thermosaccharolyticum	120°C	3 - 4[2]
Desulfotomaculum (Clostridium) nigrificans	120°C	2 - 3[2]

Note: (1) ICMSF, 1980a, Table 1.9, p.26
(2) ICMSF, 1980a, Table 1.8, p.25

Table 5. D-values and F-values of non-spore forming micro-organisms at two temperature [a].

Organism	D-value[b] (85°C,sec)	D-value (65°C,sec)	z-value (°C)	F-value[c] (calculated for 7D) (85°C,sec)	(65°C,min)	Heating medium
Vibrio cholerae	0.16	11.7	10.5	1.12	1.4	buffer
	0.29	93.0	7.7	2.03	10.8	crabmeat
V. parahaemolyticus	0.14	2.8	14.8	0.98	0.33	clam
Listeria monocytogenes	0.16	39.8	8.4	1.12	4.6	crabmeat
	0.02	11.2	7.2	0.14	1.3	milk
	0.09	28.2	8.0	0.63	3.3	milk
	0.007	19.8	5.8	0.05	2.3	skim milk
	0.02	17.2	6.8	0.14	2.0	cream
Staphylococcus aureus	0.002	15.0	5.1	0.01	1.7	various foods
	0.04	132.0	5.5	0.28	15.4	various foods
Salmonella typhimurium	0.002	2.3	6.2	0.01	0.3	milk
	0.001	4.2	5.5	<0.01	0.5	— [d]
Salmonella Senftenberg	0.017	53.6	5.5	0.18	6.3	—
Yersinia enterocolitica	0.0007	21.4	5.5	<0.01	2.5	milk
Shigella dysenteriae	0.0002	3.0	4.7	<0.01	0.3	milk
Campylobacter jejuni	0.0007	1.03	5.8-6.7	<0.01	0.1	skim milk
Non-spore-forming bacteria[e]	0.008-0.01	60-180	4-6	<0.01~0.07	7.0~21.0	various foods

[a] Referred and adopted from T.E. Rippen & C.R. Hackney, Food Technol., Dec. 1992, pp. 88 (Table 1).

[b] D-value (decimal reduction times, in minutes or seconds) are mostly calculated from values determined at lower temperatures and should be considered as estimated values.

[c] F-value: Accumulated heat exposure to destroy a given number of organism in seconds or minutes at a specified temperature.

[d] Not reported.

[e] *Pseudomonas, Achromobacter, Enterobacter, Micrococcus, Lactobacillus.*