Clostridium botulinum in vacuum packed (VP) and modified atmosphere packed (MAP) chilled foods

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Chapter Four - Storage and Handling of Chilled Food

Recent decades have seen a considerable increase in legislation setting maximum temperatures during the production, distribution and retailing of chilled food. Surveys on the temperature performance of commercial chill chains are relatively scarce however, and official sampling of the microbiological quality of commercially available foodstuffs often fail to report product temperatures at the time of sampling.

As soon as the food is purchased by the consumer it is outside any legislative requirements. Consumer handling of products may not be as intended or envisaged by the manufacturer. Again there are relatively few published studies on the performance of domestic refrigerators and on consumers' attitudes to chilled food and their handling procedures in the home.

4.1 Pre-distribution temperatures

No published data are available regarding pre-distribution storage temperatures, i.e. product storage by manufacturers prior to despatch to their customers.

However, UK manufacturers' on-site storage and despatch of chilled prepared foods is usually at ≤5°C, and often under "deep chill".

General French chilled food manufacturing industry practice is reported to involve storage at <4°C and can be for a relatively long term period (from days to approximately three weeks) (SYNAFAP, Personal communication).

Storage at such low temperatures effectively extends shelf life in relation to non-proteolytic *C. botulinum* since growth rates are so slow, or there is no growth at all if <3°C. This principle is reflected in the CCFRA (1996) industry code (see Chapter 3).

4.2 Legislated commercial temperatures

Nationally legislated temperature rules and commercial agreements set maximum temperatures for certain commercial chilled foodstuffs. A lack of an EU harmonised approach is believed to be largely due to the uneven development of markets internationally (see Tables 4.1 and 4.2, the following text, and SCOOP report (1996)).

Table 4.1: Retail temperature requirements in various European countries (ECFF, Personal communication)

Product Type	Required retail temperature (°C) in specified country						
	Belgium	Finland	France	Germany*	Italy	NL	UK***
Air or product temperature?		Air except protein	Air				Product
Fresh-cut produce	7 LN	8 LN	4 LN	7		7 LN	8 LN
Soups, Sauces	7 LN	6 NGL	4 LN			5	8 LN
Sandwiches	7 LN	6 NGL				7 LN	8 LN
Ready to cook dough	7 LN					7 LN	8 LN
Fresh pasta, plain & filled	7 LN	8 LN			4 LN	5	8 LN
Fresh gnocchi	7 LN	8 LN			NGL being developed	5	8 LN
Pizza	7 LN	6 NGL				7 LN	8 LN
Savoury pastries and quiches	7 LN	6 NGL				7 LN	8 LN
Dressed salads, dips	7 LN	6 NGL	4 LN	7		7 LN	8 LN
Sweet pastry desserts	7 LN	8 LN				5	8 LN
Other chilled ready meals	7 LN	6 NGL 8 LN	4 LN			5	8 LN
Raw red meat	7 LEU	4 (max 6) NGL	7 LEU	7 LEU	7 LEU	7 LEU	7 LEU
Raw poultry	4 LEU	4 (max 6) NGL	4 LEU	4 LEU	4 LEU	4 LEU	4 LEU
Raw game	7 LEU	4 (max 6) NGL	7 LEU	7 LEU	4 (small size); 7 (big size) LEU	7 LEU	4 LEU
Minced red meat	2 LEU	2 LEU	2 LEU	2 LEU	2 LEU	7	2 LEU
Minced poultry meat	4 LEU	4 LEU	4 LEU	4 LEU	4 LEU	4	4 LEU
Meat preparation	4 LEU	4 LEU	4 LEU	4 LEU	4 LEU	4	4 LEU
Chilled cooked meat products	7 LN	6 NGL	4 LN			5	8 LN
Chilled cured meat products	7 LN	7 LN				7	8LN
Chilled fermented meat products	7 LN	7 LN				7	8LN
Raw fish, cooked and chilled crustaceans and molluscs	melting ice LEU	0 to 3 NGL	melting ice LEU	2	0 to 4 LN	4	melting ice LEU
Cured fish		6 NGL			0 to 4 LN	7	
Smoked fish	4 LN	6 NGL**			0 to 4 LN	7	8 LN
Dairy Desserts	7 LN	8 LN	4 LN	10	4 LN	7	8 LN
Fermented dairy products, not heat treated	7 LN	8 LN		10	4 LN	7	
Non cured cheese	7 LN	8 LN		10		7	
Cured cheese		8 LN		10		7	

LEU = covered by EU legislation; LN = covered by national legislation; NGL = covered by national guidelines other than those adopted by legislation

* Germany: Legal temperature requirements only exist for milk, meat and fish. For other products temperatures are on the basis of convention. ** Finland, cold smoked VP fish and raw lightly salted fish (gravad) 0 to 3°C (national commercial agreement & recommendation of National Food Agency). ***UK, chill temperature is specified as 8°C in England, Wales and NI. In Scotland, chilled food is to be stored in a refrigerator, or refrigerating chamber, or a cool ventilated place.

Canada: Product temperature should be maintained between -1°C and 4°C. If product is found to be 7°C or warmer on receipt by a warehouse operator or in foodservice "instructions for special handling" should be requested from the manufacturer. These instructions may consist of any available method for effectively lowering temperatures such as low temperature rooms with air circulation and proper use of dunnage or separators in stacking. (Food Institute Canada, undated).

USA: Refrigerated, potentially hazardous food (i.e. requiring time/temperature control) shall be at a temperature of 5°C or below when received, unless a specific law applies (e.g. milk, molluscan shellfish). Cook-chill in reduced oxygen packages or sous vide must be cooled to 5°C in the package or bag and then cooled to 1°C or less within 48 hours of reaching 5°C, and either held at 1°C and consumed or discarded within 30 days after the date of preparation, or if removed from a storage unit that maintains a 1°C food temperature, held at 5°C or less for no more than 72 hours before consumption (CFSAN, 2005).

CODEX: For refrigerated foods, an important safety hurdle to control microbial growth is refrigeration (for example, +4°C). Any recommendation for specific temperatures should be considered guidelines only. The actual temperatures used will depend upon the requirements for the product, and processes used in terms of safety (CODEX, 1999).

Table 4.2: Maximum Retail Storage Temperatures for Chilled Ready Meals in some EU Countries (CCFRA, 2004)

Country	Maximum legal retail storage temperature (°C)
Belgium	7
Denmark	5
Finland	8*
France	≤4
Spain	0-3
Sweden	<8
UK	8**

* In Finland, commercial agreement between retailers and manufacturers to operate at 6°C.
**In UK, chill temperature is specified as 8°C in England, Wales and Northern Ireland. In Scotland, chilled food is to be stored in a refrigerator, or refrigerating chamber, or a cool ventilated place.

The EU SCOOP Report (1996) states that "it is not necessary to recommend a single storage temperature for all chilled foods, irrespective of the processing received and, conversely, a large number of product-specific temperatures would not be practical. In practice, both temperature and shelf life need to be considered together." The report made a number of recommendations for further work to be carried out, which are still valid:

1. To clearly define the shelf life concept(s) and to agree common definitions at a European Community level
2. The Commission should consider conducting a survey of food and air temperatures in retail display cabinets in Member States to indicate the practicability of setting broad or product-specific temperatures across the Community
3. To monitor temperature fluctuations in the chilled food chain from production through to the point where the consumer selects the product
4. Options for the accurate prediction of food temperature behaviour during transport, storage and retail display should be explored

5. Ways of linking temperature requirements in 'vertical' directives [Note: no longer in force] with any temperature requirements at the retail level should be explored
6. The role food labelling might have in ensuring that foods are held at appropriate temperatures and with a satisfactory shelf life should be explored
7. Data relating to the microbial safety of foodstuffs should be collected and presented in a systematic and well structured format to aid the dissemination of important information to relevant authorities
8. Information on specific factors such as pH and a_w need to be available, particularly for more complex foods, e.g. recipe dishes/fermented foods.

Internationally, the UN "Agreement on the International Carriage of Perishable Foodstuff and on the Special Equipment to be used for such Carriage" (ATP) applies. ATP is an Agreement between States, and there is no overall enforcing authority. ATP applies to transport operations performed on the territory of at least two of Contracting Parties (i.e. countries – see below). In practice, highway checks are carried out by Contracting Parties, and non-compliance may then result in legal action by national authorities against offenders in accordance with their domestic legislation. ATP itself does not prescribe any penalties.

A number of countries, including the UK, have adopted the ATP as the basis of their national legislation: Austria; Azerbaijan; Belarus; Belgium; Bosnia and Herzegovina; Bulgaria; Croatia; Czech Republic; Denmark; Estonia; Finland; France; Georgia; Germany; Greece; Hungary; Ireland; Italy; Kazakhstan; Lithuania; Luxembourg; Monaco, Morocco; Netherlands; Norway; Poland; Portugal; Romania; Russian Federation; Serbia and Montenegro; Slovakia; Slovenia, Spain; Sweden; The former Yugoslav Republic of Macedonia; UK; USA; and Uzbekistan.

However, the Agreement's product scope is limited as international trade in prepared chilled foods is also limited. Examples of agreed distribution temperature are shown in Table 4.3.

Table 4.3: International Distribution Temperature Agreement - Conditions for the Carriage of Certain Foodstuffs which are Neither Quick (deep)-frozen nor frozen (ATP, 2003)

Foodstuff	Maximum temperature (°C)	Notes
Red offal	3	In principle the duration of carriage should not exceed 48h
Butter	6	
Game	4	
Milk (raw or pasteurised, for immediate consumption)	4	In principle the duration of carriage should not exceed 48h
Industrial milk	6	In principle the duration of carriage should not exceed 48h
Dairy products (yoghurt, kefir, cream and fresh cheese)	4	In principle the duration of carriage should not exceed 48h 'Fresh cheese' means non-ripened (non-matured) cheese which is ready for consumption shortly after manufacturing and which has a limited shelf life
Fish, molluscs and crustaceans	Must always be carried in melting ice	In principle the duration of carriage should not exceed 48h
Meat products	6	Except for products stabilised by slating, smoking, drying or sterilisation
Meat (other than red offal)	7	
Poultry and rabbits	4	

4.3 Commercial Temperature Control in Practice

A UK retailer survey showed that the average temperature of retail storage was 4°-6°C. (CCFRA, 2004). Microbiological surveys by the PHLS (now HPA) in the UK have reported ranges of product temperatures on sale. On average, 94% of the 10,596 retail samples taken in three recent reports were found to be at ≤8°C. However, the reports did not detail the actual temperatures, simply that they were lower than 8°C (Table 4.4). This is perhaps an area overlooked in such surveys, giving actual temperatures and not simply noting < or > value would be a useful addition and give a greater value to the reports.

Table 4.4: UK PHLS/HPA Retail product temperatures

Product	Storage temperature (°C)	% Samples held at temperature	Number of samples	Outlet types	Ref.
Cold meat and pate	≤8	95	3,766	Supermarkets, butchers, delis, market stalls, other retail	Elson *et al.* (2004)
	>8	5	215		
	Total		3,981		
Bagged prepared RTE salad vegetables	≤8	94	3,511	Retail outlets	Sagoo *et al.* undated (2001 survey)
	>8	6	229		
	Total		3,740		
VP and MAP cooked RTE meats at the end of shelf life	<5	71	2,030	Supermarkets, corner shops, butchers, greengrocer, delis, market stalls, farm shops	Sagoo *et al.* (2006)
	>5-8	24	685		
	>8	6	160		
	Total		2,875		
Overall totals	**≤8**	**94**	**9,992**		
	>8	**6**	**604**		
	Total		**10,596**		

The Food Safety Authority Ireland, in surveys of the microbiological quality of certain retailed foods, reported on product temperatures at the time of sampling from points of sale:

- The core temperature of 168 samples of pre-packed sandwiches obtained from retail premises which had been prepared and packed on-site or which had been delivered from off-site manufacturers was measured, and 57% of samples were at >5°C, 26% of samples were at >10°C and 8% were at >15°C (Table 4.5).
- The temperature displayed in storage units of retailed pre-packed cooked sliced ham (MAP) for 14% of samples was above 5°C, and for 2% of samples the core temperatures >10°C (Table 4.6). The mean core temperature in the ham was 5.7°C, and the range was 1.5°-12.7°C.

Table 4.5: Measured core temperatures of pre-packed retailed sandwiches in Ireland (FSAI, 2002)

Measured temperature (°C)	Number of samples	% samples
0-5	74	43
>5-10	51	30
>10-15	30	17
>15	13	8
Total >5	94	57
Total >10	43	26
Total	168	100

Table 4.6: Storage unit temperature and measured core temperatures of MAP pre-cooked sliced ham in Ireland (FSAI, 2003)

Storage Unit Temperature (°C)		Product Core Temperature (°C)			
Temperature displayed	Number (%) of samples within temperature range	Number of samples for which core temperature was taken	Min	Mean	Max
<0	9 (6)	7	2.2	4.2	5.4
0-5	134 (81)	73	1.5	5.6	12.7
>5-10	20 (12)	9	3.7	6.2	9.2
>10-15	3 (2)	3	9.5	10.6	11.3
Total	**166 (100)**	**92**	**1.5**	**5.7**	**12.7**
>5°C	**23 (14)**	**12**			
>10°C	**3 (2)**	**3**			

A French study carried out in winter 2001 and spring 2002 (Cemagref/Ania, 2004) found that around 90% of yoghurts were kept at <6°C, and 66% of meat products were kept at <4°C. However the weakest link in the chain was the consumer (53% of yoghurts at <6°C, and 25% of meat products at <4°C). It was also found that 57-67% of product shelf life was spent in commercial refrigeration (Table 4.7).

Table 4.7: Average Duration in Different Environments related to types of Products in the French Commercial Chill Chain (Cemagref/Ania, 2004)

Chain Segment	Dairy Products	Delicatessen & Charcuterie	Pre-packed meat
Refrigerated transport	6h (2d)*	6h (21h)	5h (22h)
Wholesaling	2d (10d)	1d (7d)	9h (4d)
Display cabinet	4d (21d)	5d (18d)	4d (13d)
Transportation after purchase	58 min (7h)	75 min (13h)	66 min (6h)
Domestic refrigeration	3d (26d)	4d (23d)	3d (15d)

*The number is the average, with the maximum duration in parenthesis

The average minimum, mode and average maximum temperature of commercial refrigerated transportation were -2°C, 3-4°C, and 8°C (Cemagref/Ania, 2004). It was found that 30% of commercial transportation in France was above the legal maximum temperature of 4°C, with 4% above 6°C (Table 4.8).

Table 4.8: Distribution of Average Temperatures during Refrigerated Transport in the French Commercial Chill Chain (Derens *et al.*, 2004)

Average Temperature (°C)	Number of lorries at specified temperature	Percentage of lorries at specified temperature	Cumulative percentage
-2 to -1	7	0.9	0.9
-1 to 0	19	2.5	3.4
0 to 1	60	7.7	11.1
1 to 2	98	12.6	23.7
2 to 3	166	21.4	45.2
3 to 4	196	25.3	70.5
4 to 5	143	18.5	88.9
5 to 6	57	7.4	96.3
6 to 7	22	2.8	99.1
7 to 8	7	0.9	100

Total number of samples = 775

In Sweden, Rosengren and Lindblad (2003) in 2001 sampled six groups of RTE (ready-to-eat) foods from retail stores, food production plants, restaurants and other mass catering establishments and found that about 40% of fish samples were stored at temperatures higher than 4°C and 15% were stored above 8°C.

The Finnish National Food Agency (2006) in its study of the microbiological quality of prepared salads found that the average storage temperature was 5.4°C, and 10% of the 116 samples were above 10°C. In a 2000 National Food Agency survey of 315 retail cold storage units, 52% of VP fish products were held at 3°C, 44% between 3-8°C and 4% above 8°C. A 1995 study found a temperature of 8°C was exceeded in 20% of cases.

Various surveys have shown the temperature of foods in US chilled food distribution channels are frequently in the range of 45-55°F (7.2°-12.8°C) (Food Spectrum, 2002). Jol *et al.* (2005) report that “While major manufacturers and retailers operate a constant and effective cold chain, surveys in the US have revealed that 20% of domestic and commercial refrigerators operate at a temperature of >10°C”. A further US survey found that 48% of product temperatures in retail refrigerators were >5.0°C and 17% were >8.3°C (Table 4.9).

Table 4.9: Frequency Distribution of USA Retail Refrigerator Product Temperatures (Audits International, 1999)

Product temperature (°C)	Percentage of refrigerators at specified temperature
0	6
0.5-1.6	5
2.2-3.3	15
3.8-5.0	27
5.5-6.6	21
7.2-8.3	10
8.8-10.0	10
10.5-11.6	3
12.2-13.3	2
13.8-15.0	0.8
15.5-18.3	0.9

An Australian government survey (Adams and Ashton, 2002) of ham sold through butchers and delicatessens found that only one of the 27 premises sampled (4%) was able to provide a sample with a surface temperature of less than 5°C. All other samples were recorded with temperatures ranging from 6-15°C, mean 8.5°C.

An ANZFA (2001) study of 483 Australian food businesses reported that 90% of businesses sampled stored potentially hazardous food at or below 5°C. Displayed potentially hazardous food were stored at or below 5°C in 82% of businesses sampled, but 10% of the businesses did not have a method for ensuring the displayed food remained safe.

Numerous other surveys have been carried out on the microbiological quality of chilled foods in various countries, but storage/product temperatures (and allocated shelf lives) are not recorded as a matter of course, raising questions regarding the usefulness of such work as potential tools for effecting positive change.

4.4 Temperatures from Shop to Home

The frequency of shopping governs the length of time chilled food is stored in the home. It must be noted that shopping patterns have changed in the UK over the last 15 years; new developments include the introduction of online ordering from major multiples with home delivery by the retailer or a third party using refrigerated vehicles. The transportation, storage and temperature profiles reported in the 1991 and 1992 UK surveys cannot therefore be taken to be relevant to the UK today in relation to online shopping from major multiples.

In a UK survey of consumers in the early 1990s (James and Evans, 1992a), 99% of the survey population were reported to shop at least once a week; 24% shopped for chilled food on two days a week, 34% shopped on 3-4 days per week, and 26% shopped on 5-7 days per week. Generally shopping was divided into trips for large quantities (defined as greater than one bag) and small amounts of food (less than one bag). The majority of households (85%) shopped for small quantities of chilled food on a variable basis, as required.

A majority of participants in this UK survey carried out their main shopping between 1 and 5 miles from their homes and most (85%) used a car to transport their main shopping home (James and Evans, 1992a). Unprotected chilled food will warm up during transportation. The survey results showed that consumers took on average 43 minutes to bring meat, fish or dairy items home from the shops and place them in a refrigerator. Although most people brought food home well within 60 minutes there were a number of items that took far longer to be brought home (up to 2 days) and placed in a refrigerator. Although insulated bags and boxes are widely sold only a small percentage (13%) used them to transport some of their food home. The vast majority (87%) of people did not use any means of protecting food from temperature gains during transportation.

A survey of French domestic chilled storage and transport practices found mean product transportation times by consumers from the retailer to home storage ranging from 58-75 min, with the overall average across the products studied being 66 min (Table 4.7).

Increases in product temperatures during transportation can be considerable. In UK investigations, the temperatures of 19 different types of chilled product (including a variety of fish products) were monitored during a simulated journey from the supermarket to home (James and Evans, 1992a). One sample of each product was placed in a pre-cooled insulated box containing eutectic ice packs and the second left loose in the boot of the car. The car was then driven home and the product removed and placed in a domestic refrigerator after a total journey time of one hour. Initial temperatures of the chilled products measured when the food reached the car ranged from 4°C to over 20°C (Table 4.10). Some

of the fish product temperatures in samples placed in the boot rose to around 38°C during the one hour car journey, whilst most of the samples placed in the insulated box cooled during the car journey except for a few at the top of the box which remained at their initial temperature. Thin sliced chilled products showed the highest temperature changes during transport. After being placed in the domestic refrigerator, "warm'" chilled products required approximately 5 hours before the temperature at the surface was reduced below 7°C.

Table 4.10: Maximum temperatures measured in UK fish products after being transported for 1 hour in the boot of a car without protection or within a cooled insulated container (James and Evans *et al*., 1992a)

Product	Maximum temperature (°C)	
	Unprotected transport	Transported in cool box
Trout	28	5
Prawns	37	14
Smoked salmon	38	18

4.5 Mail Order/Website Postal Sales

A UK (MAFF, 1991) survey of mail order foods found that the temperature of a simulated food product (sterile agar in water gel) was >8°C for 70% of the distribution time (Table 4.11). In this study the average temperature of mail order foods (smoked salmon and smoked salmon trout) recorded on receipt was 15°C, with a minimum of 11°C, and a maximum of 19°C (Table 4.12). All were the fish at > 8°C.

Table 4.11: Temperatures of Simulated Food Products - UK Mail Order (MAFF, 1991)

Temperature (°C)	Percentage of time at temperature
<5	10
5-8	20
>8	70

Table 4.12: Distribution of Temperatures of Mail Order Products on Receipt (MAFF, 1991)

Temperature (°C)	Number (%) of packs at temperature on receipt
11	1 (2)
12	4 (9)
13	7 (16)
14	4 (9)
15	7 (16)
16	5 (12)
17	11 (26)
18	2 (5)
19	1 (2)
Total	43 (100)

The time taken for packages to arrive at their destinations was usually 2-3 days, the maximum being 10 days. It is not known whether these data are a valid indicator of current temperature profiles during postal delivery of chilled foodstuffs.

Owing to an exemption for food "which, as part of a mail order transaction, is being conveyed to an ultimate consumer" there is no legal requirement in England, Wales and Northern Ireland to keep chilled foods at 8°C or cooler. However, the food temperature must be maintained at a safe level. MOFFA (2006) state that "if it is likely to rise in transit above 8°C, the mail order operator should be confident that this is safe by reference to supporting technical or other data. Long established practices that have proved safe over many years are relevant in this context."

The Food Standards Agency (2006) states on its website that foods sent through the post requiring refrigeration, including vacuum-packed products such as smoked fish, must be kept cool while they are being transported. Consumers are advised to "check with the supplier what they do to keep it cool until delivery".

In the USA perishable foods must not be held between 40°-140°F (4.4°-60°C), including those distributed by the mail order industry and foods prepared and mailed from home (FSIS, 2003). However, data demonstrating the level of compliance could not be located. USDA (FSIS, 2003) advises consumers as follows regarding the receipt of perishable mail order foods:

- Make sure the company sends perishable items, like meat or poultry, cold or frozen and packed with a cold source. It should be packed in foam or heavy corrugated cardboard.
- The food should be delivered as quickly as possible – ideally overnight. Make sure perishable items and the outer packaging are labelled "Keep refrigerated" to alert the recipient.
- When you receive a food item marked "Keep Refrigerated" open it immediately and check its temperature. The food should arrive frozen or partially frozen with ice crystals still visible. Even if a product is smoked, cured and/or fully cooked, it is still a perishable product and must be kept cold. If perishable food arrives warm, notify the company. Do not consume the food. Do not even taste suspect food.
- Tell the recipient that the company has promised a delivery date. Or alert the recipient that "the gift is in the mail" so someone can be there to receive it. Don't have perishable items delivered to an office unless you know it will arrive on a work day and there is refrigerator space available for keeping it cold.

4.6 Farmers' Markets

National rules apply but little specific guidance is available to operators.

FSA Scotland (2005) states that:

- Chilled food should be kept at a temperature of 5°C or less (range 0-8°C)
- Chilled food should be transported by temperature controlled vehicle to and from the market and stored on site under temperature controlled conditions. However, small traders may use icepacks in insulated containers, provided the temperature is kept at 5°C or below.
- In the case of fish, ice should be provided for keeping the temperature at 5°C or below.

No significant data are available to demonstrate the level of compliance with these recommendations. Recent PHLS/HPA surveys (Elson *et al.,* 2004; Sagoo *et al.,* 2006) included sampling from "market stalls" but data are not separated in the reports (Table 4.4).

4.7 Catering

UK national legislation is applicable, and a study carried out in 2002 assessed the level of compliance (Table 4.13). The data from this single study show that just over three quarters of the 3,709 samples of open, ready to eat salad vegetables taken from catering premises were at or below 8°C.

Table 4.13: UK/PHLS Study – Catering Premises Selling Open Ready to Eat Salad Vegetables (Sagoo *et al.*, undated)

Location	Product temperature (°C)	Number of samples	% Samples
Refrigeration in foodservice and preparation area	≤8	1,246	65
	>8	681	35
Refrigeration post-sale display (in foodservice and preparation area)	≤8	583	98
	>8	11	2
Total: Refrigeration in foodservice and preparation area	**≤8**	**1,829**	**73**
	>8	**692**	**27**
Display in customer self-service area	≤8	754	81
	>8	180	19
Post-sale display in customer self-service area	≤8	249	98
	>8	5	2
Total: Display in customer self service area	**≤8**	**1,003**	**84**
	>8	**185**	**16**
Grand total	**≤8**	**2,832**	**76**
	>8	**877**	**24**
	Total	**3,709**	

4.8 Domestic Refrigerators

Worldwide there are about 10^9 domestic refrigerators and freezers (Billiard, 2002). According to the Office of the Deputy Prime Minister (ODPM, 14.3.06) in 2003 there were 2.1×10^7 households in the UK. UK household refrigerator/fridge-freezer penetration is >99% (AMA Research, 2003). Household numbers are projected to rise to 2.6×10^7 by 2026, of which 150,000 are projected to be due to a higher number of single people living alone (ODPM, 14.3.06).

A total of 1.9×10^7 domestic refrigerator/fridge-freezers were sold between 1999 and 2005 (Table 4.14), which implies that that on average a UK household replaces its refrigerator/fridge-freezer every 7.75 years. The improved energy efficiency of UK domestic refrigeration equipment is documented (MTP, 2006) but it is not known how the replacement of equipment has affected, if at all, UK domestic refrigerator temperature performance. The last UK domestic refrigerator survey (1990) is therefore two generations out of date and needs to be re-run.

Table 4.14: UK Domestic Refrigerator and Fridge-Freezer Sales (1999-2005) [MTP (2006)]

Year	**Unit sales per year**
1999	2,833,625
2000	2,762,962
2001	2,227,753
2002	2,697,797
2003	2,757,137
2004	2,783,235
2005	2,809,656
Total	18,872,165

In January 2006, ISO/DIS 15502 ('Household Refrigeration appliances – characteristics and test methods') was published in the UK as BS EN ISO 15022: 2005, and includes temperature performance standards including for chilled compartments, which few fridges sold in the UK have (Table 4.15). Compliance with these standards would ensure better domestic temperature control of chill foods, and contribute to microbiological food safety.

Table 4.15: ISO 15502 Specified Domestic Refrigerator Storage Temperatures

Temperature within specified compartment of domestic fridge			
Fresh food storage compartment		Chill compartment (Instantaneous)	Cellar compartment
Range	Mean		Range
0-8°C	≤4°C	-2 to +3°C	+8 to +14°C

The various compartments are defined as follows:

- chill compartment is intended specifically for the storage of highly perishable foodstuff in which the above specified storage temperature can be maintained.
- fresh food storage compartment: is intended for the storage of unfrozen food at the temperature specified.
- cellar compartment is intended for storage of particular foods and beverages at a temperature warmer than that of the fresh food compartment.

There is no legal requirement in the UK for domestic refrigerators to have chill compartments. However, it is noteworthy that the French Government issued Decree 2002-478 concerning "domestic refrigerators and thermometers designed to indicate the temperature inside these appliances". It specified that as of 10 September 2002, all domestic refrigerators must incorporate a chill compartment (with a mean temperature of ≤4°C), a temperature-indicating device and a temperature-regulating device. The adoption of such an approach in the UK would ensure better domestic temperature control of chill foods, and contribute to microbiological food safety.

It should also be noted that domestic refrigerators are designed to perform to the above temperature standards according to the climate (ambient temperature) in which they are intended to be operated (Table 4.16). It is therefore important that the correct class of refrigerators is being supplied and used by consumers according to the local climate.

Table 4.16: ISO 15022 Domestic Refrigerator Climate Classes

Class	Symbol	Range of ambient temperatures in which the appliances are intended to be used and for which the required storage temperatures shell be fulfilled
Extended temperate	SN	+10 to +32
Temperate	N	+16 to +32
Subtropical	ST	+16 to +38
Tropical	T	+16 to +43

4.9 Domestic Food Refrigeration Temperatures in Practice

Surveys of consumer storage and handling of refrigerated foods (Table 4.17) indicate that performances are similar throughout the world.

Table 4.17: Surveys of Domestic Storage/Handling of Refrigerated Foods

Country	Reference
USA	VanGarde & Woodburne, 1987
China	Shixiong & Jing, 1990
UK	Evans *et al*., 1991; Evans, 1992; James & Evans, 1992a; James & Evans, 1992b
Northern Ireland	Flynn *et al*., 1992
France	Victoria, 1993
New Zealand	O'Brien, 1997
Greece	Sergelidis *et al*., 1997
The Netherlands	Notermans *et al*., 1997 (data from 1994 study)
USA	Daniels, 1998
UK	Johnson *et al*., 1998
Australia	Jay *et al*., 1999
USA	Audits International/FDA, 1999
USA	CFSAN/FSIS, 2001
France	Laguerre *et al*., 2002
Northern Ireland	Jackson, 2003
US	Redmond & Griffith, 2003
Sweden	Marklinder *et al*., 2004
Ireland	Kennedy *et al*., 2005
Portugal	Azevedo *et al*., 2005
Greece	Koutsoumanis & Taoukis, 2005

The temperature at which a refrigerator operates is critical for the safe storage of chilled food. A recommendation made in 1991 in the UK concerning the microbiological safety of foods advised that the maximum temperatures in domestic refrigerators should not exceed 5°C (Richmond, 1991). In view of the period since the last survey was carried out, it is not clear whether this has been achieved.

Awareness of the correct refrigerator temperature has been reported to be variable. An Irish study found 22% of consumers aware of the correct refrigerator temperature (Kennedy *et al*., 2005). While a recent Swedish survey (Marklinder *et al*., 2004) found a much better level of awareness amongst its survey group, with 85% of respondents knowing the recommended refrigeration temperature (in this case 8°C). However, not all of those consumers put their knowledge into practice; the Swedish survey found 40% of food storage temperatures exceeded the maximum recommended temperature for the food being stored. Only 25% knew, or regularly measured, the temperature of their refrigerator. In the Irish study, 23% of those asked had a refrigerator thermometer.

A US Government report (CFSAN/FSIS, 2001) reported that 73% of domestic refrigerators were found to be at ≤5°C and 4% at >8.3°C (Table 4.18). Jol *et al.* (2005) report that while major manufacturers and retailers operate a constant and effective cold chain, surveys in the US have revealed that 20% of domestic and commercial refrigerators operate at a temperature of >10°C.

Table 4.18: Frequency Distribution of Home Refrigerator Temperature from a Survey of 939 U.S. Refrigerators (Adapted from Table 111-8 FDA *Listeria* Risk Assessment, CFSAN/FSIS, 2001)

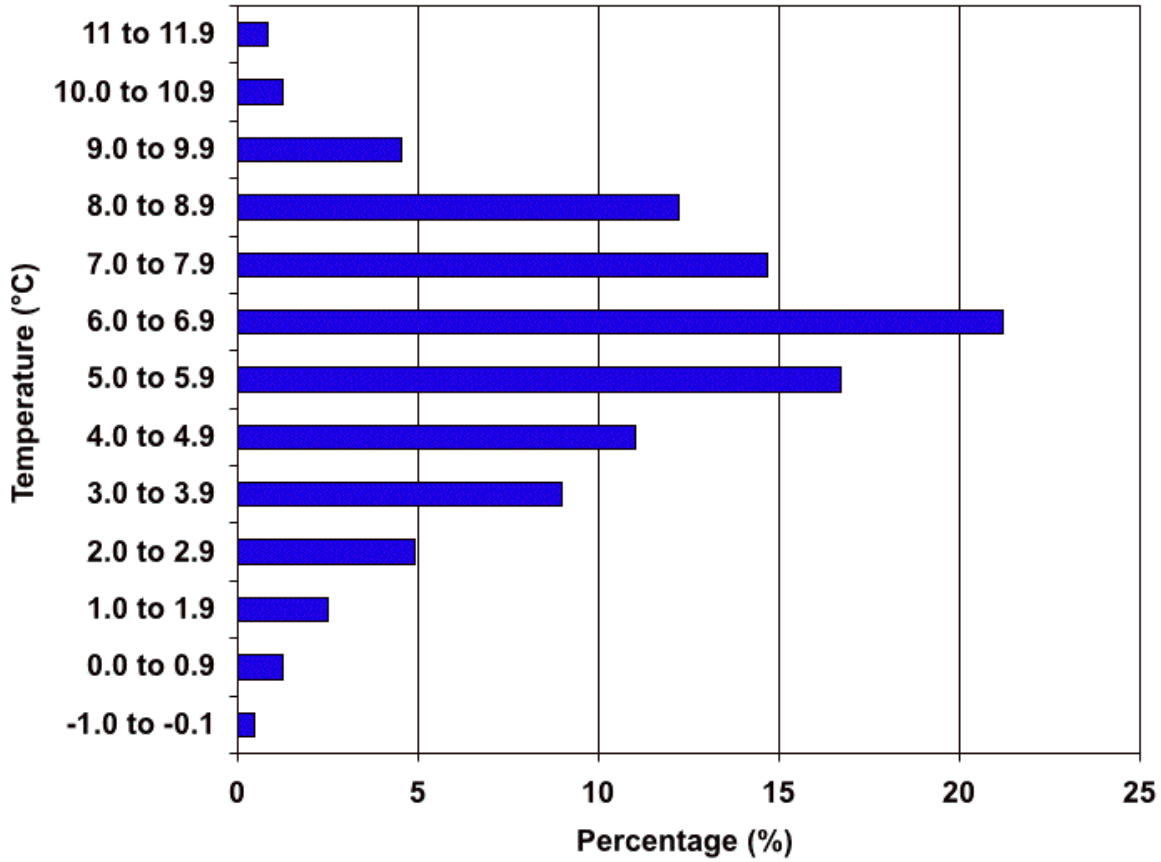
Refrigerator Temperature (°C)	Percentage of refrigerators at specified temperature
0.0	9
0.5-1.6	10
2.2-3.3	25
3.8-5.0	29
5.5-6.6	18
7.2-8.3	5
8.8-10.0	3
10.5-11.6	0.4
12.2-13.3	0.5
13.8-15.0	0.4
15.5-17.2	0.1

An Australian telephone survey (Jay *et al*., 1999) found only 16% of respondents knew the temperature of their refrigerator. A 2004 New Zealand survey of domestic refrigerator temperatures found that 16 out of 53 fridges tested (30%) were operating above 5°C (NZ Foodsafe Partnership, 2004). Twenty six (49%) showed temperatures ranging from 5°C-7°C. Four of the 53 fridges (7%) had average air temperatures above 7°C, and the warmest average air temperature recorded was 9.9°C. The lowest recorded temperature at any one time was -2.5°C. Almost 72% of the fridges surveyed recorded higher temperatures on the top shelf than on the bottom shelf. Of all the fridges surveyed, 23 (43%) had average air temperatures between 1°C and 5°C.

A survey of 2001/2002 found that 47% of yoghurt samples in French domestic refrigerators were at >6°C, and more than 75% of meat product samples were at >4°C (Berens *et al*., 2004). In addition, 5% of domestic refrigerators were operating at >10°C.

In the last major public UK survey (Evans *et al*, 1991) results showed that the mean temperature over 7 days (evaluated from top, middle and bottom sensors) ranged from -1°C to 11°C. The overall mean air temperature for all the refrigerators in the survey was 6°C, with 70% of refrigerators operating at average temperatures above 5°C (Figure 4.1). [Note, the earlier comments regarding the current validity of this work given the renewal rates of domestic refrigeration equipment in the UK].

Figure 4.1: Overall mean temperatures for all refrigerators in UK survey (Evans *et al*., 1991)



A recent review of all European studies showed that overall the average air temperature in European refrigerators would appear to be 6.64°C (Nauta *et al*., 2003).

A detailed survey of food temperatures of various products stored in Swedish consumers' refrigerators found that 83-94% were at >5°C, 22-44% were at >8°C, and 5-19% were at >10°C 22-44% (Table 4.19). Marklinder *et al.* (2004) also found that mean food temperatures were not related to the age or type of refrigerator in Sweden.

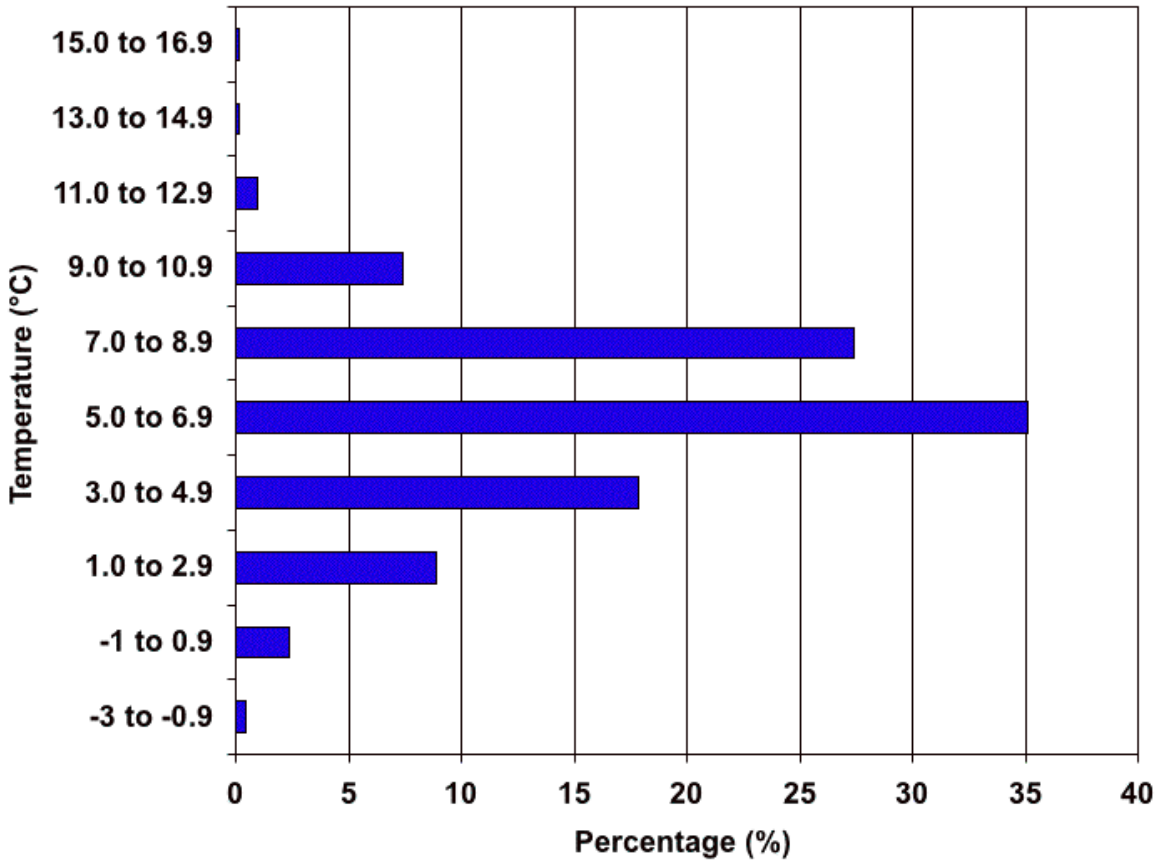
A figure of 60-70% of domestic refrigerators operating at an average temperature >5°C appears to be relatively common to many studies throughout the world (Table 4.19).

Table 4.19: Temperatures Measured in Surveys of Domestic Refrigerators

Reference	Country	Number of samples	Measurement	T_{min}	T_{mean}	T_{max}	% >x°C
Rose *et al.,* 1990	UK	75 (air)	unknown		<5	15	6%>5°C
Evans *et al*., 1991	UK	252 (air)	Data logger (3 levels: T, M, B)	0.9	6.0	11.4	70%>5°C
Flynn et al., 1992	Northern Ireland	150 (air)	Thermometer (3 levels: T, M, B)	0.8	6.5	12.6	71%>5°C
Victoria, 1993	France	102 (air)	Thermometer (3 levels: T, M, B)			14	70%>6°C
Notermans *et al*., 1997	The Netherlands	125 (air)	Thermometer				70%>5°C
O'Brien, 1997	New Zealand	50 (air)	Thermometer (2 levels: T, B)	0	4.9	11	60%>4°C
Sergelidis *et al*., 1997	Greece	136 (air)	Thermometer				50%>9°C
Daniels, 1998	USA	106 (air)	unknown				69%>5°C
Johnson *et al.*, 1998	UK	645 (air)	Thermometer	-2	7	13	70%>5°C
CFSAN/FSIS, 2001	USA	939	unknown				73% ≤5°C; 4% >8.3°C
Laguerre *et al*., 2002	France	119 (air)	Data logger (3 levels: T, M, B)	0.9	6.6	11.4	80%>5°C
Jackson, 2003	Northern Ireland	30	Data logger (1 level M)	-5	4.5	13.0	53%>5°C
Marklinder *et al*., 2004	Sweden (Jan-Mar and Sept-Nov 2002)	102 households, 705 food samples	Data logger	0.2 (VP salmon)	7.1	12.3	88%>4°C; 38%>8°C; 11%>10°C
				0.2 (fresh herring fillets)	6.5	12.8	83%>4°C; 24%>8°C; 7%>10°C
				0.6 (milk)	6.9	13.2	92%>4°C; 31%>8°C; 11%>10°C
				0.8 (minced meat)	6.2	11.3	85%>4°C; 22%>8°C; 6%>10°C
				1.1 (sliced cooked ham)	7.2	12.3	90%>4°C; 44%>8°C; 10%>10°C
				1.8 (RTE green salad)	7.4	18.2	94%>4°C; 39%>8°C; 19%>10°C
				2.4 (soft cheese)	6.8	13.6	93%>4°C; 27%>8°C; 5%>10°C
Cemagref/Ania, 2004	France	314 product samples/ fridges	Data logger	yoghurt			47%>6°C; 5%>10°C
				meat			75%>4°C; 5%>10°C
Kennedy *et al*., 2005	Ireland	100	Data logger (1 level M)	-7.9	5.4	20.7	59%>5°C
Azevedo *et al.,* 2005	Portugal	86	Digital thermometer				70%>6°C
Koutsoumanis & Taoukis, 2005	Greece	250	Data logger (3 locations)	-2.5			85%>5°C
Terpstra *et al*., 2005	Netherlands	31	Glass thermometer	3.8		11.5	21%>7°C

While an increasing number of refrigerators are sold with a single point temperature display, Laguerre *et al*. (2002) found that the temperature measured using a thermometer does not represent the "true operating conditions of the refrigerator". Indeed temperatures in refrigerators are not static. Various studies such as Koutsoumanis and Taoukis (2005) note major temperature variations throughout a refrigerator. An analysis of percentage time spent between certain temperatures carried out by Evans *et al.* (1991) in the UK, calculated for all refrigerators that the greatest proportion of time (80%) was spent between 3.0°C and 8.9°C. Approximately 28% of the time was at <5°C, 35% of the time was at 5.0-6.9°C, 28% of the time was at 7.0-8.9°C, and 9% of the time was spent above 9.0°C (Figure 4.2). Only four refrigerators (2%) in the whole survey operated below 5°C during all the monitoring period, and 33% of refrigerators spent all their time above 5°C.

Figure 4.2: Frequency distribution of temperatures in all refrigerators (UK study) (Evans *et al*., 1991)



The mean temperature range within a refrigerator was found to vary between refrigerator types. Ice box refrigerators had the smallest range (average 1.8°C); whereas the range in temperature in fridge-freezers and larder refrigerators was nearly twice as great (average of 3.4°C in fridge-freezers and 3.7°C in larder refrigerators).

A survey carried out in China found higher temperature ranges within domestic refrigerators with only 2% of the refrigerators surveyed operating with a temperature range of less than 6°C. It was found that 34% of fridges had a temperature range 8°C -12°C, and that 64% had a temperature range greater than 12°C (Shixiong & Jing, 1990).

From analysing the data from the various surveys reported in Table 4.19, it can be ascertained that 39% of the 3,607 domestic refrigerators worldwide were below 5°C, and that 80% were below 8°C (Table 4.20).

Table 4.20: International Domestic Refrigerator Temperature Performance

Temperature reported (°C)	Number of fridges at specified temperature	Percentage of fridges at specified temperature	Cumulative percentage
<4°C	143	4.0	4.0
4.0-4.9°C	1,255	34.8	38.8
5.0-5.9°C	120	3.3	42.1
6.0-6.9°C	24	0.7	42.8
7.0-7.9°C	1,356	37.6	80.4
8.0-8.9°C	68	1.9	82.3
9.0-9.9°C	633	17.5	99.8
≥10°C	8	0.2	100

Raw table in Table 4.19

Selecting for UK survey data from Table 4.19, it can be seen that more than 65% of UK refrigerators were at or above >5°C (Table 4.21). The mean reported temperature is 6.6°C. This is comparable with the overall international position.

Table 4.21: UK Domestic Refrigerator Performance

Temperature reported (°C)	Number of fridges at specified temperature	Percentage of fridges at specified temperature
<5°C	397	34.5
≥5°C	755	65.5

Raw table in Table 4.19

4.10 Domestic Chilled Food Storage Practices

Marklinder *et al.* (2004) found in Sweden that in most cases, perishable foods were not stored for more than 3 days (Table 4.22). A UK consumer study (Evans, 1992) in which the majority of respondents thought that most chilled food should be stored for 2 days or less.

Table 4.22: Stated Domestic Storage Times for Short Shelf Life Products – Swedish Consumers (Marklinder *et al.* 2004))

	Domestic storage times for short shelf life products in Sweden (% of time)*		
Storage time	Minced Meat	Herring fillet	RTE green salad
<1 day	27	23	17
1 day	42	33	37
2 days	17	25	24
3-4 days	4	2	5
5-6 days	0	2	0
7 days	0	2	0
Consume by/best before date	10	10	6
Own judgement	0	2	0
Other/no opinion	0	2	12

*There were 52 observations for minced meat and herring fillets and 102 observations for RTE green salads

A French survey (Table 4.7) found that mean domestic storage times of all purchased product types ranged from 3 to 26 days, but in the case of pre-packed meat ranged from 3 to 15 days. The overall mean storage time was 3 days.

All three studies (France, Sweden, UK) therefore found that chilled food domestic storage times were on average short (in the order of 3 days) or that consumers believed they should be.

Marklinder *et al.* (2004) found that respondents opinions about long shelf life products storage times varied depending whether the packs were opened or not (Table 4.23).

Table 4.23: Swedish Consumers' Stated Domestic Storage Times for Opened or Unopened Packs of Long Shelf Life Chilled Products (Marklinder *et al*., 2004)

Storage time	Domestic storage times for long shelf life products in Sweden (% of time)*			
	Salmon (%)		Ham (%)	
	Opened	Unopened	Opened	Unopened
1 day	10	2	2	0
2 days	21	10	5	0
3-4 days	23	2	32	2
5-6 days	6	2	12	0
1 week	10	10	25	12
2 weeks	0	0	2	6
3 weeks	0	0	0	0
'Best before' date*	12	44	7	54
Judgement	10	10	13	15
Other/no opinion	10	21	2	12

* VP salmon shelf life commonly 3-5 weeks after packing. Ham ~3 weeks; there were 52 observations for salmon opened, salmon unopened and ham unopened, and 101 observations for ham opened

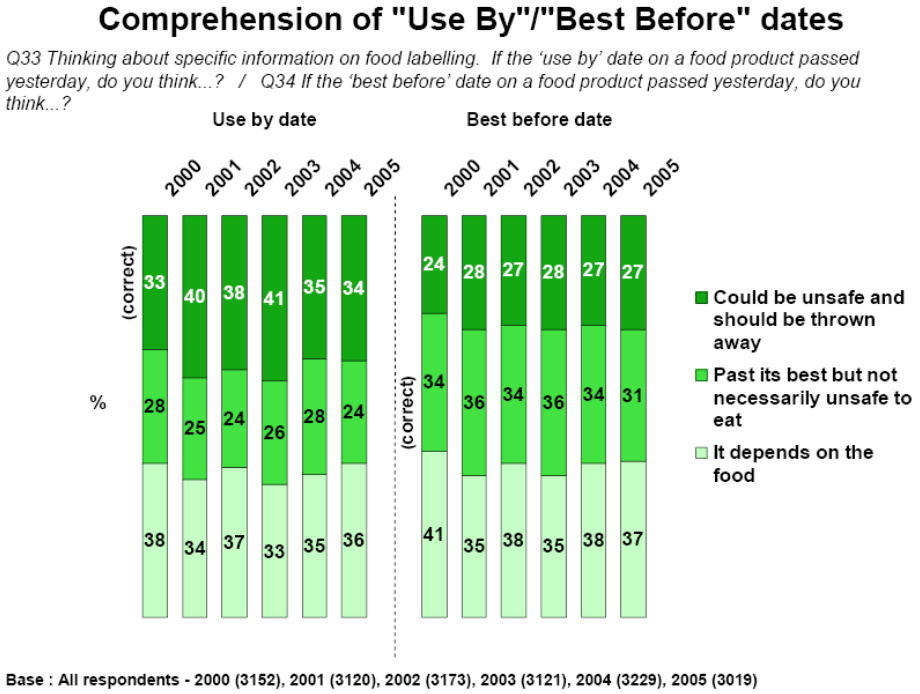
Shorter storage times were stated for opened than unopened packs, and for unopened packs it was more common to base the decision of storage time on the use by/best before date. Most respondents did not store an opened VP salmon pack for more than a few days, whereas half of them said that unopened packs could be stored up to the "best before" date. In principle this might lead to storage times of 5 weeks, 38% of the time at temperatures >8°C. Similarly, most respondents determined storage time of unopened ham packs on the basis of the "best before" date (reported to be about 3 weeks from packing) but did not store opened packs for more than 1 week. It was found that 44% of the time storage was at >8°C.

A UK study (Evans *et al.*, 1991) found that:

- 84% consumers 'always' checked product shelf life in shops
- 50% 'always' look for longest shelf life pack
- 74% used their own judgement regarding consumption of the product if the shelf life had expired
- 19% 'very rarely' threw food away if it was past its labelled shelf life
- 17% of products in fridges were past their shelf life
- 26% products would be eaten after expiry of their use by dates
- 49% would ignore shelf life if a time temperature indicator read 'OK'

Annual FSA consumer attitude surveys since 2000 have shown that the level of comprehension of "use by" and "best before" dates has been consistent since the start of the study in 2000. However, only one-third of UK respondents correctly interpret each term (Figure 4.3).

Figure 4.3: Comprehension of 'Use by' and 'Best Before' Dates (FSA, 2005)



The US FDA is reportedly concerned that consumers interpret the labelling terms "consume by" and "best if used by" as synonymous with "safe to consume until". At the January 2002 meeting of the National Advisory Committee on the Microbiological Criteria for Food, the Committee was asked to provide assistance to the FDA in developing a scientific framework for the establishment of safety-based "use by" date labels. Specifically, the Committee was asked to consider five questions, their conclusions on which are shown below (NACMCF, 2005):

1. What are the scientific parameters for establishing safety-based "use by" date labels for refrigerated RTE foods?

- The pathogen of concern must be able to grow at refrigerated temperatures in the food in question to a level that will be likely to cause illness in the host
- Scientific evidence that a safety based date label will reduce the risk of foodborne illness for that food must be available
- Identification of safety-based end points is necessary for establishing a safety based date label
- Determination of temperature to use for establishment of a safety based date label

2. What effects do the multiple factors that influence the growth and survival of *L. monocytogenes*, i.e. strain differences, food matrices, production and distribution systems, consumer susceptibility, etc., have on the establishment of safety-based "use by" date labels for refrigerated foods?

- Strain differences
- Food matrices
- Competing microflora and packaging
- Production, distribution and handling practices

3. What data needs to be acquired to scientifically validate and verify the adequacy of a proposed safety-based "use by" date label for a refrigerated RTE food?

- Ultimately the success of the safety based date label concept depends on how the consumer

interprets and uses the information measured both before and after implementation

4. Should safety-based "use-by" dates for refrigerated RTE foods be established using mathematical modeling techniques? If so, what modeling approaches are best suited to the development of safety-based "use-by" date labels for refrigerated RTE foods?

- The relevance and validity of a model must be carefully evaluated when determining the degree of confidence that can be given to a model's predictions

5. What impact would safety-based "use by" date labels likely have on the control of other foodborne pathogens in RTE foods?

- The impact will depend on the specific food-pathogen combination. Based on the epidemiological information the vast majority of cases of foodborne illness are due to pathogens that are incapable of growth in food at refrigeration temperatures. Thus a safety based date label for refrigerated products would have no impact on foodborne illnesses caused by these pathogens.
- For pathogens that can multiply in refrigerated ready to eat foods, the factors of primary concern are the likelihood of contamination with a particular psychrotrophic pathogen, the level of contamination, the rate of growth at refrigeration temperatures, storage and handling practices, and the level required to cause illness.
- The Committee's hazard analysis led to the conclusion that the duration of refrigerated storage is not a major factor in foodborne illness caused by *Y. enterocolitica*, *B. cereus* and non-proteolytic (psychrotrophic) *C. botulinum*. Therefore, the Committee believes that a safety based date label to limit the potential for growth of *L. monocytogenes* would have little or no impact on diseases related to these pathogens.

NACMCF (2005) concludes that educational efforts focusing on safety based date labels should also emphasise the importance of refrigeration temperature control.

4.11 Commercial Shelf Life Determination Protocols

The aim of a shelf life testing protocol is to ensure that a product is exposed to the time and temperature conditions it is likely to experience during manufacture, retail distribution, retail storage, purchase and storage by the consumer.

There are many different protocols in use throughout the food industry internationally to represent specific and general chill chains. It is believed that in practice however, it is likely that most industrially-produced chilled foods are produced, distributed and stored in retail and domestic refrigerators under similar conditions.

The selection of shelf life determination protocol is critical to the allocation of product shelf life since there are many differences regarding assumed storage temperatures and times at these temperatures.

Table 4.24 shows the agreed testing protocol intended to represent manufacture of most current chilled foods in the UK, which was developed by a working group of major UK manufacturers and retailers (CCFRA, 2004).

Table 4.24: Recommended UK Shelf Life Evaluation Protocol for Chilled Foods (CCFRA, 2004)

Manufacturing stage	Storage temperature*	Time
Under commercial control: In-house storage at manufacturer	5°C[a] or 7°C[b]	To be defined by the manufacturer and/or retailer
Distribution vehicles storage depot	5°C[a] or 7°C[b]	
Retail display	5°C[a] or 7°C[b]	
Outside commercial control: consumer purchase	22°C	2h
consumer storage	7°C	Remainder of life

* Temperatures stated assume a typical deviation of ±1°C

[a] The use of 5°C should be supported by evidence that these temperatures can be maintained throughout distribution and retail. If this is not the case 7°C should be used

[b] 7°C is recommended for use where there is insufficient data to show that a lower temperature can be maintained throughout the chill chain, or where there are concerns about the growth of pathogens such as *B. cereus* which has maximum acceptable levels within products.

For the majority of chilled prepared foods the UK major multiples' chill chains should be able to be maintained at 5°C throughout distribution and retail display. Indeed, agreed retailer own label chilled prepared food temperature on delivery to retailers' Regional Distribution Centres is commonly set at 5°C maximum through commercial agreements.

However, the CCFRA protocol notes that the England, Wales and Northern Ireland legislated temperature currently applicable to the majority of chilled foods is 8°C and states that if there is insufficient evidence to support the use of 5°C then the higher temperature 7°C±1°C should be used to give a safety margin. The rationale for the choice of storage times and conditions in this protocol is:

- 5°C being representative of on-site storage at most manufacturing sites (note usage of 'deep chill' in an increasing number of operations in the UK)
- A Working Party survey of retail storage believed that the average temperature was 4-6°C
- Purchase and transportation by the consumer was found by a Working Party survey to be a maximum average of 1 hour in the shop and a further hour for loading the shopping into the car, driving home and unloading shopping into the refrigerator
- Storage in a domestic refrigerator was found in a MAFF survey (Evans *et al.,* 1991) to be at 6°C on average, with the majority (74%) of UK refrigerators surveyed operating at <8°C. A temperature of 7°C±1°C was believed by the Working Party to cover the maximum operating ranges of the majority of domestic refrigerators in the UK.

A French national protocol for the determination of shelf life of perishable refrigerated foods was published by AFNOR (2003). It sets out different approaches for the determination of shelf life dependent on the chill chain (Table 4.25).

Table 4.25: French Shelf Life Determination Protocol in Relation to Chill Chains (AFNOR, 2003)

Chill Chain Type	Storage Regime
Insufficiently known or controlled, storage temperature believed to be somewhat long at t_1	t_1 for one third of the estimated shelf life t_2 for two thirds of the estimated shelf life
Partially controlled chill chain	t_1 for two thirds of the estimated shelf life t_2 for one third of the estimated shelf life
Totally controlled chain	t_1 for the whole of the estimated shelf life

Where:
t_1 is the fixed storage temperature by legislation (4°C for chilled prepared foods) or the temperature fixed by the manufacturer; and
t_2 is a representative temperature of a reasonable breach of the chill chain or a modification of the storage temperature (e.g. in the home). t_2 is in practice taken to be 8°C (based on the findings of a survey of consumer behaviour carried out in France (Cemegref/Ania, 2004).

The standard application practice of the French protocol is for the distribution chain to be treated as "partially controlled chill chain", since storage at 4°C by consumers seems unlikely. A "totally controlled chill chain" would for example be on-site production for on-site consumption, e.g. hotel/restaurant catering.

The US Refrigerated Foods Association (2002) has proposed a draft 'Protocol for Determining the Shelf Life of Refrigerated Foods', comprising:

- Shelf Life Verification: covering microbiological, chemical and sensory analysis.
- Challenge Studies (with respect to *Listeria monocytogenes* and *C. botulinum*): in products when changes in formulation, packaging etc. are made. *Clostridium sporogenes* will be used as a surrogate organism for *C. botulinum*. Only products which have a pH $\geq$4.6 and have been produced under reduced oxygen conditions, including MAP, should be challenged with *C. sporogenes*.
- Testing Protocol for Refrigerated Food Shelf Life: to validate that the shelf life that has been established for a specific product is appropriate. All products will be tested at six different ages regardless of length of expected shelf life. Shelf life analysis is dependent upon examination of batches of samples until the shelf life becomes unacceptable. Sampling intervals should be determined at 20% of product shelf life, which comprise six different ages from fresh to full shelf life. For example, if a product with an extended shelf life of 30 days is analysed, sampling intervals should consist of day 0, 6, 12, 18, 24 and 30.
- For the purpose of verification, the criteria shall be strictly applied on the product(s) held at 4°C. For product(s) held at 10°C the results shall be used to help the manufacturer understand any inherent weaknesses that may exist as well as recognize the reality of the distribution system.

However, it is important to note that *C. sporogenes* is more commonly used as a surrogate for proteolytic *C. botulinum* (e.g. in thermal tests). Since it does not grow below 10°C it is unlikely to be a good surrogate for non-proteolytic *C. botulinum* in these tests if the chill chain is maintained. The protocol therefore appears to be designed primarily to assess the growth potential in relation to significant temperature abuse conditions (i.e. >10°C).

4.12 Conclusions

Within the UK, when held and distributed by the manufacturer, it is likely that chilled food is maintained at no more 5°C, and probably lower. Indeed, agreed retailer own label chilled prepared food temperature on delivery to retailers' Regional Distribution Centres is commonly set at 5°C maximum, through commercial agreements.

The maximum temperature specified in legislation for retail of chilled food is 8°C in England, Wales and Northern Ireland. In Scotland the requirement is to keep chilled food in “a refrigerator, or refrigerating chamber, or a cool ventilated place”. Neither is there is not a harmonised approach to legislated temperature rules within the EU, with temperatures of 0°C to 8°C specified in different countries. There can also be different requirements for different food groups.

In practice, surveys of all types of chilled food outlets (including major multiple retailers, farmers markets, small stores and other outlets) indicate that in the UK, the average temperature at retail was 4°C-6°C, with only 6% of samples at >8°C. The position appears similar in many other European countries.

In the UK, a 1990 study showed that transportation of food from the point of purchase to the domestic refrigerator took an average of 43 min, with most achieved in 60 min. The majority of people (87%) did not chill the food during transport, and in some cases the food reached temperatures in excess of 20°C, albeit for a short period of time. It took several hours for the food to cool to below 7°C. The increased use of insulation bags or boxes would help consumers maintain the chill chain.

Chilled food purchased through mail order is exempt from legislation in England, Wales and Northern Ireland, although the temperature should be maintained at a “safe level”. A MAFF study in 1991 reported that mail order chilled foods spent 70% of their time at 8°C or higher, and that the average temperature on receipt was 15°C. MOFFA (Mail Order Fine Foods Association) state that “if the temperature is likely to rise in transit above 8°C, the main order operator should be confident that it is safe by reference to supporting technical or other data”.

Domestic refrigerators are present in >99% of households in the UK, and on average are replaced every 8 years. Refrigerators provide a key food safety device within the domestic kitchen, their correct operation will reduce the risks of the growth of food poisoning organisms in foods stored within them. Unfortunately there is a lack of recent published data on the temperatures of domestic refrigerators, with the last UK domestic refrigerator survey carried out in 1990. In view of the elapsed time, there would be merit in repeating this survey. This would provide up to date information on current practice.

The 1990 UK survey found that the mean domestic fridge temperature ranged from -1°C to 11°C over a 7 day period, and that the overall mean temperature was 6.6°C, with 65-70% of fridges at more than 5°C. There was variation in performance between fridges, and within each fridge over time. Different temperatures were also recorded in different parts of single fridges. Overall, for all domestic fridges the time spent at various temperatures were as follows; 28% of the time at <5.0°C, 35% of the time at 5.0-6.9°C, 28% of the time at 7.0-8.9°C, and 9% of the time at >9°C. The position appears similar in other countries, and an average temperature of 6.64°C has been reported for European fridges. In 1991, Richmond recommended that the maximum temperature of domestic fridges in the UK should not exceed 5°C, in view of the period since the last survey was carried out, it is not known whether this has been achieved.

A survey of consumer behaviour in France established that for short shelf life chilled products, approximately 60% of the shelf life was spent in commercial refrigeration, and 40% in domestic refrigeration. The general applicability of this to other countries is not known, given different practices in various countries.

UK consumer understanding of the “use by date” or “best before date” is poor, and UK consumer handling of chilled foods in practice needs to be more widely studied. Recent FSA data indicate that 27-34% of consumers believe that food past the “use by date” or “best before date” should be thrown away, 24-31% of consumers believe that such food might be past its best but not

necessarily unsafe to eat, and 36-37% believe that the action would depend on the food. An earlier survey found that 26% of consumers would eat products after the expiry of their use by date.

It is suggested that the UK continues to strive for better temperature control throughout the chill chain (including domestic storage), and that 5°C is adopted as a target for best practice. This could be aided by new domestic refrigerators including chill compartments and a temperature measuring device to assist consumers in assuring the appropriate chilled storage of foods. This proposal is made in order to further extend the margins of safety of chilled foods with respect to psychrotrophic foodborne pathogens (since their growth is slower at 5°C than 8°C), rather than on the basis of any specific problems.

4.13 References

Adams, B., and Ashton, S. (2002) Microbiological Quality of ready to eat ham sold by butchers and delicatessens. Sunshine Coast Public Health Unit Project Report. http://www.foodstandards.gov.au/mediareleasespublications/foodsurveillancenewsletter/autumn2002.cfm

AFNOR (2003) XP V 01-003 Lignes directrices pour l'élaboration d'un protocole de validation de la durée de vie microbioloque.

AMA Research (2003) Kitchen Appliance Report UK (2003). http://www.amaresearch.co.uk/KitchenAppliance03s.html (accessed 16/3/06)

ANZFA (2001) National Food Handling Benchmark 2000/2001 Report. Campbell Research & Consulting.

ATP (2003). Agreement on the international carriage of perishable foodstuffs and on the special equipment to be used for such carriage (ATP). As amended on 7 November 2003. Economic Commission for Europe. Inland Transport Committee. ECE/TRANS/165. United Nations. http://www.unece.org/trans/main/wp11/wp11fdoc/Atpeng.pdf (accessed 24/4/06)

Audits International/FDA. (1999). U.S. Food Temperature Evaluation, Design and Summary Pages. 1-10.

Australian Food and Grocery Council. (1999). Cold Chain Code of Practice.

Azevedo, I., Regalo, M., Mena, C., Almeida, G., Carneiro, L., Teixeira, P., Hogg, T. & Gibbs, P. A. (2005) Incidence of *Listeria* spp. in domestic refrigerators in Portugal. Food Control 16, 121-124.

Billiard, F. (2002) Food Safety and Refrigeration. FAO/WHO Global Forum on Food Safety Regulators. Marrakech, Morocco, 28-30/1/02. www.fao.org/DOCREP/MEETING/004/AB435E.HTM (accessed 14/3/06)

CCFRA (Campden and Chorleywood Food Research Association) (1996) Code of practice for the manufacture of vacuum and modified atmosphere packaged chilled foods with particular regard to the risks of botulism. Guideline No. 11.

CCFRA (2004) Evaluation of Product Shelf-life for Chilled Foods. Guideline No. 46.

Cemagref/Ania (2004) La chaîne du froid du fabricant au consommateur. Froid No. 1042, 29-36.

CFSAN/FSIS (2001) HHS Listeria Risk Assessment. http://www.foodsafety.gov

CFSAN (2005) Food Code. www.cfsan.fda.gov/~dms/fc05-toc.html

CODEX (1999) Code of Hygienic Practice for Refrigerated Packaged Foods with Extended Shelf Life. (CAC/RCP 46)

Daniels, R. W. (1998) Home food safety. Food Technology 52, 54-56.

Derens, E., Guilpart, J., Palagos, B., Prosen, E. (2004) Donnés chiffrées sur la chaîne du froid des produits réfrigérés. Froid No. 1045, 27-32.

Elson, R., Burgess, F., Little, C.L., and Mitchell, R.T. (2004) Microbiological Examination of ready-to-eat cold sliced meats and pate from catering and retail premises in the UK. Journal of Applied Microbiology 96, 499-509.

Evans, J. (1992) Consumer handling of chilled foods - perceptions and practice. International Journal of Refrigeration 15, 290-298.

Evans, J. A., Stanton, J. I., Russell, S. L. and James, S. J. (1991) Consumer handling of chilled foods: A survey of time and temperature conditions. *MAFF Publications, London PB 0682*.

Elintarvikevirasto (2000) Tyhjiöpakattujen kalavalmisteiden listeriatilanne parantunut. 7 June 2000. http://www.eela.fi/ajankohtaista/tiedotteet_r.html?&Id=1033722035.html (accessed 26/3/06)

Finnish National Food Agency (2006) EU project on quality of convenience salads implemented by the National Food Agency. http://www.palvelu.fi/evi/show_inform.php?inform_id=349&lang=3&back=inform_frontpage.php%3Flang%3D3%23a349

Flynn, O. M. J., Blair, I. & McDowell, D. (1992) The efficiency and consumer operation of domestic refrigerators. International Journal of Refrigeration 15, 307-312.

Food Institute of Canada (undated) Draft Canadian Code of Recommended Handling Practices for Chilled Food.

Food Standards Agency (2006) Online and Mail Order. www.eatwell.gov.uk/keepingfoosafe/shoppingforfood/onlinemailorder

Food Spectrum LLC (2002). Retail Prepared Refrigerated Foods: The Market and Technologies. http://www.foodspectrum.com/completeReport.html

FSA (2005) Consumer attitudes to food standards. COI Ref: 268650

FSA Scotland (2005) Food Safety Guide for Farmers Markets In Scotland.

FSAI (2002) Microbiological Safety of pre-packed sandwiches. *Third Quarter National Microbiological Survey (NS3).*

FSAI (2003) Microbiological quality/safety of pre-packed cooked sliced ham. *First Quarter National Microbiological Survey 2003 (NS1).*

FSIS (2003) Mail Order Food Safety. www.fsis.usda.gov/OA/pubs/mailorder.htm

FSIS (2001) Draft Assessment of the Relative Risk to Public Health from Foodborne *Listeria monocytogenes* among selected categories of Ready-To-Eat Foods. www.foodsafety.gov/~dms/lmrisk.html (accessed 19/3/06).

Health and Welfare Canada (1992) Guidelines for the production, distribution, retailing and use of refrigerated prepackaged foods with extended shelf-life. Guideline No. 7. Food Directorate, Health Protection Branch, March 1, 1992.

ISO/DIS 15502:2005 (2005) Household refrigerating appliances - Characteristics and test methods. International standards Organization. www.iso.org (accessed 24/4/06)

Jackson, V. (2003) Food Safety Knowledge and Practices in Irish Homes. PhD Thesis.. University of Ulster at Jordanstone.

James, S. J. and Evans, J. (1992a) Consumer handling of chilled foods - temperature performance. International Journal of Refrigeration 15, 299-306.

James, S. J. and Evans, J. (1992b) The temperature performance of domestic refrigerators. International Journal of Refrigeration 15, 313-319.

James, S.J., (2003) Developments in domestic refrigeration and consumer attitudes. Bulletin of the IIR. No. 2003-5

Jay, L. S., Comar, D. and Govenlock, L. D. (1999). A national Australian food safety telephone survey. Journal of Food Protection 62, 921-928.

Johnson, A. E., Donkin, A. J. M., Morgan, K., Lilley, J. M., Neale, R. J., Page, R. M. and Silburn, R. (1998). Food safety knowledge and practice among elderly people living at home. Journal of Epidemiology and Community Health 52, 745-748.

Jol, A., Kassianenko, A., Wszol, K., Oggel, J. (2005). Issues in Time and Temperature Abuse of Refrigerated Foods. www.foodsafetymagazine.com/issues/0512/co104.htm Accessed 12/3/06.

Kennedy, J., Jackson, V., Blair, I. S., McDowell, D. A., Cowan, C. and Bolton, D. J. (2005). Food safety knowledge of consumers and the microbiological and temperature status of their refrigerators. Journal of Food Protection 68, 1421-1430.

Koutsoumanis, K. and Taoukis, P. S. (2005) Meat safety, refrigerated storage and transport: modelling and management. Chapter 23, pp. 503-561. *Improving the safety of fresh meat*, edited by J.N. Sofos. (Woodhead Press).

Laguerre, O., Derens, E. and Palagos, B. (2002) Study of domestic refrigerator temperature and analysis of factors affecting temperature: a French survey. International Journal of Refrigeration 25, 653–659.

MAFF (1991) The Microbiological Status of Some Mail Order Foods.

Marklinder, I. M., Lindblad, M., Eriksson, L. M., Finnson, A. M. and Lindqvist, R. (2004) Home storage temperatures and consumer handling of refrigerated foods in Sweden. Journal of Food Protection 67, 2570-2577.

MOFFA (Mail Order Fine Foods Association)(2006) Industry Guide to Good Hygienic Practice: Mail Order (draft).

MTP (2006) Fridge-freezer, Refrigerator sales 1999-2020. http://whatif.mtprog.com/SummaryData.aspx (accessed 16/3/06)

NACMCF (2005) Considerations for the Establishing Safety-Based Consume-By Date Labels for Refrigerated Ready-to-Eat Foods. Journal of Food Protection 68, 1761-1775.

Nauta, M. J., Litman, S., Barker, G. C. and Carlin, F. (2003) A retail and consumer phase model for exposure assessment of *Bacillus cereus*. International Journal of Food Microbiology 83, 205-218.

Notermans, S., Dufrenne, J., Teunis, P., Beumer, R., te Giffel, M. and Peeters Weem, P. (1997). A risk assessment study of *Bacillus cereus* present in pasteurized milk. Food Microbiology 14, 143-151.

NZ Foodsafe Partnership (2004). One in three fridges could make you sick. 23 November 2004. New Zealand Foodsafe Partnership Media Release. www.foodsafe.org.nz (accessed 23/11/04)

O'Brien, G. D. (1997). Domestic refrigerator air temperatures and the public's awareness of refrigerator use. International Journal of Environmental Health Research 7, 141–148.

ODPM (14/3/06) New Projections of households for England and the Regions to 2026. *ODPM Statistical Release 2006/0042.* http://www.odpm.gov.uk/index.asp?id=1002882&PressNoticeID=2097 (Accessed 16/3/06)

Redmond, E. C. and Giffith, C. J. (2003) Consumer food handling in the home: A review of food safety studies. Journal of Food Protection 66, 130-161.

Richmond, M. (1991) The microbiological safety of food part II. Report of the committee on the microbiological safety of food. HMSO, London.

Rose, S. A., Steadman, ,S., and Brunskill, R. (1990) A temperature survey of domestic refrigerators. CCFRA Technical Memorandum No. 577.

Rosengren, Å., and Lindblad, M (2003) *Listeria monocytogenes* I kyld konsumtionsfärdig mat. Livsmedels Verket, Riksproject 2001.

Sagoo, S.K., Little, C.L., Ward, L., Gillespie, I.A., and Mitchell, R.T. (undated) LACORS/PHLS Coordinated Food Liaison Studies: The Microbiological Examination of Bagged Prepared Read-to-Eat Salad Vegetables from Retail Establishments.

Sagoo, S.K., Little, C.L., Allen, G., Williamson, K., and Grant, K. (2006) LACORS/HPA Co-ordinated Food Liaison Group Studies: Microbiological Examination of Vacuum Packed and Modified Atmosphere Packaged Cooked Ready-To-Eat Meats at End of Shelf-life from Retail Premises (in press). www.lacors.com

Sergelidis, D., Abrahim, A., Sarimvei, A., Panoulis, C., Karaioannoglou, Pr. and Genigeorgis, C. (1997) Temperature distribution and prevalence of Listeria spp. in domestic, retail and industrial refrigerators in Greece. International Journal of Food Microbiology. 34, 171-177

SCOOP Report (1996) Studies Relating to Temperature Control. Report to the European Commission Task SCOOP/MICR/2.2.

Shixiong, B. and Jing, X. (1990). Testing of home refrigerators and measures to improve their performance. *Progress in the Science and Technology of Refrigeration in Food Engineering*, Meeting of IIR Commission B2, C2, D1, D2/3, Dresden (Germany). pp. 411-415.

Terpstra, M.J., Steenbakkers, L.P.A., de Maertelaere, N.C.M. and Nijhuis, S. (2005). Food storage and disposal: consumer practices and Knowledge. British Food Journal 107, 526-533.

Van Garde, S. J. and Woodburne, M. J. (1987). Food discard practices of households. Journal of the American Dietetic Association 87, 822-829.

Victoria, R. (1993). Ne joves pas avec le froid. *50 millions de consommateur* 267, 36–37.

US Refrigerated Foods Association (2002). Refrigerated Foods Association Protocol for Determining the Shelf Life of Refrigerated Foods. Final Version Submitted October 7, 2002. http://www.refrigeratedfoods.org/ShelfLifeProtocol.doc (accessed 24/4/06)