Consumer handling of chilled foods: Temperature performance

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Chilled foods are stored for periods of between a few hours and many days in domestic refrigerators. However, there are little published data on the temperature performance of domestic refrigerators within the home. A survey has been taken in 252 households in the UK and some of the results are presented in this paper. The refrigerators investigated in the survey were found to have an overall mean temperature of approximately 6°C, which ranged from 11.4 to −0.9°C. Temperature ranges over the whole refrigerator varied from 4.5 to 30.5°C with 3.7% of the total being warmer than 20°C. On average 29.9% of refrigerators operated below 5°C and 66.7% operated below 7°C. Few refrigerators (7.3%) ran, on average, above 9°C. No refrigerator characteristic (apart from type) could be related to temperatures or temperature distribution in the refrigerators investigated.
(Keywords: domestic refrigerators; temperature; chilled food)

Manipulation des produits réfrigérés par les consommateurs: Température assurée

Les aliments réfrigérés sont entreposés dans les réfrigérateurs domestiques, pour des périodes allant de quelques heures à plusieurs jours. Cependant, peu de données ont été publiées sur la performance des réfrigérateurs domestiques en matière de température, au domicile des consommateurs. Une enquête a été effectuée auprès de 252 ménages au Royaume Uni, et on présente quelques résultats dans cet article. Les réfrigérateurs considérés dans l'enquête avaient une température globale moyenne d'approximativement 6 deg C (elle variait de 11,4 à −0,9 deg C). Les plages de température globale allaient de 4,5 à 30,5 deg C, mais pour 3,7% des réfrigérateurs, la température était supérieure à 20 deg C. En moyenne, 29,9% des réfrigérateurs fonctionnaient à une température inférieure à 5 deg C, et 66,7% à une température inférieure à 7 deg C. Peu de réfrigérateurs (7,3%) fonctionnaient à une température supérieure à 9 deg C. Aucune caractéristique des réfrigérateurs, mis à part leur type, ne pouvait avoir une incidence sur les températures ou sur la distribution de température, dans les réfrigérateurs étudies.
(Mots clés: réfrigérateurs domestiques; température; produit réfrigéré)

As a chilled product moves along the chill chain it becomes increasingly difficult to control and maintain its temperature. Temperatures of bulk packs of chilled produce in large store rooms are far less sensitive to small heat inputs than single consumer packs in transport or open display cases. Before 1 April 1991, when the new Food Hygiene (Amendment) Regulations 1990 were implemented, there were no regulations in the UK to cover the temperature of chilled foods during distribution and retail display. The regulations, which are fully implemented over a two-year period, divide the majority of chilled foods into two groups: one consisting of the most *Listeria*-sensitive foods will have a maximum temperature during storage, transport and display of 5°C, whilst other foods considered less sensitive will have to be maintained below 8°C. Consistent policing of this new legislation should substantially improve the bacterial quality of chilled food when it is purchased by the consumer.

Although this new legislation should ensure that food producers and retailers maintain acceptable product temperatures during the distribution chain, they lose control when the product leaves the retail store. After a chilled product is removed from a display cabinet it spends a period outside a refrigerated environment whilst it is carried around the store and then transported home. In the first section of this paper some limited data on the temperature increase that can be obtained in this period are presented together with data about the rate of cooling that is subsequently achieved when the food is placed in a domestic refrigerator.

In a recent survey taken in China[1] only 2.3% of domestic refrigerators were found to operate with a temperature range of less than 6°C within the storage compartment: 34.1% had differences of 8–12°C, 34.1% in the range 12–14°C and 29.5% differences greater than 14°C. No similar data have been located for the UK or Europe. As part of a more wide-ranging survey of the consumer handling of chilled food, commissioned by the Ministry of Agriculture, Fisheries and Food (MAFF)[2], the Research Centre has gathered data on temperature in domestic refrigerators. The survey population consisted of 252 households selected from the towns of Weston-super-Mare, Bridgwater and Taunton. The survey was divided into two parts: the first was taken between September and December 1989 and the second between February and May 1990; the aim being to reflect varying seasonal ambient weather conditions. Each part of the survey consisted of 126 households split evenly between the three towns. The second part of this paper reports data on domestic refrigerators, with other aspects of the survey being reported in a second paper[3].

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Table 1 Maximum temperature (°C) measured in products after being transported for 1 h in the boot of a car without protection or within a cooled insulated container
Tableau 1 *Températures maximales (deg C) mesurées sur les produits après 1 heure de trajet jusqu'au domicile, dans la malle d'un véhicule ou dans un conteneur isotherme*

Product	Unprotected	Cool box
Beef pie	24	7
Chicken sandwich	32	10
Cooked chicken	28	12
Minced beef	18	9
Prepared salad	29	14
Quiche	26	18
Sausage (raw)	28	15
Smoked ham	30	14
Trout	28	5
Brie cheese	28	11
Coleslaw	30	14
Lasagne	21	6
Pate	25	13
Prawns	37	14
Raw chicken	24	4
Sausage roll	28	12
Smoked salmon	38	18

Transport from retail store to domestic storage

Over a 3 d period two samples of 19 different types of chilled product were purchased from a large retail store and carried to a car parked in the adjoining car park where temperature sensors were inserted into each sample. The sensors were attached to a miniature data-logging system (Stick-On, ACR Systems Inc.). One sample from 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 back to the centre and the product removed and placed in a domestic refrigerator after a total journey time of one hour. The ambient temperature during the journeys ranged from 23 to 27°C.

Initial product temperatures measured when the food reached the car ranged from 4 to over 20°C. The high temperatures measured in the thin sliced products such as salmon and ham were most probably due to heat pick-up during the time spent in the shopping trolley. Temperatures in larger products were indicative of the average display temperature together with a slight increase in the trolley. The initial temperatures indicated that one group of chilled products including minced beef, ready meals, raw chicken and beef pies were displayed at approximately 5°C. A second group including sausage rolls, sandwiches, quiche and prepared salads were close to 10°C. It was surprising to find cooked chicken in the second group. Some product temperatures of samples placed in the boot rose to approaching 40°C (*Table 1*) 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 products, i.e. smoked salmon trout (*Figure 1a*), showed the highest temperature changes during transport. Thicker products like cooked chicken (*Figure 1b*) were less influenced. After being placed in the domestic refrigerator it required approximately 5 h before the temperature was reduced below 7°C (*Figure 1a* and *b*).

Predictions made by using a mathematical model that calculated bacterial growth from temperature–time relationships indicated that increases of up to two generations in bacterial numbers (*Table 2*) can occur during this transport and domestic-cooling phase. The model assumes that bacteria require a period to acclimatize to a change in temperature (the lag phase) and that no acclimatization had occurred during display. If this rather optimistic assumption is not made, then up to 4.2 doublings of *Pseudomonas* and growth of both *Salmonella*

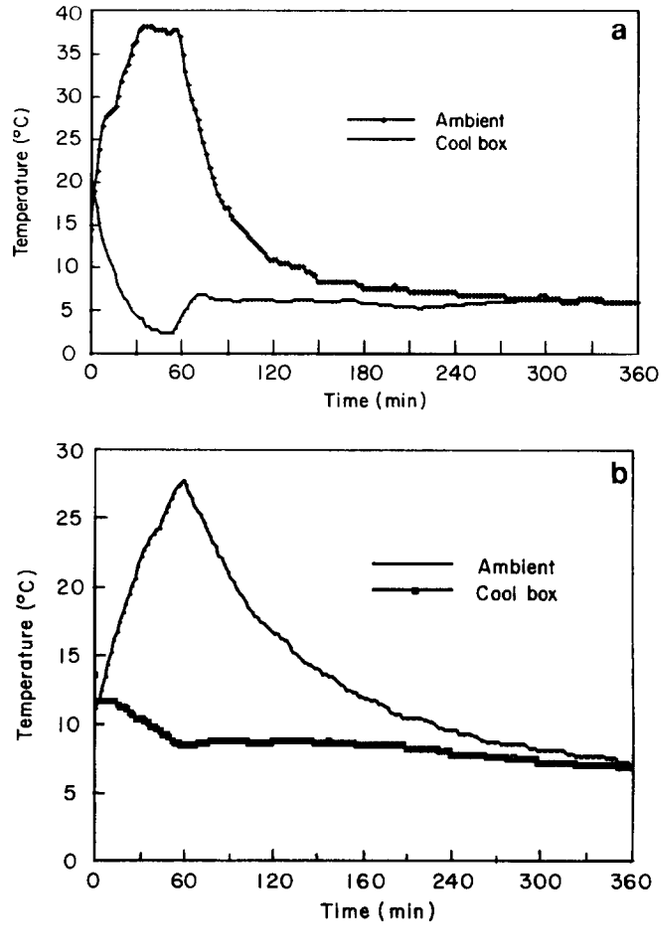

Figure 1 Temperature change in (a) smoked salmon trout and (b) Tandoori chicken during transportation home and being placed in a domestic refrigerator
Figure 1 *Changement de température dans (a) du saumon fumé et (b) du poulet tandoori, au cours du trajet jusqu'au domicile et dans le réfrigérateur domestique*

Table 2 Increase in bacterial numbers (generations) during 1 h in a car followed by 5 h in a domestic refrigerator
Tableau 2 *Augmentation du nombre de bactéries (en générations) pendant 1 heure de transport dans une voiture, suivie de 5 heures dans un réfrigérateur domestique*

Product	Conditions	*Pseudomonas*	*Clostridium*
Pate	Ambient	1.5	0.4
	Cool box	<0.4	0
Raw chicken	Ambient	1.6	0.2
	Cool box	0	0
Cooked chicken	Ambient	1.8	0.7
	Cool box	0	0
Prawns	Ambient	1.3	1.6
	Cool box	0	0
Brie cheese	Ambient	2.2	0.8
	Cool box	0	<0.1

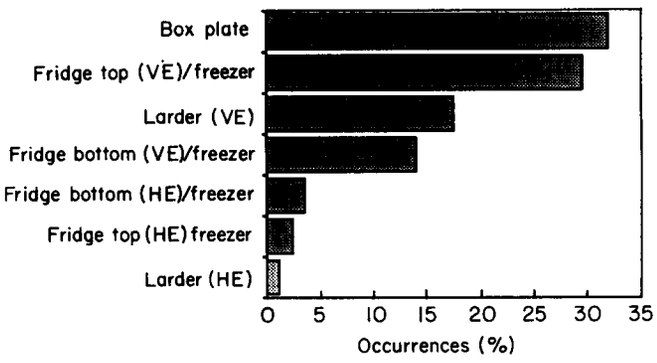

Figure 2 Percentage of different types of refrigerator found in survey: VE, visible evaporator; HE, hidden evaporator
Figure 2 *Pourcentage des différents types de réfrigérateurs considérés dans l'enquête: VE, évaporateur visible; HE, évaporateur caché*

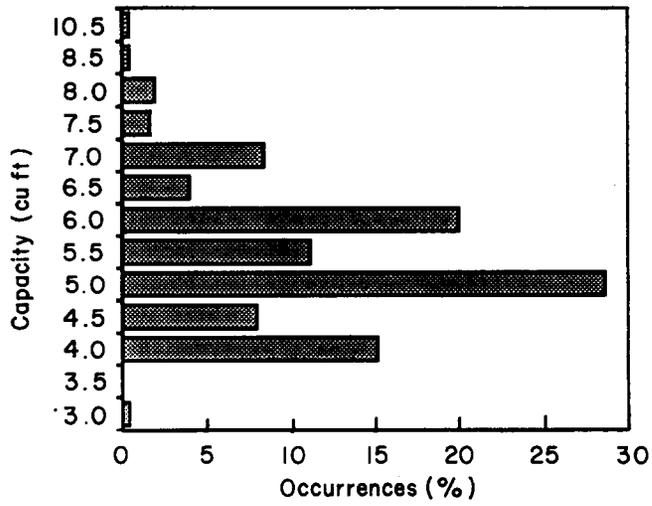

Figure 3 Percentage of different sizes of refrigerator found in survey
Figure 3 *Pourcentage des différentes dimensions des réfrigérateurs de l'enquête*

and *Listeria* were predicted. Very small increases in bacterial numbers (under 0.4 generations, *Table 2*) were predicted when the insulated box was used due to the lower product temperatures.

Within the home

In the initial part of the survey data were obtained on the refrigerators that were present. Only three of the 252 households surveyed did not have a working refrigerator. One of these owned a refrigerator that had recently stopped working and was planning to obtain a new model. One further person owned a refrigerator that was only used occasionally and was not in use during the survey. The most popular refrigerator design was a 'fridge–freezer' (49.4%), followed by the box-plate (31.9%) and larder refrigerators (18.7%). A more detailed breakdown of the types of refrigerator found in terms of refrigerator configuration and coil design is shown in *Figure 2*.

The capacity of the chilled food section of each refrigerator was visually assessed. Of refrigerators in the survey 82.9% were found to be between 4 and 6 cubic foot (cu ft) (1 cu ft $\approx$ 0.028 m^3). Less than 5% of the refrigerators were smaller than 3.5 cu ft or larger than 7.5 cu ft (*Figure 3*). Only three refrigerators (1.2%) had a fan mechanism in the chilled food section.

The age of each refrigerator was determined from information provided by the householder. A general assessment of the condition and type of refrigerator was also taken into account to ensure that the information was reasonably accurate. The majority of refrigerators (88%) were less than 10 years old. Over half (58.2%) were less than five years old and a small number (5.2%) were older than 20 years. Age differences were found to be affected by refrigerator type. Box-plate refrigerators were aged up to 31 years, whereas fridge–freezers were aged up to 18 years and larger refrigerators up to 10 years.

The appliance on the left- and right-hand side of each individual refrigerator was noted. Free standing was the most popular refrigerator position, which accounted for 13.6% of the results. When divided into the number of appliances with potential heat sources on either one or both sides, 25.5% of appliances had a potential heat source on one side and 1.2% had a potential heat source on both sides. Potential heat sources were dishwashers, freezers, ovens, tumble dryers and washing machines. Over half (59.8%) of householders positioned their refrigerators away from immediate heat sources, but with a unit or wall on either one or both sides.

The condition of the seals around the door of each refrigerator was judged subjectively on a scale from excellent to poor. Excellent was described as nearly new with good seal and no tears in the rubber. Seals that were poor were usually torn and perished and did not seal the door well. Of the refrigerator seals examined 60% were described as excellent or good and only 10% as poor. The seal condition was correlated with refrigerator age to determine whether poorer seals were found in older refrigerators. The resulting correlation was found to be relatively low (0.56), indicating that older refrigerators did not necessarily have worse seals. It is possible that some older refrigerators may have had seals replaced.

Mechanisms for setting refrigerator temperatures varied between different makes and models of refrigerator and therefore the refrigerator setting as a percentage of the full setting was recorded for each individual refrigerator. The greatest number of participants (21.8%) were found to set their refrigerators at between 41–50% of the maximum setting (*Figure 4*). Few participants set their refrigerators at less than 20% (7.3%) or greater than 80% (8.9%) of the full setting.

Only 15.1% of participants kept a thermometer in their refrigerator. One person owned a refrigerator with an integral thermometer that enabled temperatures to be read whilst the refrigerator door was closed. Thermometers were kept in the middle section of the refrigerator by 50% of participants with thermometers, and in the top by 23.7%. Only three people (1.2%) varied the thermometer position to measure temperatures in various parts of their refrigerator. If a thermometer was present the temperature reading was noted immediately after opening the refrigerator door. Under half (42.1%) of readings were below 5.9°C, with the greatest number of these being between 4 and 5.9°C. Five thermometers were either inaccurate or unreadable because of difficulty in finding the thermometer before ambient temperatures affected the reading.

Participants were asked to state the temperature at

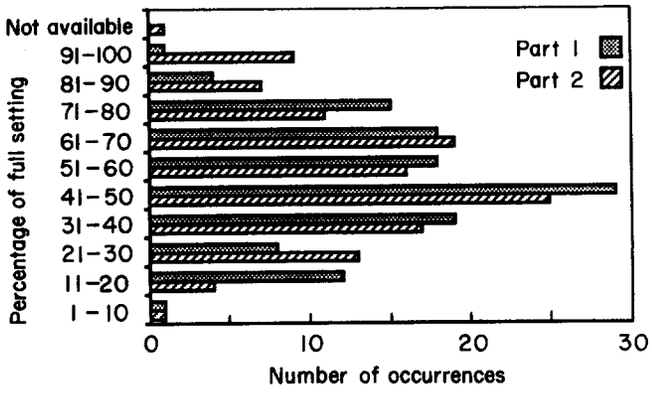

Figure 4 Temperature control settings on refrigerators
Figure 4 *Emplacements des capteurs de température dans les réfrigérateurs*

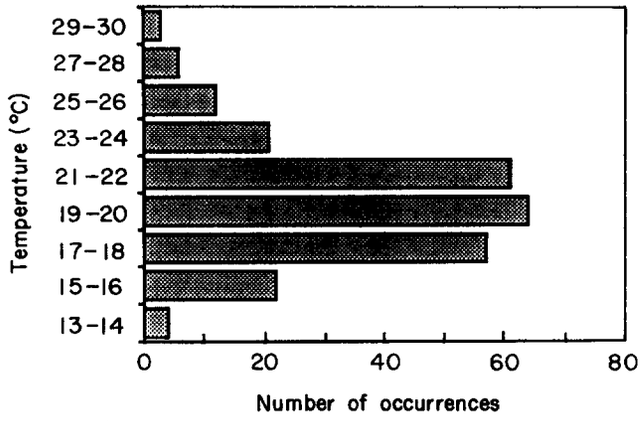

Figure 6 Ambient temperature near refrigerators
Figure 6 *Température ambiente près des réfrigérateurs*

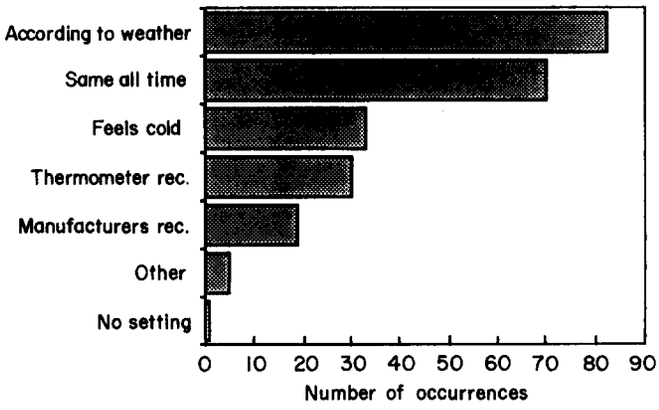

Figure 5 Methods used to set refrigerator temperature
Figure 5 *Méthodes utilisées pour fixer la température du réfrigérateur*

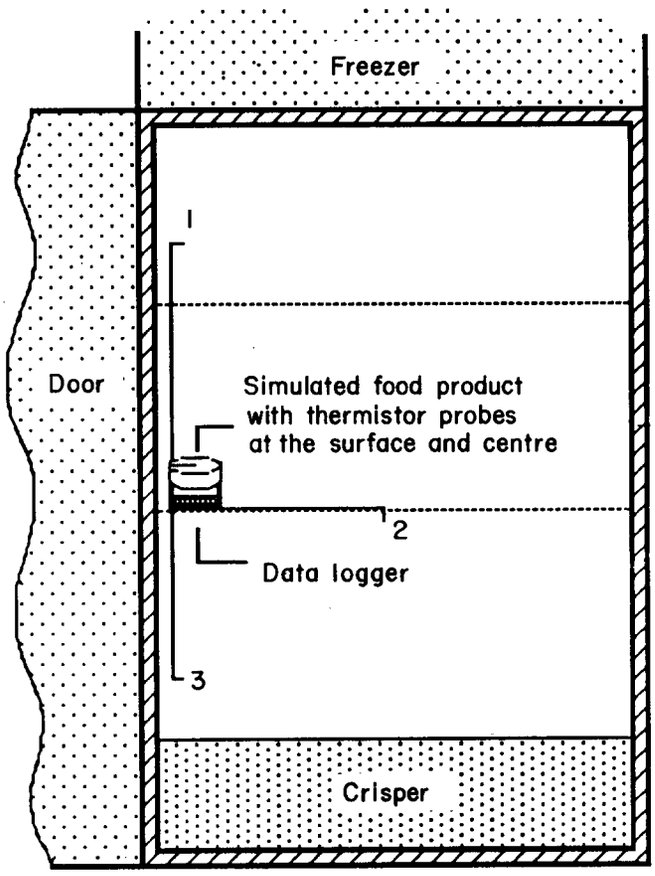

Figure 7 Positions of temperature sensors in refrigerators: 1, 2 and 3 are thermistors placed in air at top, middle and bottom of the refrigerator
Figure 7 *Emplacements des dispositifs de mesure de la température, dans les réfrigérateurs: 1, 2 et 3 sont des thermomètres placés dans l'air, en haut, au milieu et au bas du réfrigérateur*

which they tried to run their refrigerator. Nearly all participants were unable to name actual temperatures and gave answers based on the method actually used to set the temperature dial (*Figure 5*). A large number of people (32.8%) set their refrigerators according to the weather, setting the refrigerator to a lower temperature (higher setting) in the summer. It was interesting to note that although 38 participants had a thermometer in their refrigerator only 30 actually used the information to set their refrigerator temperature.

A spot reading of the ambient temperature near to each householder's refrigerator was recorded. The greatest number of people (72.2%) kept their houses at between 17 and 23°C, with an overall mean temperature of 20.6°C (*Figure 6*). Very few participants kept temperatures close to the refrigerator at less than 15°C (1.6%) or greater than 25°C (8.4%). Therefore, presuming that the spot readings recorded were representative of temperatures over a longer period, the majority of refrigerators would have been operating within the temperate zone conditions for which they were designed.

Finally, a miniature data-logger (Stick-On) with three air and two product sensors was placed into the refrigerator to monitor temperatures every 8 s and to record mean temperatures approximately every 5 min for a period exceeding 7 d. Air temperature sensors were positioned in the top, middle and bottom sections of the refrigerator. A simulated food product (87 mm diameter by 28 mm high disc of Tylose in a petri dish) was placed on the middle shelf. Sensors were placed in the geometric centre and centrally on the surface of the Tylose disc (*Figure 7*). After retrieving the loggers the data were

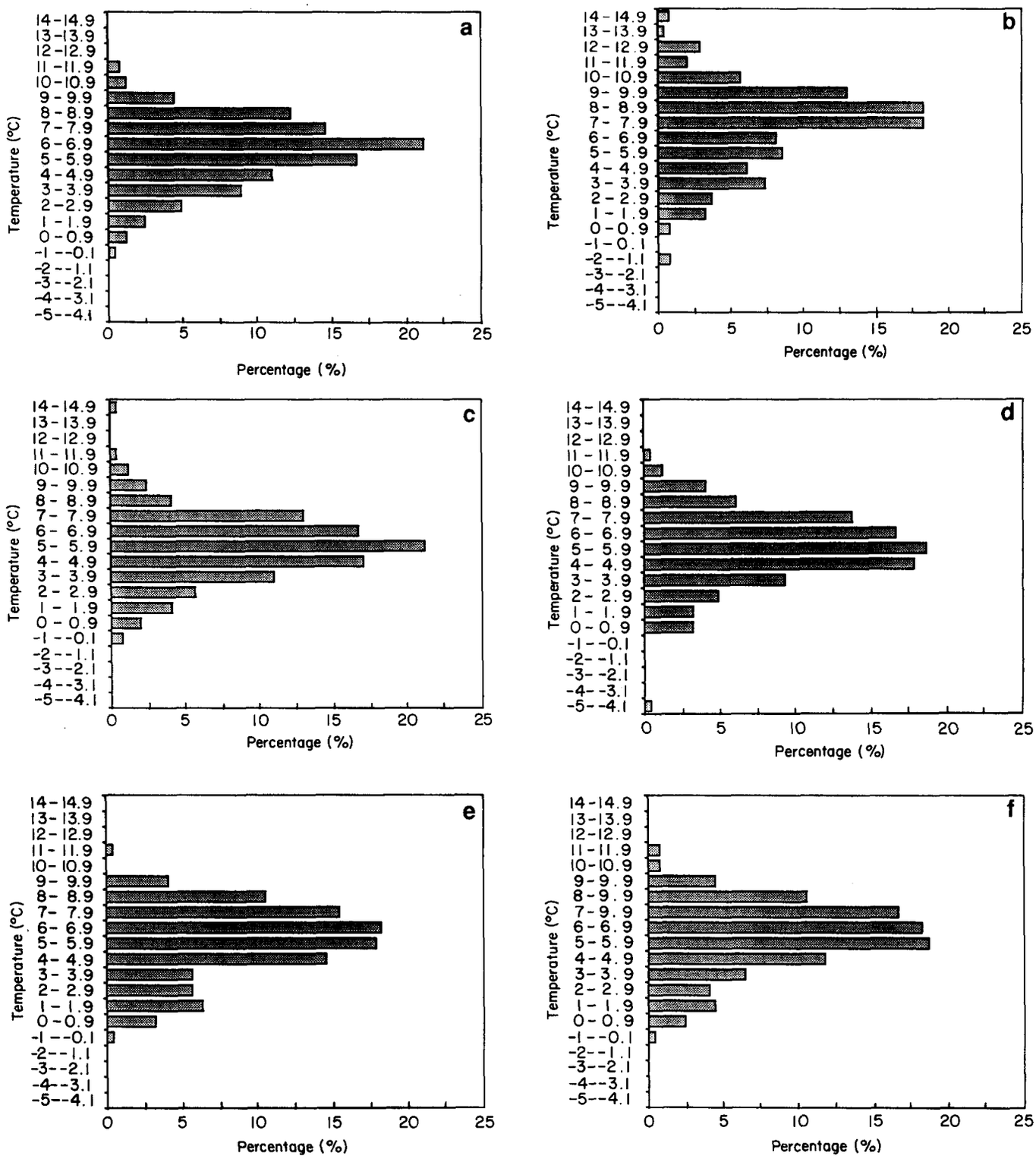

Figure 8 Percentage of refrigerators and the mean temperature measured at (a) overall, (b) top, (c) middle, (d) bottom, (e) product surface and (f) product centre

Figure 8 *Pourcentage des réfrigérateurs et température moyenne mesurée aux emplacements suivants: (a) dans tout le réfrigérateur; (b) en haut; (c) au milieu; (d) dans le bas; (e) à la surface du produit; et (f) à coeur du produit*

down-loaded onto an Amstrad 1640 PC before transfer to an Apple Macintosh, where the central 7 d temperature data were extracted for further analysis. Mean, minimum and maximum temperatures together with their standard deviations and cumulative frequency distribution were evaluated at each position in each refrigerator. Overall mean refrigerator temperatures were calculated from the above data.

The temperatures recorded in each individual refrigerator over the 7 d period were analysed and mean air temperatures calculated for the top, middle and bottom together with an overall air temperature for the whole refrigerator (*Figure 8a–d*). The product surface and product centre means were also calculated (*Figure 8e* and *f*). The highest recorded mean temperature was 11.4°C and the lowest −0.9°C, producing a range in mean tempera-

Table 3 Percentage of refrigerators with highest and lowest mean temperatures at top, middle or bottom
Tableau 3 *Pourcentage de réfrigérateurs enregistrant les températures moyennes les plus élevées et le plus basses, en haut, au milieu et au bas*

Position	Mean temperature	
	Highest	Lowest
Top	69.92	20.33
Middle	8.13	45.12
Bottom	21.95	34.55

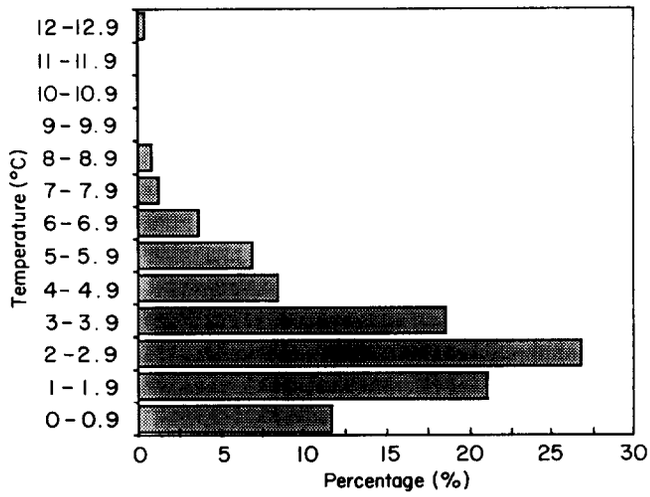

Figure 9 Difference between highest and lowest mean temperatures in refrigerators
Figure 9 *Différence entre les températures moyennes les plus élevées et les plus basses, dans les réfrigérateurs*

tures of 12.3°C. The overall mean air temperature for all the refrigerators in the survey was 6.04°C. In 69.9% of refrigerators the warmest place was in the top, and in 45.1% the coolest palce was in the middle (*Table 3*).

Analysis of variance of mean refrigerator temperatures revealed that overall refrigerator temperature and temperatures in the middle, bottom and at the simulated product surface and centre were not statistically different. The mean for all temperatures at the top of refrigerators was significantly higher ($P < 0.001$) than those for other positions.

In most refrigerators (86.9%) the range in temperatures between the highest and lowest mean was less than 5°C, with the greatest range being 12°C (*Figure 9*). However, if individual minimum and maximum temperatures were examined, much larger temperature ranges were calculated (*Figure 10*): the minimum range was 4.5°C and the largest 30.5°C (if recorded temperatures had not been averaged over 5 min periods these ranges may have been even greater).

Often the temperature at the top of a refrigerator is quoted as being approximately 5°C higher than temperatures at the bottom of a refrigerator. To test this theory the mean temperature at the bottom of all refrigerators examined was subtracted from the mean temperature at the top of each refrigerator. Only 6.9% of refrigerators

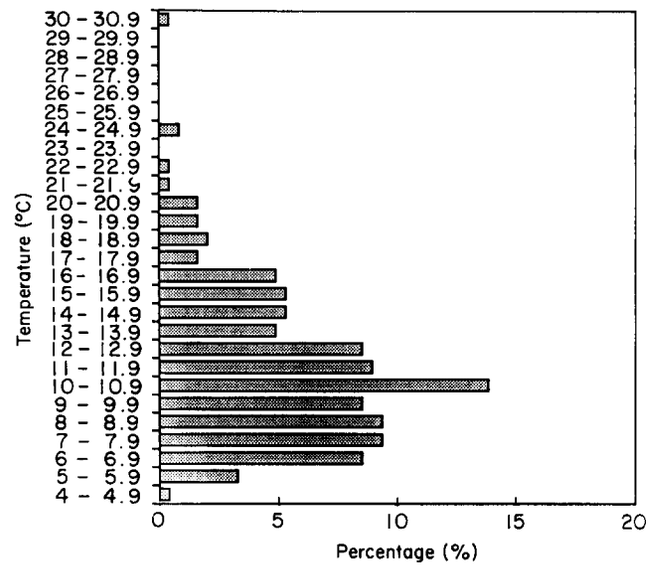

Figure 10 Difference between highest and lowest temperatures in refrigerators
Figure 10 *Différence entre les températures les plus élevées et les plus basses, dans les réfrigérateurs*

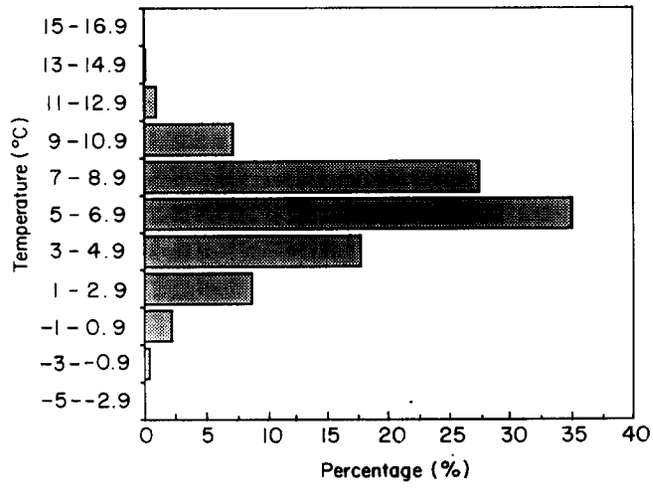

Figure 11 Percentage of time spent in different temperature ranges by average refrigerator
Figure 11 *Pourcentage du temps durant lequel un réfrigérateur moyen fonctionne à différentes plages de temperature*

fell within the 5–5.9°C category. A number of refrigerators (26.3%) were colder at the top than the bottom and therefore produced negative values. The minimum top-minus-bottom temperature found during the survey was −6.9°C and the maximum 12°C.

Frequency distribution of the percentage time spent between certain temperatures during the survey was calculated for all refrigerators. The greatest proportion of time (80.3%) was spent between 3 and 8.9°C (*Figure 11*). Only small amounts of time were spent above 9°C.

Only four refrigerators (1.6%) in the whole survey operated below 5°C during all the monitoring period and 33.3% of refrigerators spent all their time above 5°C. If divided into time spent below 5°C, 9.8% of refrigerators spent 90% or more of their time below 5°C and 27.4% of refrigerators spent 50% or more of their time below 5°C.

Analysis

Temperature data

Temperatures in each individual refrigerator monitored in the survey were analysed by analysis of variance (ANOVA) to determine whether a relationship existed between refrigerator temperature and refrigerator characteristics.

Mean temperatures over the whole refrigerator, in the top, middle and bottom sections and the product centre and surface were analysed against:

1. refrigerator type (box-plate, fridge-freezer, larder);
2. refrigerator setting (as percentage of full setting)
3. refrigerator size;
4. seal condition;
5. refrigerator age;
6. housing category of householder;
7. number per household;
8. age of householder;
9. ambient temperature in kitchen.

ANOVA revealed significant differences ($P < 0.001$) in refrigerator type and therefore refrigerator type was included in all further ANOVA. When analysed with refrigerator type all other refrigerator characteristics were not significant ($P > 0.05$). Therefore the only recorded refrigerator characteristic found to influence refrigerator temperatures was refrigerator type.

ANOVA revealed that box-plate refrigerators operated at lower temperatures than fridge–freezers or larder refrigerators ($P > 0.001$), which was due to fridge–freezers and larder refrigerators being warmer in the top section. Further analysis demonstrated that statistical differences only occurred between box-plate refrigerators and fridge–freezers and larder refrigerators with visible evaporators. Temperatures of all fridge–freezers and larder refrigerators were statistically similar.

The relationship between minimum temperature and refrigerator setting was investigated to determine whether the minimum recorded temperature was related to the base running temperature of refrigerators. Correlation between setting and minimum temperature was low (-0.247), indicating that the refrigerator setting could not be related to minimum temperatures.

Temperature distribution within refrigerator types was demonstrated by sorting top, middle and bottom temperatures into ascending temperature order. Results revealed that all larder refrigerators and 84.6% of fridge–freezers were warmest in the top section. Box-plate refrigerators were warmest in the bottom section in 59.7% of cases.

Further analysis of temperature distribution within refrigerator types revealed that statistical differences only occurred in fridge–freezers with a top refrigerator and visible evaporator and larder refrigerators with visible evaporators. The top sections of these refrigerators were significantly warmer than all other refrigerator types and positions.

Range in mean refrigerator temperatures

The range in mean temperatures was examined to determine the temperature variability within each type of appliance. The range varied from a minimum of 0.1°C to a maximum of 12°C with a mean range for all refrigerators of 2.9°C.

When refrigerators were examined by type a significant difference ($P < 0.001$) between types was found. Box-plate refrigerators operated over a narrower range of temperatures (mean range 1.8°C) than fridge–freezers (mean range 3.4°C) and larder refrigerators (mean range 3.7°C).

Discussion and conclusions

This study has looked at the two aspects of the chill chain that immediately precede the final preparation and consumption of the chilled food, the transportation of the food from retail to domestic storage and domestic refrigeration.

It is clear from the results presented in the first section that the temperature of chilled foods can rise to unacceptably high values if transported, without insulation, in a car boot. These data were obtained in June 1989, a very sunny period, but higher ambient temperatures are not uncommon in mid-summer. The predictions made show that substantial increases in bacterial numbers can occur during transportation and subsequent recooling. It is not difficult to think of even worse situations where chilled products are kept in the open backs of estate cars for many hours on hot summer days. However, a combination of increased consumer education and the use of insulated/pre-cooled containers should solve this particular problem. One refrigerator manufacturer is already advertising[4] that insulated bags are provided with their appliance to reduce temperature rises during transportation.

The basic design of domestic refrigerators has not changed in the last fifty years although their use and lately the type, complexity and microbiological sensitivity of the foods stored in them has changed markedly. Designers have responded to market demands for more compact appliances and more features, e.g. chilled drink and ice dispensers, but temperature control is only advertised as a sales point on more expensive multi-compartment refrigerators. Consumers now purchase and store a wide range of ready meals and other chilled products and they have demanded and obtained substantial reductions, and in some cases the total elimination, of preservatives and additives in these products. New chilled products are, therefore, inherently more bacterially sensitive and require closer temperature control than their predecessors. The introduction of new food temperature legislation should result in improved temperature control to the point of retail sale. If current predictions that eating habits will change from the current pattern of set meals to irregular frequent consumption are fulfilled, then the consequence is likely to be a demand for and purchase of more pre-prepared chilled foods and more visits to domestic refrigerators.

The refrigerators investigated in the survey were found to have an overall mean temperature of approximately 6°C in a temperature range from 11.4 to −0.9°C. Temperature ranges over the whole refrigerator varied from 4.5 to 30.5°C, with 3.7% of these being warmer than 20°C. On average 29.9% of refrigerators operated below 5°C and 66.7% operated below 7°C. Few refrigerators (7.3%) ran on average above 9°C. However, certain positions in the refrigerators ran at warmer temperatures

with 24.8% of positions at the top being above 9°C and an average temperature of 31.6°C being recorded in the middle of one refrigerator for 5 min of the monitoring period.

Overall the warmest temperatures were found in the top sections with temperatures in all other sections being statistically similar. Further analysis revealed that statistical differences in temperature distribution only occurred in fridge–freezers (with refrigerators at the top) and larder refrigerators, both with visible evaporators. The top part of 84.6% of fridge–freezers and all larder refrigerators were warmest. Box-plate refrigerators were found to have the lowest overall mean temperatures and the most even temperature distributions.

No refrigerator characteristic (apart from type) could be related to temperatures or temperature distribution in the refrigerators investigated. The results indicated that overall there was little difference between refrigerator settings, sizes, seal conditions or ages, but this may be due to the limited number of replicas in some categories. Few participants set their refrigerators at less than 20% or greater than 80% of the full dial setting and few refrigerators were below 4 cu ft or above 7 cu ft. Only 5.2% of refrigerators were more than 20 years old and only a small number (10%) had poor seals. The results show that temperatures in older refrigerators of a particular type were no worse than new ones of the same type. This indicates that changes in refrigerator design and control have had little effect on mean temperatures over the past 30 years.

Refrigerator temperatures were not related to ambient temperature. This was rather surprising because ambient temperatures are known to affect performance and are part of the BSI[5] (British Standards Institution) and ISO[6] (International Standards Organization) standard tests. The result may have been influenced by the data, which were mainly clustered between 17 and 23°C (72.2% of results), a range that may not have been large enough to affect significantly refrigerator temperature.

The social status and age of the householder and number of people per household were also found to be independent of refrigerator temperature. There is therefore no real evidence to suggest that any particular social or age group achieved better refrigerator temperature control. The number of people in households might be expected to affect refrigerator temperatures because in large households the loading and use would probably be greater. However, the results may have been influenced by the small number of very small (one member) or large (over five members) households (households with 2–4 members accounted for 83.3% of the results).

In laboratories, research has shown that refrigerator design and temperature setting affect temperature control and distribution. Factors such as loading patterns, loading of warm food and door openings are also known to influence refrigerator temperatures[7]. Further work is required to determine their influence in a practical situation.

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