Case Study: Sous vide

October 2016

About case studies

The Environmental and Occupational Health team provides scientific and technical advice and support to the health care system and the Government of Ontario. We have created the case study series to share the diverse environmental health issues we have encountered and encourage dialogue in these areas.

This response was originally produced on July 2016. Note that the specifics about the location and requestor involved have been removed.

The following was selected as a case study because of the growing popularity of sous vide in Ontario.

Background

This document was prepared so that the reader should be able to:

- Describe sous vide cooking
- List the main microbiological safety concerns associated with sous vide cooking, and
- Apply the Hazard Analysis Critical Control Point (HACCP) system for sous vide cooking

Methods

In order to identify relevant literature on sous vide, Public Health Ontario (PHO)'s library services performed a literature search on the microbial safety of sous vide cooking using the following databases:

1. Ovid MEDLINE
2. Food Science Source
3. Environment Complete, and
4. Scopus.

The search was limited to literature published in English from January 1, 2006 to May 2016. The search strategy included terms such as sous vide, chill-cook process, water bath, vacuum seal, *E-coli, Listeria spp, Clostridium botulinum, Salmonella,* infection, outbreak food poisoning, food contamination, food microbiology, HACCP, meta-analysis and systematic review.

The search yielded 346 citations after duplicate records were removed. Titles and abstracts were screened for relevance by two individuals. Additional articles were identified through cited reference searching of full-text articles (including those published prior to 2006). Papers were selected if they investigated the microbial safety of sous vide cooking. In addition, a grey literature search was performed using the same keywords on Google. The first 100 Google search results retrieved were reviewed. A total of twenty three records are included in this report.

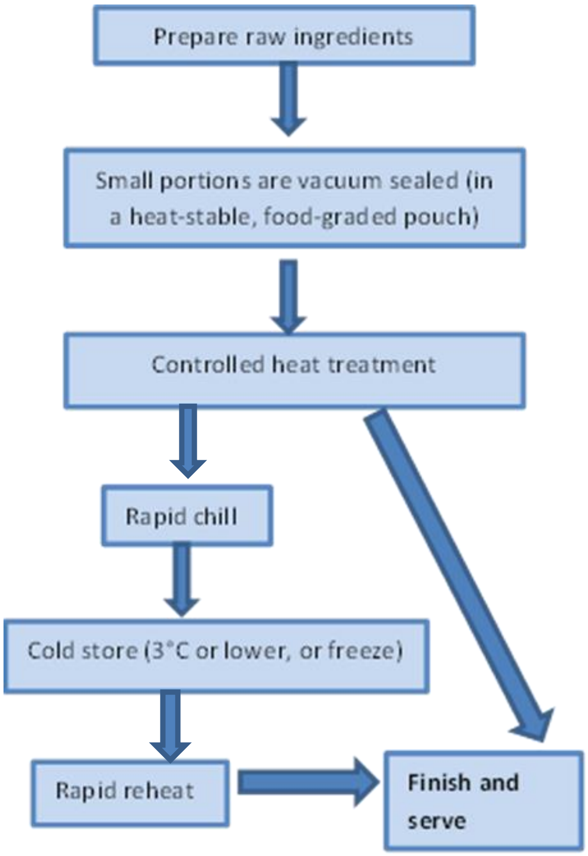
What is Sous Vide?

Sous vide is "under vacuum" in French. The technique was first developed for use in restaurants in 1974 by Georges Pralus, a French chef.[1] It differs from traditional cooking in two major ways: raw food is vacuum-sealed in heat-stable, food-grade plastic pouches then cooked at low temperatures.[2] Cooking and pasteurization occurs at time/temperature combinations sufficient to destroy vegetative pathogens to produce food with longer shelf life and better sensory quality than traditionally prepared food.[3,4,5] This is usually achieved in a water bath (alternatively steam oven) set to temperatures lower than used in conventional cooking but applied for a longer time period. The term sous vide is also used to describe the final product. [6,7]

In recent years, there has been growth in the use of sous vide processing technology.[8] Presently, sous vide cooking is practiced in some food establishments in Ontario as well as home kitchens. A number of sous vide cookers for home use exist.[9]

Sous vide cooking can be "cook-serve" or "cook-chill/cook-freeze". Cook-serve is when the finished product is served after the cooking process is completed. Cook-chill or cook-freeze is when a cooked product is rapidly chilled and stored in cold holding units for future use.[2] Figure one provides a generic flow diagram of the sous vide process.

Figure 1: Generic flow diagram for sous vide process [2]



As shown in Figure 1, common process steps involved in sous vide include:

Prepare raw ingredients for packaging: This stage involves preparing raw ingredients and the composition of the dish. For example, potentially hazardous foods may be stored, meats may be thawed, seasoning and other ingredients added, and vegetables may be blanched. Using fresh and good quality ingredients, temperature control, good hand hygiene, implementation of quality control measures, and prevention of cross contamination can minimize microbial growth during this stage.[8]

Vacuum packaging: Proper vacuum packaging is essential for effective heat transfer during heat treatment step. Heat transfer is 23 times better through liquid than through air.[6] Vacuum packaging also reduces the risk of cross-contamination during storage and inhibits oxidation. The anaerobic environment inside the packaging prevents the growth of most spoilage organisms and aerobic pathogens. However, it is also ideal for growth of anaerobic pathogens such as *Clostridium botulinum.*[2] To minimize migration of chemical compounds from the packaging plastic to the food during the heat treatment, British Columbia Centre for Disease Control (BCCDC)'s "*Guidelines for restaurant sous vide cooking safety in British Columbia*" recommends that operators use BPA free packaging designed for use in sous vide processing that are made of polyethylene or polypropylene.[6]

Heat treatment/cooking step: Heat treatment in sous vide is a mild heat pasteurization process.[3,4] It uses precisely controlled heat over longer cooking periods to achieve 6D reduction[*] of *Listeria* and vegetative cells of *C. botulinum* and 7D reduction of *Salmonella*.[2] To ensure adequate cooking, food pouches in the same water bath are completely submerged and not tightly arranged or overlapped. The water bath should be preheated to the desired temperature before submerging sealed pouches. Cooking duration is timed after food has first come up ("come up time") to the required temperatures. Temperature should be measured at the center of the thickest part of the food to ensure target internal temperatures are achieved.[2,10] The physical attributes of the food (e.g. shape, thickness, density) affects the time required for heat treatment. Different time/temperature combinations can provide equivalent bacterial reduction for the same food. Table 1 shows time sufficient to pasteurize meat, fish or poultry in water baths at different time/temperature combinations.[2] Temperatures below 60°C should not be used for sous vide cooking of poultry.[6]

[*] For *C. botulinum* and *Listeria*, pasteurization is achieved with a pathogenic load reduction of six orders of magnitude, or a 6D reduction (six logarithms, e.g., from 10^3 to 10^{-3}).[11]

Table 1: Time (minutes) sufficient to pasteurize meat, fish, or poultry in water baths from 60°C to 66°C.[2]

Thickness (mm)	60°C	61°C	62°C	63°C	64°C	65°C	66°C
5	0:51	0:40	0:31	0:25	0:20	0:17	0:14
15	1:13	1:02	0:53	0:47	0:42	0:38	0:35
25	1:41	1:30	1:21	1:16	1:08	1:03	0:59
35	2:09	1:56	1:46	1:38	1:31	1:26	1:21
45	2:42	2:29	2:17	2:08	2:00	1:53	1:48
55	3:26	3:11	2:58	2:47	2:38	2:30	2:23
65	4:15	3:58	3:43	3:31	3:20	3:11	3:02

Table adapted from Baldwin (2012)[2]
Note: This table is based on 2 minutes at 70°C with z=7.5°C for 6 log reduction of *Listeria monocytogenes*.[11]

Rapid chilling: Heat processing during sous vide cooking does not reduce pathogenic spores to a safe level. Thus it is essential that food not served immediately is chilled rapidly to minimize bacterial growth.[2] Vacuum-packed sous vide food should be chilled to 3°C or lower (within two hours).[12] This can be achieved by placing the food in an ice bath or by using blast chillers or water cascade systems.

Cold holding: Chilled sous vide items should be stored in cold holding units and maintained at an internal temperature of 3°C or lower to prevent growth of anaerobic spore-forming pathogens such as non proteolytic *Clostridium botulinum, Clostridium perfringens and Bacillus cereus*.[6,13] To maintain low storage temperature, sous vide items can be stored in covered pans with alternating layers of ice in a walk-in-cooler. The microbiological health risk related to *Bacillus* and *Clostridium* spp in sous vide products is small as long as storage temperatures are low (3°C and lower).[13]

Limiting storage times is another way to control the growth of pathogens in sous vide food. Storage for extended periods of time is not recommended unless the product is frozen.[12] The key concern is that certain strains of C. botulinum can grow at 4°C. If the food has a pH >4.6 or available water ≥0.92, cold holding times should be limited. Baldwin recommends that sous vide products can be kepts for up to 30 days below 3.3°C.[2]

At refrigeration temperatures, some food safety experts recommend that sous vide foods not be stored for more than 15 days. (Aug. 2016 email from Dr. Keith Warriner, University of Guelph; unreferenced.) Others, such as the Food Authority in Australia recommends that refrigeration storage of pasteurised sous vide food in restaurants should be limited to a maximum of ten days.[12] United States Food and Drug Administration recommends a maximum of seven days for storage of sous vide cooked food in cold holding units.[19]

Reheating after cold holding storage: Baldwin reports that sous vide food can be reheated in a water bath before finishing for service, generally at or below the temperature it was cooked in (for example meat is typically reheated to 55°C).[2] The Food Safety Authority of Ireland recommends the cooked food be reheated, before consumption, to a core temperature of at least 70°C.[10] New South Wales Food Authority in Australia recommends that the total time before food is consumed or discarded not exceed four hours, if it is maintained at temperatures between 5°C to 60°C.[12]

Microbiological safety concerns associated with sous vide processing

Sous vide cooking uses lower temperatures than conventional cooking. This temperature may not be high enough to deactivate all pathogens in food, and it will not destroy bacterial spores. The anaerobic environment of vacuum sealed sous vide products provides ideal growth conditions for anaerobic spore forming pathogens such as *C. botulinum, C. perfringens* and *Bacillus cereus. Listeria, Salmonella,* and pathogenic *E. coli* can also survive in anaerobic environments.[6] Two of these are discussed further below.

Non proteolytic, or psychotropic *C. botulinum* is one of the main concerns with sous vide products. Non proteolytic *Botulinum* strains can grow and produce toxin at temperatures of less than 10°C.[14] Lindstrom et al. tested for *C. botulinum* and *C. botulinum* toxin in 96 samples of various low acid sous vide processed food products after storage for 14 to 28 days at 4°C and 8°C. After sous vide processing for 2 min at 85°C and storage, all products showed *Botulinum* growth, and one ground beef sample stored at 8°C became positive for toxin. Increased duration of processing (67 min at 85°C) resulted in growth but not toxin production in one ground beef sample after 21 days at 8°C. In pork cube samples tested, no growth was detected.[15]

In another study, Hyytia-Trees et al. evaluated the safety of 16 sous vide pork and beef products. Raw beef and pork were inoculated with non-proteolytic group II *C. botulinum* spores at 2.0 log-CFU/kg and 5.3 log CFU/kg. Following thermal processing, the sous vide products were stored at 4°C or 8°C until their recommended shelf life and seven days past their shelf life, which varied from 14 to 21 days. There were more positive *C. botulinum* samples at the lower inoculum level compared to the higher inoculum level post processing. Only two of the 16 products were found to be negative for botulinum spores and neurotoxin after thermal processing. Toxigenesis was detected in two samples with the higher inoculum stored at 8°C. The study concluded that most of the thermal processes were inadequate for eliminating spores.[5]

These studies demonstrate that the processing temperatures commonly employed in sous vide cooking may not eliminate *C. botulinum* spores.[5,15] Cold holding temperature and holding time are the two parameters that can control for the growth of *C. botulinum* in sous vide products. To control for the growth of botulinum spores and production of toxins, vacuum packaged sous vide food should be held below 3°C.[6,13]

A report from the Botulinum Working Group of European Chilled Food Federation concluded that sous vide processed products that are kept in anaerobic environment should be stored below 3°C to ensure safety. Alternatively, heat treatment sufficient to deliver a 6 log reduction in spores of non proteolytic strains of *C. botulinum* and storage below 10°C, or application of intrinsic preservation factors (e.g. acidic pH) has also been shown to be effective in ensuring safety of hermetically sealed sous vide products.[16] Table 2 demonstrates the time/temperature requirement for toxin production by *C. Botulinum*.

Listeria monocytogenes is another pathogen of concern with sous vide products. It is widespread in the environment and can grow in low oxygen environments and at refrigeration temperatures. It is also one of the most heat resistant non-spore forming pathogens.[2]

Factors influencing deactivation andgrowth or resuscitation of heat injured *L. monocytogenes* cells include the length of time and temperature applied during the heating process, the cold storage temperature, and the length of time stored at cold holding units.[17]

Heat treatment at 75°C can reduce the number of *L. monocytogenes* by 1,000,000-fold or 6D. However, not all sous vide recipes require reaching a temperature of 75°C.[12] Nyati investigated the survival and growth of *L. monocytogenes* in broth models and in sous vide products. Raw chicken breasts inoculated with $3x10^3$ to $5x10^5$ CFU/g of *L. monocytogenes* were subjected to sous vide thermal processing at internal temperature of 68°C or 72°C for two minutes. No growth was detected during a storage period of five weeks at 3°C and 8°C. In broth cultures, heat treatment from 20°C to 70°C resulted in 4.1 to 5.6 log reduction in *L. monocytogenes* cells and a heat treatment at 70°C for 2 min resulted in a greater than 7 log reduction. Nyati also investigated the growth of *L. monocytogenes* at low storage temperatures. As the temperature decreases, pathogen generation times increase. At 0°C the generation time for *L. monocytogenes* was 100 to 165 hours and at 25°C the generation time was one hour. This study also demonstrated that lowering the pH of the product to 5 inhibited *Listeria* growth.[18]

Table 2: Time/temperature requirement for toxin production in foods that were inoculated with spores of psychotropic *Botulinum*[16]

Food	*C. botulinum* type	Inoculum per gram	Temperature (°C)	Time to toxin (days)	Reference
Beef	B	10^4	10	6	Crandall et al. (1994)
Salmon	B, E	10^4	12 8	4 8	Meng and Genigeorgis (1994)
Turkey	B, E	10^3	8	7	Meng and Genigeorgis (1993)
Salmon	B, E, F	10^2 10^3	12 8	6 9	Garcia et al. (1987)
Herring	E	10^2	10	7	Cann et al. (1965)
Cod	E	10^2	10	6	Taylor et al. (1990)
Potato	E	10^4	10	11	Notermans et al. (1981)

In another study by Hansen and Knochel, heat injured *L. monocytogenes* stationary phase[‡] cultures (with 95.0%-99.9% injured cells in the surviving population) did not grow or repair sub lethal injuries in sous vide cooked beef at 3°C, but growth was observed at 10°C and 20°C. In cultures where there were fewer than one log reduction, there was still no growth at 3°C for 30 days.[17]

Appendix 1, Tables 3 and 4 provide the time and temperature requirements to achieve 6-log reduction of psychrotrophic *C. botulinum* and *L. monocytogenes*.

In summary, the temperatures involved in sous vide processing may not be sufficient to eliminate spores and all pathogenic cells (if the initial bacterial load is high). The use of multiple strategies to control pathogen growth, such as length of time and temperature applied during the heating process, the cold storage temperature, the length of time stored in cold holding units and intrinsic properties of food (nutrient content, water activity, pH value, redox potential, the presence of antimicrobial substances), and adequate sanitation can reduce the risk of foodborne illness from sous vide foods.

‡The growth cycle of bacteria in food takes on four characteristic phases: 1) lag phase, 2) log phase, 3) stationary phase and 4) death phase.[19] The stationary phase and the death phase (decline phase) are the last two stages of bacterial growth. In the stationary phase, the rate of cell growth matches the rate of cell death. Stationary phase of bacterial growth is the phase in which the size of population of bacteria remains contstant.[22]

HACCP and sous vide

To ensure safety of sous vide products, implementation of a HACCP system at all stages of sous vide processing and distribution of end product is recommended.[4,8] HACCP is a systematic approach to the identification, evaluation, and control of food safety hazards. It is based on conducting a hazard analysis, determining the critical control points (CCPs), establishing critical limits, establishing monitoring procedures, identifying corrective actions, establishing verification procedures, and maintaining record-keeping and documentation procedures.[20]

Process flow diagram: Implementation of an HACCP system starts with the creation of a product description. It includes information such as list of ingredients, composition, packaging specification, processing time and temperatures, and labeling specifications. A process flow diagram shows the product's transition from raw ingredients to finished product and distribution.

Hazard identification and analysis: A hazard analysis at each stage of the product's transition follows. Food hazards can be classified as biological, chemical, physical, regulatory and functional hazards. Table 5 provides examples of each hazard.[8]

In sous vide cooking microbial hazards, particularly anaerobic spore forming pathogens, pose the greatest threat to consumers. *E. coli, Salmonella, Staphylococcus, Aeromonas, Listeria* and *Yersinia* species, are the main non-spore forming microbial hazards in sous vide cooking.[2,8] Pasteurization temperatures should be sufficient to deactivate the non-spore forming pathogens during sous vide processing. However, if the microbial load of these pathogens is high due to poor manufacturing practices (such as cross contamination, temperature abuse, or poor microbial quality of the raw ingredients) these pathogens can pose a risk to consumers. In these cases, the pasteurization process may not be adequate to destroy the high microbial load.[8]

Table 5: Food hazards and examples[8]

Hazard	Examples
Biological	Bacteria, moulds, parasites, and pests (birds, insects, rodents)
Chemical	Antibiotic or insecticide residues, sanitizing/disinfecting chemicals, heavy metals, and naturally occurring toxins
Physical	Hair, nail clippings, plastic dirt, glass splinters, peeling paint and metal.
Regulatory hazards	Labelling errors
Functional hazards	Packaging defect (leak in a hermetically sealed pouch)

Determining critical control points (CCP): A critical control point is a point in the process that eliminates or reduces the hazards identified. CCPs associated with HACCP systems for sous vide process may include:

- Quality of raw materials
- Safe food handling of potentially hazardous food prior to and after vacuum sealing
- Time/temperature processing
- Sanitary and adequately vacuum packaged condition (no leakage of hermetically sealed plastic bags)
- Control of the chill chain throughout the process (processing, storage, transportation, etc.)[13,21]

Monitoring, verification and record keeping: The last steps in HACCP include monitoring of identified CCPs, identifying corrective actions to take if critical controls are not met, establishing verification procedures and maintaining record-keeping and documentation procedures. Appendix 2 Figure 2 provides an example of a monitoring form for sous vide products.

Key points

- In recent years, there has been growth in the use of sous vide processing technology. Sous vide cooking is now practiced in some food establishments in Ontario. It is also being done in home kitchens.
- The vacuum packaging of sous vide products provides an anaerobic environment that reduces the risk of cross-contamination during storage and inhibits oxidation, but provides an ideal growth environment for spore-forming pathogens such as *C. botulinum* and facultative anaerobes such as *Listeria monocytogenes.*
- Heat treatment in sous vide is a mild heat pasteurization process. It does not reduce pathogenic spores to a safe level. Also, if the initial microbial load of the raw ingredients is high, the heat treatment may not be sufficient to destroy all vegetative pathogens.
- Rapid chilling and cold storage to 3°C and lower and limiting storage times after cooking are ways to control for the growth of pathogens post heat treatment.
- Factors affecting safety of sous vide products include:
  - **Formulation and intrinsic properties of food**
  - **Sanitation**
  - **Type of food packaging**
  - **Temperature applied during the heating process**
  - **Length of heating process**
  - **The cold storage temperature, and**
  - **The length of time stored in cold holding units (shelf life).**
- A properly administered and monitored HACCP system can assist in producing safe sous vide products.

Where can I get more information?

For more detailed information on sous vide cooking, please refer to:

- BC Centre for Disease Control, Guidelines for restaurant sous vide cooking safety in British Columbia. Jan 2016. Available from: http://www.bccdc.ca/resource-gallery/Documents/Guidelines%20and%20Forms/Guidelines%20and%20Manuals/EH/FPS/Food/SVGuidelines_FinalforWeb.pdf

- NSW Food Authority, Sous vide: Food safety precautions for restaurants. Available from: http://www.foodauthority.nsw.gov.au/_Documents/scienceandtechnical/sous_vide_food_safey_precautions.pdf

APPENDIX 1

Table 3: Lethal rates for psychrotrophic *Clostridium botulinum* (to achieve 6-log reduction) [23]

Temperature (°C)	Time (minutes)	Lethal Rate
80	270.3	0.037
81	192.3	0.052
82	138.9	0.072
83	100.0	0.100
84	71.9	0.139
85	51.8	0.193
86	37.0	0.270
87	27.0	0.370
88	19.2	0.520
89	13.9	0.720
90	10.0	1.00
91	7.9	1.260
92	6.3	1.600
93	5.0	2.000
94	4.0	2.510
95	3.2	3.160
96	2.5	3.980
97	2.0	5.010
98	1.6	6.310
99	1.3	7.940
100	1.0	10.000

Table 4: Lethal rates for *Listeria monocytogenes* (to achieve 6-log reduction) [23]

Temperature (°C)	Time (minutes, seconds)	Lethal Rate
60	43’ 29”	0.046
61	31’ 44”	0.063
62	23’ 16”	0.086
63	17’ 06”	0.117
64	12’ 40”	0.158
65	9’ 18”	0.215
66	6’ 49”	0.293
67	5’ 01”	0.398
68	3’ 42”	0.541
69	2’ 43”	0.736
70	2’ 00”	1.000
71	1’ 28”	1.359
72	1’ 05”	1.848
73	0’ 48”	2.512
74	0’ 35”	3.415
75	0’ 26”	4.642
76	0’ 19”	6.310
77	0’ 14”	8.577
78	0’ 10”	11.656
79	0’ 06”	15.849
80	0’ 05”	21.544
81	0’ 04”	29.286
82	0’ 03”	39.810
83	0’ 02”	54.116
84	0’ 02”	73.564
85	0’ 01”	100.00

APPENDIX 2

Figure 2: An example of a monitoring form for sous vide food (Aug. 2016 email from Dr. Keith Warriner, University of Guelph; unreferenced).

Item	Cooking Temp	Cooking Time	Temp reached at core	Temp 2h post cook	Cooling time to reach 4C	Deviations and corrective actions	Person monitoring
Rib Eye Steak	55C	4h	63C	10C	90min	Chiller had power outage so transferred to ice bath for cooling	A. Cook

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