NSW GOVERNMENT | Food Authority

Sous vide

Food safety precautions for restaurants

NSW/FA/CP058/1207

Foreword

Sous vide translates from the French as 'under vacuum'. In culinary terms it has come to mean a process of cooking under vacuum in sealed pouches (oxygen barrier bags), at precise (and sometimes low) temperatures and often for long times. *Sous vide* can be used to prepare foods with an extended shelf life for retail sale or use in food service. However, *sous vide* can also be used to prepare foods with qualities that cannot be achieved when using traditional cooking techniques. Some *sous vide* recipes result in food that remains raw or undercooked.

This document includes information on the service of raw and undercooked foods. This information is provided in response to a growing trend for *sous vide* use by restaurants and to encourage the use of safer choices for this type of product: it is not an endorsement of the service of raw or undercooked foods. The onus of delivering a safe product to the consumer resides with the business.

The Food Standards Code says that a food business must:

> *where a process step is needed to reduce to safe levels any pathogens that may be present in the food, use a process step that is reasonably known to achieve the microbiological safety of the food.*

Cooking is a process known to achieve the microbiological safety of food and by choosing to serve raw or undercooked animal foods restaurateurs must acknowledge that there will be a residual public health and business risk.

Section 1.6 of this document provides details on the public health risks of raw and undercooked foods. As an alternative to the service of raw or undercooked foods chefs should first consider the service of cooked food prepared using times and temperatures from Table 2 or Table 3 that follow.

Contents

Executive summary

There are several types of *sous vide* foods. This document is about food safety hazards of cook serve and short term cook chill *sous vide* foods. Some issues are common to extended shelf life *sous vide* foods but guidance on the preparation of these foods is readily available.

Sous vide seems like a new food service technology but it has a history spanning four decades in France and two decades in other international marketplaces. It finds application in many market segments including extended shelf life ready meals. It is also found in catering companies, restaurants and, increasingly, *sous vide* has been embraced by home cooks.

There is a history of *sous vide* food causing concern to regulators. There is little evidence of *sous vide* food causing outbreaks of foodborne illness. However there are foreseeable hazards in three broad areas that must be managed:

1. Foods held in the temperature danger zone, defined as 5°C to 60°C by the Australia New Zealand Food Standards Code, for extended periods are potentially subject to bacterial growth, for example, during low temperature long time (LT LT) cooking processes, product cooling or product reheating.
2. Foods stored under refrigeration for extended periods are potentially subject to growth by cold tolerant pathogens. The growth of *Listeria monocytogenes* is a risk as is growth and toxin production by non-proteolytic *Clostridium botulinum*.
3. Food cooked at low temperatures for short periods will, in essence, remain raw and pathogenic bacteria and parasites, if present, might survive.

The risks associated with *sous vide* foods will be **reduced** if:

- thinner portions of food are prepared so that heating and cooling are rapid.
- water bath temperatures of at least 55°C are used so that the growth of *Clostridium perfringens* is first prevented and then destruction of the cells commences.
- the time food is held below 54.5°C during cooking is limited to six hours.
- commercial equipment with adequate heating capacity and excellent temperature control is used.
- water and/or food temperatures are checked using a tip sensitive digital thermometer that is accurate to 0.1°C.
- prepared foods are not stored for extended times unless processes have been validated.
- risks are not compounded. Cooking large portions of mechanically tenderised meat for extended times at low temperatures would be irresponsible.
- if you choose to include on your menu foods that remain essentially raw they should only be served following a request by an informed, healthy adult who willingly accepts the risks associated with raw foods.

New practitioners of *sous vide* must be aware of the food safety risks and avoid overly experimental applications of the technology. Today’s leaders in *sous vide* produce quality food without losing sight of food safety.

Introduction

This chart illustrates the variety of processes used to prepare *sous vide* foods. The blocks with bold font and pink-striped fill relate to extended shelf life products such as ready meals or foods produced by some large caterers. The guidance in this document does not address specific issues relating to extended shelf life *sous vide* products, for example those with a shelf life greater than ten days.

The Wide Spectrum of *Sous Vide*

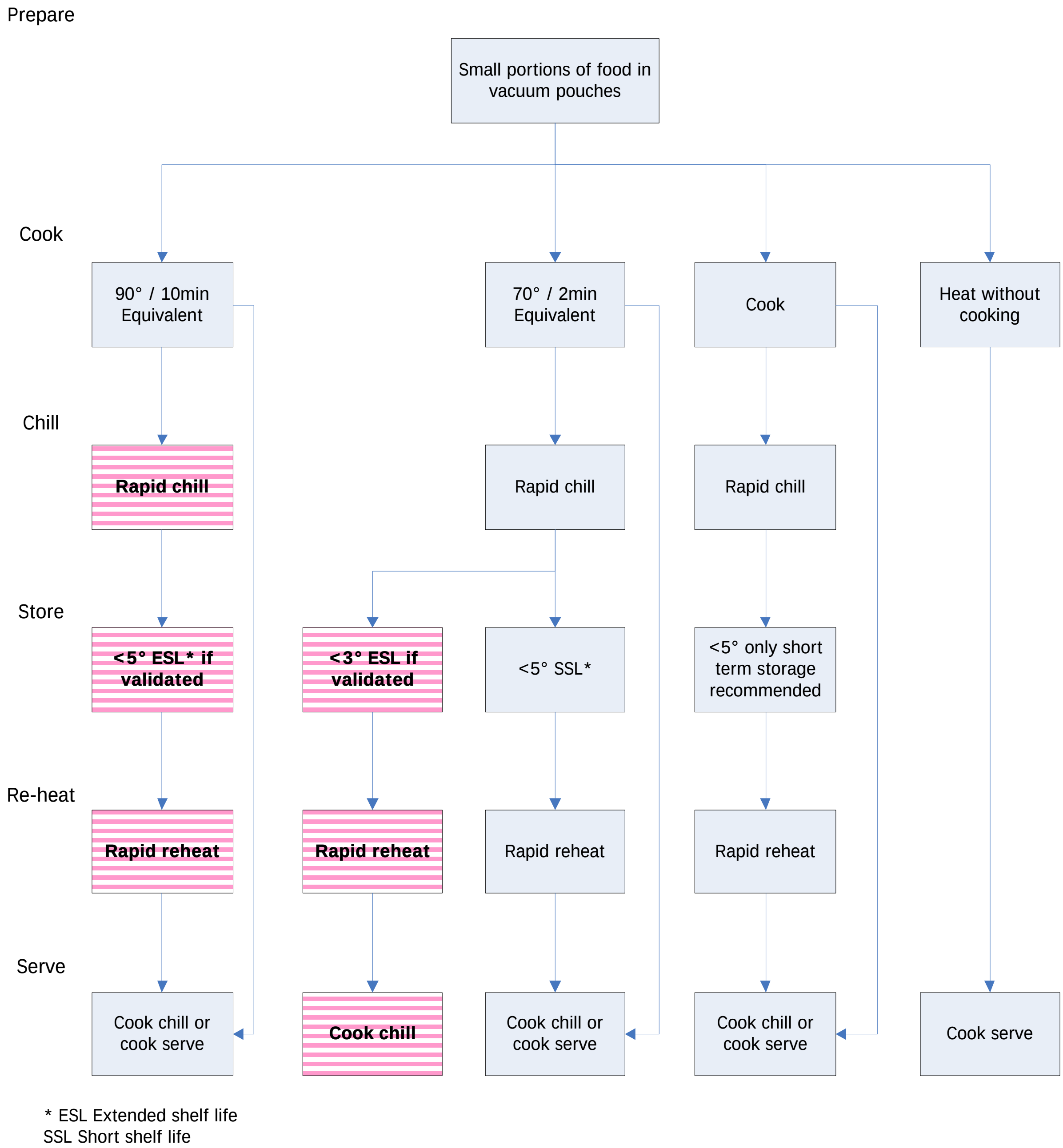

Figure 1: ***Sous vide*** **processing**

Sous vide processing

Sous vide translates from the French as 'under vacuum'. In culinary terms it has come to mean a process of cooking under vacuum in sealed pouches (oxygen barrier bags), at precise (and sometimes low) temperatures and often for long times. Creed (1998) quotes the widely accepted definition developed by the *Sous Vide* Advisory Committee (SVAC):

> *Sous vide (also known as Cuisine en Papillote Sous Vide) is an interrupted[1] catering system in which raw or par-cooked food is sealed in a vacuumed laminated plastic pouch or container, heat treated by controlled cooking, rapidly cooled, and then reheated for service after a period of chilled storage.*

Sous vide can be used to prepare foods with an extended shelf life for retail sale or use in food service. In these examples the 'interrupted catering system' is the relevant characteristic. However, *sous vide* can also be used to prepare foods with qualities that cannot be achieved when using traditional cooking techniques. In this instance 'in-pouch' cooking under precise and often delicate conditions provides the sought-after characteristics and refrigerated or frozen storage might not be part of the process.

The wide range of products known as *sous vide* can be divided into four broad categories.

- **Processed 90/10**. Heated to reduce the numbers of non-proteolytic *Clostridium botulinum* by 99.9999%. This moderately severe process is likely to be used for retail ready meals or extended shelf life cook chill foods. One conventional process calls for the slowest heating part of the food to be exposed to a combination of temperature and time equivalent to 90°C for 10 minutes. Lower temperatures can be used but exposure times increase significantly.
- **Processed 70/2**. Heated to reduce the numbers of *Listeria monocytogenes* by 99.9999%. This is commonly known as food pasteurisation and it could be used by restaurants, caterers and some manufacturers of extended shelf life foods. One conventional process calls for the slowest heating part of the food to be exposed to a combination of temperature and time equivalent to 70°C for 2 minutes. Lower temperatures can be used but exposure times increase significantly.
- **Cooked**. This term mainly refers to taste, texture and appearance but it has also become associated with certain minimum heating processes for meats. Cooked but not necessarily pasteurised foods will be encountered in restaurants and home *sous vide*. One process specified by the US Food Safety Inspection Service (FSIS, 2011) calls for the slowest heating part of the food to be heated to 63°C followed by a 3-minute rest time. Lower temperatures can be used to prepare rare meats but exposure times increase significantly. Higher temperatures are specified for poultry and mechanically tenderised, injected, comminuted or stuffed meats. Extended times can be used to tenderise cheaper cuts of meat.
- **Lightly processed**. Some *sous vide* recipes do not result in cooked food. Any contaminant bacteria or parasites that might be present are likely to survive.

In food service operations *sous vide* foods will generally be cooked in a finely controlled circulating water bath or a combination steam/forced convection oven. Larger catering companies or manufacturers preparing ready meals might use an enclosed vessel (sometimes called a retort) with a water cascade system to first heat and then cool the pouches of food.

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[1] Interrupted – implies a holding step, as in cook chill as opposed to cook serve for immediate use

Concerns about food safety

Sous vide has been embraced by a number of celebrity chefs and use of the technique is spreading in culinary circles. A similar surge in popularity of *sous vide* in New York CBD restaurants, in part, resulted in an effective ban on 'reduced oxygen packaging' (ROP) pending individual approval from the city's Department of Health and Mental Hygiene (NY Times, 2006). One concern was that chefs trained in *sous vide*, aware of the hazards, had been joined by those who were not aware. The Department was concerned that ROP suppressed the growth of spoilage bacteria while providing a suitable environment for pathogens such as *Listeria monocytogenes* and *Clostridium botulinum*. To gain approval to use ROP, food establishments were required to have a food safety plan for each food item and multiple barriers against the growth of *Listeria* and *Clostridium* were required (eg pH, water activity).

Retail *sous vide* foods such as ready meals and, more generally, vacuum packed and modified atmosphere chilled foods, have a good record of food safety. The Institute of Food Research (Peck et al 2006) found no cases of foodborne botulism could be attributed to correctly stored commercial chilled foods in the UK or overseas. Guidance on the preparation of *sous vide* ready meals and cook chill foods generally is readily available—see Cox and Bauler (2008), UKFSA (2008) and FSAI (2006). This document does not address food safety risks for ready meals and other extended shelf life foods, although many of the issues of restaurant *sous vide* overlap with those for extended shelf life foods.

The extent of foodborne illness attributable to restaurant prepared *sous vide* is not as clear, but reports of foodborne illness are at least rare, and no reports of illness explicitly naming *sous vide* foods have been found in the scientific literature or outbreak databases. However, there are foreseeable hazards that must be managed. *Sous vide* literature has focussed on botulism, but there are other potential hazards that have received less attention. *Sous vide* hazards fall into three areas:

- Foods held in the temperature danger zone (5°C to 60°C) for extended periods are potentially subject to bacterial growth, for example, during
    - low temperature long time (LT LT) cooking processes,
    - product cooling, or
    - product reheating.
- Foods stored under refrigeration for extended periods are potentially subject to growth by cold tolerant pathogens. The growth of *Listeria monocytogenes* is a risk, as is growth and toxin production by non-proteolytic *Clostridium botulinum*.
- Food cooked at low temperatures for short periods will, in essence, remain raw and pathogenic bacteria, viruses and parasites, if present, might survive.

The established wisdom relating to food safety should not be ignored by experimental chefs. This wisdom has mainly been acquired—the hard way—through food poisoning incidents. Today's leaders in *sous vide* produce new and interesting food without losing sight of food safety.

Food safety hazards

1.1 Low temperature cooking – bacterial growth

Scientific literature on bacterial growth in low temperature cooking processes is quite limited. The Food Safety and Inspection Service of the United States Department of Agriculture (FSIS, 1999) mentions the risk of 'slow come up time' for certain meat and poultry products. The guideline states that 'dwell times of greater than 6 hours in the 50°F (10°C) to 130°F (54.4°C) range should be viewed as especially hazardous, as this temperature range can foster the growth of many pathogens of concern'. Food can dwell in this temperature due to 'slow come up time', or by being held for an inordinate amount of time in that range. The guideline notes that the multiplication of pathogens can be so great then even recooking may be ineffective in making the product safe. Toxigenic bacteria can release toxins into the products. Some of the toxins, such as those of *Staphylococcus aureus*, are extremely heat stable and are not inactivated by normal recooking temperatures.

The Food Code (US Food and Drug Administration, 2009) includes several clauses on time as a public health control. Clause 3–501.19 (1) (B), is similar in intent to the '4-hour/2-hour rule' for temperature control outlined in Safe Food Australia (ANZFA, 2001). The US Food Code allows for a maximum of four hours between 5°C and 57°C, whereas the comparable Australian guideline temperatures are 5°C and 60°C.

Low temperature long time (LT LT) cooking is not new. Braising and crockpot cooking are familiar examples. It is now being used by some steak houses to prepare prime roasts and some *sous vide* recipes use the technique. The main benefit is tenderisation of cheaper meat cuts. Care must be taken if unusually low temperatures are used to achieve low levels of doneness. Extra care is required if mechanically tenderised meat is used because bacterial contamination present on the surface is spread through the meat to the slowest heating/cooling spots.

The main food safety risks of LT LT cooking are *Clostridium perfringens* and bacteria that form heat stable toxins in food, *Bacillus cereus* and *Staphylococcus aureus*. *Clostridium perfringens* appears to be the pathogen best adapted to growth during processing of *sous vide* meats (Willardsen et al 1978) and if this organism is effectively controlled the risks from the other bacteria will be minimal.

The emergence of LT LT cooking results in some foods being held at temperatures for periods of time that do not comply with Australian or US guidelines. Mathematician and published author on *sous vide*, Douglas Baldwin (2010; 2011; 2012), includes some recipes (tables of cooking times) where the combination of temperature and time is outside the guidelines.

Baldwin only tabulates times that comply with the US Food Code four hour limit for foods that are served unpasteurised. However, for foods that are pasteurised during cooking he allows up to six hours to reach 54.5°C. This combination of time and temperature challenges two familiar concepts—the 'temperature danger zone' and the '4-hour/2-hour rule'. However, based on the FSIS comments (above) and the studies of Willardsen et al (1978), the NSW Food Authority accepts that any risk to food safety is low.

Under Pressure, a *sous vide* recipe book by chef Thomas Keller (2008) which has sold well in the professional cooking category, does not include recipes likely to be in conflict with the '4-hour/2-hour rule'.

Hands-on: *Sous vide* low temperature long time (LT LT) cooking

This section is about LT LT production of cooked foods. Table 1 and Table 2 have been prepared by Baldwin (personal communications 2011, 2012). The times shown allow for product heating followed by pasteurisation (Table 1), or cooking (Table 2). The times are estimates and they are prepared using information about heat transfer through foods and the lethal impacts of cooking temperatures on bacteria that are significant causes of foodborne illness.

Where water baths are used it is important that they return to the set temperature quickly after the addition of food. Temperature recovery will be faster if a commercial water bath heater/stirrer with a high power heating element is used. Sophisticated temperature control is important and high technology controllers (often labelled or described as PID controllers) are specified. Operating temperatures should be checked with an accurate thermometer.

Table 3 records the holding time required to pasteurise the food after the target temperature has been achieved. It can be used when pouches have in-pack thermometers, for example, in combination steamer/forced convection ovens, high temperature water baths or water cascade systems.

The estimates calculated by Baldwin can be used for cook serve food or food stored for a few days. Extended shelf life cook chill foods or foods with unusual recipes require expert and tailored thermal process development. Estimates of lethality vary depending on the characteristics of food used in the trial. Baldwin's (2011) web guidance provides a good example. He presents calculations for lean fish based on observations made on cod, and for fatty fish based on observations made on salmon. Process times for salmon are longer than for cod. Food composition affects pasteurisation time.

Many factors can affect lethality, for example:

- Cox and Bauler (2008) note that the presence of lysozyme and other related enzymes might interfere with the lethal rate.
- Pasteurisation of cream requires a more severe process than pasteurisation of milk (because the higher fat content protects the bacteria).
- Chocolate requires a severe process to assure the elimination of *Salmonella*.
- Heavily salted food protects *Listeria* and more severe pasteurisation processes are required.

For a discussion about the variation in published estimates of thermal lethality (D and *z*–values) see Warne (2011) and van Asselt and Zwietering (2006).

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Table 1: Approximate time (Hours : Minutes) to heat and pasteurise refrigerated beef

Thickness (mm)	Water bath temperature °C											
	55	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**
5	3:33	2:41	2:00	1:30	1:08	0:51	0:40	0:31	0:25	0:20	0:17	0:14
10	3:35	2:43	2:04	1:36	1:15	1:00	0:49	0:41	0:35	0:30	0:27	0:24
15	3:46	2:55	2:16	1:48	1:28	1:13	1:02	0:53	0:47	0:42	0:38	0:35
20	4:03	3:11	2:32	2:04	1:44	1:28	1:17	1:08	1:01	0:56	0:52	0:48
25	4:17	3:25	2:46	2:18	1:57	1:41	1:30	1:21	1:13	1:08	1:03	0:59
30	4:29	3:38	3:00	2:32	2:11	1:55	1:43	1:33	1:26	1:19	1:14	1:10
35	4:45	3:53	3:15	2:46	2:25	2:09	1:56	1:46	1:38	1:31	1:26	1:21
40	4:59	4:07	3:29	3:00	2:39	2:22	2:09	1:59	1:50	1:43	1:37	1:32
45	5:21	4:29	3:50	3:22	3:00	2:42	2:29	2:17	2:08	2:00	1:53	1:48
50	5:45	4:53	4:14	3:44	3:21	3:03	2:49	2:37	2:27	2:19	2:11	2:05
55	6:10	5:18	4:39	4:08	3:45	3:26	3:11	2:58	2:47	2:38	2:30	2:23
60	6:38	5:45	5:06	4:35	4:10	3:50	3:34	3:20	3:09	2:58	2:50	2:42
65	7:07	6:15	5:34	5:02	4:36	4:15	3:58	3:43	3:31	3:20	3:11	3:02
70	7:40	6:45	6:03	5:30	5:04	4:42	4:23	4:08	3:54	3:43	3:32	3:23

Table 1, provided by Douglas Baldwin (personal communication, 8 September 2011), differs from Baldwin's web guidance because it is based on the USFDA thermal processing values for seafood. The values are noted to be conservative and to apply to all foods (USFDA 2011). The USFDA values were recommended by Warne (2011) in a report on low temperature cooking of beef prepared for Meat and Livestock Australia (MLA).

Baldwin's published tables are calculated based on best fit estimates of thermal inactivation from the results of numerous individual trials. His estimates are science based but more conservative values have routinely been used by regulatory agencies.

Table 2: Approximate time (Hours : Minutes) to heat and cook refrigerated beef

Thickness (mm)	Water bath temperature °C											
	55	56	57	58	59	60	61	62	63	64	65	66
5	1:16	0:54	0:38	0:28	0:21	0:17	0:14	0:12	0:09	0:08	0:07	0:06
10	1:24	1:02	0:47	0:38	0:31	0:27	0:23	0:21	0:19	0:18	0:16	0:15
15	1:37	1:15	1:00	0:51	0:44	0:39	0:35	0:32	0:30	0:28	0:26	0:25
20	1:54	1:32	1:17	1:06	0:59	0:53	0:49	0:45	0:42	0:39	0:37	0:35
25	2:08	1:46	1:31	1:20	1:11	1:05	1:00	0:56	0:52	0:49	0:47	0:44
30	2:23	2:00	1:44	1:33	1:24	1:17	1:11	1:07	1:03	0:59	0:56	0:54
35	2:38	2:15	1:58	1:46	1:36	1:29	1:23	1:18	1:13	1:09	1:06	1:03
40	2:53	2:29	2:12	1:59	1:49	1:41	1:34	1:29	1:24	1:20	1:16	1:13
45	3:15	2:51	2:32	2:18	2:07	1:58	1:51	1:45	1:39	1:34	1:30	1:27
50	3:39	3:13	2:54	2:39	2:27	2:17	2:09	2:02	1:56	1:50	1:46	1:41
55	4:04	3:37	3:17	3:01	2:48	2:37	2:28	2:20	2:13	2:07	2:02	1:57
60	4:31	4:03	3:42	3:24	3:10	2:58	2:48	2:40	2:32	2:26	2:20	2:14
65	4:59	4:30	4:07	3:49	3:34	3:21	3:10	3:00	2:52	2:45	2:38	2:32
70	5:30	4:59	4:34	4:14	3:58	3:44	3:32	3:22	3:13	3:05	2:58	2:51

Table 2, provided by Douglas Baldwin (personal communication, 21 February 2012), is based on thermal processing studies for meat used by the FSIS (2009) in development of their guidance on cooking times. The FSIS guidance is applicable to 1) beef, lamb and veal steaks and roasts, 2) pork chops, ribs and roasts, and 3) fish. Higher temperatures are recommended for poultry, eggs and minced meat.

When water baths are operated at temperatures well above the target temperature for the food or if combination steam/forced convection ovens or water cascade systems are used food temperatures are usually monitored by probes placed at the slowest heating point of the food. Table 3 shows times for pasteurisation and FSIS cooking of meat chops, roasts and steaks. Timing starts when the core temperature has been reached.

Table 3: Recommended hold time / temperature combinations for pasteurisation[1] and cooking[2] of meats

Core temp °C	Pasteurisation time[3] Minutes : Seconds	Cooking time[4] Minutes : Seconds
55	200:	69:
56	147:	46:
57	109:	30:
58	80:	20:
59	59:	14:
60	44:	9:
61	32:	6:
62	24:	4:
63	18:	3:
64	13:	2:
65	10:	1:05
66	7:	0:42
67	6:	0:30
68	4:	Less than 20 seconds
69	3:	
70	2:	
71	1:29	
72	1:05	
73	0:48	
74	0:36	
75	0:26	
76+	Less than 20 seconds	

Note 1: Pasteurisation – a 6-log *Listeria monocytogenes* process applicable to all foods.

Note 2: Cooking – a 5-log *Salmonella* process for meats excluding poultry.

Note 3: Adapted from Warne (2011). Seconds are only shown for short processes and other times have been rounded to the next minute.

Note 4: Figures have been interpolated from FSIS (2009) guidance and have also been rounded up.

1.2 Product cooling – bacterial growth

The potential for bacterial growth during cooling and reheating of *sous vide* foods is no different to conventional processes. The Food Standards Code addresses the issue. Guidance is available in *Safe Food Australia* on the FSANZ website[2] and *Food safety guidelines on applying the '4-hour/2-hour rule' for temperature control* on the NSW Food Authority website[3].

Clostridium perfringens is the major cause of foodborne illness associated with inadequate cooling and reheating of foods. This pathogen has important characteristics that result in it being a regular cause of foodborne illness:

- It forms a tough heat resistant spore that is not killed during normal cooking. Under suitable conditions the spore will germinate to produce actively growing bacteria.
- It grows in the absence of oxygen and food packed under vacuum in a pouch provides an ideal environment for growth.
- The bacteria can grow exceptionally quickly in warm food, especially meat. They will double in number every ten minutes at optimal temperatures and grow quickly in the range 30–50°C.
- When temperature abused food is consumed the bacteria will form spores in the gut and, in the process, release a toxin. If large numbers of the bacteria were present in the food the toxin will result in food poisoning with profuse diarrhoea and severe cramping pain.

Hands-on: *sous vide* cooling

Baldwin (2011) provides very useful guidance on cooling *sous vide* products in slush ice. This method is commonly used in restaurants and homes. Table 4, which is derived from his web guide, shows approximate cooling times in slush ice (water which is at least half crushed ice) for food in a pouch. The times depend on the thickness and shape of the food. Note that as the thickness of a food doubles the cooling time triples.

Large restaurants, caterers and ready meal companies might use blast chillers or water cascade systems for cooling. In these systems cooling is usually monitored using in-pack temperature probes. Some businesses with good portion control, sufficient historical data and well controlled equipment will be able to validate cooling cycles. In-pack probes or tip sensitive digital thermometers could then be used to verify internal temperatures at reduced frequency.

[2] http://www.foodstandards.gov.au/scienceandeducation/publications/safefoodaustralia2nd519.cfm

[3] http://www.foodauthority.nsw.gov.au/_Documents/industry_pdf/4_hour_2_hour.pdf

Table 4: Approximate cooling time (Hours : Minutes) from 55–80°C to 5°C for *sous vide* food in slush ice

Food thickness (mm)	Food shape		
	Slab-like	Cylinder-like	Sphere-like
5	0:05	0:03	0:03
10	0:14	0:08	0:06
15	0:25	0:14	0:10
20	0:35	0:20	0:15
25	0:50	0:30	0:20
30	1:15	0:40	0:30
35	1:30	0:50	0:35
40	1:45	1:00	0:45
45	2:15	1:15	0:55
50	2:45	1:30	1:00
55	3:15	1:45	1:15
60	3:45	2:00	1:30
65	4:15	2:15	1:45
70	4:45	2:45	2:00
75	5:30	3:00	2:15
80	–	3:30	2:30
85	–	3:45	2:45
90	–	4:15	3:00
95	–	4:45	3:30
100	–	5:00	3:45
105	–	5:30	4:00
110	–	6:00	4:30
115	–	–	4:45

The Food Standards Code (FSANZ 2011) requires:

- A food business must, when cooling cooked potentially hazardous food, cool the food
    - a) within two hours—from 60°C to 21°C, and
    - b) within a further four hours—from 21°C to 5°C,
- unless the food business demonstrates that the cooling process used will not adversely affect the microbiological safety of the food.

Sous vide food of suitable thinness and shape will comfortably meet cooling time targets when cooled in slush ice, blast chillers or water cascade systems.

1.3 Extended refrigerated storage of food – botulism

Botulism is a term used to describe an intoxication caused by *Clostridium botulinum* neurotoxins. From a food safety point of view *C. botulinum* remains one of the most important foodborne bacteria. It is characterised by its:

- growth in the absence of air,
- production of a tough spore that survives normal cooking,
- growth across a wide temperature range, including some strains that grow at refrigeration temperatures, and
- production of the most potent group of biological neurotoxins known (Szabo and Gibson, 2003).

A product stored in a sealed pouch, prepared using a delicate cooking cycle and stored refrigerated for lengthy periods, presents an environment where non-proteolytic (cold-tolerant) strains of *C. botulinum* are an undoubted hazard. Most of the food safety concerns about these types of products have been focussed on the potential for growth and toxin production by these strains.

In 2008 the UK Food Standards Agency (UKFSA) provided guidance on the safety and shelf life of vacuum packed and modified atmosphere packed chilled foods with respect to non-proteolytic *C. botulinum*. The UKFSA summarised the recommendations of their Advisory Committee on the Microbiological Safety of Food (ACMSF 2007 and 1992) on vacuum packaging and associated processes. The ACMSF (2007) recommended a maximum ten day shelf life for vacuum and modified atmosphere foods stored between 3°C and 8°C when other controlling factors could not be identified. The report noted that at <3°C the growth of non-proteolytic *C. botulinum* does not occur and that foods stored at less that 3°C are outside the scope of the guidance.

The ACMSF recommended that, in addition to chill temperatures which should be maintained throughout the food chain, the following controlling factors should be used singly or in combination to prevent growth and toxin production by non-proteolytic *C. botulinum* in chilled foods with a shelf life of more than ten days:

- A heat treatment of 90°C for 10 minutes or equivalent lethality.
- A pH of 5 or less throughout the food and throughout all components of complex foods.
- A minimum salt level of 3.5% in the aqueous phase throughout the food and throughout all components of complex foods.
- A water activity of 0.97 or less throughout the food and throughout all components of complex foods.
- A combination of heat and preservative factors which can be shown consistently to prevent growth and toxin production by cold tolerant *C. botulinum*.

Comprehensive Australian hands-on guidance has been prepared by Cox and Bauler (2008).

1.4 Extended refrigerated storage of food – listeriosis

Foodborne listeriosis is a relatively rare but serious disease with high fatality rates (20–30%) compared with other foodborne microbial pathogens, such as *Salmonella*. The disease largely affects specific segments of the population who have increased susceptibilities. *L. monocytogenes* is an opportunistic pathogen that most often affects:

- people with a severe underlying disease or condition, eg immunosuppression, HIV/AIDS and chronic conditions such as cirrhosis that impair the immune system,
- pregnant women,
- unborn or newly delivered infants, and
- the elderly.

L. monocytogenes is widely dispersed in the environment and foods. An important factor in foodborne listeriosis is that the pathogen can grow to significant numbers at refrigeration temperatures when given sufficient time. Although listeriosis is a relatively rare disease, the severity of the disease and the very frequent involvement of industrially processed foods, especially during outbreaks, mean that the social and economic impact of listeriosis is among the highest of the foodborne diseases (WHO, 2004).

Cox and Bauler (2008) provide the following guidance on control of *L. monocytogenes* in cook chill foods:

- Because of its sensitivity to heat, cooking will reduce the number of *Listeria monocytogenes* 1,000,000-fold provided all parts of the food reach a temperature of, or equivalent to, 75°C. This is known as a 6D process.
- Although growth does not stop, storage at ≤5°C will substantially slow the growth of *Listeria monocytogenes* in cook chill foods.
- Limiting storage times or shelf life is the other major control that can be used.

Hands-on: refrigerated storage of *sous vide* foods

Modern culinary *sous vide* is less about extended storage and more about taste. For example, Thomas Keller's book, *Under Pressure* (2008), does not encourage storage for extended periods unless the food is frozen. The book focuses on the gastronomic benefits of cooking under vacuum at very controlled temperatures. Food safety is accentuated up-front and if others follow his storage advice *C. botulinum* will not be the risk. Baldwin (2011) provides sound advice on storage temperatures with only brief storage periods recommended at temperatures above 3.3°C (Baldwin 2011).

The NSW Food Authority's default guidance for *sous vide* food and certain other products in sealed packages which are protected from contamination after thermal processing is below:

- With a 90°C/10 minute equivalent cook and storage at 5°C – shelf life as validated.
- With a 70°C/2 minute equivalent cook and storage at <3°C – shelf life as validated.
- With a 70°C/2 minute equivalent cook and storage at 5°C – a 10 day shelf life.

The process controls and support programs required to validate an extended shelf life are generally not plausible in a busy restaurant kitchen. Restaurants should limit refrigerated storage of pasteurised *sous vide* foods to ten days. Cooked but not pasteurised foods should only be held refrigerated for brief periods. Kennedy (2004) refers to 'short term cook chill' and notes that it is often called '5-day cook chill', as that is a common time period used by mass caterers. Five days at 5°C is the recommended upper limit for storage of cooked but not pasteurised *sous vide* food.

1.5 Product reheating – bacterial growth

The potential for bacterial growth during cooling and reheating of *sous vide* foods is no different to conventional processes, and the guidance documents mentioned in section 1.2 are relevant.

C. perfringens is commonly encountered in food service and home catering settings. Often large portions of food and more than one failure to handle food safely are involved. Examples include the following:

- A restaurant cooks a casserole, curry or chilli in a large stock pot, cools it for two hours on the kitchen bench and refrigerates it overnight. The food is ladled into a tray in the hot display to reheat and then served at lunch time. The food at the centre of the stock pot never cooled and slowly reheated to only a low temperature while on display. *C. perfringens* grew to very large numbers and many customers developed food poisoning.
- A large roast, eg a turkey, was cooked the day before a large family function. It was cooled on the bench for several hours, wrapped in aluminium foil and then refrigerated. It was reheated briefly in an overworked oven prior to service. Again the food was not properly cooled or reheated. *C. perfringens* grew to large numbers and caused illness in many that attended the function.

Small portions of *sous vide* food are relatively easy to cool and reheat. With attention to detail the risk of *C. perfringens* in small pouches of *sous vide* food can be controlled.

Hands-on: *sous vide* reheating

Baldwin (2011) tabulates heating times for *sous vide* products in a finely controlled water bath. These times provide useful guidance on reheating of foods. Table 5, which is derived from his web guide, shows approximate heating times for refrigerated food in a pouch to a temperature 0.5°C below the temperature of the water bath.

Clause 7(4) of the Food Standards Code (FSANZ 2011) requires:

> *A food business must, when reheating previously cooked and cooled potentially hazardous food to hold it hot, use a heat process that rapidly heats the food to a temperature of 60°C or above, unless the food business demonstrates that the heating process used will not adversely affect the microbiological safety of the food.*

The clause is subjective and guidance is provided in *Safe Food Australia* (ANZFA 2001):

> *This requirement only applies to potentially hazardous food that is to be held hot, for example in a bain marie. It does not apply to food that is being heated for immediate consumption. This food can be heated to any temperature as it is not being heated for holding hot.*
>
> *Potentially hazardous food that has been previously cooked and cooled and is to be held hot must be heated rapidly to a temperature of 60°C or above. 'Rapidly' has not been defined, but the time taken to heat all the food to 60°C should not exceed two hours.*
>
> *A food business may use an alternative heating process if the business can demonstrate that the alternative process does not compromise the microbiological safety of the food.*

Sous vide enthusiasts prefer not to reheat using a temperature above that used during cooking. Baldwin (2011), for example, refers to meat typically being reheated at 55°C since the ideal serving temperature for meat is 50°–55°C. The Food Standards Code does not establish parameters for reheating food for immediate service, except to generally require that food is safe. The '4-hour/2-hour rule' in *Safe Food Australia* (ANZFA 2001) provides general guidance.

As a general rule, the total time that a ready-to-eat potentially hazardous food can be at temperatures between 5°C and 60°C is 4 hours. The 4-hour limit is based on a worst-case scenario. After this time the food must be discarded. The total time is the sum of the time the food is at temperatures between 5°C and 60°C after it has been cooked or otherwise processed to make it safe.

If the food is to be re-refrigerated, the total time a food can be at room temperature and then be safely put back in the refrigerator to use later is two hours. The '4-hour/2-hour rule' is summarised below:

- Any ready-to-eat potentially hazardous food, if it has been at temperatures between 5°C and 60°C:
  - for a total of less than two hours, must be refrigerated or used immediately.
  - for a total of longer than two hours but less than four hours, must be used immediately.
  - for a total of four hours or longer, must be thrown out.

Table 5: Approximate heating time (Hours : Minutes) for refrigerated *sous vide* food to 0.5°C less than the water bath's temperature

Food thickness (mm)	Food shape		
	Slab-like	Cylinder-like	Sphere-like
5	0:05	0:05	0:04
10	0:19	0:11	0:08
15	0:35	0:18	0:13
20	0:50	0:30	0:20
25	1:15	0:40	0:25
30	1:30	0:50	0:30
35	2:00	1:00	0:45
40	2:30	1:15	0:55
45	3:00	1:30	1:15
50	3:30	2:00	1:30
55	4:00	2:15	1:30
60	4:45	2:30	2:00
65	5:30	3:00	2:15
70	–	3:30	2:30
75	–	3:45	2:45
80	–	4:15	3:00
85	–	4:45	3:30
90	–	5:15	3:45
95	–	6:00	4:15
100	–	–	4:45
105	–	–	5:00
110	–	–	5:00
115	–	–	6:00

From Baldwin 2011.

For compliance with the guidance documents prepared to support the Australian Food Standards Code Tables 5 and 6 should be used as follows:

- For pasteurised or cooked and properly cooled foods to be reheated for hot holding food: the objective is to heat food to 60°C within 2 hours – reheat in a 60.5°C (or higher) water bath for the times shown in light green Table 5 or Table 6.
- For pasteurised or cooked and properly cooled foods to be reheated for immediate service: the Food Standards Code does not prescribe a time limit but a reasonable target is 4 hours (the '4-hour/2-hour rule') – reheat in a 55°C (or higher) water bath for the times shown in light green or dark green shown in Table 5 or Table 6.
- For larger portions of pasteurised or cooked and properly cooled foods to be reheated for immediate service: the Food Standards Code does not prescribe a time limit but a reasonable target is to heat the food to 60° C within 4 hours (the '4-hour/2-hour rule') – this can be achieved using higher water bath temperatures and checking the temperature at the centre of the food with a tip sensitive digital thermometer. However, use of a 60.5°C water bath for the times shown without highlight in Table 5 or Table 6 will be low risk.

Baldwin also provides times for heating food from frozen. Time limits are extended by three hours to allow time for the food to thaw and enter the temperature danger zone.

Table 6: Approximate heating time (Hours : Minutes) for frozen *sous vide* food to 0.5°C less than the water bath's temperature

Food thickness (mm)	Food shape		
	Slab-like	Cylinder-like	Sphere-like
5	0:07	0:07	0:06
10	0:30	0:17	0:12
15	0:50	0:30	0:20
20	1:15	0:40	0:30
25	1:45	0:55	0:40
30	2:15	1:15	0:55
35	3:00	1:30	1:15
40	3:30	2:00	1:30
45	4:30	2:30	1:45
50	5:15	2:45	2:00
55	6:15	3:15	2:30
60	7:15	4:00	2:45
65	8:15	4:15	3:15
70	–	5:00	3:45
75	–	5:45	4:15
80	–	6:30	4:45
85	–	7:15	5:15
90	–	8:00	5:45
95	–	8:45	6:15
100	–	–	7:00
105	–	–	7:30
110	–	–	8:15
115	–	–	9:00

From Baldwin 2011.

Small portions of *sous vide* foods can be reheated in required time frames. Faster heating times can be achieved by using higher water bath temperatures. *Sous vide* food for larger functions could be reheated using a combination steam/forced convection oven. For these methods reheating is usually monitored using in-pack temperature probes. Some businesses with good portion control, sufficient historical data and well controlled equipment will have validated reheating cycles. In-pack probes or tip sensitive digital thermometers would be used to verify internal temperatures at reduced frequency.

There may be foods where suggested temperatures are inconsistent with the production of very rare or undercooked foods. These foods are best prepared as cook–serve foods.

1.6 Serving raw or undercooked foods – infectious bacteria, parasites or viruses

The US Centers for Disease Control and Prevention nominate a number of simple precautions that consumers can use to protect themselves from foodborne diseases (CDC, 2010). The first of these is:

> *Cook meat, poultry and eggs thoroughly. Using a thermometer to measure the internal temperature of meat is a good way to be sure that it is cooked sufficiently to kill bacteria.*

Many other food agencies make very similar recommendations including the NSW Food Authority (NSWFA, 2011d). Despite the advice, people still choose to eat a wide variety of raw or undercooked animal products. For example:

Carpaccio	*Fruits de mer*	Rare hamburger	Egg nog
Ceviche	Hoe	Sashimi	Kibbe
Egg butter	Steak tartare	Tiramisu	

The risk with these foods is related to the potential and, in some cases, likely presence of pathogenic bacteria, parasites or viruses. The risks can be illustrated by:

- disease prevalence statistics:
    - *Vibrio parahaemolyticus* infection accounted for 45–60% of food related infections in Japan (Berger, 2011). This organism is associated with seafood and the illness is related to the high consumption of raw seafood in Japan.
    - In France, more than 200 cases of hepatitis E are reported each year. It has been clearly shown in developed industrialised countries that pigs are reservoirs of the virus. Acute hepatitis E has been linked to persons who consumed uncooked pig liver sausages. These sausages are good candidates for the transmission of hepatitis E because they are made with pig liver, are not cooked during the manufacturing process, and are often eaten uncooked (ProMed Mail, 2011).
- outbreak reports:
    - Two children died and 56 people became ill in Japan from *E. coli* following consumption of yukkoe, a raw beef dish, in a Korean style barbeque restaurant (Bites, 2011).
    - Nine cases of paragonimiasis (a parasitic infection) were caused by the consumption of raw or undercooked crayfish in Missouri (Bites, 2010).
    - In 2010 a *Salmonella* outbreak in Albury made 179 people sick. Home-made aioli, a garlic mayonnaise that includes raw egg, was the cause. (NSWFA, 2011b).
- information from the scientific literature:
    - In recent decades, the custom of eating foods raw, or only partially cooked, has grown worldwide and has led to the emergence of parasitic diseases in ethnic groups where eating raw or undercooked meat was not previously common (Macpherson, 2005).

- Three large studies in Europe have pinpointed uncooked meat as the most important risk factor for *Toxoplasma gondii* infection in pregnant women. Toxoplasmosis is generally considered a serious health problem in pregnant women, who can pass the infection to the foetus or newborn, and people who are immunocompromised (Kijlstra & Jongert, 2008).
- The tradition of eating raw fish is becoming increasingly fashionable in many countries. This had led to a dramatic rise in the incidence of fish borne parasitic infections in previously unaffected ethnic groups (Macpherson, 2005).
- All wild caught seawater and freshwater fish must be considered at risk of containing viable parasites of human health concern if these products are to be eaten raw or almost raw (EFSA, 2010).

Some *sous vide* recipes call for low temperature short time (LT ST) cooking and in some cases the final food remains raw or undercooked. Such foods have a higher risk of causing bacterial, viral or parasitic illness.

Hands-on: safer alternatives – raw and undercooked animal products

These products should not be used for cook chill food service.

Businesses must be aware that meat, seafood and eggs that have not been cooked present an increased level of food safety risk to people. Vulnerable people such as children, the elderly, immunocompromised people or those with a serious illness can suffer are at greater risk of suffering from the more severe consequences of foodborne illness.

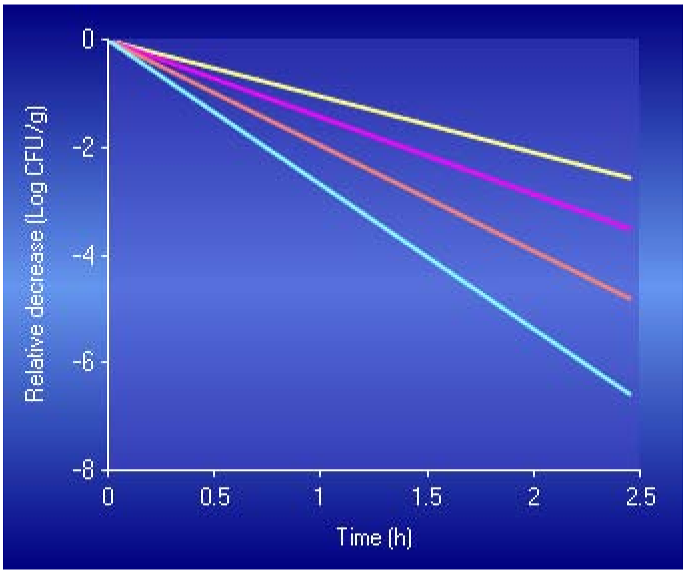
Table 7. Tactics to improve the safety of raw and undercooked animal products

Hazard	Tactics
Seafood: Parasites	• Purchase safer fish: marine fish are safer than freshwater fish; farmed (pellet feed) fish are safer than wild caught fish; higher value marine fish (tuna, Atlantic salmon) are safer than lower value marine fish (mackerel, squid)[4]. • Carefully examine fish during cleaning and filleting. Parasites are small but many can be seen with the naked eye or when fillets are 'candled' (a strong light is shone through the fillet). • Use sashimi grade fish that is inspected during processing. • Freeze fish prior to preparation. For fish to be consumed without adequate cooking the European Food Safety Agency (EFSA, 2010) requires the following: o Freeze at minus 15°C for at least 96 hours, or o Freeze at minus 20°C for at least 24 hours, or o Freeze at minus 35°C for at least 15 hours. • Cook all parts of the fish to 60°C for 1 minute (EFSA, 2010). This mild cooking process will be compatible with many fish recipes.

[4] Information on parasites that impact the safety of seafood is provided in *Seafood safety scheme: periodic review of the risk assessment* (in press) to be published on www.foodauthority.nsw.gov.au

Hazard	Tactics
Seafood: Bacteria	The main bacterial pathogen of marine origin in Australia (*Vibrio parahaemolyticus*) dies when exposed to refrigeration temperatures (ICMSF, 1996a) and is inactivated by fairly mild cooking temperatures (van Asselt and Zwietering, 2006). However, fish contaminated with bacteria from the kitchen environment or food handlers might not be made safe by mild cooking processes. • Do not cook minced or reformed seafood (including fish cakes and products formed using transglutaminase or other 'meat glues') using low temperature short time (LT ST) processes. • The 'parasite cook' recommended by EFSA will provide control of *Vibrio parahaemolyticus.*
Meats: Parasites	• Purchase through professional supply chains. Meat inspection prevents meat infected with many, but not all, parasites from being marketed. • Freeze meat prior to preparation. The EFSA fish freezing requirements above will provide useful control.
Meat: Bacteria	• Do not cook mechanically tenderised, minced, pumped, rolled or reformed meats (including meats prepared using 'meat glue') using low temperature short time (LT ST) processes. • Avoid very low temperature cooking. Water bath temperatures above 55°C and, more generally, meat surface temperatures above 54.5°C will provide a measure of decontamination as cooking proceeds. • *Sous vide* chefs should test recipes to see if slightly higher temperatures can be used. Figure 2 shows relative thermal inactivation of *Salmonella*, generated by the ComBase predictive microbiology modelling website. The yellow curve shows some reduction at 54.5°C with increasing lethality at 55°C (pink), 55.5°C (orange) and 56°C (blue). A small increase in temperature above 54.5°C will provide markedly increased destruction of surface bacteria. As noted above, bacteria are typically found on the surface of meat providing it has not been tenderised, minced, pumped, rolled, reformed or 'glued'.
Eggs: Bacteria	*Sous vide* recipes that result in fully cooked eggs are available and their use is recommended.

Figure 2. Hypothetical thermal destruction of *Salmonella* at temperatures from 54.5°C to 56°C



Key: Yellow (top line) 54.5°C; Pink (2nd line) 55°C; Orange (3rd line) 55.5°C; and Blue (bottom line) 56°C.

Scale: -2 = 99% reduction; -4 = 99.99% reduction; -6 = 99.9999% reduction of *Salmonella.* From ComBase (http://www.combase.cc/index.php/en/predictive–models)

As an alternative to serving raw or undercooked foods, chefs should consider serving cooked food prepared using times and temperatures from Table 2 or Table 3.

Conclusion

Sous vide seems like a new food service technology but it has a history spanning four decades in France and two decades in other countries. It has been found in many markets including extended shelf life ready meals. Today it is used by catering companies, restaurants and, increasingly, home cooks.

Sous vide has concerned regulators at times during its history. There are risks with *sous vide* that must be managed. Leading *sous vide* chefs are aware of these risks and food safety has been prominent in their kitchens and recipe books. As far as can be determined from the scientific literature and foodborne illness databases, *sous vide* chefs have been successful in managing food safety and food poisoning attributed to *sous vide* has not been identified.

The risks associated with *sous vide* foods will be reduced if:

- thinner portions of food are prepared so that heating and cooling are rapid.
- water bath temperatures of at least 55°C are used so that the growth of *Clostridium perfringens* is first prevented and then destruction of the cells commences.
- the time food is held at temperatures below 54.5°C during cooking is limited to 6 hours.
- professional equipment with adequate heating capacity and excellent temperature control is used.
- water and/or food temperatures are checked using a tip sensitive digital thermometer that is accurate to 0.1°C.
- prepared foods are not stored for extended times unless processes have been validated.
- risks are not compounded. Cooking large portions of mechanically tenderised meat for extended times at low temperatures would be irresponsible.
- if you choose to include on your menu foods that remain essentially raw they should only be served following a request by an informed, healthy adult who willingly accepts the risks associated with raw foods.

New practitioners of *sous vide* must be aware of the food safety risks and avoid overly experimental applications of the technology.

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Appendix: Variation to the 4-hour/2-hour rule

In the main, information contained is this document is consistent with the Australia New Zealand Food Standards Code and its associated guidance materials. However, section 1.1 contains includes some cooking times that are inconsistent with the '4-hour/2-hour rule'. The tables were developed and published by Baldwin (2011).

Baldwin is very widely quoted in food enthusiast circles. Some of his *sous vide* work is published in peer reviewed journals and his self published material is submitted to food scientists prior to publication. Baldwin is a PhD student in mathematics and has 6 refereed mathematical publications. He is a *sous vide* enthusiast and has turned his mathematical prowess to establishing cooking times for *sous vide* foods. Food safety is prominent in his book and web-based guidance material.

Baldwin only tabulates times that comply with the U.S. Food Code 4 hour limit for foods that are served unpasteurised. However, for foods that are to be pasteurised he allows up to 6 hours to reach 54.4°C. This limit is based on data presented in a paper by Willardsen et al (1978) and is designed to limit the growth of *C. perfringens* prior to pasteurisation. That means that cooking cycles for thicker cuts are limited to higher temperature water baths so that internal temperatures reach target within 6 hours.

The tables are designed so that the food spends a maximum of 2 hours and 10 minutes at temperatures where *C. perfringens* growth is rapid, i.e. 35°–54.4°C (Douglas Baldwin personal communication 13 August 2011). Willardsen et al (1978) note that *C. perfringens* is the organism of primary concern in LT LT cooking of beef because of its rapid growth at relatively high temperatures and its ability to cause illness. The figure below from Willardsen et al (1978) is informative.

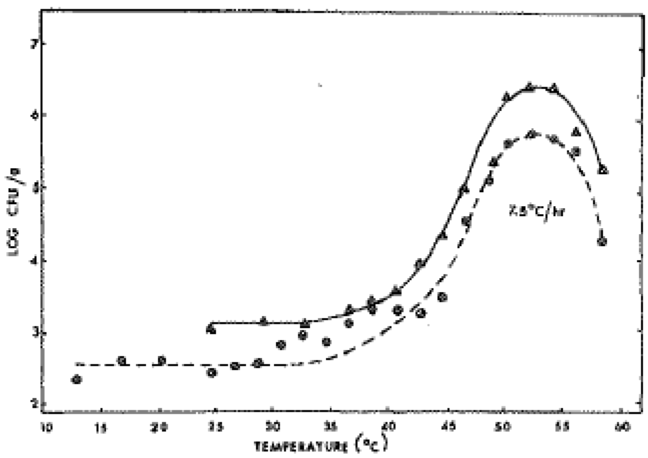

Fig. 3—Influence of initial temperature on growth of Clostridium perfringens 8-strain composite in autoclaved ground beef at constantly rising temperature rate of 7.5° C/hr.

Two trials on the growth of *C. perfringens* in autoclaved beef are shown. In both cases the temperature rises 7.5°C per hour. In one trial the initial temperature is about 12.5°C and the other it is 25°C. In both cases growth does not occur or is only slow until above 30°C and inactivation of the cells starts between 50°C and 55°C. The ICMSF (1996b) notes that optimum growth temperature for *C. perfringens* is 43°–47°C which is consistent with the graph.

Another figure from Willardsen et al displays the growth of *C. perfringens* at constantly rising temperatures with rates of increase from 4.1°C to 12.5°C per hour.

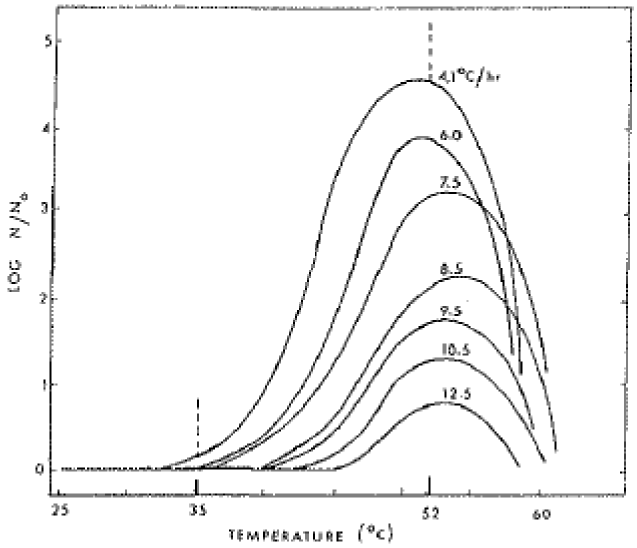

Fig. 4—Influence of constantly rising temperature rates on growth and survival of Clostridium perfringens 8-strain composite in autoclaved ground beef. Rising temperature rates ranging from 4.1°C/hr to 12.5°C/hr indicated by numerical values on curves. Initial population approximately 10^3 cfu/g.

Slow rates of temperature increase lead to large numbers of *C. perfringens* and high rates of temperature increase result in much lower numbers. The graphs also show the rapid decrease in cell numbers at temperatures between 50°–55°C.

The limit of 2 hours and 10 minutes between 35°C and 54.4°C implies a temperature rise of about 9°C per hour, resulting in a significant reduction in growth compared to lower temperatures. In *sous vide* systems with water bath temperatures set at 55°C the temperature increase is likely to exceed 9°C per hour at 35°C and tail off towards 55°C.

The combination of the short time at temperatures where growth of *C. perfringens* is rapid, the higher rate of temperature increase and the subsequent rapid decrease in cell numbers, support the opinion that any residual risk is low.

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