AN INVESTIGATION INTO THE NECESSITY FOR A CODE OF PRACTICE IN THE CHILLED FOOD DISTRIBUTION AND RETAIL SECTORS IN IRELAND

SUBMITTED BY
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I hereby certify that this material which I now submit for assessment on the programme of study leading to the award of Master of Science, is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

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AN INVESTIGATION INTO THE NECESSITY FOR A CODE OF PRACTICE IN THE CHILLED FOOD DISTRIBUTION AND RETAIL SECTORS IN IRELAND

Abstract

In recent years, the chilled food sector has been the fastest growing area of the Western food market, with sales increasing by 5% per annum in some countries. There has been an increase in the distance between areas of production and major areas of consumption of food which has meant a greater reliance on transport and distribution. Data from Irish, U.K. and some international literature have shown some need for concern regarding temperature control at the transport, retail and consumer levels.

This research project was devised with the following objectives:

1. To examine the literature in relation to chilled food and the chilled food chain.
2. To interview representatives of companies involved in the distribution and retail sale of chilled foods with regard to handling of chilled foods for the purpose of ascertaining company policy.
3. To measure air temperatures, between-pack temperatures, product temperatures and relative humidity at a sample of distribution premises and retail outlets.
4. To compare and evaluate observed temperature measurements and practices with stated company policies.
5. To compare observed practices with refrigeration company recommendations.
6. To devise a Code of Practice in relation to temperature control, based on the results found.

Visits were made to a range of distribution and retail premises where measurements of air temperature, between-pack temperature and relative humidity were taken. Observations were made on the handling of chilled foods.

The results showed a wide variation within each supermarket and also between supermarkets. The proportion of measurements which exceeded the reference temperature of 3°C varied, but in some cabinets 100% of measurements exceeded 3°C. There was a significant number of measurements at high temperatures, up to 18°C. Relative humidity readings were also quite variable. Some deficiency in company policies was noted. The results show that concern about temperature abuse in the chilled food chain in Ireland would certainly justify the formulation of a Code of Practice.

CHAPTER 1: INTRODUCTION

1: INTRODUCTION

By definition, chilled foods are perishable foods which, to extend the time during which they remain wholesome, are kept within specified ranges of temperature above their freezing points and below 8°C. The chilled food chain is the sequence of temperature controlled operations from initial harvesting, post-production cooling, manufacture or slaughter to the preparation of the product for final consumption (IFST, 1991). Foods are chilled to maintain quality and extend shelf life by delaying spoilage.

The chilled foods market has shown strong growth in the past 10-15 years, particularly in relation to ready-prepared meals. However there have been many separate developments in the past 50 years which have seen the chilled food category expand from being made up mainly of simple meats and other provisions to include the vast range of products which are available today.

1.1 THE DEVELOPMENT OF THE CHILLED FOOD DISTRIBUTION INDUSTRY

Stephens has discussed the changes in the way perishable foods were sold and transported over the past forty years (1985). Food rationing was in force in the UK up to 1954 and trading was restricted to the small "corner shop". There were some chain stores, but these operated an over-the-counter service. Temperature-controlled transport was only used for imported meat and the growing frozen food market. Self-service shops and supermarkets appeared in the early 1950's and led to a new development : pre-packed foods. However, counter service was still in operation for perishable provisions which were unrefrigerated. Marks & Spencer stopped selling these provisions in the late 1940's, but 10 years later decided to re-introduce them in pre-packed form. The company saw the need for refrigeration of these pre-packed foods and ran trials of prototype chilled counters in a few stores in 1959. Deliveries were made to the stores every morning.

Up to 1960, provisions were delivered in ambient-temperature vehicles, with open carts sometimes being used for meat delivery. With the new trade in packaged perishable foods, new technology had to be found. The body of the vehicle was insulated and chilled using a block of solid carbon dioxide (dry ice) which was hung in a net from the roof. Racks which held aluminium trays were fitted in the vans. Deliveries were generally made early in the morning, the majority of products being sold that day and having a very short shelf life. Further improvements in temperature control of delivery vehicles were initiated by the introduction of oven-ready (as opposed to frozen) chicken, which was more perishable than the other products carried.

The new vans were mechanically (as opposed to the use of eutectic plates, which provide a "cold reserve") refrigerated by liquid nitrogen or liquid carbon dioxide, the objective being to maintain a temperature within 1° of freezing point and with an upper limit of 5°C. These temperatures were then applied to all chilled foods, with the exception of meat pies, where up to 10°C was permissible. As the range increased so did the number of suppliers, which made direct delivery more complicated. In the late 1960's, the first co-ordinated distribution system for chilled food was set up for Marks & Spencer. There were six regional depots to which suppliers made deliveries of pre-chilled food (they were rejected if outside the correct temperature range) by midnight. Orders for individual stores were made up and delivered by opening time. However, in the early 1980's there was still restricted availability, with the product range being limited on Mondays.

The main changes since then have been an extension of the product range which is still ongoing, with over 900 new St. Michael products appearing between 1988 and 1990. There have also been improvements in standards and the introduction of the "sell-by" system of open dating which was developed in the 1960's to prevent sale of "out-of-life" products.

1.2 THE IMPORTANCE OF THE CHILLED FOOD INDUSTRY

In recent years the chilled food sector has been the fastest growing area of the Western food market, with sales increasing by 5% per annum in some countries. The Food Products Intelligence Centre in the U.K., which monitors new products, recorded 35 appearing in the U.K. market in 1972 and, in contrast, the FPIC recorded 945 new products in 1990, of which 80% were own-label branded (Bond, 1992). In Ireland, the most recent (1987) Household Budget Survey illustrates the importance of chilled foods to the Irish consumer. The average weekly expenditure on chilled foods, including meat, fish and dairy products was £24.14 out of a total food expenditure of £56.26, which represents 43% (Central Statistics Office, 1989). The major reason for this growth in chilled foods is that this sector is perceived by consumers as being fresh, natural, free from preservatives, of better quality than other similar foods, with an extended shelf life and date coded for safety (Bøgh-Sørensen, 1990). Consumers have a desire for products with "close to fresh" characteristics (Stringer, 1990a). Other advantages include microwave-ability, presentation and convenience.

Rationalisation in the food industry, with manufacturing and packaging operations becoming more centralised and increasing distances between areas of production and major areas of food consumption,.has resulted in a greater reliance on transport and distribution, with the introduction of depots where foods are stored, orders made up and foods transferred into vehicles for transportation to the retail outlet (Bøgh-Sørensen, 1990). The relatively small geographical area of the U.K and Ireland helps efficient distribution. Because many of the foods held in this manner are microbiologically sensitive, careful temperature control is a necessity. Many food manufacturers have elaborate and reliable quality systems in place to take account, amongst other topics, of this need, but in order to ensure proper standards of quality and safety, in foods as delivered to the consumer, the chill chain needs to be maintained at all stages during and post manufacturing.

This work seeks to examine relevant food quality and safety policies and practices in the chilled foods distribution and retail sectors, and, in the light of findings encountered, to make suggestions for a suitable Code of Practice which might be used by persons in these businesses.

1.3 LOW TEMPERATURES AND CHILLED FOODS

Within the broad spectrum of "chilled foods" there are a number of sub-groups which have different qualities and requirements.

1.3.1 Meat

(this section refers to red, i.e. non-poultry, meat)
Temperature abuse has a cumulative effect on the appearance, microbiological quality and shelf life of meat (Malton, 1978). This author found that insufficient chilling at the slaughterhouse was a common problem in his study.

In a study by Gunwig *et al.* (1990), certain undesirable practices were observed. Chilled products, once delivered to the retail outlet, were left exposed to weather conditions for an hour or more. Meat was frequently repacked and stored for up to seven days at retail level in cabinets which were often overloaded. Butchers were observed to have poor personal hygiene. It was found that poultry was less likely to suffer serious temperature abuse, because the carcasses were air chilled at the slaughterhouse.

Modified atmospheres (MA) have been used to improve retail storage of meat. This has certain advantages, for example, the better appearance and colour of the meat, longer shelf life and better hygienic and shock resistant packaging. Also, trade marks can easily be marketed and cuts containing a bone can be packaged. Shelf life is increased from 2 to 8 days. The onset of growth is delayed so there is a reduced risk of microbial growth. Disadvantages have also been noted, for example the meat may be tougher due to insufficient maturation, while off-flavours and off-odours can develop early due to oxidation of fat. Packs require more space during distribution and storage and are unsuitable for freezing. MA packaging is currently replacing vac-pack and conventional packs (Bøgh-Sørensen, 1990). Deep chilling (also known as superchilling), where the food is held below 0°C but at a high enough temperature so that ice does not form (normally between -2°C and 0°C), has also been used to extend shelf life.

1.3.2 Poultry and Poultry Products

In response to the need for fast chilling of poultry carcasses, a number of chilling methods were developed as an alternative to the use of mechanically cooled chilling rooms, which took 24 hours of storage at -1°C to 2°C to chill an average-sized carcass.

Air chilling

Air chilling involves hanging the eviscerated birds on special racks which travel through a cooling tunnel containing a stream of refrigerated, humid air. The temperature of the circulating air may be reduced to -10°C to counteract weight loss by evaporation. The chilling time is, on average, about 1.5 hours. Carcasses may be sprayed with potable water during the chilling in order to achieve the maximum cooling rate by water evaporation from the product surface.

Immersion chilling

Chilling of eviscerated carcasses by immersion in cold water or ice slush was practised in the U.S. as early as 1910. However in the late 1960's, it was observed to lead to cross-contamination because the water became heavily contaminated (Veerkamp, 1990). In 1971, the European Union issued a rule banning the process after 1976, but this was superseded by legislation in 1976 which permits counter-current immersion chilling only for frozen poultry.

The aforementioned processes are both first-stage chilling operations. Deep chilling is a second-stage operation and is a common practice nowadays. The poultry is sold as fresh, but is stored at -2° to -4°C from the chilling stage onwards (Veerkamp, 1990).

1.3.3 Fish

A major proportion of the distribution time of fish is spent on the fishing boat, so it is imperative that the fish is rapidly chilled immediately after landing. Ice is usually used, but chilled seawater is an alternative which may be used. Deep chilling is used in Portugal, but this can be expensive and can also cause changes in the texture of the fish. Another process which can be used is crust-freezing, which involves freezing a 1mm layer of the fish. This equilibrates the temperature during storage and does not have any effect on sensory qualities. Fish should be stored at a temperature as close as possible to 0°C but not below (Whittle, 1990). Fish is subject to rapid deterioration as it is generally highly contaminated, so it can only tolerate low levels of temperature fluctuation and strict temperature control is vital (Moral, 1990). The level of export of fish from Ireland is quite high, at 70%. There is a large amount of salmon transported to the USA by air freight in special containers with dry ice to maintain the temperature at 0°C to 2°C (Somers, 1990).

1.3.4 Dairy Products

An important point in relation to dairy products, especially yoghurt, is that, if held below a certain temperature, the constituents may become separated (Goad, 1989). Shelf life can be reduced due to development of off-flavours which may occur after exposure of the product to direct sunlight, diffuse daylight or artificial light (Tuohy, 1990). Also, storage of transparent milk containers next to fluorescent lights can lead to ultraviolet oxidation of the milk fat and reduction of the vitamin content (Hinsperger, 1990). Tuohy reported in 1990 that the most important factor affecting the keeping quality of milk was post-pasteurisation contamination with Gram-negative rods, especially *Pseudomonas* species. He also noted that temperature was very important for milk - an increase from 5°C to 9°C during distribution would reduce the residual shelf life for consumers by 10-17%. For example, in milk storage stability trials, pasteurised milk stored at 4°C was organoleptically acceptable for 17-18 days, while similar milk stored at 11°C (simulating temperature abuse) only lasted for 5 days. He observed that sell-by dates in Ireland and the U.K. accommodated about 5-6 days storage compared to 10-12 days in the U.S.

1.3.5 Fruit and Vegetables

It has been estimated that 25% of harvested produce is never consumed, due to spoilage. The use of refrigeration, controlled atmospheres (CA) and modified atmospheres (MA) has helped to delay spoilage and improve shelf life during storage and transport (Petropakis, 1990).

Foods that contain a high proportion of water, including fruit, vegetables and meat, have high thermal capacities (the amount of heat required to raise the temperature of 1kg of the material by 1°C), but they have different densities. The cells of fruit and vegetables continue to respire post-harvest, thereby producing heat. It is vital that they are pre-cooled before loading into a transport container, as heat of respiration is reduced at lower temperatures (Sharp and Spraggon, 1987). In fact, produce should be cooled as soon after harvesting as possible to maintain quality There are different methods of doing this, such as vacuum cooling, hydrocooling and positive ventilation. Relative humidity affects weight loss by evaporation and may cause shrivelling in fruit, if too low. Low relative humidity can be advantageous for certain fruit allowing better flavour development (International Institute of Refrigeration, 1966). It is also important that during transport, all stored fruit should have a similar degree of ripeness. Temperature control of stored produce is also important to minimise spoilage due to chemical and enzymatic processes, which are affected by temperature. Chilling injury of the food can occur at a temperature which is too low, and is characterised by discolouration, pitting, microbial spoilage and failure of immature fruit to ripen, so the storage temperature must be slightly above this, and preferably as close to it as possible. The optimum storage temperature depends on the produce, e.g. 0 to 2°C for soft fruit and most vegetables, 7 to 10°C for pineapple and melon, 12°C for banana and grapefruit. Ventilation is also a requirement for the storage environment as carbon dioxide and other volatile substances are given off which may affect shelf life (Jamieson, 1980). Ethylene is an example of such a volatile substance which may cause premature ripening (Sharp, 1991).

1.3.6 Bakery Products

Included here are breads and confectionery, the latter generally containing a higher proportion of shortening and sugar. Storage at temperatures from -3°C to 6°C is used to retard fermentation, which stops entirely below -7°C. Products containing fruit or whipped cream cannot be stored at room temperature for more than 1 day, if quality is to be maintained. Relative humidity is also important and must be high to prevent drying out. Where fermentation retardation is desirable, products are stored at about -3°C for 5 to 10 hours. If a longer storage time is needed, fermentation must be stopped by the use of lower temperatures.

The effects of chilling on dough for rolls include a reduction in volume, a harder crust and impaired browning when cooked. There are some advantages in appearance, texture and flavour, however. With regard to confectionery products, temperature-related control of fermentation is mainly used for yeast-raised fine doughs, such as puff pastry or doughnuts. The dough is prepared at 10°C to 12°C and stored overnight at 2°C to 4°C which will lead to an increase in volume and ripening of the dough. Uniformly high relative humidity is also needed (Bruemmer, 1990). Staling of bread occurs more quickly at lower temperatures (Brown, 1992).

Obviously, with so many types of foods requiring temperature control, and often at different temperatures, or other individual storage requirements, it is imperative that the food manufacturer is aware of the controls needed to maintain the product quality at the highest possible level for the longest possible time. This will ensure that the maximum financial return is obtained, while guaranteeing the safety of the product for the consumer. In summary, the manufacturer must realise the importance of quality control.

1.4 QUALITY ASSURANCE IN THE CHILLED FOOD INDUSTRY

In Ireland, the food industry has shown an awareness of the importance of quality control, with many firms seeking accreditation with ISO 9000 and the Irish Quality Association. However, it is unclear how deep-rooted this apparent commitment to quality is and whether it extends along the length of the chilled food chain. Although it may be relatively straightforward for a food manufacturer to implement a quality assurance programme throughout food manufacturing operations, it may be another matter to guarantee quality once the food leaves the factory. At this stage, the manufacturer often transfers control of the products to a different party, usually a distribution company. Even where distribution is carried out by the firm itself, the nature of the operation means that it is difficult to exercise control over the product.

There is some literature currently available to aid food manufacturers and other interested parties ensure good quality control. For example, the Chilled Food Association has produced a comprehensive set of guidelines which classify chilled foods into six categories and set specific hygiene and control requirements for each category. There is a specific section on hygiene during the distribution and retail sale of chilled foods. The guidelines recommend that Good Manufacturing Practice (GMP) be followed and that a HACCP system should be implemented by members of the Association. All Association members are independently audited to ensure compliance with the Guidelines (Chilled Food Association, 1993). The UK Dept. of Health has published a comprehensive set of guidelines on cook-chill and cook-freeze catering systems which provide useful information on the handling of chilled foods in general (UK Dept. of Health, 1989).

The US National Food Processors Association have produced guidelines which identify control points and critical factors which can be applied to a wide variety of chilled foods. They provide detailed recommendations covering handling of chilled foods, product concept and formulation, packaging, labelling, pre-distribution storage, distribution, retailing and food service (NFPA, 1989). SYNAFAP (1989) gives microbiological specifications for chilled products, based on the French Hygiene Regulations and recommends that a HACCP system be implemented.

There are some organized programmes for implementing quality assurance within a manufacturing or distribution operation. One programme which is being increasingly considered is the HACCP "concept".

1.4.1 HACCP

HACCP or Hazard Analysis Critical Control Point is a proven safety concept which is recommended by organisations such as the U.S. National Food Processors Association, to ensure, as far as possible, the safety, especially the microbiological safety, of processed and other foods. The system was first introduced at a 1971 conference and it was used by the U.S. space programme in 1972, to ensure the safety of the astronauts' food (Corlett, 1989). Hazard analysis means the identification of potentially hazardous ingredients, processes and storage conditions which may affect the safety or the quality of the product. Critical control points are the stages where there is a potential risk to the safety or quality of the product, if proper control is not exercised. The HACCP system has the advantage of identifying stages in the process where errors could occur, even if they have not already done so (Shaw, 1992).

It involves a number of steps:
(a) describing the product, including how it will be used;

(b) preparing a flow diagram for the manufacturing and distribution stages;
(c) carrying out a risk analysis for the raw materials and ingredients, the product, the packaging (this also involves changing the design to reduce the risks e.g. incorporating barriers to microbial growth such as low pH etc.);
(d) selecting critical control points (CCPs), which should be indicated on the flow diagram;
(e) establishing a monitoring procedure, which includes taking appropriate preventive action, when necessary.

(Corlett, 1989).

Campden Food and Drink Research Association has published a number of documents on HACCP which describe its principles and give advice on the implementation of a HACCP system; for example Technical Manual No. 19: Guidelines to the establishment of HACCP or Technical Manual No. 38: Haccp: A practical guide. CFDRA has also developed a HACCP Software Training Tool. The HACCP system should be fully documented, verified and reviewed regularly to check its effectiveness (Bryan, 1990).

1.4.2 Good Manufacturing Practice

Good Manufacturing Practice (GMP) is the quality control programme which has been traditionally used in industry. It is a less formal programme than the more recent HACCP. To incorporate GMP, certain stages should be considered and controlled:

(a) raw material suppliers and the specifications which they are given;
(b) raw material checking, storage and rotation;
(c) factory layout planning, construction and environmental control;
(d) plant selection and maintenance;
(e) segregation of "clean" and "dirty" areas;
(f) cleaning methods and frequency;
(g) training and supervision of staff;
(h) integrated control and monitoring of all heating and cooling processes;
(i) effective hygiene control;

(j) some raw material and finished product testing;
(k) storage and distribution control;
(l) retail control, perhaps by means of an audit;
(m) consumer education and control.

(Petitt, 1990)

Quality Control during the post-manufacture stages is especially important, because even if a GMP programme is in place, support must be obtained from all those involved in the cold chain. The programme can be adapted to include controls over conditions of storage and distribution - Good Commercial Practice (GCP) or it can also include the retail and consumer stages - Good Commercial and Consumer Practice.

1.4.2 LISA

This acronym means Longitudinally Integrated Safety Assurance. It resembles the HACCP approach, but differs from it by being extended to control safety at the stages involved after the processing stage, including the consumer stage. The system is not a new one - its development was pioneered by Sir Graham Wilson, who talked in 1953 of the need to concentrate less on sampling and more on maintaining high quality during processing and preventing contamination (Mossel, 1990). This approach has been described as safety assurance "from farm to fork". It starts with raw materials and follows through to consumption of the food by the consumer (Mossel and Struijk, 1992). The principles of LISA can be summarised in the "Wilson Triad":

(a) elimination of undesirable microorganisms as far as possible by minimising colonisation of the raw materials and maximising microbial lethality while maintaining nutritive value and organoleptic quality of the food, followed by;

(b) avoiding re-contamination of processed items to maintain what has been achieved in (a) by using hermetic packaging before food is processed, or by using aseptic packaging;

(c) where intrinsic protection against microorganisms is not successful, distribution and storage must be under conditions which will arrest or at least significantly retard growth of those microorganisms surviving steps (a) and (b) i.e. low temperature.

The first stage in LISA is control of raw materials, which must involve written agreements with suppliers, ensuring the supplier will adhere strictly to GMP. The composition and the microbiological quality of the material should be certified, where possible. During processing, pathogenic microorganisms should be eliminated or reduced to a safe level. In a worst-case scenario they must be reduced to an ALARA (As Low As Is Reasonably Attainable) level. Regular monitoring will identify failures in processing if they occur and therefore marker organisms are used. Re-contamination must be avoided at all stages of the chill chain and thus all personnel involved have responsibilities. Temperature monitoring is also important. The consumer must accept responsibility for handling of the food after purchase, but can be assisted by clear, informative labelling on packs (Mossel and Struijk, 1992).

The LISA system differs from more inspection-based practices in that the monitoring of microbiological quality is looked upon as inspection, not as intervention. It is accepted that sampling on its own cannot ensure product safety. Therefore it is coupled with preventive quality assurance and good manufacturing and distribution practices (GMDPs). The aim of monitoring is to detect process failures at an early stage and rectify them immediately (Mossel, 1990).

Although there is evidence that Irish firms are beginning to take quality control seriously, it is less clear how important they rate the treatment of the product once it leaves the factory. Previous work in this country has indicated some storage of perishable foods in retail chill cabinets at unsatisfactory temperatures (Doyle, 1987, undergraduate dissertation, Gormley, 1990).

Most recently, the results of a survey published in Consumer Choice magazine and reported in The Irish Times found that the microbiological quality of pre-packaged chilled prepared meals on sale in Ireland gave some cause for concern. None of the branded products tested contained pathogenic microorganisms, but some samples showed high numbers of total bacteria and some brands had a number of samples containing excessive amounts of Enterobacteria. Of the products tested, 20% contained Enterobacteria in amounts which would suggest that the food presented conditions suitable for the growth of pathogens. Results of sampling of unbranded lasagne purchased in delicatessens, supermarkets and small restaurants showed that 25% of these samples contained total bacteria in numbers ranging from 460,000/g to 3,000,000/g. Furthermore, pathogens were isolated in 19% of samples, including *Listeria monocytogenes, Clostridium perfringens* and *Escherichia coli* all of which potentially cause food poisoning (Consumer Association, 1993).

1.5 PSYCHROTROPHIC MICROORGANISMS

The temperatures at which chilled foods are held become most important when looked at in the context of the potential they pose for the growth of micro-organisms. Whether food is in its natural state or highly processed, it is not possible to guarantee its sterility i.e. that it contains absolutely no micro-organisms, without destroying its organoleptic and nutritional qualities. Natural habitats with an almost permanently cold temperature have been colonised by microorganisms which have become biologically adapted to the cold, and can grow at temperatures close to 0°C. These organisms may be known as psychrophiles (cold-loving).

In 1975, it was proposed that the term psychrophile be defined as an organism which has an optimum temperature for growth of 15°C or lower, and a maximum temperature for growth of 20°C or less. The term psychrotroph is used for those organisms which are cold-tolerant and have a maximum temperature for growth above

20°C (Gounot, 1991). However they do not survive pasteurisation (Jeong and Frank, 1988).

True psychrophiles are only found in permanently cold habitats, such as the ocean, deep alpine lakes, polar areas etc. However, psychrotrophs are common in foods and come from water, soil, air and directly from foods such as fish and vegetables. The ability of psychrotrophs and psychrophiles to grow at low temperatures is due to adaptations in cellular proteins and lipids (Gounot, 1991). It is the psychrotrophic group which are of most concern in relation to chilled foods. The micro-organisms which may potentially grow in food can be divided into those which are pathogenic i.e.. cause food-borne illness, and those which cause spoilage of the food, so that it may be safe to eat, but is undesirable because of slime, off-odours or off-flavours.

Tables 1.1 and 1.2 show the minimum growth temperatures respectively of various spoilage and pathogenic microorganisms associated with chilled foods, based on a review of the current literature.

TABLE 1.1: MINIMUM GROWTH TEMPERATURES (MGTs) OF SOME PATHOGENS ASSOCIATED WITH CHILLED FOODS

ORGANISM	MGT (°C)	MEDIUM	SOURCE
Aeromonas	0-1°C	-	Walker, 1990a
Aeromonas hydrophila	-0.1°C	chicken broth	Walker and Stringer, 1990
(clinical isolates)	4°C	-	Palumbo, 1986
Bacillus cereus	<4°C	milk, broth	Walker and Stringer, 1990
(psychrotrophic strain)	7°C	vegetable inoc.	Palumbo, 1986
Campylobacter	34-36°C	agar media	Walker and Stringer, 1990
	25-30°C	broth	
Clostridium botulinum			
TYPE A	10°C	n.s.	Walker and Stringer, 1990
TYPE B	3.3°C	n.s.	Walker and Stringer, 1990
TYPE E (growth & toxin production)	3.3°C	heat-treated beef stew	Palumbo,1986
TYPE F (growth)	4°C	n.s.	Walker,1990b
Clostridium perfringens	5°C	broth	James, 1990
	15°C	beef	James, 1990

TABLE 1.1 (CONTINUED)

ORGANISM	MGT (°C)	MEDIUM	SOURCE
Escherichia coli			
Enteropath.	7.1°C	chicken broth	Walker and Stringer, 1990
Enterotox. (growth & toxin production)	4°C	broth	Palumbo, 1986
Listeria monocytogenes	-0.4°C	n.s.	Walker and Stringer, 1990
	3°C	culture	Palumbo, 1986
Plesiomonas shigelloides			
one strain:	0°C	n.s.	Walker and Stringer, 1990
separate strain	5°C	n.s.	Walker and Stringer, 1990
Salmonella	4°C	agar	Walker and Stringer, 1990
	6.7-7.7°C	heat-treated chicken dish	Palumbo, 1986
Staphylococcus aureus	7.7°C	heat-treated custard	Palumbo, 1986
Vibrio species.	2°C	broth	Nielsen and Zeuthen, 1986

TABLE 1.1 (CONTINUED)

ORGANISM	MGT (°C)	MEDIUM	SOURCE
Vibrio cholerae	8-15°C	n.s.	Walker, 1990b
Vibrio parahaemolyticus	5°C	laboratory media	Palumbo, 1986
	8°C	food	" "
	3-13°C	n.s.	Walker, 1990b
Yersinia enterocolitica	-1.3°C	milk	Walker and Stringer, 1990
	0°C-1°C	meat	

Notes:
Enteropath.: enteropathogenic
Enterotox.: enterotoxigenic
Inoc.: inoculum
n.s.: not specified

TABLE 1.2:
MINIMUM GROWTH TEMPERATURES OF SOME SPOILAGE ORGANISMS ASSOCIATED WITH CHILLED FOODS

ORGANISM	MGT	MEDIUM	SOURCE
Brochothrix thermosphacta	-2°C	broth culture	Nielsen, Zeuthen, 1986
Lactic Acid Bacteria	0°C	n.s.	Nielsen, Zeuthen, 1986
Pseudomonas species.	0-2°C	n.s.	Walker, Stringer, 1990
Serratia liquefaciens	>0°C	broth culture & sausage	Nielsen, Zeuthen, 1986
Some yeasts & moulds	0°C	n.s.	Walker, Stringer, 1990

Notes:
n.s.: not specified

1.5.1 Pathogens

The most important pathogens in relation to chilled foods, including severely temperature-abused foods are discussed below. They are presented according to increasing minimum temperatures for growth.

Yersinia enterocolitica

Yersiniosis, the illness caused by this organism most commonly involves acute gastroenteritis, diarrhoea etc. (Walker, 1992). Raw

and cooked meats, poultry, seafood, dairy products and vegetables have all been found to be contaminated (Walker, 1992). 22% of pasteurised milk samples examined by Schofield contained *Yersinia*, as did 15% of cook-chill meals and 22% of coleslaws. This is not surprising, as it is a ubiquitous organism and can be found in many foods, although often in a non-pathogenic form (Schofield, 1992). Walker stated in 1990 that the organism has been isolated from both healthy and ill people, from a wide range of animals, from water, sewage and soil. According to Gibson (1990) it grows well in refrigerated foods, such as raw milk, shellfish, meats, vegetables and salads. He states, however, that the biotype found most frequently in food, the environment and the gastro-intestinal tract is of little clinical importance.
Outbreaks of illness have implicated foods such as pasteurised milk, tofu and chocolate milk.

This organism has been reported by Walker and Stringer, (1990) as having a minimum growth temperature of -1.3°C in milk and of 0 to 1°C in meat, both of which would include normal refrigerated storage, during which it grows well. In a study on vacuum packs stored at different temperatures, *Y. enterocolitica* was found to grow on beef at rates similar to or faster than those of the spoilage flora (Gill and Reichel, 1989). Thus visually acceptable food could be a health risk. Its incidence has increased in the past 10-15 years, as have reports of the organism having been isolated from food. However, as with most emerging new organisms, these could be explained by an increased awareness of the disease and improvements in detection techniques (Schofield, 1992).

Yersinia should be readily controllable since it is a heat-labile organism (Walker, 1992) and does not compete well with other bacteria (Walker and Stringer, 1990). The heat resistance of *Aeromonas hydrophila, Pleisiomonas shigelloides, Yersinia enterocolitica and Escherichia coli* 0157 was evaluated in homogenates of chicken, pork and prawns. *Yersinia enterocolitica* was the most heat resistant (Betts *et al*, 1993). It is also sensitive to irradiation and disinfectants in use in the food industry. There are conflicting reports of its response to freezing. It is resistant to modified atmospheres except very high levels of carbon dioxide at temperatures less than 5°C (Walker, 1990a).

Aeromonas species

Incidence of gastroenteritis due to *A. hydrophila* have involved oysters and prawns but no fully documented outbreaks of disease have been reported due to this organism (Walker, 1992). It causes two types of gastroenteritis, known as "cholera-like" and "dysentery-like" (Walker, 1990a). Wound infections and septicaemia due to *A. hydrophila* have been reported, and it is generally accepted to be pathogenic to humans, fish, amphibians and reptiles. It may possess enterotoxigenic or cytotoxic properties (Barnhart *et al*, 1989).

In an American study, it was isolated from 98% of broiler carcasses and it is known to be widely distributed in natural waters (Kirov *et al*, 1990). In a survey of a commercial poultry processing plant, *A. hydrophila* was found on 98% of all carcasses tested and in 92% of chilling water samples (Barnhart *et al*, 1989). *A. hydrophila* has been isolated from ill and healthy people, animals, water, sewage and soil (Walker, 1990a). *Aeromonas* species. are commonly found on many raw meats, offal and fish, but there is little evidence of it being responsible for clinical diarrhoeal infections. Haemolytic and cytotoxic strains have been recovered from a variety of cook-chill foods e.g. cold pasta or rice dishes and also cooked meats and prepared salads (Schofield, 1992). In another survey of chicken, ground beef, ground pork and pork sausage, *Aeromonas* was found in all but two of the samples, often in relatively high numbers (Okrend, Rose, and Bennett, 1987). According to another source, *Aeromonas* was isolated from 80% of poultry and offal samples, from 37% of cooked meat samples and from 22% of salad samples (Gibson, 1990).

The minimum growth temperature of this water-borne pathogen is -0.1°C and it was reported to grow at similar or faster rates to spoilage flora in vacuum-packed beef (Gill and Reichel, 1989). It was implicated in a food poisoning outbreak, where the organisms had survived in oysters frozen at -72°C for 18 months, so it can survive freeze-injury (Walker and Stringer, 1990). It is considered to be heat-sensitive (Walker, 1992, 1990). *A. hydrophila* is resistant to freezing, sensitive to irradiation, resistant to modified atmospheres, except those with very high concentrations of carbon dioxide, sensitive to disinfectants such as chlorine, quaternary ammonium compounds and iodoform and it has a variable response to microbial competition (Walker, 1990a). There are some difficulties in its identification (Schofield, 1992).

Listeria monocytogenes

One of the most well-known pathogens in relation to chilled food is *Listeria monocytogenes*. It causes listeriosis, most commonly in susceptible people (Marfleet and Blood, 1987), the symptoms of which range from a mild, 'flu-like illness to meningitis, septicaemia, stillbirths and abortions in pregnant women. Pregnant women and their foetuses, the elderly and immunocompromised people are worst affected and, in these groups, mortality can be about 30%, if abortions are included (Gilbert, Hall, and Taylor, 1989). The incidence of human listeriosis worldwide is unknown and sporadic cases can frequently go undetected (Jones, 1990). However, cases in Britain are known to have increased substantially over the past 20 years, and to have almost doubled between 1986 and 1987 (Gilbert, Hall, and Taylor, 1989).

The organism has been found in many foods, including meat, poultry, dairy products, seafood and vegetables, including some foods which had undergone a heat process thought sufficient to kill the organism. It is possible that many such foods have been contaminated after processing.

Its occurrence and simulated growth in several foods have been extensively reported in recent years by many authors. In Northern Ireland, the overall incidence of *Listeria* species. in raw milk samples was found to be 25% and of *L. monocytogenes*, 15.3%

(Harvey and Gilmour, 1992). Beckers, Soentoro, and Delfgou-van Asch (1987) and Lovett, Francis, and Hunt (1987) also reported on the incidence of *Listeria* species in raw milk. *L. monocytogenes* was found in 7% of soft cheeses by Roberts in 1989 and 2 out of 374 samples of soft and semi-soft cheeses by Farber *et al.* (1987).

In the U.S., 41 out of 658 samples of raw beef were positive for *L. monocytogenes* (Carosella, 1990). It was isolated from 72% of samples of pre-packed ham from a single manufacturer in the U.K. In a subsequent study, it was detected in 3% of samples of pre-packed sliced meats (Velani and Gilbert, 1990). *Listeria* was found on 93 of 175 samples of vacuum-packed processed meats which were sampled at the retail outlet (Grau and Vanderlinde, 1992).

In a major British survey, organised by the Public Health Laboratory Service (PHLS), in which a total of 18,337 samples, of a wide range of foods, were examined, *Listeria* was detected in 10% of samples and *L. monocytogenes* in 6% of samples (McLauchlin and Gilbert, 1990). In another PHLS survey, 1301 samples of cooked poultry and chilled meals were examined. *Listeria* was found in 12% of poultry samples and 18% of chilled meals. In the U.K., 60% of raw chickens (both fresh and frozen), and 10% of soft cheeses were contaminated with *L. monocytogenes* (Pini and Gilbert, 1990). Genigeorgis, Oanca and Dutulescu (1990), Kerr *et al.* (1990) and Varabioff (1990) also reported on the incidence of *Listeria monocytogenes* in poultry.

In a Canadian survey of 110 samples of vegetables, no *L. monocytogenes* were found. These results were supported by another survey, reported by Petran, Zottola, and Gravani (1988) in which *L. monocytogenes* was not found in any samples of vegetables. In yet another survey the pathogen was found in 56% of chicken legs, 86% of ground meats and 20% of fermented sausages (Farber, Sanders, and Johnston, 1989). In a Spanish survey, *L. monocytogenes* was found in 7.8% of vegetable samples, 17% of minced meat samples and 7.5% of bivalve molluscs (de Simon, Tarrago, and Ferrer, 1992). *Listeria* was found on 31% of meat slicer blades, of which 13% were *L. monocytogenes*

(Humphrey and Worthington, 1990). The organism is widely distributed in the environment and grows aerobically and anaerobically (Jones, 1990).

Palumbo in 1986 observed its growth in a culture at 3°C and in milk and lamb at 4°C to 6°C. He also noted that this organism is more pathogenic when it grows at low temperatures. More recently, in 1990, Walker and Stringer reported on its growth at -0.4°C in chicken broth. To kill *Listeria monocytogenes*, food should be heated to at least 70°C for 2 mins. Strict temperature control, despite a low reported minimum growth temperature, will slow down growth of the organism (Walker, 1992). Most strains will not grow at pH above 9.6 or below 5.5, but inhibition of the organism at low pH depends on the acid involved; organic acids are more inhibitory than hydrochloric acid. The organism will grow in 10% sodium chloride, and can survive for up to a year in 16-20% sodium chloride. It can also survive long periods of drying and of freezing and thawing (Jones, 1990). It was found to survive during the spray-drying process. In the cheese-making process, lactic acid bacteria will retard, but not inhibit the growth of *L. monocytogenes* (Marth and Ryser, 1990).

Clostridium botulinum

This anaerobic sporeformer causes human botulism which results from the ingestion of a neurotoxin, which is among the most lethal substances known. It blocks the release of a neurotransmitter and causes a general weakening of the limbs, paralysis and suffocation (Evans, 1995). It causes death at worst and at best a long slow convalescence before recovery. The organism is associated with high-protein foods e.g. meat, fish. During sous-vide cooking, the time and temperature used may not be sufficient to destroy spores, which may germinate and grow in the anaerobic environment of the pouches during refrigerated storage (Walker, 1992). The types of toxins and foodstuffs associated vary from country to country. Meat products, especially pork and pork-based products, fish, fruit and vegetables are all associated. Most of the foods involved in food poisoning incidents are home-produced. Refrigerated processed foods of extended durability (REPFEDs) have been identified as high risk because they undergo very little heat treatment, with an extended storage life at low temperatures, have low levels of preservative added and modified atmopspheres (Evans, 1995) .Foods which also pose particular dangers are vacuum-packed or MA packed cooked meats and raw fish and canned, heat treated shellfish where the organism may grow and produce toxin before spoilage becomes apparent. If spores are present in infant foods, they may be potentially infective and give rise to toxigenesis in the intestine of the infant, without the need for toxin production in the food (Schofield, 1992).

There are 7 exotoxins produced by different strains, A-G, of which all, except types C and D are deadly to humans, but are destroyed by heating at 80°C for 10 mins. Types B and E can grow at 3.3°C and type E was found by Palumbo (1986) to produce toxin in heat-treated beef stew substrate at 3.3°C. He also reported that type F grew at 4°C and A grew at 10°C. *C. botulinum* is inhibited by curing salts and high concentrations of sugar (Gibson, 1990a). The effect of sub-lethal treatment on the heat resistance of two strains of *Listeria monocytogenes* and one strain of *Cl. botulinum* was studied in chicken and tomato homogenates. It was found that there was increased heat resistance, but once the heat treatment is over, the resistance begins to be lost (Appleyard and Gaze, 1993). The growth of *Cl. botulinum* non-proteolytic type B and E was studied in samples of chicken and cod which received a mild heat treatment and were subsequently held at 5^{oc}, 8^{oc} and 15^{oc} for up to 12 weeks. At 5^{oc} and 8^{oc} spores which survived could grow and produce toxin in the food without the food appearing spoiled. At 15^{oc}, which simulates severe abuse temperatures, toxin was produced by type B and E strains within one week (Brown *et al*,1991).There have been no documented outbreaks in Ireland (Evans, 1995).

The UK Advisory Committee on the Microbial Safety of Food has recommended time-temperature combinations for the inactivation of *Cl. botulinum.* Chilled foods have been categorized according to the risk of growth of the organism. The Group recognized the necessity for a comprehensive Code of Practice for vacuum-packaged and similarly processed chilled foods (UK Advisory Committee on the Microbial Safety of Food, 1992).

Clostridium perfringens

This sporeforming pathogen is reported to have a minimum growth temperature of 5°C in broth and 15°C in beef (James, 1990) - the latter temperature would signify severe temperature abuse. It is necessary to have high numbers of the bacteria present in the food to cause illness (Dainty *et al.*, 1989). It was isolated from 45% of cooked meat samples in Japan (Kokubo *et al.*, 1986). The organism is anaerobic, so it may pose a problem with vacuum-packed or MA/CA packaged food, particularly if subject to temperature abuse.

Salmonella

Salmonella is a frequent cause of food-borne illness and is associated with many foods, including poultry and raw milk. Although 20,000 people in Chicago suffered *Salmonella* food poisoning which was attributed to pasteurised milk (Foster, 1990), there is no evidence to show that it survives pasteurisation, so post-pasteurisation contamination is likely to have occurred. In a survey by Carosella (1990), 36 of 2151 samples of raw beef contained *Salmonella*. *Salmonella* has been reported to grow at 5.1°C in chicken broth (Palumbo, 1986) and at 4°C in agar (Walker and Stringer, 1990). *Salmonella heidelberg* grew in products such as chilled pasta and meat dishes at 12°C and it was stated that a storage temperature of 6°C would eliminate the possibility of growth of this organism as well as *Staphylococcus aureus and Bacillus cereus* (Bialkowska *et al.*, 1988). At temperatures close to its minimum for growth, it grows very slowly (Gibson, 1990a). During frozen storage,*Salmonella* dies slowly and it resists drying. It is eliminated from food by thorough, rapid heating as most strains are not heat resistant (Gibson, 1990b).

Escherichia coli

E. coli can produce traveller's diarrhoea and is a natural inhabitant of the intestine. It is widely distributed in nature. There are 4 main strains of this organism which are involved in food-borne illness; enteropathogenic (ECEP), which grew at 7.1°C in chicken broth , enterotoxigenic (ECET), which grew and produced toxin at 4°C in milk and broth (Walker and Stringer, 1990), enteroinvasive (ECEI), which does not produce toxin, and enterohaemorrhagic (ECEH), which produces two toxins and causes haemorrhagic colitis. Limited growth of this strain has been reported at 6°C and 7°C (Walker, 1992). Olsvik and Kapperud (1982) reported growth of enterotoxigenic *E. coli* at 4°C in heat-treated milk. Some strains are more virulent than others and can cause other infections, such as infections of the urinary tract. A new group of strains was discovered in Canada in the late 1970s: vero-cytotoxin producing strains (VTEC). They produce a powerful cytotoxin (VT) which causes two clinical syndromes; a severe bloody diarrhoea known as haemorrhagic colitis and a haemolytic uraemic syndrome which is the leading cause of acute renal failure in children and can sometimes be fatal. The most important serotype is VTEC 0157:H7 (Food Safety Advisory Committee, 1994). Beef is the most important source of *E. coli* 0157 but it was found on 1.5% of pork samples, 1.5% of poultry and 2% of lamb samples in the USA and Canada. A study is currently ongoing at the National Food Centre, Dublin, to examine meat samples from Dublin retail outlets for the presence of *E. coli* 0157. 50 minced beef samples have been examined and have shown negative results, but one out of nine samples of salami (12%) has shown up positive for 0157.The pathogen can survive refrigeration, freezing, high salt concentrations (6.5%), low pH (4.7) and modified atmosphere packaging.

Pleisiomonas shigelloides

One strain was found to grow at 5°C and another strain at 0°C (Walker & Stringer, 1990), but the organism is not normally considered to be psychrotrophic (Schofield, 1992). It causes gastroenteritis, characterised by diarrhoea, abdominal pain and nausea. Infection in the young, old and immunocompromised may be fatal (Schofield, 1992). Septicaemia and meningitis may also occur in weak individuals. Food-borne outbreaks have all involved seafood, although water was implicated in a large outbreak in Japan. Its incidence in seafood has ranged from 15 to 100% of samples, but it has also been found in water, mud sediment and animals. It is sensitive to heat and freezing, and there has been a variable response to competing microorganisms (Walker, 1990a).

Vibrio parahaemolyticus

This food poisoning organism associated with seafood can grow as low as 5°C on laboratory media and 8°C in food (Palumbo, 1986). *Vibrio* species. which causes illness and spoilage has been found to grow at 2°C in broth (Nielsen and Zeuthen, 1986).

Staphylococcus aureus

This organism causes illness when its enterotoxin is ingested. It grew at 7.7°C in heat-treated custard and produced toxin at 10°C in lab-cured ham (Palumbo, 1986). It can grow at pH from 4.2-9.3 and at salt concentrations of up to 15% NaCl. It produces several enterotoxins such as A, B, C_1, C_2, C_3, D and E, with A, B and C being especially heat-resistant (Gibson, 1990b).

Bacillus cereus

B. cereus has been shown to cause two different forms of gastroenteritis, as well as other infections. There are two types of toxin produced by this sporeforming organism - a heat labile toxin which causes diarrhoea and a heat resistant one which causes vomiting (Gibson, 1990). Foods implicated in outbreaks of illness include milk and milk products, rice and other starchy foods such as macaroni (Meer *et al*, 1991). The reported minimum growth temperatures of strains which cause illness are 10°C to 15°C, but isolates from outbreaks grew and produced toxin at 4°C (Walker, 1992). Strains causing spoilage may grow at 1°C (Walker, 1992).

Schofield (1992) reported germination of spores as low as -1°C. The spores may germinate and grow in pasteurised or heat-treated foods in which competitor organisms have been killed. The optimum temperature for toxin production is 32°C to 37°C and it has not been proven clearly whether toxin is produced at low temperatures (Schofield, 1992). Numbers of the organisms in raw milk can be reduced by having healthy livestock and good hygiene in relation to equipment. Vegetative cells are quite sensitive to heat and disinfectants (Meer *et al*, 1991).

Campylobacter

This is the most commonly reported cause of gastrointestinal disease in the U.K. Raw milk and undercooked chicken are commonly implicated (Walker, 1992). Poultry is said to be regularly contaminated (Gibson, 1990). The infectious dose of *Campylobacter* is very low, so if food is contaminated already, even if stored below 3°C, the organism may survive in sufficient numbers to cause illness, without the need for growth (Walker, 1992).

This organism is not so significant for chilled foods, only those which are severely temperature abused as it does not grow at less than 25°C, but it can survive at lower temperatures (Walker and` Stringer, 1990), so if a food undergoes periods of normal refrigerated storage as well as periods of temperature abuse, the organism could still survive, perhaps in high numbers. The organism requires microaerophilic conditions e.g. 5% oxygen and 10% carbon dioxide (Gibson, 1990).

1.5.2 Spoilage Microorganisms

Chilled foods, particularly protein foods, often spoil rapidly at temperatures higher than normal refrigeration temperatures. Spoilage may be defined as any single symptom or group of symptoms of overt microbial activity, manifest by changes in odour, flavour or appearance. The food may then still be safe to eat, but is undesirable because of visible growth e.g. mould, bacteria or yeast colonies, or due to the production of odours, slime, pigments or enzymes, which themselves cause deterioration of the food. It is preferable that growth of spoilage organisms takes place more rapidly than growth of pathogens, so that food appears inedible before it poses a risk of food poisoning. Spoilage microorganisms, for convenience, will be divided into six categories: gram-negative rod-shaped bacteria, coliforms; gram-positive sporeformers; lactic acid bacteria; other bacteria; yeasts and moulds.

Gram-negative Rod-Shaped Bacteria

This group includes the most common causes of spoilage of chilled food, *Pseudomonas* primarily, but also *Acinetobacter*, *Aeromonas*, *Alcaligenes*, *Alteromonas*, *Flavobacterium*, *Moraxella*, *Shewenella* and *Vibrio* species. (Walker, 1992).

Pseudomonas has a reported minimum growth temperature (MGT) of 0°C to 2°C (Walker and Stringer, 1990). MGT's for the rest of the group range from -3°C to 0°C and growth at 5°C to 10°C is rapid. In fresh, chilled meat, *Pseudomonas* will dominate the final spoilage microflora, even though they represent a minor proportion of the initial population, because of their advantages in relation to growth rates over other microorganisms (Gill and Newton, 1978). In fact, they have been reported to be dominant at all temperatures up to 15°C on poultry (McMeekin and Thomas, 1980). Members of this group also dominate the spoilage flora of fish (Hobbs, 1983) and meat (Prieto *et al*, 1992). Nortje *et al*, (1990) also found that pseudomonads were the dominant spoilage organisms on chilled meat and abattoir carcass meat. *Pseudomonas fragi* is reported as the most common pseudomonad on meat (Prieto *et al*, 1992). Spoilage by *Pseudomonas* may be characterized by production of enzymes, off-odours, off-flavours, rancidity, production of slime and visible growth. *Alteromonas putrefaciens* and some pseudomonads produce sulphide-like off-odours in poultry (McMeekin and Thomas, 1980). Generally, this group is not heat-resistant, although some enzymes produced by

Pseudomonas may be. Post-pasteurisation contamination may occur (Walker and Stringer, 1990).

Coliforms

Also known as enteric bacteria, this group includes some psychrotrophic strains, although growth at low temperatures is slower than with *Pseudomonas*. They include *Citrobacter, Enterobacter, Escherichia, Klebsiella, Proteus and Serratia* species. They have been reported in foods such as vacuum-packed meats, poultry, cured meats, milk and dairy products and may cause gas production, acid, slime, bitter flavours, off-odours and visible growth. This group may be a significant component of spoilage microflora at temperatures above 5°C and up to 15°C (Walker and Stringer, 1990). The MGT for this group may be -2°C to 8°C. They may grow in mild acid foods and do not always need oxygen to grow. Coliforms which originate from the intestinal tract are used as indicators of faecal contamination after processing (Walker, 1992).

Gram-Positive Sporeformers

As the name suggests, microorganisms of this group may produce spores which can withstand heating so that the germinated cells can be dominant, all other competitors having been destroyed. The minimum growth temperature may be 0°C to 5°C with the fastest growth occurring above 8°C. The spoilage strains of *Bacillus* and *Clostridium* are members of this group (Walker, 1992).
B. cereus may grow below 5°C and its enzymes cause spoilage of milk. The minimum growth temperature of other *Bacillus* species. is 0°C to 2°C. *Bacillus* were reported to be the most prevalent spoilage organisms on meat at the end of the storage period (Nortje *et al*, 1990). At temperatures of mild abuse, *Clostridium* species. may cause late blowing of hard cheeses due to gas production (Walker and Stringer, 1990).

Lactic Acid Bacteria

This group includes *Lactobacillus*, *Lactococcus*, (formerly known as *Streptococcus*) *Leuconostoc* and *Pediococcus* species. Their growth at refrigeration temperatures is very slow, if at all, therefore they are poor competitors unless growth of other flora is inhibited. However, the minimum growth temperature for lactic acid bacteria has been reported as 0°C and for *Lactobacillus* as 5°C by Nielsen and Zeuthen in 1986. Their main advantages are their being more tolerant of low pH and low a_w. They are dominant on vacuum-packed foods and some modified atmosphere foods. They may produce anti-microbial compounds and reduce the pH of food. Spoilage is caused by the production of acid and sometimes gas (Walker, 1990a). *Lactobacillus* is anaerobic and aerotolerant, but is slow growing.

Other Bacteria

This group includes *Brochothrix thermosphacta*, *Micrococcus*, *Corynebacterium*, *Kurthia and Arthrobacter* species. *Br. thermosphacta* grew as low as -2°C in broth culture (Nielsen and Zeuthen, 1986), but according to Zeuthen (1990), the organism had a lag phase of 1 to 1.5 weeks at 2°C. It may dominate the microflora of vacuum-packed products and it has been isolated from spoiled frankfurters, sausages and cured meats. It produces off-odours, but does not cause spoilage problems on fresh meat. Prieto *et al* (1991) stated, however, that it has a high spoilage potential on lamb carcasses, due to production of odiferous compounds. *Micrococcus* species. are tolerant of salt and may spoil cured meats by producing slime, souring or pigmented growth. Some thermoduric strains may survive pasteurisation of milk and then grow and cause spoilage (Walker and Stringer, 1990). *Brochothrix thermosphacta* is a facultative anaerobe and may cause spoilage in vacuum-packed meats.

Yeasts and Moulds

Yeasts are not good competitors in chilled foods - their growth rates are relatively slow and foods are generally contaminated only from the environment. Yeasts are mainly saccharolytic or lipolytic and usually only spoil protein foods if they contain increased amounts of carbohydrate or fat, or if the food is stored at low temperatures for a long time. Some yeasts are cold-tolerant and can grow below 0°C due to certain physiological advantages. They can be successful competitors if the food is heavily contaminated. Yeasts may produce antibacterial substances such as active preservatives, or they may raise the pH by using up acid. In a survey, carried out by Banks (1985), 69% of dairy products and 76% of meat products were contaminated with yeasts. But yeasts have not been a cause of serious problems in chilled foods . Yeasts can grow with or without oxygen, but moulds require oxygen. Yeasts and moulds are less restricted than bacteria in terms of low pH, reduced a_w and the preservative content of food, but they are sensitive to heating (the mould *Byssochlamys* being able to produce heat-resistant ascospores). Mould ascospores may be transmitted by air movements. The types of yeasts which spoil foods include *Candida, Debaryomyces, Hansenula, Kluveryomyces and Saccharomyces.* Moulds causing spoilage in chilled foods include *Aspergillus, Cladosporium, Geotrichum and Mucor.* Yeasts and moulds may be deliberately added to some foods e.g. to add flavour to cheese (Walker, 1992). Spoilage products may include slime, pigmented growth, acid, gas, alcohol, off-odours and off-flavours (Walker and Stringer, 1990).

It is important to note that in relation to minimum growth temperatures of microorganisms, an MGT measured in laboratory agar or broth, where conditions of pH, nutrients and a_w are optimal for growth, may not reflect the true MGT of the organism in a foodstuff. Also, at temperatures approaching the MGT, the lag phase before growth occurs will be at its longest, and it may take several days, or even weeks for the population to double. If food is stored at a temperature just below the MGT, the microorganisms may be able to survive, and if the temperature is subsequently raised, growth may then occur. Obviously if storage is to render food safe to eat, the required low temperatures must be maintained at all stages of the life of the food until it is eaten. In other words the chill chain must not be broken.

1.5.3 Predictive Modelling

Various models have been put forward to predict likely survival and growth patterns in specific foods, in order to ascertain the shelf life of the food. Growth responses of microorganisms to factors such as temperature, pH and Aw are predicted based on basic compositional information on the food or product, combined with time-temperature data collected from the chilled food chain. Mathematical models are used to make predictions.

Modelling can reduce the need for microbial examination of new products and therefore conserve resources. It does have some disadvantages, however. Substantial amounts of data are needed, even for the simplest models, on the effects of of the various factors on microbial growth rates. The models must be validated for different foods and it is difficult to make predictions on the lag phase of growth (Gibbs and Williams, 1990).

Food Micromodel is a computer software package distributed by Leatherhead Food Research Association which combines predictive modelling with computer technology to aid in the prediction of safety of foods. It reduces the need for challenge testing (where foods are inoculated with microorganisms and the results studied). It has a number of uses and is the result of a MAFF-funded research project on predictive microbiology and its applications in the area of food safety (Anon, 1995).

1.6 TRANSPORT OF CHILLED FOODS

The most common method of maintaining temperature control during the transportation of chilled foods is mechanical refrigeration (as opposed to non-electrical methods of maintaining low temperatures such as liquid nitrogen or eutectic beams).

1.6.1 Principles of Mechanical Refrigeration

A vapour compression refrigeration system comprises four interlinked components, an evaporator, a condenser, a compressor and an expansion device. In the compressor, a refrigerant fluid (as a vapour) is compressed to a higher pressure and a higher temperature. This gas is then cooled and liquefied in the condenser. This liquid then passes through a restrictor to a lower pressure area, as it cools further. The cold liquid is then used to absorb heat, which is used to vaporise the liquid, which is then returned to the compressor and the cycle begins again (Heap, 1992).

There are a number of different methods used to cool food. Blast chillers are commonly used for prepared foods. They pass cold air over the food at a high speed, normally at least 4 metres per second. Carbon dioxide or liquid nitrogen may also be used as refrigerants, but the former may cause surface freezing and the latter has a temperature of -196°C and so must be more carefully controlled. Hydrocoolers use chilled water which is sprayed onto the product, or alternatively, the product may be immersed in the water in an immersion tank. This provides rapid cooling and there is no risk of surface freezing. It is generally used for fruit and vegetables, as they can withstand immersion. The water is normally recirculated, so it must be kept clean. Vacuum coolers are used for prepackaged leafy vegetables. The wet produce is placed in a sealed chamber at a low pressure and cooling occurs by evaporation of moisture. The other method of cooling, used for large volumes, is to place the produce in a cool store and allow it to cool, using only the circulation of cool air. This is quite slow, however (Heap, 1992).

Virtually every method of transport including road, air, rail and sea can be used for chilled foods.

1.6.2 Road Transport

This is the most common method of transport in Ireland and it is used over a wide range of distances, whether from one end of the country to the other, or for short distances e.g. from a distribution depot to a local customer in an urban area. This variability may influence the potential for temperature abuse. When a vehicle is travelling over a long distance, the doors remain closed for a long period of time and the mechanical refrigeration system can run smoothly in an enclosed environment. But in an urban area with short runs and frequent drop-offs, the doors of the vehicle are opened more often. This introduces ambient air to the refrigerated compartment which has to be cooled before the next door opening. Hubbard (1992) has commented on this and recommend that the length of time the door is kept open should be minimized. If the refrigeration plant is run from the engine, the engine must be kept running and this is expensive. Hubbard has suggested the use of eutectic beams as a possible solution. Plastic beams are filled with a eutectic liquid which has a predetermined freezing point. The eutectic is frozen, using an electric condensing unit, and this "cold reserve" in the beams is gradually released over a period of time, which maintains the temperature of the vehicle hold during delivery periods. One advantage of this type of system which is designed specifically for a particular vehicle and the company's needs, is that, using a thermostatically controlled fan, warm air can be cooled after a door opening more rapidly than with the mechanical refrigeration system alone.

Another method of reducing the air temperature in road transport vehicles is by using liquid nitrogen, held in an insulated tank, connected to a spray bar which runs along the ceiling of the vehicle. The liquid nitrogen is vaporised immediately it enters the air in the vehicle and cools the air. The flow is cut off when the correct temperature is reached. This method has a number of advantages such as silent operation, low maintenance, low capital costs etc, but running costs are about 2.2 times that of a mechanical system.

In 1978, Malton described 4 types of vehicle used for transport of meat. His article still has some relevance:

(a) refrigerated, insulated vans or trailers, which use mechanical refrigeration;

(b) insulated vehicles without refrigeration;

(c) vehicles, neither refrigerated or insulated; and

(d) flat, open lorries.

Obviously, it would be desirable for transport of all chilled foods to be carried out by refrigerated, insulated vans and the use of unrefrigerated, open lorries would be highly undesirable. He noted that problems may result from drivers having a poor understanding of the capabilities and procedure for running the vehicles. He also stated that vehicles should never be used for cooling of food, only for maintaining pre-cooled foods at the desired temperature. This applies to all methods of transport. Malton emphasised the need for efficient air flow around the load and also the need for efficient and speedy loading procedures. It is preferable to have sealed and refrigerated loading bays, where the loading operation into the container can be carried out under temperature-controlled conditions (Malton, 1978).

As well as the classification given above, refrigerated road transport vehicles can be classified as (i) semi-trailers, in which the refrigeration unit can be run independently of the tractor or pulling unit, and (ii) the rigid type, which can have an independently run unit or one which is run from the vehicle engine. The former is mainly used for long-distance transport, where there are few stops. The latter are used for multiple deliveries, generally over a smaller area. It is possible to use sensors (in a refrigerated vehicle) to monitor the temperature of the air entering the cargo space and the air returning to the refrigeration unit. These will be connected to a display, usually located in the driver's cab or perhaps externally (Heap, 1992).

Swedish legislation requires that delivered products must have a temperature of 8°C or less. In a Swedish survey, Ronnegård (1983) found that 19% of deliveries had temperatures higher than 8°C. In another survey, product temperatures at the start of distribution varied from 5.2°C to 9.6°C and during distribution, air temperatures varied from 3°C to 9.5°C. In an Irish survey (Bøgh-Sørensen, 1990), product and air temperatures were between 1.6°C and 4.8°C over long distance transport. No temperatures over 10°C were recorded. In another survey, reported by Gunvig (1990), conditions in distribution of meat from three slaughterhouses to supermarkets were examined. The mean product temperatures were found to be 6.6°C, 3.8°C and 6.1°C. The initial temperature was above 5°C at the time of loading in 97 out of 112 cases of transport via a depot. In 30 out of 34 cases of transport direct from the slaughterhouse, the initial product temperature was too high at the time of loading. The highest temperature recorded was 15°C. He concluded that insufficient chilling at the slaughterhouse was the cause of problems. It seems that with road transport, problems mainly stem from loading and unloading. Also, vans with multi-drops were more likely to result in a rise in product temperature (up to 4°C rise) (Bøgh-Sørensen, 1990). With multi-drops, and when the food is pre-cooled, the surface temperature of the product is likely to be higher than the core temperature (Napleton, 1992).

1.6.3 Hypobaric Container Transport

Hypobaric storage involves close regulation of temperature, relative humidity, number of air changes and the maintenance of low pressure. A normal refrigeration unit is used with an air-tight container which is evacuated using a pump. Pressure is controlled by a standard vacuum-regulator. Controlled, humidified air is fed in. The container used is similar to the normal 40-foot refrigerated container. The main advantage of storage under a low pressure is an extension of storage life. Also, meat stored in this way had significantly lower bacterial counts (Jamieson, 1980).

1.6.4 Air Transport

Transport by air may be the choice for high value, highly perishable products where short transport time is important, or to supply products quickly to meet market demand. Countries such as Australia and New Zealand use this method more regularly than European countries. Sharp and Spraggon (1987) monitored a mixed load of fruit on a flight from Sydney to London. The ambient temperature of the container averaged 19.5°C. The cargo hold of the aircraft was not refrigerated and only lightly insulated, resulting in it being affected quickly by the temperature at the airport in stopovers, reaching 34°C in Kuala Lumpur. These authors recommended that:

(a) aircraft containers should be insulated;

(b) products to be transported should be pre-cooled before loading, which is more effective than using dry ice in the container during the trip; and

(c) the container should be filled to capacity to slow down the rate of warming.

In relation to the British experience of air transport, where winter ambient temperatures are low, a Marks & Spencer spokesperson observed that the ratio of perishable to total cargo is generally small and many airports used by M & S have virtually no chilling or cool storage facilities. Normally the cabin and cargo holds are not chilled. British Airways stated that there can be a 2 hour delay between flight arrival and the placing of a consignment under refrigerated conditions (Gormley, 1990). Obviously, a high ambient temperature at the airport could have a serious impact on product quality. In fact up to 80% of the total journey time can be spent travelling to the airport and waiting on the tarmac. Other air transport problems noted by this source include the fact that about 10% of cargo is not routinely sent on its proper flight. Relative humidity in the hold may fall to 5% at high altitudes which leads to drying out of unwrapped foods. Crushed ice surrounding the produce e.g. seafood, will counteract this and also help maintain low temperatures, but meltwater can cause problems. It is also important that when the cargo arrives at the destination airport it can be delivered promptly therefore it should be organised not to arrive during non-working times or on public holidays. The types of cargo transported by air include seafood, meat, fruit, vegetables and flowers. Airfreight is mainly handled by freight forwarders. Those specialising in perishable cargo may have cool storage facilities at their depots.

1.6.5 Rail Transport

Rail is not a widely used means of transporting chilled foods, but it can become more important in winter following deterioration of road conditions; in Greece, for example, 9% of fresh produce is moved by train (Petropakis, 1990). The use of this method is in decline because railcars are not as flexible or as easily manouverable as road containers. Blocks of ice are used as the refrigerant in Greece whereas in the USA, mechanically refrigerated railcars with controlled atmospheres are used for long distance transport.

1.6.6 Sea Transport

Transport by sea is typically used over long distances for chilled meat carcasses or fruit. The pre-cooled food is normally carried in refrigerated containers (about 6-12m long, holding up to 26 tonnes of product) which maintain its temperature. The floor of the container is sectioned to allow for air movement beneath the cargo. There are two types of container: the porthole or insulated container which has two holes in the end wall through which refrigerated air can be delivered and exited using a portable refrigeration unit clipped onto the container, or from the central plant on the ship. The second type of container is the integral container, which has its own built-in refrigeration unit and fans to distribute cool air throughout the container. Most units have a temperature chart recorder fitted. These refrigerated containers are easier to transport overland, but have to be carried on the deck of the ship, because higher ambient temperatures may exist in a closed hold, and there may be problems with the running of the refrigeration system. Another type of container is used mainly for long distance sea transport where the journey time may be up to 6 weeks. They are called intermodal freight containers or ISO containers and have an integral refrigeration system which is highly developed and allows a high degree of control (Heap, 1992).

For shorter journeys, the ro-ro system is more common, where the produce will be in a container attached to a truck which provides the refrigeration plant and the truck simply drives onto and off the ship (Irving, 1988). Modern containers may have a number of compartments capable of operating at different temperatures and separated by a bulkhead, so that chilled, frozen and ambient-temperature products may be transported simultaneously.

1.7 BULK AND WAREHOUSE STORAGE OF CHILLED FOODS

Cool storage is defined as storage in which the product contains no ice, and the temperature is above -2°C (Cleland, 1990). There are different types of cool store, depending on what is being stored;

(i) unwrapped meat and poultry - large bulk storerooms.

(ii) fruit, meat, poultry, fish - controlled atmosphere storage rooms, which may have scrubbers to remove carbon dioxide.

(iii) jacketed cold stores - where walls, floor and ceiling of the store are cooled with minimum air movement.

When a consignment is being placed in a cool store, it must be pre-cooled, where possible, so that it is at the same temperature as the air in the cool store. This means minimizing any heat loads produced during loading and unloading processes. Extra refrigeration capacity must be provided for products which respire, such as fruit (James and Bailey, 1990).

The UK Electricity Association recommends a number of factors to be borne in mind when specifying or designing a cold store:

(i) frequency and size of consignments; so that storage time for each consignment, and therefore size of store necessary can be calculated;
(ii) amount of thermal insulation necessary to maintain temperature, at satisfactory running costs;
(iii) air curtains or "flap" plastic doors may be necessary for stores with frequent movements of stock; and
(iv) continuous temperature monitoring equipment.

Air movement within the store must be taken into consideration when siting the evaporator unit. Temperature controlled loading bays are preferable, so that stock is protected during loading operations and temperatures are maintained (Heap, 1992). Dock levellers may also be necessary, to deal with vehicles of different heights. Some cold stores may have multi-temperature chambers with humidity control. This is all considerably in advance of the first cold stores, built around 1750, which were underground wells or pits, lined with bricks and which contained ice from local lakes. Around 1800, the first commercial cold stores were built at seaports to store carcass meat, dairy products and fruit (Toole, 1990).

1.8 RETAIL CHILLED FOOD DISPLAY

Following bulk storage the next important stage in the chilled food chain is the retail display of food in refrigerated display cabinets. There are two types of cabinets; the vertical, multi-deck cabinets for self-service by the customer and the less common delicatessen or "serve over" cabinets. With the multi-deck ones, the evaporator is in the base of the cabinet, or it may be located in a central plant in large stores. Air is blown from behind the shelves forward, and also downwards from the front top of the cabinet. The warm air is returned via a grille at the base of the cabinet. With the serve-over cabinets, the food sits on a base, over which air is blown. The air comes from an evaporator at the rear and may be gravity-fed or fan-assisted. Cabinets vary from those which are completely closed, access only being possible for the server through doors at the rear, to those which are open at the rear with a high glass serve-over front, to those which have access at the front for the customer, with or without doors. The velocity of air speed is important, as the food is often unwrapped, and may dry out if air speed is too fast. Weight loss due to dehydration is estimated to cost at least £5 million every year in the UK.

There is some conflict between the need for attractive, convenient display of the product and the provision of correct storage conditions. Modern cabinets with doors which are more efficient thermal insulators may have disadvantages for the retailer (Heap, 1992). In a survey by Gormley (1990), temperatures in retail display cabinets were generally found to be satisfactory, with some exceptions where temperatures were found to be slightly higher. Mean temperatures ranged from -1.6° to 4.0°C. Only a few products were above 8°C and then only for a short time, but some products did remain above 5°C for significant periods of time. James and Evans (1990) reported on surveys in very large retail outlets and found air temperatures to be wildly fluctuating e.g. from 5°C to 20°C and product temperatures ranged from 6°C to 12°C. They found that the greatest temperature control was obtained in a lightly-loaded display unit in an air-conditioned supermarket. Rose found that product temperatures ranged from -8°C to 18.4°C and that air temperatures ranged from -5°C to 13.8°C in a U.K. survey of retail outlets. She also concluded that product temperatures in delicatessen counters were significantly higher than in self-serve cabinets. There was a small but significant correlation between the temperatures displayed on the cabinet gauge and the recorded air temperatures (Rose, 1986).

Modern refrigerated display cabinets are designed to maintain temperatures of -2°C to 2°C but this capability can be influenced by a number of factors which hamper the efficient running of the unit. In a retail store, air movement due to poor positioning of units in relation to doors and air conditioning vents can interfere with the flow of air around the cabinet. Overloading of cabinets, especially with warm products, particularly just before peak shopping periods or following large deliveries, can also interfere with the cabinet's operation. Ice can build up on the evaporator coils between defrost cycles (James, 1993).

According to Olsson (1990), the position of the food on the shelf affected the product temperature, with those at the front being 2°C to 4°C warmer than those at the back. He stated that approximately 50% of packs in the upper layer of the cabinet would be expected to have a temperature of over 5°C. He also noted that night caps or curtains, when used on cabinets, reduced both the mean product temperature and the level of energy consumption by the unit. He stated that products spend most of their storage lives in the cabinet and so staff need to be given more information on loading and handling.

Gormley (1990) also observed that poor product temperatures can also be due to the use of strong lighting, incorrectly adjusted thermostats and interference with original cabinet design by the retailer. Doyle (1987, undergraduate dissertation) found that 65% of large supermarkets had significantly overloaded cabinets. The problem in relation to this practice is that it can cause air vents to be blocked and air flow patterns to be disturbed.

1.9 CONSUMER HANDLING OF CHILLED FOODS

In this study, the domestic fridge and the way the food is handled before it reaches it after leaving the retail store, cannot be ignored, as this is the final link in the chilled food chain and, more importantly, the one over which the food manufacturer has least control. The transport stage to the consumer's home has the greatest potential for abuse. In two surveys by Colwill (1990), only 13% and 8%, respectively, of respondents used a cool bag or similar device. Food was out of refrigeration for an average of 1 hour, but times varied from 10 minutes to 6 hours. In an Irish survey, conducted by French (1991) for an undergraduate dissertation, 18% of respondents took between 30 minutes and a few hours to transport the food to their homes. It is also worth noting that only 9% of respondents in this survey were aware of the need for temperature control in relation to meat and dairy products. James and Evans (1990) observed that on tests of food transported in a car boot, the temperature rose to 30°C, and when placed in a domestic fridge, the temperature did not decrease to 7°C until 5 hours later. They noted the possibility of increases of up to two generations in bacterial counts during the transport and cooling phase in the home. They also found that more than 85% of household fridges operated at temperatures greater than 5°C. In another Irish survey by Gormley (1990), the overall mean fridge temperatures ranged from 3.8°C to 6.2°C. The British Standard BS EN 28187 of 1992 recommends that the main compartment of the fridge be between 0°C and 7°C. There is no corresponding Irish standard.

1.10 TEMPERATURE MONITORING

The quality of a food product when eaten is dependent on the treatment received throughout its life and most importantly on its temperature history. This variability makes shelf life predictions and date labelling very difficult for manufacturers as the future exposure of the food product is an unknown variable at the time of manufacture. There are five different ways of approaching shelf life prediction:

(a) literature values e.g. those published previously, such as those by the US army, or other authors;

(b) distribution turnover; using the known distribution times for a similar product as the basis for the shelf life, but this can be inaccurate;

(c) distribution abuse test;the product can be collected at the supermarket and stored in the laboratory under conditions simulating home-use conditions;

(d) consumer complaints; information from customers complaining about spoiled foods can be a useful source of information about the likely abuse food encounters; and

(e) accelerated shelf life testing (ASLT); this is the most common form of estimating shelf life; the finished product is stored under abuse conditions and then examined at the end of its shelf life; the information obtained is then used to project shelf life under abuse conditions.

(Labuza and Taoukis, 1990).

It is useful to routinely assess the temperature of a food along the chill chain, so that an assessment can be made of whether the estimated shelf life is realistic. There are a number of different ways of monitoring temperature.

(i) <u>An environmental monitoring system</u> can be set up in a transport container or in a food store etc.. Sensors can be located at different locations e.g. monitoring air temperatures in the delivery and return air streams to assess whether the refrigeration system is functioning correctly. The location of the sensors is important and should give a representative indication of the general temperatures. They should also be placed where they will not be damaged during normal operations and where they can be accessed, if necessary (Woolfe, 1991). An example of an environmental monitoring system for transport vehicles is "Cool Cat". It is a microprocessor based system, which has sensors placed at a number of points in a container, which can monitor temperatures at up to seven locations in a container. The information is fed back to the microprocessor and can subsequently be fed into a computer. It also has an alarm facility to notify the driver if a pre-set temperature limit is exceeded. It can also be used for cold stores (Cairns, 1985). Monitoring of this type, which uses a number of sensors, is called intensive monitoring. It involves more detailed analysis of results, but it gives a more graphic portrayal of the effectiveness of a distribution system, and is especially suited to the setting up of an effective chill chain (Sharp, 1991).

(ii) The next stage of testing, which can be used if the monitoring system shows something amiss, is to use non-destructive testing e.g. to monitor the "between-pack" temperatures, by locating sensors snugly between two flat, uniform packs, to give some idea of the temperature of the product without actually rendering it unsaleable. A number of sampling points should be used and if possible, the warmest points in the load should be included.

(iii) If these tests have been carried out and the results appear to be outside the acceptable range, then destructive product testing is the final monitoring option. This should be carried out using a pre-cooled probe with a robust, sharp, stem. Again, locations should be selected to include the warmest part of the cargo (Woolfe, 1991).

Equipment used should be accurate, relatively easy to use, fast to respond and robust enough to withstand regular use. There are three types of digital thermometers available; those with thermocouples, precision thermistors and platinum resistance thermometers, all of which have varying qualities (Fairhurst, 1990). Thermocouples consist of two wires of different metals which are joined together at the measuring point (the hot junction) and generate an electric current when this is heated. They are connected to a sensitive voltage measuring instrument, a voltmeter, at the cold junction. The voltmeter measures the voltage potential difference between the two junctions. Thermocouples are the most common type of measuring instrument for the food industry (Bishop, 1993). A thermistor is a semi-conductor of electricity which acts to regulate the flow of electricity through it. It exhibits a change in resistance to the flow of electricity with temperature, which is predictable (Shugar and Ballinger, 1990). Platinum resistance thermometers have sensors which consist of a coiled platinum wire or platinum film on a substrate using thin film techniques. The electrical resistance of platinum changes with temperature in a regular and defined manner (Bishop, 1993).

Thermometers require regular re-calibration to ensure a continued high level of accuracy and reliability Bishop (1993) recommends that once every twelve months is sufficient for modern thermometers before recalibration is required, unless the unit is in daily use, when recalibration would be necessary more on a more frequent basis. Measuring instruments also need to be tested to guarantee their accuracy e.g. by comparing the thermometer against one of known accuracy.

Tolstoy (1991) described the monitoring of temperatures of deliveries by his company. He stated that any batches having a temperature above 7°C were immediately rejected. Over a period of 14 months, it was found that temperature abuse was not uncommon. The number of batches rejected dropped significantly during the winter months, so he concluded that the external temperature had an influence on the product temperature. Over a period of about a year, the number of rejections was seen to drop. He concluded that this was due to suppliers making a greater effort to maintain product temperature at the proper level. It can be concluded therefore that the introduction of a strict monitoring and rejection programme may have a positive influence on temperature control.

General advice on how Environmental Health Officers should carry out temperature monitoring and the qualities desired of equipment are given in the Food Safety (Northern Ireland) Order 1991, Code of Practice No. 9 (UK. DHSS., 1991). This includes the matters such as the necessity for calibration and testing of equipment, pre-cooling thermometer probes before taking measurements.

Time-Temperature Indicators (TTIs) are small devices, which should be inexpensive and can be attached to a food package. Their purpose is to give an indication of the temperature history of a product by showing an easily recognisable change e.g. a colour change, with variations in temperature. The rate of change is temperature dependent and should be easily correlated to the extent of deterioration of the food (Taoukis and Labuza, 1989).

They could be used in conjunction with or instead of date labelling. They could be used to give information on whether to accept or reject a product, to give a full or partial temperature history, or in the case of temperature indicators, to give information on the current temperature of a product, or on whether temperature abuse has occurred above a certain (threshold) temperature. The devices should be easily applied to food packages, should have a known irreversible response to temperature which is accurate and reproducible and they should be tamper-proof. There are many different processes which can be used as the basis for TTI's, such as enzyme reactions, polymerization, liquid crystals, and they usually involve a colour change.

The main problems with TTI's are that they are applied to the outside of the package, so they give an indication of the surface temperature only, and also the fact that some of them may be complex and will necessitate an education campaign for consumers. Consumers may be confused if there is some conflict between the best-before date and the TTI (Woolfe, 1992).

AAIR is the EU Agriculture and Agro-Industry Research Programme which aims for a better match between the production of biological resources and their usage by consumers. Research is currently ongoing on the safety and quality of refrigerated, ready-to-eat foods in Holland and in Belgium on the development of new time-temperature indicators (Anon, 1993).

1.11 SPECIALIST MANUFACTURING AND HANDLING SYSTEMS FOR CHILLED FOOD

1.11.1 Cook-Chill Catering

In normal catering, both production and consumption of the product occur on the same premises, with as little time delay.as possible between the two. There is often a peak of activity in the kitchen just before service, as all the ingredients must be ready simultaneously. The cook-chill process changes this and cold storage is used as a "time buffer" to allow production to be spread more evenly over a longer time. The catering becomes production oriented instead of service oriented. Production can also become centralised into one central production unit. The main advantage of cook-chill catering is to save costs, while increasing output. The food can be held for up to 5 days, including the days of production and service, at between 0°C and 3°C. The food is then reheated to temperature of at least 70°C (Sheppard, 1987). In cook-chill catering, large numbers of people are normally catered for and the maintenance of strict temperature control becomes very important, if a mass outbreak of food-borne illness is to be avoided. It must also be borne in mind that this type of catering is commonly used in hospitals and similar institutions, where the consumers may be ill or elderly and thus more susceptible to food poisoning.

The Irish Food Safety Advisory Committee has published a set of guidelines covering many aspects of cook-chill and how such products should be handled, including raw materials, pre-cooking stages, cooking, subsequent chilling, storage, distribution and reheating of chilled meals. The guidelines are very specific and detailed and give time and temperature limitations in storage and distribution if chilled foods undergo temperature abuse. For example, if the products are stored at 3^{oc} or below for the entire time, a storage life of 5 days is specified, but if the food encounters between 4^{oc} and 10^{oc}, it is stated that the food should be consumed within 6 hours of the temperature abuse or else destroyed. Recommended reheating times and temperatures are given. An extensive list of "essential control checks" is given to be followed to ensure product safety. One useful recommendation is that samples of each batch of food be taken and kept for at least five days. This allows for easier investigation of food poisoning incidents (Food Safety Advisory Committee, 1991).

1.11.2 <u>The Sous-Vide System</u>

This system originated in France, where now over 700 establishments use the process. Also, sous-vide products are sold in retail outlets in France (Stringer, 1990b). It is a relatively new development which deserves some attention, since the process includes a period of chilled storage. It entails the food being cooked under controlled time and temperature conditions in heat-stable vacuumized pouches. The food is then rapidly chilled to a temperature between 0°C and 3°C in less than 90 minutes, until reheated for consumption within 21 days.

The main advantages of this system are related to the organoleptic quality of the food. Because of the sealed pouch used, no flavour or aroma compounds are lost during cooking. Therefore, there is less need for flavour enhancers or other flavour additives. It is also a flexible cooking system, well suited to banqueting and *a la carte* catering. As for food safety, the sealed pouches have the advantage of preventing cross-contamination during cooking and storage. It also allows the use of central kitchens for the initial preparation and cooking process where hygiene conditions may be more easily controlled. The food can be distributed after chilling and reheated at the point of sale. In this case the distribution step must also be tightly controlled.

The atmosphere within the pouch is mainly anaerobic and thus enables the growth of pathogens such as *Cl. perfringens*, *Cl. botulinum* Types B and E and also *B. cereus* and *L. monocytogenes*. Spoilage is mainly caused by lactic acid bacteria. Thus careful supervision and management of the process is essential for food safety. The time-temperature aspect is vital and holding at below 3°C after <u>rapid</u> chilling must be guaranteed. The initial cooking process must ensure destruction of all vegetative microbial cells. The specific time-temperature combination must be calculated for each product, as some will involve a long, slow cooking and others a more rapid cooking at a higher temperature. When reheating, the food must reach a temperature of at least 65°C. During distribution and storage a temperature below 3°C must be constantly maintained to guarantee shelf life. Brown et al (1991) recommended that all parts of the food should reach a temperature of $90^{o}C$ for 7 minutes to reduce numbers of the organism by a factor of 10^6.

It is also important to ensure the integrity of the pouch in sous-vide cooking, as it prevents contamination of the contents. It must be protected from mechanical damage, which may be done by packing it into a protective carton. The vacuum must be applied properly and the pouch and, particularly, its seams must be capable of withstanding the pressure changes encountered during the process.

The best way of ensuring that the correct time-temperature combination is achieved in practice, is to insert a temperature probe into one pouch of a batch, and to leave it in place, so that it can be checked throughout the whole process. To prevent damage to the pouch, this is done using a valve. A full record of temperatures is vital (Majewski, 1990).

This process has a high degree of safety, but only if managed strictly at all times. It is very susceptible to abuse by untrained personnel or unapproved operators, so proper regulation and control is of paramount importance. There is no specific legislation controlling sous-vide in Ireland.

1.11.3 The CAPKOLD/CRYOVAC System

There are two methods of producing food with this system:
(1) if the food is pumpable e.g. soups, sauces which have a food particle size of less than one inch diameter. The food is prepared and cooked in a steam-jacketed kettle which has a horizontal agitator to ensure the solids are uniformly dispersed. The food is cooked to 82°C and then pumped through a draw-off valve to a filling station and into plastic bags, which are sealed with a metal clip. The food is then cooled in a revolving water bath to between 1° and 4°C.

(2) The second method is used for joints of meat, which are packed into plastic bags, the bags evacuated and clipped. The food is slowly cooked in water tanks (the water temperature being 66°C to 79°C) for up to 8 hours. The tank then is put on a chilling

cycle, when iced water is circulated and the temperature of the food is reduced to below 4°C.

The food is guaranteed by the manufacturers of the equipment to have a shelf life of at least 21 days. As with cook-chill and sous-vide, the system has great potential for danger if not operated to a very high standard (Majewski, 1989), hence the necessity for adequate regulation.

1.12 LEGISLATION

Quite often, the distribution of chilled foods may involve the crossing of international borders. Free trade is necessary and must be facilitated, so national laws cannot act as barriers, as has been seen in the EU. Certain international controls have been put in place to facilitate easy trade.

In Ireland, the main legislation controlling the handling of food is the Food Hygiene Regulations (1950) and the subsequent amendments of 1971 and 1989. The 1989 amendments extended the controls applying to food stalls and specify that

> "meat and meat products, milk and milk products and all other foods and food material susceptible to rapid bacterial growth are kept at a temperature of 3°C or less except when heated or cooked for sale as hot food"
>
> (Article 26A, sub-article 5).

Controls on the transport of chilled food were amended in 1989 also, the specification being that the

> "proprietor of the food business in connection with which a food vehicle is for the time being in use shall..................ensure that meat, meat products (other than fish or fish products), chilled food, chilled food materials, ice cream and all foods susceptible to rapid bacterial growth are transported at an internal temperature of
>
> not more than 7°C in the case of meat in carcases, half carcases or quarters;
> not more than minus 12°C in the case of frozen meat;
> not more than minus 17°C in the case of ice cream;
> not more than 3°C in the case of all other such foods, food products or materials"
>
> (Article 28, sub-article 5, sub-paragraph i).

The above stipulations in Article 28 do not apply to

> "meat in carcases, half carcases, quarters or meat offals transported between an abattoir and a butchers shop over a distance not exceeding five miles"
>
> (Article 28, sub-article 5, sub-paragraph ii

of the Food Hygiene (Amendment) Regulations, 1989).

The U.K. Food Hygiene Regulations of 1990 and 1991 (which are currently under review) specify a number of different temperatures at which chilled food should be stored and displayed, depending on the food. These are illustrated in Table 1.3.

TABLE 1.3: UK LEGISLATION FOOD TEMPERATURE REQUIREMENTS

FOOD	PRODUCT TEMPERATURE
Soft cheese, pate and cooked meats	5°C (or less)
Prepared salads, ready meals	8°C " "
Meals which will be heated before consumption	8°C " "
Desserts	8°C " "
Cooked pies (with some exemptions)	8°C " "
Sandwiches,rolls " "	8°C " "
	(UK MAFF, 1990, 1991)

French Hygiene Regulations for extended storage chilled foods state that products with a 21 day shelf life must receive a heat process equivalent to 100 minutes at 70oc followed by storage at 0 to 3oc and should be of good microbiological quality after a challenge of 14 days storage at 4oc and 7 days at 8oc (Betts, 1992).

There is a proposed Codex Alimentarius Code of Hygiene Practice for Pre-cooked and Cooked Meals in Mass Catering, which deals with the hygienic requirements for cooking and handling cooked and pre-cooked foods for large numbers of people. In this code - chilled foods are defined as "product maintained at temperatures not exceeding 4°C in any part of the product and stored for no longer than 5 days". The code involves the use of HACCP. In 1989, it was agreed that a separate code should be drawn up to cover refrigerated, pre-prepared, extended shelf life foods.

The Agreement on the International Carriage of Perishable Foodstuffs (ATP Agreement) sets common standards to facilitate international distribution (Turner, 1992). The maximum temperatures at which certain foods may be carried are specified:

7° C	for meat
6°C	for meat products, butter
4°C	for poultry, milk, dairy products
3°C	for offal
2°C	for fish

(Bøgh-Sørensen, 1990).

The Agreement also sets standards for the transport equipment e.g. containers (Turner, 1992).

1.13 RATIONALE FOR THE STUDY

In the handling, distribution, storage and retail display of this type of food product, considerable opportunity exists for temperature abuse which can lead to product deterioration and/or consumer hazard. It is therefore necessary to ensure that proper systems exist to control and monitor food, and that equipment is suitably designed, constructed and used to ensure that optimum conditions exist, or that any failure or malfunction will be quickly detected and corrected. This imparts significant responsibilities on food companies in distribution and retailing, and this study purports to determine and evaluate existing practices and policies and, in the light of findings, to propose a Code of Practice which could be put into practice by the relevant industry in order to ensure adequate temperature controls.

1.14 OBJECTIVES OF THE PRESENT STUDY

1. To interview representatives of companies involved in
   (i) the storage and distribution of chilled foods and
   (ii) the retail sale of chilled foods with regard to handling of chilled foods for the purpose of ascertaining company policy.

2. To measure air temperatures, between-pack temperatures, product temperatures and relative humidity at a sample of distribution premises and retail outlets.

3. To compare and evaluate observed temperature measurements and practices with stated company policies.

4. To ascertain the recommended practices in relation to refrigeration equipment by interviewing representatives from refrigeration companies

5. To compare observed practices with refrigeration company recommendations.

6. To devise a Code of Practice in relation to temperature control based on the results found.

CHAPTER 2: MATERIALS AND METHODS

2: MATERIALS AND METHODS

Two major sectors of the chilled food chain were chosen for investigation in this study i.e. the transport and distribution sector and the retail sector. Interviews were conducted with staff, temperature and relative humidity measurements were taken in each case and, finally, observations of existing practices were made.

2.1 MATERIALS

2.1.1 Temperature Measurements

For the air temperature readings in the retail outlets, an Eirelec model 5005 type T thermocouple (0.1°C resolution) was used. Three interchangeable probes were used with this thermometer:

1. The Eirelec TT115 probe, a durable, general purpose probe;
2. the Eirelec TT102 probe, a general purpose probe which has a faster response time than the TT115;
3. The Eirelec TT101 probe, designed for taking between-pack measurements.

In general, the TT102 was used to take air temperatures from the retail outlets, as it was faster to respond than the TT105. The TT101 was used for taking the between-pack readings.

In addition, a Universal Enterprises PDT300K portable digital thermometer was used in the distribution premises.

These thermometers had been calibrated by the manufacturer to NAMAS standard, at the time of purchase, two days before despatch for delivery. The temperature measurements were all taken within six months, before recalibration would be required.

2.1.2 Relative Humidity Measurements

An Eirelec PL200 thermo-hygro recorder and printer logger was employed.

2.2 METHODOLOGY

The Transport and Distribution Sector

Interviews were held with appropriate representatives of eight separate companies involved in transport or distribution of chilled products. The companies are identified by letter from S to Z. In the cases of Companies T and Z, interviews were conducted, but it was not possible to take temperature measurements or make observations in the company premises. The representatives were generally people with responsibility for warehousing and/or transport, for example, a transport manager, a more senior person such as a general manager, or managing director if the company was a small one. These interviews were primarily for the purpose of ascertaining company policy with regard to the handling of chilled foods, together with other relevant, detailed information.

A visit was then made to a cold store on the company premises, where observations were made and various temperature readings were taken.

2.2.1 Interviews with Company Representatives From Distribution Sector

Type and extent of business

Specific questions were asked to clarify the importance of chilled food distribution in relation to the rest of the company's business. Questions covered the following areas:
(i) the scale of the company's business in chilled foods;

(ii) the geographical area covered in the distribution network;
(iii) types of clients e.g.. whether supermarket chains, independent grocery shops, catering outlets etc.;
(iv) types of products dealt with e.g. chilled, frozen or ambient temperature products (or all three), and the proportion of the company's business each represented;
(v) number and types of transport vehicles;
(vi) number of employees;
(vii) and whether any outside contractors were used, and if so, for which operations.

Company policy on handling of chilled foods

Specific questions were asked to determine company policy on the handling of chilled foods. The following areas were covered:

(i) a typical "pathway" for a batch of product, for example, where it was manufactured, how it was transported to the distribution company's premises (whether this was the company headquarters or a regional distribution depot), who was responsible for this initial transportation and how long it took, how long a typical batch would remain on the company's premises and how long the batch would typically spend in transit to the retail outlet. Such investigation was deemed necessary to calculate the total time taken for the the batch to travel from the manufacturer's premises to the retail outlet;
(ii) the product types dealt with;
(iii) whether vehicles were pre-chilled before the product was loaded;
(iv) whether orders were made up in an ambient area or in a cold store;
(v) whether the company had a temperature-controlled loading area or any other special arrangements for

maintaining product temperature during loading operations;

(vi) whether the retail outlets had any specifications regarding both the required and acceptable temperatures for those products being delivered;

(vii) whether staff accepting deliveries at the retail outlet checked the temperature of incoming deliveries, and if so, whether this was carried out on a routine or occasional basis;

(viii) the cold store temperature;

(ix) whether there were any temperature alarms linked to the cold store or the transport vehicles;

(x) whether foods which needed to be held at different temperatures were transported together or separately, and if together, whether any special arrangements were made e.g.. the use of multi-compartment vehicles capable of maintaining several different temperatures simultaneously;

(xi) contingency arrangements made by the company e.g. to have back-up cold storage capacity, or to have a refrigeration engineer on call;

(xii) arrangements, if any, made for training of staff such as drivers, whether training was formal or informal and who was responsible;

(xiii) whether the vehicles were the dual-power type, which can be run by an electric motor as well as by the vehicle's engine;

(xiv) how cleaning of vehicles was carried out and how often;

(xv) and, if the company was a wholesaler, it was asked whether the business was of a "tele-sales" or "van-sales" type operation.

Questions were also asked to determine how important a quality system was to the company i.e.. if they had (or were attempting to gain, at some stage in the future) any kind of formal quality accreditation.

2.2.2 Temperature Measurements from Cold Stores

The Food Safety (Northern Ireland) Order 1991: Code of Practice No. 9: Enforcement of the Temperature Control Requirements of Food Hygiene Regulations (UK Department of Health and Social Services, 1991) was used as a basis for taking all of the temperature measurements. It recommends that a person taking temperature measurements should not prejudice product temperatures by leaving cold room doors open for long periods or by disturbing the air curtain in a cabinet. The Code of Practice also makes the recommendation that the thermometer probe be pre-cooled in the cabinet before taking a reading. These points were taken into consideration when the temperature measurements were carried out.

Air Temperature Measurements

The probe was rested on a shelf in a central position in the cold store. It was placed well away from the door and in an elevated position, so that its tip was not touching any shelf, product or anything which would prevent its giving a true representation of the air temperature in the cold store. The temperature readings (including the between-pack and product temperature readings) were taken on a single occasion, during operating hours and under normal operating conditions. Temperature measurements were not taken while the refrigeration plant was on a defrost cycle.

Between-pack Temperature Measurements

The between-pack probe works by being placed in close contact with two surfaces, the temperature of these being measured. This gives the best possible non-destructive indication of the product temperature. It has the disadvantage of only being suited to regular-shaped packages since with any irregularities in package shape the probe is, in effect, taking the air temperature. The probe was positioned between two flat packages and pushed in as far as possible, so that it was not influenced by the air temperature in the cold store. A site was chosen to give a representative figure for all the stock in the cold room, so products which had only recently been placed in the cold store could not be used. The upper package had to be sufficiently heavy to ensure good contact between the probe and the package.

Product Temperature

This is a destructive type of measurement, so it was not possible to carry it out often. The PDT300K thermometer was used. A package of product was selected as being representative of the stock present, and the probe was inserted into the interior of the product.

In all cases, the probe remained unmoved and in place, for about 3-4 minutes, or until the display remained stable for at least 10 seconds. The probes were pre-chilled in the cold store before use.

Cold Store Temperature Gauge

This reading was taken by observing the reading of the temperature gauge. This was done at the same time as the other readings were taken.

2.2.3 Observations From Distribution Cold Stores

General observations were made on:

(i) the level of activity in the cold store, including the frequency of door openings;

(ii) the types of products in stock;

(iii) the quantity of stock present and what level of capacity was available for incoming stock;

(iv) how the products were stacked within the cold store and whether a system of stock rotation was in operation.

The Retail Sector

Interviews were held with representatives of two supermarket chains. These representatives were usually involved in Quality Control and Staff Training. The interviews were for the purpose of elucidating company policy on the handling of chilled foods.

The interviews were followed by a visit to a number of branches of the supermarket chain. These visits included talks with a member of the store management in order to get an overview of how the particular branch handles chilled foods. Detailed temperature and relative humidity measurements were taken from each of the refrigerated display cabinets and cold stores in the supermarket. While the temperature and relative humidity readings were being taken, observations were made on various operational matters.

2.2.4 Interviews with Representatives of Retail Outlets

The two retail companies were identified by letter i.e. Company Q and Company R. Questions were asked to determine if the company had a policy on the handling of chilled foods, and if so, how they communicated this policy to their staff.

Questions were asked in relation to the following:

(i) whether the temperature of incoming deliveries to stores was checked and, if so, how this was done, by whom, and whether it was carried out on a regular or occasional basis;

(ii) the temperature the company expected deliveries to be at, and the procedure followed if the temperature was not satisfactory;

(iii) the operating temperature of the cold stores;
(iv) whether the companies thought they had sufficient cold storage facilities;
(v) the amount of stock carried, in general, and how long a typical batch of chilled product would remain in the store;
(vi) the type of refrigeration system used, i.e. whether individual refrigeration units or units run off a central plant;
(vii) whether the individual stores had temperature alarms on the refrigeration systems;
(viii) whether staff received any training in the handling of chilled foods, and if so, what the nature of this training was and who was responsible;
(ix) whether staff received any instruction on the correct method of loading refrigerated display cabinets;
(x) whether any routine checks were made on the temperature of the display cabinets, and if so, how often this was carried out, by whom, and how it was done i.e. whether the display gauge on the cabinet was checked, or whether a hand-held probe was used;
(xi) how often the refrigeration equipment was serviced;
(xii) any contingency arrangements provided for; and
(xiii) whether the suppliers' premises or the premises of distribution companies were ever visited.

Visits to Individual Retail Outlets

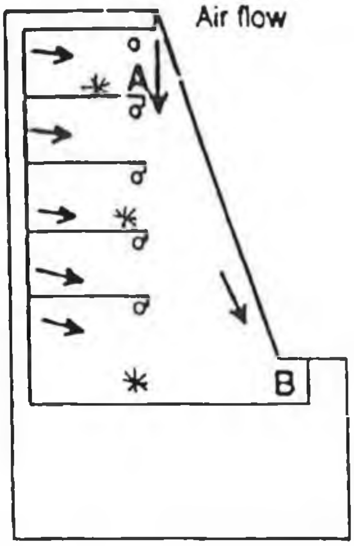
Visits were made to individual outlets. These comprised of three branches of one supermarket multiple, two branches of a separate multiple and one large independent supermarket (of similar size to the other supermarkets). The individual supermarkets were identified by a letter from A to F. In relation to the supermarkets, temperature readings were taken from each of the refrigerated display cabinets and cold rooms in the stores and relative humidity measurements were taken from each of the refrigerated display cabinets. The temperature measurements were taken over the course of a single day, under normal operating conditions, while the store was open for business. None of the cabinets were on a defrost cycle when the temperature measurement was carried out.

2.2.5 Air Temperatures of Refrigerated Display Cabinets

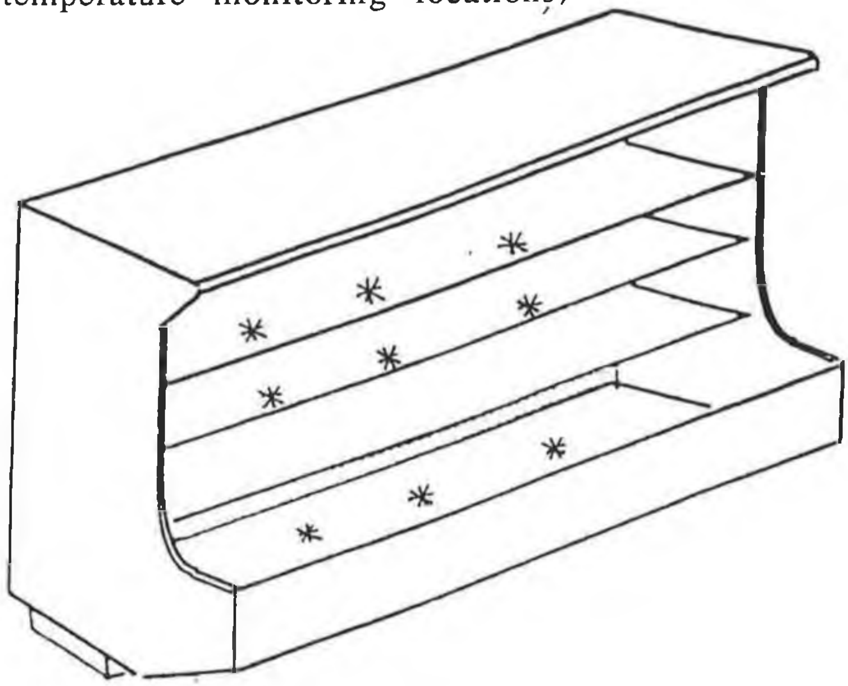
Initially, the probes were pre-chilled by placing them in a refrigerated cabinet for 2-3 minutes.
Then the cabinet was surveyed to ascertain the number of shelves it contained and its length. For a cabinet with three shelves, readings were taken from all three shelves. For a cabinet with five shelves, readings were taken from the top, bottom and middle shelves. For each shelf, a reading was taken approximately every 2 metres along the length of the cabinet. Therefore the number of measurements taken in each cabinet is related to the length of the cabinet. Thus there was one measurement taken per shelf in the smallest cabinets and thirteen per shelf in the largest cabinet. There were twenty-one measurements taken in the longest delicatessen-type cabinet. This type of cabinet had only one shelf for storing food and the thermometer probe was placed on this. The measurements were taken at regular intervals. The readings for each shelf were taken directly below the equivalent reading for the shelf above. There was a single measurement taken at each location within the cabinets. Figure 1 illustrates the locations where temperature measurements were taken in a typical cabinet.

FIGURE 1: ILLUSTRATIONS OF REFRIGERATED DISPLAY CABINETS

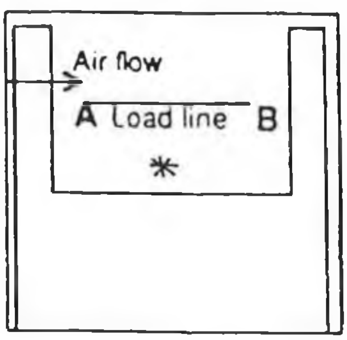
(showing typical temperature monitoring locations)



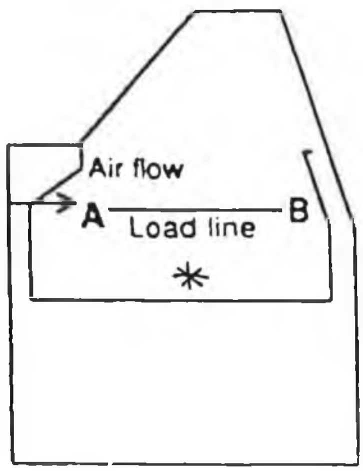
Section through Multi-Shelf Type Cabinet



Multi-Shelf Cabinet



Section through Island-Type Cabinet



Section Through Delicatessen Serve-Over Cabinet

Notes:

*: location of temperature monitoring probe.

In the case of the fish display cabinets (Tables 3.20 and 3.21) the fish was displayed on a layer of ice. The air temperature was taken 1cm above the surface of the ice. Some of the cabinets in the "other" category were very small and only required one temperature measurement.

The probe was placed in the chosen location, well into the centre of the shelf. The base of the probe was resting on a food package and its tip was elevated slightly and not touching either the package or the shelf, thus ensuring that only the air temperature would be taken. The probe had to be located in the centre of the shelf so that the reading would not be affected by air movement. The probe was left in place for approximately 3 minutes or until the display had remained stable for at least 10 seconds. The readings were then recorded and the probe moved to the next location as quickly as possible, so that it would be exposed to ambient air temperature for the shortest possible time.

2.2.6 Between-Pack Temperature of Refrigerated Display Cabinets

The probe was pre-chilled as before. The locations were chosen with the aforementioned principles in mind. A lesser number of readings was taken in this case, as only a limited number of areas in the cabinets had sufficiently uniform-shaped packages, with sufficient weight on the probe to ensure good contact between the probe and the package. Where a suitable location was found, the probe was placed firmly between two packs and left in position for approximately 3 minutes or until the display remained stable for at least 10 seconds.

In the case of the serve-over cabinets, the same principles were applied, except that these cabinets had only a single shelf, instead of three or five. Food was generally unwrapped or in very small packages in these cabinets, so it was not practical to take between-pack measurements.

It was anticipated that the results of temperature measurements, observations and evaluation of company policies would clarify whether the formulation of a Code of Practice was justified.

2.2.7 Relative Humidity of Refrigerated Display Cabinets

The measurements of relative humidity were taken at the same locations in the cabinets as the air temperature, and at the same time. The same principles applied to ensure the measurement was taken in the air and was not affected directly by nearby packaging.

2.2.8 Air Temperatures of Cold Rooms

With the cold rooms, it was only possible to take air temperatures as food was often unwrapped or in bulk containers and stacked on the shelves in insufficient depth to permit between-pack measurement. The air temperatures were taken as for the cold stores in the distribution depots.

Where a temperature gauge could be located on the cabinet or cold store, a reading was noted at the time of taking the other measurements at that location.

2.2.9 Observations From Retail Outlets

Together with all the measurements taken in the retail outlets, observations were made on the following:

(i) stacking and loading methods;
(ii) food types stored together;
(iii) general hygiene in cabinets, cold rooms and ancillary areas;

(iv) whether any staff were seen to be checking the temperature of the cabinets;

(v) whether a temperature alarm system was in operation;

(vi) any information provided to customers e.g. on temperatures of cabinets, defrost times etc.

(vii) how deliveries of chilled foods were dealt with and by whom.

2.2.10 <u>Interview with Refrigeration Company Representative</u>

An interview was also held with a representative of a refrigeration supply company to get general information on refrigerated display cabinets and how they should be operated and maintained.

CHAPTER 3: RESULTS

The results are presented as follows: the findings from interviews with representatives of distribution companies are given first. These are followed by the temperature measurements taken from the distribution companies' premises which are given in Table 3.1. The findings from interviews with supermarket company representatives are given next, followed by results of temperature and relative humidity measurements (Tables 3.2 to 3.31 inclusive). The final set of results is made up of findings from interviews with refrigeration company representatives.

3.1 INTERVIEWS WITH REPRESENTATIVES OF DISTRIBUTION COMPANIES

Interviews were held with representatives of eight separate companies involved in transport or distribution of chilled foods. Varying types and amounts of information was obtained and due to the differences in business and circumstances with each company, the results will be given individually. The companies have been identified by letter.

Company S

This company was discovered to be primarily dealing in frozen foods, with a very limited business in chilled foods. Therefore the interview was not as detailed as with the other companies. Frozen and chilled foods are distributed to restaurants, hotels and hospitals. Rigid, dual powered trucks which can be run off an electric motor when the vehicle's engine is turned off and have a temperature gauge are used for transport.

Deliveries from suppliers are rejected if found to be at a temperature outside the desired range, but the representative admitted that most checking of temperature of deliveries occurs in relation to frozen food. Chilled food is stored in the company's cold store at between -2°C and 2°C. A temperature recorder which gives a printout in the cold store is checked regularly. Order picking takes place inside the cold store. Some of the company's customers take the temperature of deliveries using a digital probe.

Company T

This company operated out of a large warehouse using 12 vehicles ranging from medium-sized vans to articulated trucks. Their largest customer is a company which manufactures dairy products. Products are delivered to multiple supermarket groups, smaller independent supermarkets and wholesalers in the Republic of Ireland only. They are the only distribution company providing this service throughout the Republic of Ireland.

Temperatures are monitored in the warehouse and also all of the vehicles have gauges displaying the air temperature. Between-pack temperatures of incoming deliveries were taken. It was also stated that most of their customers take the temperature of deliveries on arrival and they have not had any experience of rejection of deliveries due to inadequate temperature control.

Company U

This company, which are distributors, retailers and wholesalers of chilled and frozen fish, shellfish and poultry, operates out of premises in the centre of Dublin. Most of their business is carried out within a 50 mile radius of Dublin. Any countrywide distribution is done by courier using refrigerated vehicles. Products are sold to all of the major supermarket chains, small independent shops and catering outlets. A fleet of about 15 medium-sized rigid trucks is used for transport.

Fish is mainly purchased in the West of Ireland after which it is transported to the premises in Dublin, where it is filleted, placed in layers, alternating the fish with layers of ice and plastic sheets and then sealed into a polystyrene carton. Transport is carried out overnight. Shellfish is imported from all over the world. The company operates two "factory ships" which can process fish on board ship for export or the Irish market. The trucks are fitted with a temperature gauge and plastic strips at the door area and are pre-chilled before loading. Daily readings are taken of temperatures in the trucks and in the cold stores. Some checking of temperatures of deliveries is carried out by customers. An outside company is sometimes used for back-up cold storage and an engineer is permanently on call in case of breakdown. The company is striving for ISO 9000. It was admitted, however that unrefrigerated trucks are sometimes used if loading by forklift of a refrigerated truck is not possible due to the size of the door opening.

Company V

This company specialises in distribution of frozen foods but also deals with chilled cheese, margarine, pasta sauce, mayonnaise, pizza bases, fresh poultry and cooking oil (which is an ambient-temperature product but is stored in the chilled store for convenience). Ten refrigerated rigid 8 metre trucks, in which the refrigeration system is dual-powered, are used to deliver to their customers in the catering and retail sectors. All of their suppliers deliver to their premises. The company distribute around the Republic of Ireland using depots in Dublin, Cork and Galway. Delivery is carried out 5 days a week.

The temperature of incoming deliveries is checked and recorded and the delivery is rejected if it is outside the range: -2°C to 2°C. The chilled food storage area was found to be extremely understocked at the time the premises was visited. A temperature recorder activates an alarm in the manager's office if the temperature falls outside a certain range. The trucks also contain temperature recorders which the driver checks on reaching a destination and records the temperature in his log. The trucks are pre-chilled before loading and the refrigeration unit is left on during loading. Loading is carried out in a temperature-controlled loading area. Vehicles are cleaned every evening (inside and outside on alternate days). Staff are trained by the two shift supervisors. The company operates a stock rotation system where batches are colour coded. It was also observed that there were numerous notices displayed around the premises, informing staff about various aspects of product handling and company rules.

Company W

This company also specialises in frozen foods which make up 80% of its business, but distributes milk, processed fish, spiceburgers, bacon, sausages and about 15 other lines throughout the 32 counties. Delivery is mainly to the branches of a major supermarket chain, with few other customers. Depots are in Cork, Limerick, Galway and the North of Ireland. There are 15 drivers in Dublin. Incoming deliveries from the UK are delivered within 24 hours, 6 days a week by a private haulage company. Trucks are mainly of the large rigid type and generally run at frozen temperatures, but can be adjusted up or down.

Incoming deliveries are checked to ensure that they are of the correct temperature as soon as they arrive. The recommended temperature is 2°C, but 3°C will be tolerated, otherwise the delivery would be rejected. The supermarket chain carries out checks on deliveries, which must not be in excess of 4°C, to ensure acceptance. Various spot checks on trucks and the cold store are usual. Drivers are trained in how to handle products and also in the maintenance of refrigeration units in the vehicles.

Company X

Company X distributes chilled, frozen and ambient products to all the branches of a single customer - a restaurant chain, throughout the 32 counties. They use rigid and articulated trucks which are divided into three separate compartments for the three types of foods (ambient, chilled and frozen).

In the chilled storeroom, which has adequate capacity, a temperature recorder gives a printout in a graph form every day. The store is run at 2°C to 4°C and a bottle of water is kept inside it for the purpose of checking the temperature using a probe, which eliminates the need for destructive product testing. This probe is calibrated in iced water every day. There are plastic strips at the entrance to the cold store and there is a policy of stock rotation. Orders are made up inside the store, and held there until loading, to minimise the amount of time the products spend at room temperature. The vehicles are pre-cooled only on days with a high ambient temperature. A recorder monitors the temperature in the vehicles every 5 to 15 minutes and gives a weekly graph printout. On reaching the destination restaurant, the vehicle will not be opened until ready to be unloaded. The loading/unloading process is said to take between 15 minutes and 1 hour. Staff at the restaurant will frequently check temperature of deliveries and if found to be outside the recommended range, a senior supervisor or assistant warehouse manager from Company W will travel to the restaurant with a temperature probe to re-check the temperature. If still found to be inadequate, the entire load will be rejected. The interior of the vehicles is usually cleaned once a week and any spillages are cleaned up immediately. Staff do not receive formal training, but have recommended company practice verbally communicated to them. The representatives interviewed had a good knowledge of the handling of chilled foods and recognised that some of the products they dealt with were very susceptible to temperature abuse. The restaurant chain is a multi-national company and representatives visit the premises of Company W occasionally to evaluate the premises. A complete audit is carried out once a year.

Company Y

Eight refrigerated transit vans are used to distribute mainly chilled products and some ambient products to independent traders and some supermarkets which, although independently owned, are members of a chain. Deliveries are made to all over Dublin and most of Leinster. The chilled food business is run on a van-sales operation, which means that stock is carried in the van to cover expected sales, which are not decided until the customer is visited. Any unsold stock is returned to the cold store in the warehouse at the end of each day. At the time of the interview, the company had just introduced a frozen food range. However, this business was small-scale and on a tele-sales basis, meaning that orders are phoned or faxed into the company and only the stock which has been ordered is carried in the vans. The frozen food was being transported in the refrigerated vans at that time and the frozen food was delivered as early in the delivery run as possible.

The van driver phones the depot each afternoon with the expected stock needed for the next day. Each morning, he visits the depot and loads the previously made-up order into the van. Any unsold stock is returned to the depot. Deliveries from suppliers, of which there are about 20-30, are not routinely checked, nor are the temperatures of stored products. However the cold store has a temperature gauge which is regularly checked. The average retention time in the cold store is 4-5 days. Deliveries in unrefrigerated vehicles will not be accepted unless in an emergency situation. The company has not had any deliveries rejected as a result of poor temperature.

Company Z

This company manufactures sausages and pudding from fresh pig carcases which are delivered each morning by two suppliers in rigid refrigerated trucks. Products are supplied to colleges, hospitals, hotels and other catering outlets in the Dublin area, using 4 small refrigerated vans.

Checks of temperature control on the suppliers are not carried out, but butchers visit the premises and visually inspect the carcases. Carcases seen to be of inferior quality are rejected. Orders are phoned in from customers, made up and stored in cold rooms until loading into the van the next day. No excess stock is carried. The temperature in each of the two cold rooms are checked twice daily, and should be at 0°C. The vans return to the depot when empty and the two vans covering the city centre generally return more than once a day to collect stock. There is a temperature gauge in the vans. Any customer complaints or problems with the refrigeration unit or the van are recorded on a daily report sheet.

3.2 TEMPERATURES MEASURED IN PREMISES OF DISTRIBUTION COMPANIES

Air temperatures and between-pack temperatures were measured in the cold rooms in the premises of the distribution companies which were visited. In two cases, it was possible to take product temperature also by inserting the probe directly into the product. The results are given in Table 3.1.

TABLE 3.1
RESULTS OF TEMPERATURE MEASUREMENTS IN DISTRIBUTION COMPANIES' COLD STORES (°C)

Temperature	Air	Between-Pack	Dial	Product
Company S	0.0	0.5	-1.0	-
Company U	5.5	2.4	2.7	-
Company V	-2.7	2.5	-	0.5
Company W	0.6	2.7	2.7	-
Company X	2.9	3.8, 3.3	2.9	2.9
Company Y	-2.3, 2.8	0.8, 2.5	-1.5, 2.0	-

Note:
There were two cold rooms at the premises of Company Y, so therefore there are two figures for each class of temperature reading.

The highest air temperature recorded was in Company U, at 5.5°C. However, the between-pack temperature was found to be 2.4°C, which would suggest that the 5.5°C was only a temporary rise perhaps due to the door being left open or a large delivery of warm product being placed in the cold store, or perhaps that the elevated air temperature had not yet made an impact on the product temperature. All of the air temperatures in the other cold stores were less than 3°C and therefore satisfactory. In fact, two were below 0°C.

Company X was the only location where the between-pack temperatures were greater than 3°C. There were two readings, of 3.8°C and 3.3°C taken in company X and these were only slightly above the recommended 3°C and compared with the product and air temperatures in company X of 2.9°C. The slightly higher between-pack temperature could be explained by the fact that the probe was inserted between two cardboard boxes (cardboard boxes being a very common method of storing products in cold stores). The product temperature was obtained by inserting the probe directly into a package of lettuce. The between-pack temperature would be more accurate when the probe is placed between, for example plastic packs of bulk meat or foil packs of butter, as would be found in a supermarket.

The temperature gauges seen appeared to be accurate as the gauge readings and the air temperatures, as measured, were often within 1°C of each other and always within 3°C.

3.3 INTERVIEWS WITH REPRESENTATIVES OF SUPERMARKET COMPANIES

Company Q

An interview was held with a person responsible for quality control, the implementation of policy, planning of new supermarkets and staff training. This company does not have a formal written policy on chilled foods, but there are a number of practices which are common to all its branches.

All potential suppliers are audited before being accepted. Spot checks of temperature are carried out on deliveries using a hand-held probe and there are also organoleptic checks of the delivery vehicle for hygiene and "coolness" and the delivery personnel for personal hygiene and the wearing of proper protective clothing, if necessary. If deliveries are found to be at too high a temperature, the supplier receives a warning, but the delivery is not rejected unless the temperature is excessively high. The limit at which a temperature is considered to be too high was not specified. If there is any doubt about the temperature history of a delivery found to be at a high temperature, the delivery is rejected.

There is back-up cold storage available and the cold stores are run at about 0°C. It is policy to keep a minimum of back-up stock in a store. A chargehand responsible for the temperature of particular cabinets reads the fixed gauge about four times daily and records the temperature on a special chart which is displayed on top of the cabinet in view of customers. There is also a sign displayed on each cabinet giving the recommended range of the cabinet and requesting customers to notify a staff member if the reading on the dial is outside this range. A digital thermometer is used to take occasional checks of the temperature in the display cabinets. It was stated that it is policy to only put cool products into the cabinets and not to cover air vents in cabinets or to stack above the load line.

Only one of the branches of Company Q which was visited had the defrost times of each cabinet printed on the cabinet.

All staff undergo a 3 day training course in food hygiene and this is followed up by a Certificate in Food Handling Course (1.5 day duration) a few months later. Some staff, for example those working behind the delicatessen counter, undergo a 1 week course. It was stated that Company Q planned carefully the location of new cabinets with regard to draughts, but it was recognised that sometimes the recommendations of quality control personnel were ignored by store management who were most concerned with maximising sales.

Company R

An interview was held with a person responsible for Quality Control and some training of staff. This company is similar to Company Q in that it does not have a formal written policy but an informal policy is operated.

The manufacturing premises of all suppliers and distribution depots, if relevant, are visited by staff of the company. Goods inwards personnel check deliveries, paying particular attention to poultry. Spot checks are carried out on delivery vehicles and if the temperature of a delivery is found to be above 5°C, the delivery is rejected.

Each store has a thermometer to check temperatures and all display cabinets have temperature gauges. A probe is used to check temperatures twice daily, and the results are recorded. The newer stores may have a temperature alarm system. It is policy to ensure cabinets are run at 3°C or less.

Regular hygiene audits are carried out on all stores. There is an ongoing staff training programme, which involves a 4 hour food hygiene course which includes the use of audio-visual material. This is followed up by a refresher course. This is supplemented by the official Health Board food hygiene course, which is given by Environmental Health Officers.

3.4 AIR TEMPERATURES MEASURED IN SUPERMARKETS

Air temperatures and between-pack temperatures were measured in each of the retail display cabinets, salad display cabinets and walk-in cold storage areas of six supermarkets. Five of the six supermarkets were branches of large multiple chains. There were two different chains involved. The remaining supermarket was of a similar size to the branches of the chains, but was independently owned.

For the purposes of presentation of results the cabinets were categorised according to the principal foods stored in them, i.e. those containing mainly meat and meat products, those containing mainly milk and dairy products, and those cabinets of a similar design to those mentioned above, but which did not contain either meat or dairy products. Some supermarkets had only meat or dairy cabinets with other foods such as fruit juices or fresh soups stored alongside meats or dairy products. Delicatessen-style serve-over cabinets, which normally contained foods such as unpackaged sliced cooked meats, unpackaged raw meat and cheeses were of a different design as the customer did not have direct access to the food and it was removed from the cabinet by a sales assistant. The other two categories were salad display bars and walk-in cold stores, which were used for storage only and not display. There were only three broadly different types of cabinet encountered, these are referred to as "multi-shelf", "milk" and "island" cabinets. The multi-shelf cabinet was the most common type seen and was an upright cabinet with 3-5 shelves and access from the front which was completely open. The milk cabinet was similar to the multi-shelf, except for the bottom of the cabinet, into which steel trolleys containing cartons of milk were wheeled. This milk cabinet was only used for the storage of milk and cream and so measurements taken are presented in the dairy category of results. The island cabinet (only seen in one supermarket) was completely different and much smaller. It looked similar to a normal chest freezer, being basically a box-like chamber, open at the top for access. It contained no shelves, the food was simply placed into the cabinet. Illustrations of cabinet types are given in Figure 1 (page 64).

During the visits to the supermarkets, observations were made on the condition of the cabinets, whether they were overloaded, whether food was placed into the cabinets without delays at ambient temperature and whether stock rotation appeared to be practised. Where readings were higher than the recommended display temperature for the food, the author examined all visible aspects of the cabinet and surrounding area and observed methods of handling of the food in order to ascertain possible causes.

The temperature of 3°C has been selected as the most appropriate maximum temperature for most products based on the minimum growth temperatures reviewed in the Introduction. The UK Department of Health recommends a temperature of 0°C to 3°C for cook-chill foods (UK Dept. of Health, 1989). The National Standards Authority of Ireland in a Draft Code of Practice for Chilled and Frozen Foods recommends a temperature of 0°C to 2°C for storage of chilled food and a temperature of less than 3°C for retail display of chilled food. The same Code of Practice recommends a Relative Humidity value of 85% to 95% (NSAI, as yet unpublished). Prescott and Geer recommended in 1936 that foods in which microorganisms can grow should be stored at less than 10°C and preferably at 4°C (Walker, 1992). The Institute of Food Science and Technology recommends that foods which spoil rapidly such as raw meat should be stored at -1°C to 2°C and other foods should be kept at 0°C to 5°C. Foods which do not rely totally on temperature control to prevent microbial growth should be stored at 0°C to 8°C (IFST, 1991). Farquhar recommended in an American code of practice that meat should be kept at -1°C to 1°C, while dairy products, cook-chill products and prepared salads should be kept at 0°C to 4°C (Farquhar, 1992). An upper limit of 3°C would represent an acceptable balance between what is readily achievable and what is necessary to reduce the risk of microbial growth.

The mean temperature has been calculated for each individual cabinet. There was no distinction made between the different shelves when calculating the mean temperature.

3.4.1 Cabinets Containing Meat and Meat Products

These were cabinets in which the majority of the cabinet space contained meat or meat products, although some cabinets may have contained other products. Cabinets were mainly of the multi-shelf variety, although Supermarket C had one island cabinet. The air temperatures for these cabinets are given in Tables 3.2 to 3.7 inclusive.

TABLE 3.2 AIR TEMPERATURES (°C)
CABINETS CONTAINING MAINLY MEAT AND MEAT PRODUCTS

SUPERMARKET A

Multi-Shelf Cabinet No. 1						
	No.	Air Temperature in °C				
Top Shelf	3	-0.3	18.2	-0.8		
Middle Shelf	3	0.8	3.6	0.4		
Bottom Shelf	3	3.3	0.7	3.6		
Mean Temperature No. 1		3.3				
Cabinet Gauge No. 1		-1.0	-1.0	-2.0		
Multi-Shelf Cabinet No. 2						
	No.	Air Temperature in °C				
Top Shelf	5	12.2	4.8	7.1	8.4	4.9
Middle Shelf	5	2.5	-1.6	-1.3	10.9	3.9
Bottom Shelf	5	0.5	-3.2	-3.2	-1.2	2.1
Mean Temperature No. 2		3.1				
Cabinet Gauge No. 2		-5.0	-7.0	1.0		
Minimum Temperature		-3.2				
Maximum Temperature		18.2				

Notes:

No.: Number of measurements taken from each shelf.

Measurements are taken at regular intervals along the length of each cabinet.

TABLE 3.3 AIR TEMPERATURES (°C)
CABINETS CONTAINING MAINLY MEAT AND MEAT PRODUCTS

SUPERMARKET B

Multi-Shelf Cabinet No. 1							
	No.	Air Temperature in °C					
Top Shelf	6	0.6	5.4	2.9	1.5	2.9	4.7
Middle Shelf	6	1.1	3.5	1.3	1.5	1.2	6.9
Bottom Shelf	6	1.4	2.4	2.2	4.0	3.5	6.8
Mean Temperature No. 1		3.0					
Cabinet Gauge		0.1	5.0				

Multi-Shelf Cabinet No. 2						
	No.	Air Temperature in °C				
Top Shelf	5	3.5	5.4	5.0	2.8	2.7
Middle Shelf	5	4.7	6.0	13.2	2.8	2.4
Bottom Shelf	5	5.1	6.5	5.6	5.3	10.0
Mean Temperature No.2		5.4				
Cabinet Gauge		2.0				

Multi-Shelf Cabinet No. 3			
	No.	Air Temperature in °C	
Top Shelf	2	7.4	7.7
Middle Shelf	1	N.R.	11.0
Bottom Shelf	2	3.5	9.3
Mean Temperature No. 3		7.8	

Minimum Temperature	0.6	Maximum Temperature	13.2

Notes:

No.: Number of measurements taken from each shelf.

Measurements are taken at regular intervals along the length of each cabinet.

N.R.: no reading possible at this location due to draught. The temperature display on the thermometer was in a constant state of flux.

TABLE 3.4 AIR TEMPERATURES (°C)
CABINETS CONTAINING MAINLY MEAT AND MEAT PRODUCTS

SUPERMARKET C

Multi-Shelf Cabinet No.1					
	No.	Air Temperature in °C			
Top Shelf	1	4.9			
Middle Shelf	1	2.6			
Bottom Shelf	1	5.8			
Mean Temperature No. 1		4.4			
Cabinet Gauge		2.0			
Multi-Shelf Cabinet No. 2					
	No.	Air Temperature in °C			
Top Shelf	4	2.8	0.1	4.5	4.6
Middle Shelf	4	-0.1	0.8	0.3	0.1
Bottom Shelf	4	2.4	2.0	1.6	1.9
Mean Temperature No. 2		1.8			
Cabinet Gauge		-0.2	-1.2		
Multi-Shelf Cabinet No. 3					
	No.	Air Temperature in °C			
Top Shelf	4	13.6	4.4	8.4	1.7
Middle Shelf	4	11.9	5.5	4.2	0.8
Bottom Shelf	4	7.3	7.2	2.7	1.6
Mean Temperature No. 3		5.8			
Island Cabinet No. 1	No.	Air Temperature in °C			
	1	2.2			
Cabinet Gauge No.1		-0.2			
Island Cabinet No. 2	No.	Air Temperature in °C			
	1	-1.9			
Cabinet Gauge No. 2		0.0			
Minimum Temperature	-1.2	Maximum Temperature			13.6

Notes:

No.: Number of measurements taken from each shelf. Measurements are taken at regular intervals along the length of each cabinet.
One measurement only was taken in island cabinets due to their size.

TABLE 3.5 AIR TEMPERATURES (°C)
CABINETS CONTAINING MAINLY MEAT AND MEAT PRODUCTS

SUPERMARKET D

Multi-Shelf Cabinet No. 1							
	No.	Air Temperature in °C					
Top Shelf	3	7.1	2.4	5.1			
Middle Shelf	3	2.3	-1.7	2.6			
Bottom Shelf	3	4.0	0.8	4.0			
Mean Temperature No. 1		3.0					
Cabinet Gauge		-3.0					
Multi-Shelf Cabinet No. 2							
	No.	Air Temperature in °C					
Top Shelf	6	1.3	-0.5	1.2	4.4	1.2	-0.3
Middle Shelf	6	0.7	-1.6	-1.0	-5.3	1.1	4.6
Bottom Shelf	6	0.0	0.8	0.0	-2.3	2.9	-0.9
Mean Temperature No. 2		0.4					
Multi-Shelf Cabinet No. 3							
	No.	Air Temperature in °C					
Top Shelf	6	-0.8	-1.3	1.2	0.5	-1.5	4.0
Middle Shelf	6	-1.4	19.3	-0.4	-0.1	-1.9	4.0
Bottom Shelf	6	-0.1	12.9	0.3	-0.7	1.5	0.9
Mean Temperature No. 3		2.0					
Minimum Temperature	-5.3			Maximum Temperature			19.3

Notes:
No.: Number of measurements taken from each shelf.

Measurements are taken at regular intervals along the length of each cabinet.

There were no cabinet gauges on Cabinets No. 2 and No. 3.

TABLE 3.6 AIR TEMPERATURES (°C)
CABINETS CONTAINING MAINLY MEAT AND MEAT PRODUCTS

SUPERMARKET E

Multi-Shelf Cabinet No. 1							
	No.	Air Temperature in °C					
Top Shelf	6	11.7	14.8	6.6	3.2	6.3	7.1
Middle Shelf	6	13.9	7.5	5.9	6.7	4.3	8.1
Bottom Shelf	6	14.8	7.8	5.5	1.7	6.8	8.9
Mean Temperature No. 1		7.9					
Cabinet Gauge		9.0	0.0				
Multi-Shelf Cabinet No. 2							
	No.	Air Temperatures in °C					
Top Shelf	3	1.4	3.6	1.6			
Middle Shelf	3	1.8	2.9	2.5			
Bottom Shelf	3	2.5	3.4	6.1			
Mean Temperature No. 2		2.9					
Multi-Shelf Cabinet No. 3							
	No.	Air Temperature in °C					
Top Shelf	1	18.2					
Middle Shelf	1	12.8					
Bottom Shelf	1	4.6					
Mean Temperature No. 3		11.9					
Minimum Temperature	1.0			Maximum Temperature			14.8

Notes:

No.: Number of measurements taken from each shelf.

Measurements are taken at regular intervals along the length of each cabinet.

There were no cabinet gauges on Cabinets No. 2 and No. 3.

TABLE 3.7 AIR TEMPERATURES (°C)
CABINETS CONTAINING MAINLY MEAT AND MEAT PRODUCTS

SUPERMARKET F

Multi-Shelf Cabinet No. 1									
	No.	Air Temperature in °C							
Top Shelf	15	1.3	1.3	4.0	2.2	3.3	7.0	3.0	2.1
		1.1	1.4	-2.1	1.2	-0.2	1.7	1.5	
Middle Shelf	15	1.1	2.4	1.8	1.0	0.3	-2.8	2.7	0.1
		0.5	-0.6	-1.5	0.1	-0.6	1.6	-0.4	
Bottom Shelf	15	2.0	3.4	-0.1	1.8	1.1	-0.5	2.4	3.2
		3.4	0.6	0.6	0.1	0.1	2.9	0.3	
Mean Temperature No. 1		1.2							
Cabinet Gauge		0.0	0.0	1.0	0.0	0.0			

Multi-Shelf Cabinet No. 2								
	No.	Air Temperature in °C						
Top Shelf	4	7.5	2.5	1.1	N.R.	N.R.	15.5	N.R.
Middle Shelf	7	2.2	2.1	-0.1	2.1	1.0	2.6	3.6
Bottom Shelf	7	1.4	0.3	0.7	-2.6	-2.4	-1.2	0.2
Mean Temperature No. 2	2.0							
Cabinet Gauge	0.0	0.0	0.0					

Multi-Shelf Cabinet No. 3				
	No.	Air Temperature in °C		
Top Shelf	3	5.7	7.5	10.3
Middle Shelf	3	5.4	6.5	9.0
Bottom Shelf	3	4.1	6.7	5.6
Mean Temperature No. 3	6.8			
Cabinet Gauge	3.0			

Minimum Temperature	-2.8	Maximum Temperature	15.5

Notes:

No.: Number of measurements taken from each shelf.

Measurements are taken at regular intervals along the length of each cabinet.

N.R.: No reading possible at this location due to draught. The temperature display on the thermometer was in a constant state of flux.

The means and ranges are informative, but may be affected by unusually high readings. These high readings occur occasionally and can often be explained simply. For example, in multi-shelf cabinet no. 3 in Supermarket D (Table 3.5) there were two readings taken of 19.3°C on a middle shelf and 12.9°C on the bottom shelf directly below. At this location, there was a draught observed to be coming from an air conditioning vent directly above. The next highest reading in this cabinet is 1.5°C, therefore the two very high readings can be seen to be highly inconsistent with the temperature in the remainder of the cabinet. However, it cannot be overlooked that there was food being stored at these high temperatures, although the duration of display is not known for foods in any of the cabinets in any location. Similarly, there is a reading absent for cabinet no. 3 in Supermarket B (Table 3.3) as a definite reading could not be taken due to the fact that the observed temperature on the thermometer was fluctuating between 5°C and 10°C. (The probe was left in place for at least five minutes, but the display was observed to be fluctuating wildly between 5°C and 10°C even after five minutes). A draught was observed to be coming from a door to a storage area which was opposite the cabinet (which contained very little stock).

The range of temperatures within the individual cabinets is very wide in Supermarket A (Table 3.2). There were some very high readings (18.2°C, 12.2°C, 10.9°C) alongside some readings below 0°C in the same cabinets (-0.8°C, -3.2°C) and a rise in temperature from the bottom to the top of cabinet is visible in Cabinet no. 2, but not in Cabinet no. 1. Cabinet No. 3 in Supermarket C also had a wide range of temperatures within a relatively small cabinet. No significant temperature gradients i.e. greater than 1°C were observed between top and bottom shelf readings in the majority of meat cabinets. There were variations found throughout all of the cabinets, along the length of the cabinet and between the different shelves.

The minimum air temperatures were below 0°C in four out of the six supermarkets and the lowest overall was -5.3°C (Supermarket D, Table 3.5).

It is interesting that the cabinet gauge in Cabinet No. 1 in Supermarket D (Table 3.5) read -3.0°C, while temperatures in the cabinet were all higher than this, ranging from -1.7°C to 7.1°C. The cabinet gauges in Cabinet No. 1 in Supermarket E showed two different temperatures of 9.0°C and 0.0°C (two gauges in different areas of the cabinet), while temperatures in the cabinet ranged from 1.7°C to 14.8°C, with a large number of temperatures above 3°C.

Tables 3.8 to 3.13 inclusive show the proportion of measurements which were above 3°C in each cabinet. This is useful as it illustrates the proportion of unsatisfactory temperatures. The proportion of results above 3°C in Supermarket E was quite high (Table 3.12) when compared to the other supermarkets. Supermarket F had a reasonably low proportion of temperatures above 3°C, except for one cabinet, in which all the readings were above 3°C (Table 3.13). The other supermarkets had varying results, with all temperatures in some cabinets greater than 3°C and a small proportion of temperatures above 3°C in other cabinets.

It is interesting to note that the proportion of between-pack temperatures is always equal to, and usually higher than, the proportion of air temperatures above 3°C.

TABLE 3.8 PERCENTAGE OF AIR AND BETWEEN-PACK MEASUREMENTS ABOVE 3°C, SUPERMARKET A

SUPERMARKET A			
CABINET TYPE	CABINET NO.	AIR %	BETWEEN-PACK %
MEAT	1	44	100
MEAT	2	47	67
DAIRY	1	75	100
DAIRY	2	100	100
DAIRY	3	100	100
COLD STORE	-	0	-
DELI.	-	67	-
SALAD BAR	-	100	-
MEAN %	-	67	93

Notes: The mean % is calculated using all the measurements obtained in the supermarket.

TABLE 3.9 PERCENTAGE OF AIR MEASUREMENTS ABOVE 3°C SUPERMARKET B

SUPERMARKET B		
CABINET TYPE	CABINET NO.	AIR (%)
MEAT	1	33
MEAT	2	73
MEAT	3	80
DAIRY	1	100
DAIRY	2	50
DAIRY	3	100
DAIRY	4	100
OTHER	1	11
COLD STORE	-	57
DELI.	-	71
SALAD BAR	-	100
MEAN %	-	70

Notes: The mean % is calculated using all the measurements obtained in the supermarket.

TABLE 3.10 PERCENTAGE OF AIR MEASUREMENTS > 3°C, SUPERMARKET C

SUPERMARKET C		
CABINET TYPE	CABINET NO.	AIR (%)
MEAT	1	67
MEAT	2	17
MEAT	3	67
MEAT	1	0
MEAT	2	0
DAIRY	1	45
DAIRY	1	0
COLD STORE	-	44
DELI.	-	52
SALAD BAR	-	100
MEAN %	-	39

Note: The mean % is calculated using all the measurements obtained in the supermarket.

TABLE 3.11 PERCENTAGE OF AIR AND BETWEEN-PACK MEASUREMENTS > 3°C, SUPERMARKET D

SUPERMARKET D			
CABINET TYPE	CABINET NO.	AIR (%)	BETWEEN-PACK (%)
MEAT	1	44	100
MEAT	2	11	100
MEAT	3	22	77
DAIRY	1	78	100
DAIRY	2	60	91
DAIRY	3	25	86
OTHER	1	100	-
OTHER	2	100	-
COLD STORE	-	100	-
DELI.	-	0	-
MEAN %	-	43	92

Notes: The mean % is calculated using all the measurements obtained in the supermarket.

In Supermarket D, the results for the "other" cabinets 1 and 2 show that all the readings were > 3°C. These two cabinets were used for the storage of various fruit and vegetables and pre-packed cut vegetables so that a temperature of less than 3°C was not necessary.
These results were excluded when the mean percentage was calculated.

TABLE 3.12 PERCENTAGE OF AIR AND BETWEEN-PACK MEASUREMENTS > 3°C, SUPERMARKET E

SUPERMARKET E			
CABINET TYPE	CABINET NO.	AIR (%)	BETWEEN-PACK (%)
MEAT	1	94	100
MEAT	2	33	86
MEAT	3	100	-
DAIRY	1	100	100
DAIRY	2	100	100
DAIRY	1	100	100
DAIRY	2	44	100
DAIRY	3	67	100
DAIRY	4	67	100
COLD STORE	-	0	-
DELI.	-	75	-
MEAN %	-	71	98

Note: The mean % is calculated using all the measurements obtained in the supermarket.

TABLE 3.13 PERCENTAGE OF AIR AND BETWEEN-PACK MEASUREMENTS > 3°C, SUPERMARKET F

SUPERMARKET F			
CABINET TYPE	CABINET NO.	AIR (%)	BETWEEN-PACK (%)
MEAT	1	13	48
MEAT	2	17	47
MEAT	3	100	100
DAIRY	1	4	64
DAIRY	2	40	47
DAIRY	1	33	100
OTHER	1	33	-
COLD STORE	-	33	100
DELI.	-	45	-
MEAN %		35	72

Note: The mean % is calculated using all the measurements obtained in the supermarket.

3.4.2 Cabinets Containing Dairy Products

This category mainly consisted of multi-shelf cabinets and milk cabinets. The air temperatures are given in Tables 3.14 to 3.19 inclusive. Supermarket C had one island cabinet also which contained yoghurt-type products (Table 3.16).

The temperatures for dairy cabinets for Supermarket E were poor (Table 3.18), with a high proportion of results above 3°C (Table 3.12). In contrast, most of the results from Supermarket F were reasonably satisfactory (Tables 3.19 and 3.13)
Supermarkets A and B had both multi-shelf and milk cabinets. The differences between the two types can be seen by comparing the results for Supermarket A (Table 3.14). The results for multi-shelf no. 1 were not satisfactory, ranging from 0.4°C to 8.0°C, with 75% of readings above 3°C (Table 3.8). However, the results for both of the milk cabinets were even higher, ranging from 7.0°C to 14.3°C, with obviously 100% of results over 3°C. While measurements taken in the top shelves were about 5°C lower than the bottom shelves, even the top shelf readings cannot be considered satisfactory. Milk cabinets were also present in Supermarkets B, E and F and most showed similar results, all except the milk cabinet in F, having 100% of readings above 3°C (Table 3.13). This is possibly due to the necessity for access by trolleys. Milk cabinet no.1 in Supermarket F had results very different from any of the others, with a mean of 3.0°C and some results below 0°C (Table 3.19). The reason for this fact is not clear except that the cabinet in Supermarket F could have been much newer than any of the others, as most of the cabinets in Supermarket F had been replaced by new ones in the previous year.
Multi-shelf cabinet No. 1 in Supermarket C had a range of 12°C within the cabinet (Table 3.16), although it was a very large cabinet (being run from a single refrigeration plant which served all the cabinets in the store). Elsewhere ranges of about 7° to 8° were quite common, but some cabinets had more narrow ranges with one having a range of only 1.2° (Multi-shelf cabinet no. 1 in Supermarket E, Table 3.18).

TABLE 3.14 AIR TEMPERATURES (°C)
CABINETS CONTAINING MAINLY DAIRY PRODUCTS

SUPERMARKET A

Multi-shelf Cabinet No. 1					
	No.	Air Temperature in °C			
Top Shelf	4	6.3	1.3	4.9	5.3
Middle Shelf	4	3.4	0.4	4.6	6.0
Bottom Shelf	4	1.4	3.3	5.5	8.0
Mean Temperature		4.2			
Cabinet Gauge		-1.0	3.0	4.0	
Milk Cabinet No. 2					
	No.	Air Temperature in °C			
Top Shelf	1	7.0			
Middle Shelf	1	7.5			
Bottom Shelf	1	14.3			
Mean Temperature		9.6			
Milk Cabinet No. 3					
	No.	Air Temperature in °C			
Top Shelf	1	8.8			
Middle Shelf	1	6.3			
Bottom Shelf	1	12.9			
Mean Temperature		9.3			
Minimum Temperature	0.4	Maximum Temperature	14.3		

Notes:
No.: Number of measurements per shelf.

Measurements were taken at regular intervals along the length of each cabinet.

TABLE 3.15 AIR TEMPERATURES
CABINETS CONTAINING MAINLY DAIRY PRODUCTS

SUPERMARKET B

Multi-Shelf Cabinet No. 1					
	No.	Air Temperature in °C			
Top Shelf	1	8.6			
Middle Shelf	1	3.5			
Bottom Shelf	1	5.5			
Mean Temperature		5.9			
Cabinet Gauge		-3.0			
Multi-Shelf Cabinet No. 2					
	No.	Air Temperature in °C			
Top Shelf	2	2.0	2.3		
Middle Shelf	2	4.5	2.3		
Bottom Shelf	2	4.0	3.9		
Mean Temperature		3.2			
Multi-Shelf Cabinet No. 3					
	No.	Air Temperature in °C			
Top Shelf	4	3.8	3.9	6.4	9.4
Middle Shelf	4	4.2	4.5	7.0	10.3
Bottom Shelf	4	5.7	5.8	8.4	11.2
Mean Temperature		6.7			
Cabinet Gauge		5.5			
Milk Cabinet No. 1					
	No.	Air Temperature in °C			
Top Shelf	2	5.8	5.6		
Middle Shelf	2	5.8	7.1		
Bottom (trolley)	2	10.6	10.6		
Mean Temperature		7.6			
Cabinet Gauge		4.0			
Minimum Temperature	2.0		Maximum Temperature		11.2

Notes:

No.: Number of measurements per shelf.
Measurements were taken at regular intervals along the length of each cabinet.
There was no cabinet gauge in Multi-shelf Cabinet No. 2.

TABLE 3.16 AIR TEMPERATURES (°C)
CABINETS CONTAINING MAINLY DAIRY PRODUCTS

SUPERMARKET C

Multi-shelf Cabinet No. 1										
	No.			Air Temperature in °C						
Top Shelf	13		-0.3	0.5	1.4	6.3	-1.3	1.2	6.8	
			7.8	4.3	3.0	4.4	6.3	1.6		
Middle Shelf	13		-0.5	-0.1	4.3	10.4	4.8	0.5	5.0	
			-0.7	1.5	0.9	3.5	5.8	-0.7		
Bottom Shelf	13		1.9	3.4	7.0	10.6	2.5	3.3	6.4	
			0.9	1.4	1.1	2.3	5.8	3.5		
Mean Temperature			3.9							
Cabinet Gauge	3.7	5.7	1.1	0.7	0.0	2.1	3.6	1.4	2.7	
Island Cabinet No. 1		No.		Air Temperature in °C						
		1			0.9					
Cabinet Gauge					4.0					
Minimum Temperature		-1.3		Maximum Temperature				13.0		

Notes:
No.: Number of measurements per shelf.

Measurements were taken at regular intervals along the length of each cabinet.

Only one measurement was taken in island cabinets due to their size.

TABLE 3.17 AIR TEMPERATURES (°C)
CABINETS CONTAINING MAINLY DAIRY PRODUCTS

SUPERMARKET D

Multi-shelf Cabinet No. 1							
	No.	Air Temperature in °C					
Top Shelf	3	7.3	4.3	2.5			
Middle Shelf	3	4.1	9.9	3.3			
Bottom Shelf	3	10.7	5.4	2.4			
Mean Temperature		5.5					
Cabinet Gauge		0.0					
Multi-Shelf Cabinet No. 2							
	No.	Air Temperature in °C					
Top Shelf	6	7.6	2.3	1.5	4.8	3.8	2.9
Middle Shelf	6	7.4	4.7	0.4	1.6	2.6	2.1
Bottom Shelf	6	5.8	6.0	4.4	0.0	4.0	0.7
Mean Temperature		3.5					
Cabinet Gauge		0.0	0.0	-3.0			
Multi-Shelf Cabinet No. 3							
	No.	Air Temperature in °C					
Top Shelf	4	1.6	4.2	1.3	9.0		
Middle Shelf	4	2.6	1.3	0.1	15.2		
Bottom Shelf	4	3.2	2.6	-0.1	0.1		
Mean Temperature		3.4					
Minimum Temperature	-0.1		Maximum Temperature			10.7	

Notes:
No.: Number of measurements per shelf.

Measurements were taken at regular intervals along the length of each cabinet.

TABLE 3.18 AIR TEMPERATURES (°C)
CABINETS CONTAINING MAINLY DAIRY PRODUCTS

SUPERMARKET E

Multi-shelf cabinet No. 1				
	No.	Air Temperature in °C		
Top Shelf	1	6.4		
Middle Shelf	1	7.9		
Bottom Shelf	1	7.6		
Mean Temperature		7.3		
Cabinet Gauge		7.0		

Multi-Shelf Cabinet No. 2				
	No.	Air Temperature in °C		
Top Shelf	3	2.6	3.5	1.4
Middle Shelf	3	2.9	3.7	6.4
Bottom Shelf	3	4.4	2.8	0.8
Mean Temperature		3.2		

Multi-Shelf Cabinet No. 3		
	No.	Air Temperature in °C
Top Shelf	1	1.8
Middle Shelf	1	4.2
Bottom Shelf	1	5.7
Mean Temperature		3.9
Cabinet Gauge		2.0

Multi-Shelf Cabinet No. 4		
	No.	Air Temperature in °C
Top Shelf		6.5
Middle Shelf		4.5
Bottom Shelf		2.3
Mean Temperature		4.4

Notes:
No.: Number of measurements per shelf.

Measurements were taken at regular intervals along the length of each cabinet.

There was no cabinet gauge in Cabinets No. 2 and No. 4.

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TABLE 3.18 (CONTINUED) AIR TEMPERATURES (°C)
CABINETS CONTAINING MAINLY DAIRY PRODUCTS

SUPERMARKET E

Milk cabinet No. 1		
	No.	Air Temperature in °C
Top Shelf	1	3.2
Middle Shelf	1	4.2
Bottom Shelf	1	8.3
Mean Temperature		5.2

Milk Cabinet No. 2		
	No.	Air Temperature in °C
Top Shelf	1	4.0
Middle Shelf	1	8.3
Bottom Shelf	1	13.0
Mean Temperature		8.4

Minimum Temperature	0.8	Maximum Temperature	13.0

Notes:
No.: Number of measurements per shelf

Measurements were taken at regular intervals along the length of each cabinet.

There was no cabinet gauge in Cabinets No. 1 and No. 2.

TABLE 3.19 AIR TEMPERATURES (°C)
CABINETS CONTAINING MAINLY DAIRY PRODUCTS

SUPERMARKET F

Multi-shelf cabinet No. 1										
	No.	Air Temperature in °C								
Top Shelf	9	2.6	0.4	0.2	-0.1	4.0	0.6	2.2	-1.8	0.0
Middle Shelf	9	1.3	1.6	-0.7	-1.2	2.5	-0.4	0.2	0.7	0.6
Bottom Shelf	9	2.0	3.0	0.7	-0.7	1.3	1.9	-0.1	2.8	2.4
Mean Temperature			1.0							
Multi-Shelf Cabinet No. 2										
	No.	Air Temperature in °C								
Top Shelf	5	0.0	0.0	0.4	3.9	6.1				
Middle Shelf	5	-1.5	0.3	1.4	3.3	5.2				
Bottom Shelf	5	0.6	1.4	2.3	4.9	6.1				
Mean Temperature		2.3								
Milk Cabinet No. 1										
	No.	Air Temperature in °C								
Top Shelf	3	1.5	1.0	0.3						
Middle Shelf	3	2.5	6.7	-1.0						
Bottom Shelf	3	-0.7	7.0	9.3						
Mean Temperature		3.0								
Cabinet Gauge		0.0	1.0							
Minimum Temperature	-1.8		Maximum Temperature			9.3				

Notes:
No.: Number of measurements per shelf.

Measurements were taken at regular intervals along the length of each cabinet.

There was no cabinet gauge in multi-shelf Cabinets No. 1 and No. 2.

3.4.3 Cabinets Containing Neither Meat or Dairy Products

Most of the supermarkets had a cabinet which did not fit into either of the above categories and contained foods such as fruit juice, pre-packed salads, fresh soup or ready-prepared meals. There were no such cabinets in Supermarket A, or Supermarket E. Supermarket B had one multi-shelf cabinet which had temperatures ranging from 0.8°C to 3.3°C, with a mean of 1.9°C (Table 3.20). There was also a display unit for orange juice, which was similar to a fish display unit in that the juice was placed on a bed of ice. The temperature of this was -1.9°C. There was also a fish display unit which had a higher temperature, 5.1°C (Table 3.20). In Supermarket C, there was a fish display unit which had temperatures of 7.5°C and 4.5°C and a small fridge in a preparation area which had a temperature of 12.6°C (Table 3.21). Supermarket D had two cabinets which both had temperatures above 3°C but they contained foods such as fruit, vegetables and salads. There was also a fridge with a door containing soup which had a temperature of 0.6°C (Table 3.22). There was one multi-shelf cabinet in Supermarket F which had temperatures ranging from 2.7°C to 3.6°C and a mean of 3°C (Table 3.23)

TABLE 3.20 AIR TEMPERATURES (°C) FROM OTHER CABINETS i.e. CABINETS NOT CONTAINING MAINLY MEAT OR DAIRY PRODUCTS

SUPERMARKET B

Multi-Shelf Cabinet No. 1				
	No.	Air Temperature in °C		
Top Shelf	3	1.9	1.6	2.5
Middle Shelf	3	2.8	0.9	0.8
Bottom Shelf	3	1.8	1.8	3.3
Mean Temperature No. 1 (°C)				1.9
Temperature of Orange Juice Cabinet				-1.9
Temperature of Fish Display Cabinet				5.1
Minimum Temperature -1.9			Maximum Temperature	5.1

Notes:

No.: Number of readings per shelf

Measurements were taken at regular intervals along the length of each shelf.

The air temperature of the fish display cabinet was taken 1cm above ice surface.

TABLE 3.21 AIR TEMPERATURES (°C) FROM OTHER CABINETS i.e. CABINETS NOT CONTAINING MAINLY MEAT OR DAIRY PRODUCTS

SUPERMARKET C

Temperature of Fish Display Cabinet	7.5	4.5	
Reading Taken From Small Fridge in Preparation Area			12.6
Minimum Temperature 4.5		Maximum Temperature	12.6

Notes:

No.: Number of readings per shelf

Measurements were taken at regular intervals along the length of each shelf.

The air temperature of the fish display cabinet was taken 1cm above ice surface.

TABLE 3.22 AIR TEMPERATURES (°C) FROM OTHER CABINETS i.e. CABINETS NOT CONTAINING MAINLY MEAT OR DAIRY PRODUCTS SUPERMARKET D

Multi-Shelf Cabinet No 1		
	No.	Air Temperature in °C
Top Shelf	1	9.9
Middle Shelf	1	8.0
Bottom Shelf	1	6.2
Mean Temperature No. 1		8.0
Multi-Shelf Cabinet No. 2		
	No.	Air Temperature in °C
Top Shelf	1	9.0
Middle Shelf	1	6.0
Bottom Shelf	1	9.0
Mean Temperature No. 2		8.0
Cabinet No. 3		
Temperature (°C)		0.6
Minimum Temperature D 0.6		Maximum temperature D 9.9

Notes:

No.: Number of readings per shelf

Cabinet No. 3 was a narrow upright cabinet with a door, which contained cartons of fresh soup.

TABLE 3.23 AIR TEMPERATURES (°C) OBSERVED IN OTHER CABINETS i.e. CABINETS NOT CONTAINING MAINLY MEAT OR DAIRY PRODUCTS SUPERMARKET F

Multi-Shelf Cabinet No. 1				
	No.	Air Temperature in °C		
Top Shelf	1	3.6		
Middle Shelf	1	2.8		
Bottom Shelf	1	2.7		
Mean Temperature No. 1		3.0		
Minimum Temperature No. 1		2.7	Maximum temp. No. 1	3.6

Notes:

No.: Number of readings per shelf

3.4.4 Salad Bars

These type of storage cabinets were present only in Supermarkets A, B and C and were self-service. There were generally two readings taken from each one. It was found that the temperature of the salad bar was extremely difficult to take due to its design without inserting the probe directly into the food. Salads were stored at unsatisfactory temperatures in all supermarkets. The lowest temperature for these salad bars was 4.5°C, so all the readings were above the 3°C level, with most approaching 10°C. These salad bars mainly contain prepared salads and different types of coleslaw, most being vegetable-based and few containing meat or fish. The temperatures for salad bars are contained in Table 3.24.

3.4.5 Delicatessen-Type Serve-Over Cabinets

These cabinets generally only have one shelf for storing food, so a series of readings were taken along the length of the cabinet. The air temperatures and maximum and minimum temperatures are given in Table 3.25.

Readings in Supermarket D were generally satisfactory (the highest temperature being only 2.4°C), although the deli-type cabinet was much smaller than in any of the other supermarkets and therefore there was a much smaller number of total readings there. The deli-type cabinet in Supermarket E had a very wide range (1.6°C to 12.6°C) and also quite a high mean (6.7°C)(Table 3.25). Fluctuations between cabinets elsewhere were about 8°C and means were generally satisfactory. These cabinets typically contained sliced cooked meats (which would be considered a high risk food), cheeses, cheesecakes, quiches etc. It is interesting to note that in Supermarket F, 4 out of the 11 readings were above 3°C and 3 of these related to the same area of the cabinet. There were also some readings below 0°C in Supermarket F (Table 3.25), which could possibly lead to surface freezing of unwrapped foods e.g. slices of cooked meat, and these low readings, when calculating the mean temperature, would disguise high readings.

TABLE 3.24
SALAD BAR TEMPERATURES
OBSERVED IN SUPERMARKETS A, B AND C

SUPERMARKET	No.	Air Temperatures in °C			
A	2	6.8	4.5		
B	4	6.8	7.1	9.2	8.4
C	2	10.2	10.3		
Minimum Temperature (of A, B and C)		4.5			
Maximum Temperature (of A, B and C)		10.3			

Notes:

No.: Number of measurements taken from the salad bar in each supermarket.

Measurements were taken at regular intervals along the length of each cabinet.

TABLE 3.25
TEMPERATURES OBSERVED IN DELICATESSEN-TYPE SERVE-OVER CABINETS

SUP.	No.	AIR TEMPERATURES IN °C										
A	9	3.5	4.9	3.3	8.6	4.2	0.0	7.6	2.5	1.1		
B	21	5.1	7.9	5.3	3.6	3.8	3.6	0.5	4.0	2.8	7.3	5.0
B		7.6	3.5	5.0	-0.8	-0.1	1.8	4.4	4.1	5.0	-0.2	
C	21	3.7	3.0	1.9	-0.2	2.6	2.3	2.1	-0.4	3.5	4.9	7.0
C		-1.6	5.3	6.3	7.3	-1.3	0.6	4.4	1.2	6.4	4.6	
D	4	1.3	-0.3	2.4	-0.6							
E	4	12.6	4.0	8.5	1.6							
F	11	-1.2	4.4	0.0	1.8	-2.5	-0.7	5.9	4.9	0.3	4.8	6.5

Minimum Temperatures		Maximum Temperatures	
Supermarket A	0.0	Supermarket A	8.6
Supermarket B	-0.8	Supermarket B	7.9
Supermarket C	-1.6	Supermarket C	7.3
Supermarket D	-0.6	Supermarket D	2.4
Supermarket E	1.6	Supermarket E	12.6
Supermarket F	-2.5	Supermarket F	6.5
Overall Minimum	-2.5	Overall Maximum	12.6

Notes:

No.: Number of readings from the delicatessen cabinet in each supermarket. It is dependent on the length of the cabinet.

SUP.: Supermarket.

The measurements have been taken along the length of all the delicatessen cabinets in each supermarket and are presented accordingly.

The minimum and maximum values are calculated using all the measurements for that supermarket.

3.4.6 Walk-In Cold Rooms

Walk-in cold rooms are large capacity cold rooms with shelves and also space for trolleys containing food to be wheeled in. Most supermarkets will have at least one in the fresh meat cutting area for the storage of bulk meat e.g. sides and quarters of meat. There may be additional cold rooms in other areas for back-up storage. The main difference between this type of cold store and the other refrigerated cabinets is that they have a door which is opened when access to the cold room is necessary and can be closed when a person is working for a period of time in the cold room. This means, theoretically, that there is less contact between the air inside the cold room and the ambient air in the supermarket, so that maintenance of the desired temperature should be easier.

The majority of temperatures in cold rooms were close to 3°C (Table 3.26). In Supermarket A and Supermarket E all the readings for the cold rooms were below 3°C. In Supermarket D, all the cold stores were above 3°C, the maximum being 5.9°C. All of the 3 results for Supermarket D were above 3°C, but two of these are only just above 3°C (3.2°C, 3.1°C). For Supermarket F, one of the cold stores was for fruit and vegetables, which do not require storage below 3°C, and two out of the other six were greater than 3°C, with a maximum temperature of 7°C. The overall highest reading was 8.3°C which was in a cold store containing dairy products. It appears that temperature control is more easily achievable in this type of store as the proportion of readings over 3°C was lower than in the display cabinets and salad bars. This is perhaps because the presence of a door to provide an enclosed space reduces the chance of warm air currents causing temperature rises, which would occur in open cabinets. The temperatures for all of the cold rooms are given in Table 3.26.

TABLE 3.26
AIR TEMPERATURES OBSERVED IN SUPERMARKET COLD ROOMS

SUP.	No.	Air Temperatures in °C								
A	3	0.8	-0.7	2.5						
B	7	-0.5	4.1	3.2	4.6	-0.2	4.6	1.5		
C	9	3.5	2.5	-1.0	-0.5	1.5	1.5	7.2	8.3	7.6
D	3	3.2	3.1	5.9						
E	2	-0.1	2.8							
F	7	1.2	1.7	0.8	2.3	4.2	7.0	7.1		

Minimum Temperatures		Maximum Temperatures	
Supermarket A	-0.7	Supermarket A	2.5
Supermarket B	-0.5	Supermarket B	4.6
Supermarket C	-1.0	Supermarket C	8.3
Supermarket D	3.1	Supermarket D	5.9
Supermarket E	-0.1	Supermarket E	2.8
Supermarket F	0.8	Supermarket F	7.1
Overall Minimum Temp.	-1.0	Overall Maximum Temp.	8.3

Notes:
SUP.: Supermarket
No.: Number of readings per supermarket

There was one reading taken in each cold room in each supermarket i.e. the nine readings for Supermarket C refer to nine separate cold rooms.

3.5 BETWEEN-PACK TEMPERATURES MEASURED IN SUPERMARKETS

There was a much smaller number of these readings because of the difficulty of finding shelves with suitable packs. Between-pack readings were generally not possible from salad bars, deli-type cabinets, cold stores or cabinets which did not contain regular packages e.g. cabinets containing fruit or vegetables. Often the top shelves of cabinets were steeper than the other shelves, which meant that packs were only stacked to a depth of one pack. The between-pack temperatures are listed in Tables 3.27 to 3.30. Some of the readings are displayed in bold print and these refer to products which had been observed to have been recently placed in the cabinet and would have been at room temperature for a certain (unknown) period of time e.g. while being cut or packaged.

Minimum temperatures were generally between -0.1°C and 2.9°C. The fact that few of the between-pack temperatures are below 0°C, compared to the proportion of air temperatures below 0°C would suggest that the products do not cool down quickly.

The maximum between-pack temperatures were generally lower than or similar to the maximum air temperatures for the meat or dairy cabinets e.g. the maximum measurement in Supermarket E was 8.8°C (Table 3.29), compared with maximum air temperatures of 18.2°C (meat, Table 3.6) and 13.0°C (dairy, Table 3.18). However, a large proportion (15 out of 23) of the individual cabinets surveyed were found to have 100% of the readings above 3°C (Tables 3.8 to 3.13 inclusive). This would imply that a high proportion of products are being stored at temperatures above 3°C.

It is not possible to make direct comparisons between the air temperatures and the between-pack temperatures as they were taken at different times of the same day.

TABLE 3.27 BETWEEN-PACK TEMPERATURE MEASUREMENTS (°C)

SUPERMARKET A

Meat Multi-Shelf Cabinet No. 1				
	No.	Between-Pack Temperature in °C		
	2	5.4	8.2	
Mean Temperature		6.8		
Meat Multi-Shelf Cabinet No. 2				
	No.	Between-Pack Temperature in °C		
Top Shelf	1	4.0	*	*
Middle Shelf	2	6.8	5.8	*
Bottom Shelf	3	2.4	4.0	1.2
Mean Temperature		4.0		
Dairy Multi-Shelf Cabinet No. 1				
	No.	Between-Pack Temperature in °C		
Top Shelf	0	*	*	*
Middle Shelf	1	*	*	6.0
Bottom Shelf	3	5.4	4.7	7.5
Mean Temperature		5.9		
Dairy Multi-Shelf Cabinet No. 2				
	No.	Between-Pack Temperature in °C		
Top Shelf	1	7.0		
Middle Shelf	1	7.5		
Bottom Shelf	1	14.3		
Mean Temperature		9.6		

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TABLE 3.27 BETWEEN-PACK TEMPERATURE MEASUREMENTS (°C)

SUPERMARKET A

Dairy Multi-Shelf Cabinet No. 3		
	No.	Between-Pack Temperature in °C
Top Shelf	1	7.4
Middle Shelf	1	7.2
Bottom Shelf	1	6.5
Mean Temperature		7.0
Minimum Temperature		1.0
Maximum Temperature		14.3

Notes: Table 3.27

No.: Number of measurements per shelf

Measurements were taken at regular intervals along the length of each cabinet.

* : Measurements were not possible in that part of the cabinet due to absence of stock or irregularly shaped packages.

TABLE 3.28 BETWEEN-PACK TEMPERATURE MEASUREMENTS (°C) SUPERMARKET D

Dairy Multi-Shelf Cabinet No.1						
	No.	Between-Pack Temperature (°C)				
Top Shelf	1	*	15.7			
Middle Shelf	2	9.0	6.1			
Bottom Shelf	2	10.6	6.9			
Mean Temperature		9.7				
Dairy Multi-Shelf Cabinet No. 2						
	No.	Between-Pack Temperature (°C)				
Top Shelf	3	7.4	6.2	6.7	*	*
Middle shelf	4	6.9	7.1	9.6	7.6	*
Bottom Shelf	4	*	7.5	5.0	2.0	5.3
Mean Temperature		6.5				
Dairy Multi-Shelf Cabinet No. 3						
	No.	Between-Pack Temperature (°C)				
Top Shelf	1	4.8	*	*		
Middle Shelf	3	7.4	6.6	4.6		
Bottom Shelf	3	1.6	4.9	4.3		
Mean Temperature		4.9				
Meat Multi-Shelf Cabinet No. 1						
	No.	Between-Pack Temperature (°C)				
Top Shelf	0	*	*	*	*	
Middle Shelf	0	*	*	*	*	
Bottom Shelf	4	3.5	4.0	4.2	4.5	
Mean Temperature		4.1				

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TABLE 3.28 BETWEEN-PACK TEMPERATURE MEASUREMENTS (°C)

SUPERMARKET D

Meat Multi-Shelf Cabinet No. 2						
	No.	Between-Pack Temperature (°C)				
Top Shelf	4	4.5	5.2	5.0	7.8	*
Middle Shelf	4	5.5	6.2	4.5	4.3	*
Bottom Shelf	5	3.3	6.1	4.0	4.9	5.9
Mean Temperature		5.2				
Meat Multi-Shelf Cabinet No. 3						
	No.	Between-Pack Temperature (°C)				
Top Shelf	4	6.1	4.4	6.4	2.7	*
Middle Shelf	4	3.5	6.2	5.7	3.9	*
Bottom Shelf	5	5.0	5.6	5.6	2.7	2.4
Mean Temperature		4.6				
Minimum Temperature		1.0				
Maximum Temperature		15.7				

Notes (Table 3.28):

No.: Number of measurements per shelf

Measurements were taken at regular intervals along the length of each cabinet.

* : Measurements were not possible in that part of the cabinet due to absence of stock or irregularly shaped packages.

TABLE 3.29 BETWEEN-PACK TEMPERATURE MEASUREMENTS (°C)

SUPERMARKET E

Milk Cabinet No. 1				
	No.	Between-Pack Temperature (°C)		
Top Shelf	0	*		
Middle Shelf	1	7.0		
Bottom Shelf	1	7.0		
Mean Temperature		7.0		
Milk Cabinet No. 2				
	No.	Between-Pack Temperature (°C)		
Top Shelf	1	8.2		
Middle Shelf	1	8.8		
Bottom Shelf	1	8.5		
Mean Temperature		8.5		
Dairy Multi-Shelf Cabinet No. 1				
	No.	Between-Pack Temperature (°C)		
Top Shelf	1	8.7		
Middle Shelf	1	8.5		
Bottom Shelf	1	7.5		
Mean Temperature		8.2		
Dairy Multi-Shelf No. 2				
	No.	Between-Pack Temperature (°C)		
Top Shelf	1	*	5.5	*
Middle Shelf	3	6.3	8.5	4.2
Bottom Shelf	2	6.2	6.5	*
Mean Temperature		5.4		
Dairy Multi-Shelf Cabinet No. 3				
	No.	Between-Pack Temperature (°C)		
Top Shelf	1	6.0		
Middle Shelf	1	4.2		
Bottom Shelf	0	*		
Mean Temperature		5.1		

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TABLE 3.29 BETWEEN-PACK TEMPERATURE MEASUREMENTS (°C)

SUPERMARKET E

Dairy Multi-Shelf Cabinet No. 4				
	No.	Between-Pack Temperature (°C)		
Top Shelf	0	*	*	
Middle Shelf	1	5.5	*	
Bottom Shelf	1	5.5	*	
Mean Temperature		5.5		
Meat Multi-Shelf Cabinet No. 1				
	No.	Between-Pack Temperature (°C)		
Top Shelf	2	5.7	7.8	
Middle Shelf	2	8.0	8.3	
Bottom Shelf	2	7.9	7.3	
Mean Temperature		7.5		
Meat Multi-Shelf Cabinet No. 2				
	No.	Between-Pack Temperature (°C)		
Top Shelf	2	6.4	*	6.2
Middle Shelf	2	*	6.9	6.0
Bottom Shelf	3	4.3	5.4	2.9
Mean Temperature		5.4		
Minimum Temperature		4.2		
Maximum Temperature		8.8		

Notes (Table 3.29):

No.: Number of measurements per shelf

Measurements were taken at regular intervals along the length of each cabinet.

* : It was not possible to take a measurement in that part of the cabinet.

TABLE 3.30 BETWEEN-PACK TEMPERATURE MEASUREMENTS (°C)

SUPERMARKET F

	Dairy Multi-Shelf Cabinet No. 1								
	No.	Between-Pack Temperatures (°C)							
Top Shelf	5	4.0	2.2	3.6	**7.7**	**4.4**			
Middle Shelf	5	3.8	1.5	2.4	**7.5**	**3.2**			
Bottom Shelf	4	*	1.7	3.2	**3.0**	**5.3**			
Mean Temperature		3.8							
	Dairy Multi-Shelf Cabinet No. 3								
	No.	Between-Pack Temperatures (°C)							
Top Shelf	1	8.1							
Middle Shelf	1	11.7							
Bottom Shelf	1	6.8							
Mean Temperature		8.9							
	Meat Multi-Shelf Cabinet No. 1								
	No.	Between-Pack Temperature (°C)							
Top Shelf	0	s.t.s.							
Middle Shelf	11	3.2	2.2	**10.4**	2.6	2.9	1.5	3.8	3.5
		4.1	2.8	2.9					
Bottom Shelf	10	4.0	4.1	2.1	4.3	1.4	3.7	0.8	-0.1
		3.1	2.5	*					
Mean Temperature		3.9							

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TABLE 3.30 BETWEEN-PACK TEMPERATURE MEASUREMENTS S (°C)

SUPERMARKET F

Meat Multi-Shelf Cabinet No. 2							
	No.	Between-Pack Temperature (°C)					
Top Shelf	3	6.0	4.5	5.8	s.t.s.		
Middle Shelf	6	6.7	2.1	0.8	4.7	2.7	6.0
Bottom Shelf	6	1.1	2.4	2.2	5.7	1.7	0.6
Mean Temperature		3.5					
Minimum Temperature		-0.1					
Maximum Temperature		11.7					

Notes:

No.: Number of measurements per shelf

Measurements were taken at regular intervals along the length of each cabinet.

* : It was not possible to take a measurement in that part of the cabinet. Part of the cabinet may have been empty or the shape of the packages may have been too irregular for close contact with the probe.

s.t.s.: Slope too steep; the angle of the shelf meant that it was only possible to stack products to a depth of one pack; this meant that it was not possible to take a between-pack measurement.

The readings given in bold type for Supermarket F refer to products that the author observed had just been placed into the cabinet.

3.6 CABINET GAUGE READINGS IN SUPERMARKETS

A comparison of any of the gauge readings with the air temperatures in that cabinet shows that the gauge reading is close to the minimum temperature in the cabinet. However, the variation in air temperatures in all cabinets, especially the larger ones is so large that the gauge reading bears little relation to the maximum temperatures found in the cabinets. Differences between the gauge reading and the maximum air temperature of 19.2°C and 12.2°C were found in Supermarket A and differences of 11.2°C were found in Supermarket B. Such differences were not uncommon. Some gauge readings did give an indication that the air temperatures in the cabinet were too high. For example, in Supermarket E, the gauge on one cabinet read 9°C and the maximum temperature was 14.8°C (Table 3.6, multi-shelf cabinet no. 1). However, a second gauge on the same cabinet read 0°C, even though there were temperatures as high as 8.9°C in that area of the cabinet.

Some cabinets had more than one gauge. In some cases, there were wide variations between the temperatures shown on the different gauges on the same cabinet. The gauge temperatures on Meat Multi-Shelf Cabinet No. 2 in Supermarket A ranged from -7.0°C and 1.0°C. There was no air temperature close to -7.0°C, the minimum temperature was -3.2°C. Similarly, the maximum air temperature was12.2°C, which does not relate to the maximum gauge temperature of 1.0°C (Table 3.2). There was also a wide variation between the two gauge temperatures of 9.0°C and 0.0°C on Meat Multi-Shelf Cabinet No. 1 in Supermarket E (Table 3.6).

A comparison of the mean percentage of air temperatures greater than 3°C for each supermarket (Tables 3.8 to 3.13 inclusive) with the mean percentage of gauge readings above 3°C (Table 3.31) also supports the above information. The respective percentages are 67% (air) and 11% (gauge) for Supermarket A and 43% (air) and 0% (gauge) for Supermarket D. It is obvious then that the gauge cannot be relied upon to give an accurate picture of air temperatures in cabinets.

TABLE 3.31 PERCENTAGE OF GAUGE READINGS ABOVE 3°C

	MEAT CABINETS	DAIRY CABINETS	MEAN PERCENTAGE
SUPERMARKET A	0	33	11
SUPERMARKET B	33	67	50
SUPERMARKET C	0	40	29
SUPERMARKET D	0	0	0
SUPERMARKET E	50	50	50
SUPERMARKET F	0	0	0
MEAN PERCENTAGE OF GAUGE READINGS > 3°C FOR ALL SUPERMARKETS			23

3.7 RESULTS OF MEASUREMENTS OF RELATIVE HUMIDITY IN SUPERMARKETS

Relative humidity measurements were taken in Supermarkets A, B, C, D and E. The individual cabinets are not distinguished but the results are separated into those which related to packaged food and those which related to unpackaged food.

Fluctuations within the same supermarket were generally around 45%. There were a large number of very low relative humidity values observed .The minimum relative humidity was generally around 35%, except for Supermarket E which had an unusually low minimum of 2% (unpackaged food, Table 3.36). The maximum values for most of the supermarkets were similar, at around 87%. The results are displayed in Tables 3.32 to 3.36 inclusive.

TABLE 3.32 RELATIVE HUMIDITY MEASUREMENTS (%)

SUPERMARKET A

Packaged Food *	
No.	%
9	73 75 53 73 65 52 72 60 68
15	55 64 77 66 78 46 56 71 72 80 49 57 61 72 80
12	71 77 78 80 71 74 75 81 64 73 76 82
3	84 82 83
3	86 84 87
Unpackaged Food *	
No.	%
9	49 56 55 75 62 57 68 56 62
2	67 64

Minimum %	3	Maximum %	87
Mean % (unpackaged food)	61		

Notes:

No.: Number of measurements taken per cabinet.

The measurements for each cabinet are given on a separate line.

* The individual cabinets are not distinguished; the results are categorised according to whether the cabinet contained food which was packaged or unpackaged.

TABLE 3.33 RELATIVE HUMIDITY MEASUREMENTS (%)

SUPERMARKET B

Packaged Food *	%
No.	
15	58 64 58 58 52 35 59 61 57 58 51 49 60 60 63
3	58 50 50
15	73 72 68 58 63 69 70 71 60 71 65 70 72 69 71
1	58
1	35
1	44
3	58 52 58
Unpackaged Food *	
No.	%
4	43 43 47 53
2	43 58
1	43
2	54 52
1	46
Minimum %	35 Maximum % 73
Mean % (unpackaged food)	48

Notes:

No.: Number of measurements taken per cabinet.

The measurements for each cabinet are given on a separate line.

* The individual cabinets are not distinguished; the results are categorised according to whether the cabinet contained food which was packaged or unpackaged.

TABLE 3.34 RELATIVE HUMIDITY MEASUREMENTS (%)

SUPERMARKET C

No.	%												
Packaged Food *													
1	46												
3	39	69	65										
3	87	76	73										
13	76	78	73	79	56	73	80	64	70	68	76	82	85
1	64												
1	38												
1	56												
1	81												
Unpackaged Food *													
1	75												
9	49	58	59	55	60	64	73	71	72				
2	81	85											
6	79	76	61	72	77	81							
6	64	57	61	72	79	81							

Minimum %	38	Maximum %	87
Mean % (unpackaged food)	69		

Notes:

No.: Number of measurements taken per cabinet.

The measurements for each cabinet are given on a separate line.

* The individual cabinets are not distinguished; the results are categorised according to whether the cabinet contained food which was packaged or unpackaged.

TABLE 3.35 RELATIVE HUMIDITY MEASUREMENTS (%)

SUPERMARKET D

Packaged Food												
No.	%											
9	47	69	61	74	61	56	79	58	58			
12	61	62	58	58	74	62	57	61	58	61	75	66
6	56	53	51	66	75	60						
9	72	63	74	72	66	72	72	67	71			
12	74	69	73	78	74	74	71	66	75	55	76	69
6	70	56	75	54	75	65						
12	36	44	51	52	55	76	36	41	46	56	54	73
6	39	61	48	57	55	69						
12	75	75	72	59	77	74	69	70	76	74	67	53
3	52	48	50									
3	56	55	56									
Minimum %	36						Maximum %	79				

Notes:

No.: Number of measurements taken per cabinet.

The measurements for each cabinet are given on a separate line.

* The individual cabinets are not distinguished; the results are categorised according to whether the cabinet contained food which was packaged or unpackaged.

There was no unpackaged food in Supermarket D.

TABLE 3.36 RELATIVE HUMIDITY MEASUREMENTS (%)

SUPERMARKET E

Packaged Food	
No.	%
3	33 49 50
3	50 57 63
3	62 62 71
12	78 84 57 50 49 56 81 87 54 51 58 57
6	83 81 58 51 55 54
9	48 53 63 47 59 60 49 54 63
9	61 65 64 54 60 63 62 59 58
3	48 51 55
3	61 62 61
3	70 68 67
Unpackaged Food	
No.	%
4	65 43 59 2

Mean % (unpackaged food)	42		
Minimum %	2	Maximum %	87

Notes:

No.: Number of measurements taken per cabinet.

The measurements for each cabinet are given on a separate line.

The individual cabinets are not distinguished; the results are categorised according to whether the cabinet contained food which was packaged or unpackaged.

There were no relative humidity measurements taken in Supermarket F

3.8 INTERVIEWS WITH REPRESENTATIVES OF REFRIGERATION COMPANIES

An interview was held with a representative of a large refrigeration company in order to elucidate recommended methods of operation and maintenance of display cabinets and also the policy of the refrigeration company in relation to the cabinets i.e. how often servicing should be carried out, stocking methods, etc.

A refrigeration unit is normally 12 metres long. Each unit has one thermostat, usually located in the base of the cabinet. When the thermostat detects that the desired temperature is reached, the refrigeration system "cuts out". When a 2°C rise is detected by the thermostat, the system "cuts in". A 1°C rise between the bottom and the top of the cabinet would be normal, but this is affected by the stock load. The location of the evaporator varies depending on the type of cabinet, with the back or the base of the cabinet being the most common locations. On existing cabinets, the air temperature is permitted to rise to 10°C (it was stated that the temperature of the product will not rise as high as 10°C) during a 1 hour defrost cycle, after which the air temperature will decrease to normal. The air temperature on all cabinets manufactured after 1994 is permitted to rise to a maximum of 5°C during the defrost cycle.

The more sophisticated, newer systems comprise a complete monitoring and alarm system. The air grilles on the cabinet should not be blocked and the level of stock on a shelf should not be stacked as high as the shelf above as both of these will interfere with the efficient circulation of air around the cabinet and especially the return of warm air to the refrigeration unit. The display dial on the cabinet gives only an approximation of the air temperature in the cabinet. The probe for the fixed gauge is located in the same place as the thermostat, in the "air off" flow, which is the coldest air at the back of the cabinet. However, the latest cabinets with monitoring systems have two probes per unit, one in the "air off" and the other in the "air on" with the temperature displayed on the dial or on the central system display unit being an average of the two temperatures and usually identical to the air temperature on the shelf. A twice daily check of the temperature is recommended the results of which should be recorded in a log book. One of the main reasons for this is that if there is a fault in a cabinet it may not become evident for up to 2 weeks, but faults can be identified earlier if the temperature is recorded regularly.

The refrigeration company recommends the installation of air curtains at external doors (where a curtain of air will prevent draughts) but this can be expensive, costing from £600-£2000. It is quite common for shelves to be removed in one area of a cabinet and hangers installed in their place, although this in normally only done in a single cabinet within a store. These hangers, known as "pick-a-bag" holders should only be installed if they are listed in the manufacturer's extras in the brochure. Cabinets are always designed to accommodate the maximum number of shelves, so it is not recommended to install extra shelves or to move shelves.

The relative humidity in the supermarket is important - if it is too high it could cause "sweating" or condensation on products which will turn to ice if the air temperature in the cabinet is below 0°C. This refrigeration company recommends the installation of air conditioning but gives no particular recommendation regarding relative humidity.

This company inquires about the proposed stock to be stored in the cabinet at the time of quoting the client. This is important because meat is stored at a lower temperature. They do not recommend changing the type of product from one cabinet to another and communicate this to the client as the efficient running of the cabinet could be adversely affected. All the necessary information e.g. cleaning requirements, is communicated to the manager or duty manager at the time of installation of the cabinet. If the client is a completely new one, this information will also be given to all the staff. A complete service is carried out twice a year and can last from two days to one week. During this service everything dealing with the operation of the cabinet is checked e.g. refrigerant gas levels, thermostats etc. It is recommended that cabinets should be cleaned thoroughly once a month.

CHAPTER 4: DISCUSSION OF RESULTS

4: DISCUSSION OF RESULTS

4.1 DISTRIBUTION COMPANIES' POLICY

The premises of Company T and Company Z were not evaluated, nor were temperature measurements taken. The policies encountered varied with Companies T, U, V, W and X having quite detailed policies which, if followed, would ensure reasonable temperature control of stock. Companies S, Y and Z have less extensive policies, but still have some recommended practices and carry out some checking of temperatures.

Temperature Checks

Most of the companies operate some random temperature checks and Companies S and X have a temperature recorder which gives a printout of temperatures in the cold store over each 24 hour period. Company V also has a temperature monitoring system which sounds an alarm if the temperature in the store rises above a certain level. Such a system is very useful, especially for larger companies with a large cold store, but may be an expensive investment for smaller companies. If a company could not afford a temperature recording or alarm system, regular and frequent (every 2-3 hours) checks of temperature using both the temperature gauge and a portable thermometer would be a useful and less expensive alternative, providing the results are recorded.

Deliveries

Only Companies S, V and W have a set temperature range for incoming deliveries and stated that deliveries will be rejected if outside that range. Companies W and X have customers who will reject deliveries if the temperature is above a set level, and Companies S, T and U have customers who sometimes check the temperature of deliveries. All of the companies stated that the temperature gauge of the cold store is checked although the frequency of checking varied, some having a continuous printout and others making random checks only.

Unrefrigerated Vehicles

Company U sometimes uses unrefrigerated vehicles because of difficulties of forklift gaining access to their normal vehicles. Company U mainly deals in fish which is extremely susceptible to temperature abuse, so that the problem of using unrefrigerated vehicles becomes a serious one. However, the fish are packaged in ice, which helps to maintain a low temperature, particularly if the delivery time is short. Problems like this should be overcome some other way, if possible, rather than undermining the quality of the product which the company has sought to ensure while in the depot. The elimination of this practice is paramount if the company wish to gain ISO 9000 accreditation, as is its aim. That Company Y would accept incoming deliveries would be accepted in unrefrigerated vehicles in an emergency situation, is a questionable practice.

Loading

Some of the companies specifically stated that orders are made up in the cold store and held there until loading, but it is likely that most companies do this anyway because it would be more convenient. Company V had a temperature-controlled loading area, so that the length of time spent loading would not have any adverse effect on the temperature of stock. Company X stated that it hoped to install this facility "within a year or two".

Company V was the only one to routinely pre-cool vehicles before loading so that the interior of the vehicle would be at a low temperature. Company X stated that it only pre-cools vehicles on days with a high ambient temperature. If stock is at a temperature below 3°C before loading (which is likely, judging by the temperatures found in the cold stores) then it would not seem necessary to pre-cool the vehicles on cold winter days, but it would be advisable to do this if the outside temperature is above about 8°C and not just on warm days with a very high temperature.

Regardless of the various policies operated by the different companies, the temperatures found in the cold stores were quite satisfactory. There were no undesirable practices observed in the depots but it is unknown what sort of treatment the stock receives once it leaves the depot. Some of the companies carried out staff training, which was generally done by supervisors (whose qualifications were unknown), rather than qualified personnel such as Environmental Health Officers. However, it is likely that supervisors would have a good deal of experience in the handling of stock. It would be beneficial for all staff involved in the handling of chilled food to receive specialised training by suitable personnel. Such training would emphasise the importance of maintaining strict temperature control throughout all stages of the chilled food chain.

4.2 TEMPERATURES IN DISTRIBUTION COMPANY'S PREMISES

The air and between-pack temperatures in all of the depots visited were broadly satisfactory. Two temperatures slightly above 3°C were found but would not constitute cause for great concern. In fact, the temperatures encountered would suggest that temperature control in storage depots is very good and that the distribution depot represents one of the strongest links in the chilled food chain.

It is not possible to comment on the accuracy of the temperature gauge attached to the cold room or cold store. In some cases there was only a difference of 1°C or less, between the gauge temperature and the measured air temperature, but in other premises the difference was of the order of 5°C. Such discrepancies pinpoint the need for separate temperature monitoring using probes.

All of the depots had sufficient storage space at the time the depot was visited. In fact, some of the cold stores appeared to be too large, being less than half full. It seems unlikely that any of the cold stores visited would ever become overcrowded unless business expanded. Stock normally spends a minimum amount of time in these cold stores, as the priority is to transport the stock to the retail outlet as soon as possible. Transport would normally take place the day following receipt, providing that day is a working day.

4.3 SUPERMARKET COMPANY POLICY

The author contacted Marks & Spencer Head Office in Dublin in order to ascertain what, if any policies they had in relation to chilled foods. It was stated that although they did have a detailed policy document concerning the handling of chilled foods, acceptance of deliveries, temperature specifications and so on, this was an "in-house" document only, and therefore not available to the author (Marks & Spencer representative, 1995).

Temperature Checks

Both companies evaluated suppliers before accepting them and carried out random, but not routine, temperature checks of incoming deliveries. Company R stated that if temperatures were above 5°C, deliveries would be rejected. Company Q stated that if the temperature of a delivery was found to be too high the supplier would receive a warning, but the delivery would be accepted. This is clearly not satisfactory as it means that there is no guarantee that incoming deliveries are below 3°C.

If a delivery is accepted at a high temperature, its temperature may have risen to close to the ambient supermarket temperature by the time it is loaded into a cabinet. A high proportion of the air temperature values found in the supermarkets studied were unsatisfactory and above 3°C. This means that there is a possibility that the (warm) food will be put into a cabinet which does not have a sufficiently low air temperature to reduce the temperature of the products to below 3°C within a reasonable time. Such temperature abuse of chilled foods over a considerable time period could undoubtedly have a serious effect on the quality of the food. In fact, based on some of the highest air temperatures found in this study, it is possible that warm food will never return to a temperature below 3°C during the time it spends in the supermarket. Bearing this in mind, it is important to ensure that deliveries are at a sufficiently low temperature.

The only way to guarantee this is to stipulate a maximum temperature for deliveries in a written contract between the supermarket and the supplier. There must be reliable equipment present in the supermarket for measuring the temperature of deliveries. If a delivery is found to be at a temperature higher than the agreed maximum, there should be a procedure agreed for ensuring that the product temperature measured is accurate. For example, the supplier should also have reliable equipment for taking the temperature. The rejection of a delivery could cost a supplier thousands of pounds. Therefore it should not be done unless there is conclusive evidence that the temperature is too high. If such a procedure is put into writing and rigidly enforced, suppliers will take whatever measures they can to ensure deliveries arrive at the correct temperature. Tolstoy (1991) found that when a system of strict rejection of deliveries having a temperature in excess of 7°C was operated, the number of rejections dropped. However, if a supermarket is strictly controlling its suppliers, this will only be beneficial if temperatures are also strictly maintained during the time the food spends under the control of the supermarket.

Company R stated that its policy is to run cabinets at 3°C or less. Supermarkets D and E were branches of the chain run by Company R. The mean percentage of air temperature measurements above 3°C was 43% for Supermarket D and 71% for Supermarket E, and so this is an example of observed practice contravening stated policy. It is commendable to state that the company strive to run cabinets below 3°C, but if regular checks of the air temperature in the cabinet were made, shortcomings as widespread as were found in this study would be identified and could be rectified.

Company Q stated that the temperature displayed on the gauge is read four times daily. It is likely that this is done, as the temperature is then displayed on a chart for customers to see. Occasional checks of the air temperature are carried out using a portable thermometer. It would be more beneficial to use the portable thermometer to take the regular checks as it gives a more accurate (based on the results of this study, which indicate that the cabinet gauge temperatures are often dissimilar to the cabinet air temperatures) estimate of the product temperature, especially if there are factors causing the air temperature in the cabinet to be increased. The three supermarkets belonging to this company had mean percentages of measured air temperatures greater than 3°C of 67%, 70% and 39%. Company R stated that its policy is to check and record the temperature of cabinets twice daily, but the two supermarkets affiliated to Company R had mean percentages of measured air temperatures in excess of 3°C, of 43% and 71%. This shows that a policy of checking dials on cabinets regularly does not ensure low air temperatures. The other possible explanation is that this policy is not being implemented properly, for example, if high readings are being ignored or not properly rectified. Policies, once formulated, have a better chance of being fully implemented if they are well documented and communicated to all staff members. Staff should be completely familiar with the specific points of the policy. Some of the newer stores of both companies have temperature monitoring and alarm systems, which are useful. However, the printout obtained from the system must be evaluated and if seen to be unsatisfactory, steps should be taken to reduce temperatures.

It was beneficial that one of the supermarkets of Company Q had the defrost times of most of the cabinets displayed on them. This was possible because most of the cabinets were run off a single refrigeration plant. It is unlikely that the exact defrost time would be known for a normal cabinet. This is beneficial for staff when checking temperatures and it would also prevent staff using the defrost cycle as an automatic explanation when high temperatures are seen. If this is company policy, it was not seen to be implemented in either of the company's two other supermarkets which were visited. However, this could be due to the fact that there was only one supermarket seen which had a single plant running the cabinets. It was also the only supermarket from Company Q which had a temperature alarm system connected to the cabinets. It is important that company policy should be implemented with the same degree of enthusiasm in all of the branches of the supermarket chain.

Staff Training

Both companies run training courses for staff. This is a necessary practice but it seems that the knowledge of temperature control needs some improvement especially for those staff who are responsible for leaving chilled foods out at ambient temperature for prolonged periods. All staff who have any involvement in handling of chilled (or frozen) foods, including goods inwards staff, delicatessen, meat counter and general staff responsible for stocking cabinets should receive extra training which emphasises the importance of maintaining the chilled food chain at all times. It would be beneficial to incorporate this into the training which all staff receive, but if this is not practical, the most relevant staff should receive it.

It seems overall that the companies have reasonably good policies which are undermined by their not being fully documented. The relevant staff may then be unsure of what the policy actually is. It is not enough for management to be aware of policy; the staff must also have a thorough knowledge of its details. A Code of Practice such as the one suggested in Section 5.2 would be useful for those Companies who need to draw up a policy document.

4.4 AIR TEMPERATURES IN SUPERMARKETS

The temperature of 3°C was selected as the temperature below which chilled foods should be stored and displayed. However, there is a number of types of food within the category of chilled food, which provide differing opportunities for the growth of microorganisms, and which therefore may require different storage temperatures to slow down microbial growth. The intrinsic properties and the nutritional status of the food determine whether a food is a good growth medium. Meat, being a highly nutritious food, is a good growth medium for microorganisms and can permit rapid growth. Therefore meat may require a lower storage temperature to slow down growth of microorganisms than, for example, vegetables, which have a lower nutritional status. Recognising this, the results of each food category will be discussed separately so that more detailed temperature requirements for each food type can be applied.

It was noted in the previous chapter that there were no significant temperature gradients between the bottom and the top of cabinets, except for some cabinets in Supermarket A and Supermarket F. The representative from the refrigeration company stated that a 1°C difference would be expected between the bottom and top shelves. The fluctuations within the cabinets (disregarding any high readings which could be explained by draughts) were generally of the order of about 8°C or more. This contrasts with the expected 1°C difference. There is a number of possible reasons for such fluctuations:

1. Overloading in one or more areas of the cabinet. This was not observed to be a common problem.
2. Blocked air grilles, due to overloading or poor loading practices, would interfere with the air flow around the cabinet, especially the return of cold air to the refrigeration unit. This was not observed but is possible and could be difficult to recognise.
3. Old, or infrequently serviced cabinets. The refrigeration unit may be unable to cope with the loading and unable to keep temperatures below 3°C. Doyle (1987) found that only 40% of cabinets are serviced regularly. This problem would be further compounded by the following occurrences.
4. Warm product being introduced to the cabinet. Cabinets are only designed to maintain temperature, not to reduce it and it would take several hours to reduce the temperature of a batch of product by a few degrees, during which time

there is a supplemental burden on the refrigeration plant and the temperatures in the remainder of the cabinet would rise slightly, depending on the temperature of the batch introduced. The air passing over the relatively warm product would become warmed and this would mean that the air temperature in the cabinet would rise.

5. Interference with the air flow within the cabinet and between the cabinet interior and the refrigeration plant. This could be due to interference with the cabinet design (Gormley, 1990) e.g. removing or moving shelves, draughts or loading arrangements. Very little moving of shelves was noticed, but draughts were observed to be a problem in all of the supermarkets despite one supermarket company (which was connected with three of the supermarkets) stating that cabinet location was important.
6. Incorrectly adjusted thermostats could also cause high temperatures (Gormley, 1990) and could be due to ignorance or the desire to save energy. Management may be unaware of the correct thermostat setting, or may be misled by a low temperature gauge reading into believing that all air temperatures within the cabinet are satisfactory even though product temperatures are likely to be higher .
7. Strong lighting was recognised as partly responsible for high temperatures by Gormley (1990), but it is difficult to estimate whether this was a factor in any of the supermarkets studied. It is certainly possible that it could have some bearing on temperatures in the top or middle shelves, as these would be relatively near the lights in the cabinets.

It is most likely that some or all of these factors interacted and combined to give the overall result of higher than desired temperatures. Overloading is the least likely explanation, because it was not observed to occur. The cabinet gauge reading, although nearly always lower than the mean temperature of the cabinet, would probably be indicative of the temperature of cold air being released from the refrigeration unit. The difference between the cabinet gauge reading and the measured air temperature is likely to be due to the fact that the cold air is being warmed as it flows around the cabinet. In an ideal situation, where none of the above factors is evident, the gauge reading should be a good indicator of air temperatures in the cabinet.

The position of the food on the shelf can affect its temperature according to Olsson (1990) but this was not investigated in this study. The air and between-pack temperatures were generally measured in the centre of the shelf.

4.4.1 Cabinets Containing Meat and Meat Products

Both the Institute of Food Science and Technology (1990) and B.P.F. Day of the Campden Food and Drink Research Association (Day, 1992) recommend that fresh red meat, poultry and fish be stored at a temperature between -1°C and 2°C. Day advises that cooked meats and uncooked bacon and ham should be stored between 0°C and 3°C. Supermarkets D and F were the only ones in which the mean temperature for meat in the supermarket was below 3°C. The percentages of results above 3°C in Supermarket E were high for meat cabinets, at 94%, 33% and 100% in the individual cabinets.

The minimum temperature in the meat cabinets was less than 0°C in four of the six supermarkets, being as low as -5.3°C in Supermarket D. Temperatures as low as this could potentially cause problems, especially in modified atmosphere packs. Some localised freezing would occur, which would melt when the temperature rose above 0°C and would result in "drip". This meltwater would look unsightly to the consumer and could deter people from buying the product.

If meat is stored at a temperature above 2°C or 3°C, spoilage organisms and pathogens, if present, will be able to grow and the shelf life of the meat will be reduced. The rate of growth is dependent on the temperature, growth occurring faster at higher temperatures. When spoilage organisms grow to high numbers, their by-products, such as off-odours or slime, will cause the food to appear spoiled to the consumer. If the meat is stored at higher than recommended temperatures, the food could become spoiled before the stated sell-by date.

It is not just spoilage organisms which can grow at refrigeration or mild abuse temperatures. The growth of pathogens in meat poses a very real threat. Table 1.1 shows that *Yersinia enterocolitica* grew at 0°C to 1°C on meat (Walker and Stringer, 1990) and *Aeromonas hydrophila* grew at -0.1°C in chicken broth (Walker, 1990a). This organism is especially worrying because it has been found to have a rate of growth similar to or faster than the spoilage flora in vacuum-packed beef (Gill and Reichel, 1989). This means that the food could contain sufficient numbers of the pathogen to make the consumer ill, without appearing spoiled. In effect the warning signs would have been removed.

Temperatures for fish display units in Supermarkets B and C are all too high (5.1°C, 7.5°C and 4.5°C) given that fish should be stored at -1°C to 2°C (IFST, 1990) and as close to 0°C as possible (Whittle, 1990). In fact, fish can only tolerate small fluctuations in temperature (Moral, 1990). The orange juice display unit (which was of similar design to fish display units) in Supermarket B (Table 3.20) had a temperature of -1.9°C, so it appears that these cabinets are capable of reaching low temperatures.

4.4.2 Cabinets Containing Dairy Products

The results for dairy cabinets varied between the different supermarkets but there was a large number of measurements above 3°C and even above 5°C, a larger proportion above 3°C than for the meat cabinets. The mean percentage of results above 3°C was 0% for Supermarkets D and F.

This category contained a different type of cabinet, which was similar to the normal multi-shelf cabinet, but could be opened at the bottom to enable special trolleys (which are commonly used to store and move around cartons of milk) to be wheeled in. It was noted that temperatures in milk cabinets were generally higher than in the other cabinets. This could be due to the fact that the bottom of the cabinet is more open than the bottom of a normal cabinet and cold air circulating around the cabinet may be more easily affected by draughts, or simply that the design of the cabinet is such that the air currents are not as effective at maintaining low air temperatures around the cabinet, especially in the bottom. This type of cabinet would obviously have advantages for supermarket staff as the milk containers do not have to be loaded individually, the trolley containing the containers being simply wheeled into the bottom of the cabinet. The top two shelves are essentially the same as in a multi-shelf cabinet, so that they should have similar temperatures.

The island cabinet in which yoghurts were stored in Supermarket C was found to have a satisfactory temperature of 0.9°C. There were two other cabinets of this type in this supermarket, which were used to store meat and they also had low temperatures, at 2.2°C and -1.9°C. Therefore, all of the readings for island cabinets were satisfactory. However, it would be misleading to conclude that all island cabinets were satisfactory for the storage of chilled foods based on just three measurements. Nevertheless, these cabinets appeared to be effective at maintaining air temperatures. Their design means that the food is effectively enclosed except at the top of the cabinet and it would seem that air flow within the cabinet is not greatly affected by outside factors such as draughts. However these cabinets were much smaller than the normal multi-shelf or milk cabinets and therefore their use in a large supermarket would be limited.

The mean temperatures of the multi-shelf cabinets containing foods such as butter, margarine, cheese (mainly hard) and yoghurts were broadly within the 0°C to 5°C range, except for Supermarket E, which had a mean temperature for multi-shelf dairy cabinets of 6.8°C. Half of the dairy cabinets in Supermarket E had 100% of readings above 3°C and the other half had at least 44% above 3°C. Supermarket F had most of the dairy products in milk cabinets stored at temperatures within the recommended range e.g. in multi-shelf cabinet no. 1, the highest reading was

4.0°C and in multi-shelf cabinet no. 2, only 20% of readings were higher than 5°C and the highest of those was 6.1°C. In Supermarket B, quite a few of the temperatures were above 5°C, the highest being 11.2°C. In Supermarket E, the temperatures were not quite as unacceptable, but there was still a high proportion greater than 5°C, the maximum being 7.9°C. There was no general pattern for dairy products in milk cabinets as variations occurred between the different supermarkets, between each of the cabinets within a supermarket and even within a single cabinet. This could also be said for the meat cabinets and the ones which did not contain either meat or dairy products. The only pattern which is obvious is that the larger the cabinet, the greater the difference in temperature within the cabinet. This could be due to the fact that the potential for natural variation is greater within a larger cabinet. Also, it is unclear how much of the cabinet is controlled by a single thermostat. The larger the cabinet, the more thermostats would be necessary to control the temperature.

The IFST recommend that milk, cream and low fat spreads should be stored at 0°C to 5°C and hard cheese, yoghurt, butter and margarine should be stored at 0°C to 8°C. These foods were commonly stored together in the supermarkets visited, except for instances where milk cabinets were used to store milk and cream only. Hence it would be difficult to apply separate temperature requirements unless the foods were stored in different cabinets. The staff would then have to be cognizant with the temperatures for the respective cabinets and the foods contained in them. In the event of foods which should be stored at different temperatures being packed side by side, the lowest temperature requirement would apply. In the case of foods such as butter and milk or low fat spreads, this would be 0°C to 5°C. None of the milk cabinets containing milk and cream had all of the temperatures within the 0°C to 5°C range. Milk cabinet No. 1 in Supermarket F, which had the best temperature control of all the milk cabinets, had 3 out of the 9 (33%) readings above 5°C. This shows that in the supermarkets studied, most of the milk and cream is being stored at temperatures higher than those recommended by the IFST.

These products always undergo pasteurisation, so they would not be expected to contain any pathogenic bacteria unless they were contaminated after the pasteurisation stage. The EU legal requirement for pasteurisation is 71.7°C for 15 seconds, but in practice, pasteurisation is carried out at about 75°C in Ireland (Dept. of Agriculture, 1994). If post-pasteurisation contamination occurs, the contaminating microorganisms would have little or no competing organisms and could grow with little inhibition, particularly if the milk is stored at temperatures above 5°C. The higher the temperature and the longer the food remains above 5°C, the faster any microorganisms can grow. The main effect of storage at temperatures of mild abuse would be to reduce shelf life, so that the actual shelf life would be shorter than that printed on the carton. Spoilage would occur by organisms such as coliforms (especially if pasteurisation is inadequate or if post-pasteurisation contamination occurs) which can cause souring of milk , gram-positive spore-forming bacteria e.g. *Bacillus* species (Walker, 1992) or gram-negative rods e.g. *Pseudomonas* species (Tuohy, 1990). Tuohy also reported in 1990 that off-flavours can also develop due to exposure of milk to light, but many modern milk containers are opaque, so this would not occur very commonly. He also noted that an increase in storage temperature from 5°C to 9°C would reduce the shelf life at the time of purchase by the consumer by 10-17%.

The main pathogens of concern in relation to milk and dairy products are *Listeria monocytogenes, Yersinia enterocolitica* and *Bacillus cereus,* which can all grow below 5°C (see Table 1.1), *Salmonella* spp., *Escherichia coli* and *Staphylococcus aureus* which can grow below 10°C and *Campylobacter* species Spoilage organisms growing in dairy products such as yeasts and moulds will shorten the shelf life of the product. The main dangers seem to be from improperly pasteurised milk and related products or from foods which are contaminated after the heat-treatment step.

4.4.3 Cabinets Containing Neither Meat or Dairy Products

The cabinets in Supermarket B, Supermarket D and Supermarket F, except for the fish display units (which have already been discussed) generally had satisfactory temperatures for the foods which were stored there, such as the more perishable types of fruit or vegetables. Fruit and vegetables are not subject to rapid bacterial growth and do not need to be stored at temperatures close to 0°C as would protein foods or cook-chill meals. Some fruit may even be damaged by storage at low temperatures such as bananas, which should be stored at 12°C or pineapple and melon which should be stored at 7°C to 10°C (Jamieson, 1980).

Supermarket C had a small fridge which was used to store a small number of vegetables and other items for the preparation of salads. Its temperature was high, at 12°C, even though the fridge had double doors. Storage of ingredients at 12°C prior to preparation of salads at room temperature followed by storage in a salad bar at 10.2°C or 10.3°C is likely to ensure that the temperature is inadequate throughout the entire process. The cumulative effects of storage at abuse temperatures, followed by transport to the home of the consumer at ambient temperatures could lead to rapid microbial growth. High numbers of bacteria could be present in the food before it even reaches the fridge in the consumer's home.

4.4.4 Salad Bars

There were only three of these, all of which had temperatures exceeding 3°C, the lowest temperature encountered being 4.5°C. The maximum temperature (10.3°C) in these salad bars was not as high as that in some of the other cabinets, but it was still too high for this type of food.

Foods such as lettuce or tomatoes to be used for the preparation of salads may not be high risk foods as regards rapid bacterial growth but once they are handled during preparation and mixed with other foods, bacteria and fungi can be introduced and the combination of foods such as mayonnaise makes the food a more nutritious growth medium.

The design of these salad bars, even where a plastic "sneeze guard" is fitted to prevent droplet contamination by customers, means that the food is very open to contamination, such as dust. Efforts are usually made to make customers use the utensils provided for dispensing the product and some supermarkets provide paper towels. However it is very difficult to control the behaviour of customers, unless there is a staff member present at all times. Utensils may get mixed up and transferred to another container resulting in cross-contamination. Where some supermarkets produce their own coleslaw and related products, they are usually given a shelf life of only a few days. However when customers are dispensing their own salads, there may not be a date of minimum durability printed on the carton. The turnover of these products is generally relatively high, although some of the more unusual salads may not sell as fast as others. The high possibility of contamination by customers makes strict temperature control all the more important, so that if spoilage or pathogenic organisms are introduced to the food, they are unable to grow, except very slowly.

Yersinia enterocolitica is said to grow well in salads (Gibson, 1990a). *Aeromonas hydrophila* was found in 22% of salad samples examined by Gibson (1990a). Both of these organisms have very low minimum growth temperatures (-1.3°C and -0.1°C, respectively, Table 1.1) so would be able to grow quite quickly at the temperatures found in these salad bars.

4.4.5 Delicatessen Serve-Over Counters

More than half (59%) of the total readings for this type of cabinet were above 3°C. These cabinets commonly store raw and cooked meats as well as soft cheeses, which all require strict temperature control. Furthermore, a lot of the foods may be stored in small portions e.g. cut raw meat, sliced cooked meat, cut cheese and toppings for pizzas. Such foods, because of their small size, can be quickly affected by temperature fluctuations. The method of dispensing delicatessen foods involves handling by sales assistants and thus a high potential for contamination. Most supermarkets, especially those part of a multiple group, give staff some basic hygiene training and the wearing of disposable gloves is common as is the provision of wash-hand basins in delicatessen and meat sales areas. Whether the staff put into practice the knowledge learned during staff training and whether the wash-hand basins are frequently and properly used is another matter. The wearing of disposable gloves should not be seen as a substitute for proper personal hygiene and it is not known how many times the gloves are used before being discarded. Even if the food is handled hygienically, the possibility for contamination from hair, sneezing, coughing, wearing of jewellery etc. remains, so there is a strong need for temperature control.

It is obvious, then, that there is no guarantee that food in these delicatessen counters is free of pathogens, or other bacteria, which if present, could grow at temperatures above 3°C. Some of the readings in the cabinets were exceptionally high (8.5°C, 8.6°C, 12.6°C). The only exception to this was Supermarket D, in which the highest temperature was 2.4°C.

Some of the air temperatures (16%) were below 0°C, with one reading in Supermarket F as low as -2.5°C. Such temperatures, especially if they persisted for a period of a few hours or more, could result in surface freezing in unwrapped foods.

Foods such as raw or cooked meat will generally have a fast turnover rate, but some of the more unusual delicatessen foods such as some cheeses will have a much slower turnover. This should be recognised by the staff who should concentrate on maintaining temperature control for all of these foods, but especially for the ones which will be in the cabinet longest. Foods such as sliced meats will generally be consumed within a few days of purchase.

4.4.6 Walk-in Cold Rooms

Most of the air temperatures in the cold rooms were around or below 3°C, with quite a few close to 0°C. Readings of 8.3°C and 7.2°C were obtained in a room for dairy products, one of 7.6°C in a provisions cold room, one of 4.6°C in a cold room for sausages, one of 4.6°C in a cold room for meat. All of these temperatures are slightly higher than recommended for what was stored there and would need to be reduced. The rest of the cold rooms were generally satisfactory.

The temperature should remain reasonably constant in this type of cold room, if the staff make an effort to keep the number and duration of door openings to a minimum. A slight rise would be expected when the refrigeration plant is on a defrost cycle but even then fluctuations should be minimised. This is why it is good practice to take and record regular readings of the air temperature with a hand-held probe. This enables the overall pattern to be seen over a long period. If a particular cold room is seen to have a constantly high temperature the problem can be investigated. Some supermarkets have more than one cold room for the same type of food, so that there is back-up capacity available if needed. Some stock could be moved to another cold room if a problem is noticed in a particular one, as long as there is no possibility of cross-contamination.

4.5 BETWEEN-PACK TEMPERATURES IN SUPERMARKETS

The between-pack temperature is supposedly a more accurate estimate of the actual temperature of the product. The UK DHSS Code of Practice (1991) states that the between-pack temperature should be within 2°C of the actual product temperature. It is affected by the type of packaging used, whether the stock has been moved recently and whether the cabinet has been on a defrost cycle recently. It has the advantage of being non-destructive i.e. the food is still marketable afterwards. It was not possible to take destructive product temperature measurements in this study. Between-pack measurements were taken only in multi-shelf and milk cabinets and therefore the number of results is not as great as for the air temperatures. The results found complement the air temperature results and create a slightly more detailed picture of the temperatures in the supermarkets.

There was a very high proportion of cabinets in which all measurements were above 3°C (15 out of 23). This means that almost two-thirds of the food in the cabinets tested was stored at temperatures higher than recommended (regardless of the air temperatures in the cabinets). It was not possible to obtain simultaneous air and between-pack temperatures for each cabinet as they were both taken at different times on the same day. This was due to the fact that the same thermometer unit was used and there was a separate probe for each measurement.

High between-pack temperatures measured could be due to the fact that the air temperature in the cabinet was too high. They could also be due to product temperatures being higher than the air temperature in the cabinet at the time they were placed in it. If this happens, a considerable time period is required for the product temperature to equilibrate with the air temperature The length of the cooling down process would be dependent on the temperature of the product but might take several hours even to bring down the temperature a few degrees. It would be a slow process because refrigerated display cabinets are only designed as holding units, not as chilling units. This process would take longer if the cabinet were fully loaded. The same factors which were discussed previously as being responsible for high air temperatures would also apply to between-pack temperatures as they are directly related to air temperatures.

Some of the air temperatures were below 0°C but there was only one between-pack temperature which was measured at below 0°C (-0.1°C). Some of the maximum between-pack temperatures were quite high but in Supermarket E, the maximum between-pack temperature was 8.8°C as compared to maximum air temperatures of 18.2°C (meat) and 13.0°C (dairy). The rest of the between-pack temperatures were generally at least 5°C lower than the maximum. The fact that maximum between-pack temperatures were generally lower than maximum air temperatures is interesting. It could be possible that the maximum between-pack temperature was related to warm product which had been put into the cabinet and had not cooled to the air temperature of the cabinet. Overall, the range of between-pack temperatures appears to be narrower than for the air temperatures, with minimum between-pack temperatures higher than minimum air temperatures. This would suggest that the product or between-pack temperature of food stored in a cabinet does not attain the same extremes of temperature as the air temperature. If this is correct, it could mean that food is not affected by extremes of temperature to the extent that it attains those temperatures. The between-pack measurements showed some foods being stored at temperatures above 10°C which, even though not as high as some of the air temperatures, is still well outside the ranges specified for the storage of chilled foods and would still constitute temperature abuse. The speed of packing food into the cabinets could be responsible for some of the high temperatures. The temperature of the food before it is loaded into the cabinet is also a factor influencing the between-pack temperature.

The between-pack temperatures would generally support the conclusions relating to air temperatures, showing that there is a large proportion of food in cabinets being stored at temperatures which are too high, even at abuse temperatures. Both sets of temperatures would indicate the possibility that warm products are commonly loaded into cabinets which puts undue strain on the refrigeration unit and leads to an excessive increase in the air temperature in the cabinet.

4.6 CABINET GAUGE READINGS

The temperature gauge readings when compared with the air temperatures were found to be far removed from the maximum air temperatures. In fact, they are not a good indication of the higher temperatures found in a cabinet. It also appeared that there were large differences between different cabinet gauge readings in the same cabinet, running off the same refrigeration plant. The refrigeration company representative stated that the probe which gives the reading on the cabinet gauge is located in the same place as the thermostat, in the coldest air at the back of the cabinet. This provides an explanation for the fact that the gauge readings are close to the minimum air temperatures and far removed from the maximum temperatures.

It seems foolhardy and potentially hazardous then, that some supermarkets place so much emphasis on the gauge readings when checking the temperature of cabinets. This is probably in part due to ignorance and to the belief that the gauge reading is accurate, but also to the fact that it takes less time to read a gauge on a cabinet than it does to set up a portable thermometer and then return it to its place after use. The results found in this work illustrate the need for the use of separate thermometers to adequately measure cabinet temperatures.

4.7 RELATIVE HUMIDITY MEASUREMENTS

Relative humidity measurements were separated into measurements for packaged and unpackaged food. Relative humidity has more of an impact on unpackaged food. The National Standards Authority of Ireland in its draft Code of Practice for Chilled and Frozen Foods (unpublished as of August 1994) recommends that unpackaged meat, fish and poultry be stored at a relative humidity of 85-95% and unpackaged vegetables be stored at a relative humidity of 90-95%. All of the measurements recorded in Supermarkets A, B, D and E were outside this range (i.e.below 85%) and 96% of readings in Supermarket C were outside it. The full list of measurements is given in Tables 3.32 to 3.36 and it can be seen that many of them are very low, at around 40-50%.

All of the readings in Supermarket E were outside the recommended range, with 65% the highest. One value of 2% was obtained in this supermarket, but it is inconsistent with the relative humidity in the remainder of that cabinet, as the closest value was 43%. This was a serve-over type cabinet which contained sliced cooked meats and other delicatessen foods. A relative humidity of 2%, if it persisted for any length of time, would cause severe dessication, especially with a food like sliced meat which is very thin. However, no adverse effects were noticed on any of the foods stored in the cabinet, so it seems likely that this 2% value had only been in effect for a short time previously. Generally, the relative humidity throughout the cabinet was low and might be expected to cause dessication of foods stored there.

A high relative humidity favours microbial growth, but a relative humidity of near saturation point (100%) is required for most bacterial growth on food, with yeasts requiring 90-92% and moulds requiring less, at 85-90%. Changes in humidity during storage may cause "sweating" - precipitation of moisture and a moist surface will encourage microbial spoilage (Frazier and Westhoff, 1988).

Apart from these disadvantages, there is an economic one. Dessication also results in a slight weight loss which is important for foods which are sold by weight as it reduces the price. Fruit and vegetables can shrivel and wilt if the relative humidity is too low, but for some fruit it helps good flavour development. Of course, the length of time the foods remain in the cabinet would be important. This is unknown here, but would be known by the supermarket staff. Sliced meats are a popular product and would have a high turnover rate. This must be balanced against the fact that high relative humidity will favour microbial growth which would be of major importance where food is unpackaged.

Relative humidity is not as important for packaged foods, but should not be too extreme. Some packaged foods are contained in gas permeable packs, through which air can permeate, so that the relative humidity would be relevant for those products. However, the relative humidity in some places was very low e.g. 33%, 36%, 38% and the rest of the readings were generally below 85%. All of the results suggest that relative humidity in supermarket cabinets generally is far too low to prevent dessication of foods and needs to be increased quite substantially. This could be done by the use of air conditioning or humidifiers.

4.8 OBSERVATIONS FROM SUPERMARKETS

There were some undesirable practices observed in the supermarkets.

Warm Loading

A rise in air temperature in the cabinet could also be due to loading warm product into the cabinet. This practice was observed in four of the six supermarkets. Many stores portion and package bulk foods e.g. in one store large blocks of cheese were cut up into small blocks, then weighed, packaged and finally placed into the cabinet. This process took at least 1-2 hours during which time the cheese was at the ambient temperature of the supermarket. Due to the small size of the final portions, which rapidly gain heat from the environment, it is quite possible that all of each portion of the cheese was close to ambient temperature by the time it was placed in the cabinet.

A similar situation was observed in another store with meat packaged in-store. This problem is not limited to food packaged in the supermarket. In another supermarket, a merchandiser (working for a dairy products company) was removing cheese from boxes and placing it in the cabinet. She had a very large amount of stock to deal with, and it filled a supermarket shopping trolley and was at the ambient temperature of the supermarket for the entire time she was working there on a very hot day in mid-August. The merchandiser spent several hours placing the products into the cabinet, the bottom shelf of which was overloaded by the time she was finished. At the time the between-pack temperatures were taken, they ranged from 4.2°C to 8.5°C (mean 6.2°C) in this cabinet (which would not constitute serious temperature abuse for hard cheese; it is somewhat surprising that the between-pack temperatures were not higher).

Refrigerated display cabinets are not designed to cool food, only to maintain low temperature Therefore the placing of a large quantity of warm product into a cabinet will put strong demands on the refrigeration plant and results in the overall air temperature of the cabinet being raised. It could take several hours for the temperature of the product to return to 3°C or the air temperature of the cabinet, during which time, microorganisms could grow and possibly reach high numbers in the food.

It is difficult to know what temperature food is at when loaded, unless its history is known or the temperature is taken directly.

Shelf Removal

The practice of removing shelves from cabinets and replacing them with steel rails on which packs can be hung (pick-a-bag holders) is mainly used to display vacuum-packed fish and was observed in some of the supermarkets visited. Significant differences in temperature were observed in this study on the middle shelf of Meat Multi-Shelf Cabinet No. 2 in Supermarket B (Table 3.3) where the rails had been introduced e.g. 13.2°C compared to 6°C and 2.8°C on either side. This was in contrast to the top and bottom shelves.where there did not appear to be any significant differences in the temperatures observed. In another cabinet (Dairy Multi-Shelf Cabinet No 1, Supermarket F, Table 3.19) differences were less marked e.g. 4°C compared to -0.1°C and 0.6°C on either side. This was observed on the top shelf which had "pick-a-bag" holders. However, the difference in temperature cannot be attributed to the removal of shelves because on the middle shelf, there was a temperature of 2.5°C, with temperatures of -1.2°C and 0.4°C on either side (two metres away). The middle shelf consisted of a normal shelf, as did the bottom shelf which also had similar temperature differences as the top shelf. In other words, the cabinet in Supermarket F had similar temperature gradients in that area of the cabinet, regardless of whether a shelf or "pick-a-bag" holders were present.

Therefore, evidence that removal of shelves interferes with air flow and results in increased temperatures in the cabinet was not conclusive in this study. Nevertheless, the refrigeration company representative stated that shelf removal was not advisable and sometimes not possible, unless facilitated directly by the manufacturer. So it would seem that the most appropriate advice would be to consult with the manufacturer of the cabinet before removing shelves to install "pick-a-bag" hangers.

Specialised Temperature Controlled Facilities

One of the supermarkets had installed a temperature-controlled cutting/butchery room, which had a temperature of 10°C-12°C. However, it was not used as much as it should have been, as the staff considered the working conditions uncomfortable. This is very unfortunate as it would have been installed at great expense. One solution would be to do something to make the working conditions more attractive to the workers such as supplying them with warmer clothing or operating a rota system to minimise the period of time spent in the room. It is not known whether the staff were consulted before the decision was taken to install the facility, but even if they were, they would not necessarily have been aware of how uncomfortable the experience of working there would be. Unless their problem can be alleviated, it would appear that the money could have been better spent on some other measures to improve quality control e.g. on staff training or purchasing temperature monitoring equipment.

Draughts

Unusually high temperatures were frequently thought to be connected to draughts which were observed to be coming from doors or from air conditioning vents. The effect of these draughts appeared to be localised. For example, in Supermarket D, there was a temperature of 19.3°C on the middle shelf of one cabinet (Table 3.5), but two metres to the left the air temperature was -1.4°C and to the right, it was -0.4°C. Similarly, on the bottom shelf, the temperature of 12.9°C was within two metres of temperatures of -0.1°C and 0.3°C. It is also noted that the observed draught from an overhead vent had no effect on the temperature on the top shelf directly above where the two high readings were found, the temperature there being -1.3°C. One supermarket appeared to be taking measures to counteract these draughts, by fitting plastic strips to a cabinet which was situated next to automatic sliding external doors. Air temperatures were still slightly high in this cabinet (ranging from 2.6°C to 5.8°C) which was not overloaded.

The problem of draughts is a difficult one to overcome as there are many sources of draughts in a supermarket. The proportion of floor space in a supermarket covered by refrigerated display cabinets is quite large, so that it is difficult to site all of the cabinets where they will not be affected by draughts. Nevertheless, this problem should be acknowledged and addressed at the design stage. Another solution would be to install air curtains, whereby air is blown across a doorway etc. to prevent air travelling through it. These are very expensive, however, and would need to be installed at every opening which causes a draught. Air conditioning vents were another observed source of draughts and cannot be improved by air curtains. These vents are usually very numerous and distributed throughout the supermarket and so are difficult to control. Plastic strips may have some beneficial effect, but the one cabinet (in Supermarket C) which had these strips still had temperatures as high as 5.8°C. Draughts are another problem which could be identified by regular temperature monitoring. Their effect is often localised, so if nothing can be done to alleviate the problem, the amount of food stored in that area of the cabinet can be kept to a minimum.

Stock Rotation

Staff were observed in one of the supermarkets to be placing a recent delivery order of whole chickens on top of the current stock i.e. so that the stock which had been in the store for the longest period of time would be sold last. This was done because the chickens were all on special offer and it was expected that the entire stock would be sold within three days. This is still a potentially hazardous procedure. This practice is dependent on the shelf life prediction printed on the package being accurate (which is quite likely) but also on the product not having suffered any temperature abuse during its life (which is much less likely, judging by the results of this study) which would automatically reduce the shelf life. Therefore, unless the full temperature history of the product is known, it would be wise to take a more cautious approach and operate a policy of strict stock rotation at all times.

Segregation of Cooked and Uncooked Foodstuffs

In the delicatessen area, good segregation of cooked and uncooked products was observed, but there seemed to be a lot of food left out at room temperature for long periods of time e.g. when cutting or packaging. This is undesirable as the same staff who are responsible for placing deliveries in the cabinets appeared to be dealing with customers at the same time, which would only serve to prolong the length of time the food spends at room temperature. In this work supermarket trolleys were observed to be full of stock at room temperature. If food is contained in a trolley, it could simply be wheeled into the nearest cold room and left there. Small quantities of stock could be removed and placed directly into the cabinet without delay. This would also have the advantage of cooling any slightly warm stock more effectively in the cold room than would be possible in a display cabinet and the warming of stock held at room temperature would be minimised. The practice of leaving stock out at room temperature is possibly due to poor work practice and laziness than to ignorance of temperature control.

Deliveries

Deliveries were observed to be left at ambient temperature for a long period of time in two of the supermarkets. In one case, for instance, frozen chips, a product which can defrost rapidly, were left on pallets in a storage area. The product had not been moved to frozen storage by the end of the fifteen minutes or so that the author was in that location. The reason for this was not obvious, but the same principles apply as to food left out at ambient temperature in the supermarket; it is poor practice, unnecessary for the most part, and should be avoided at all costs because it has a deleterious effect on food quality and shelf life.

Cold Rooms

All observations about cold rooms were positive as storage of stock appeared to be reasonable and overloading was only observed in one supermarket. Generally supermarkets appeared to have sufficient capacity. This is advantageous as cold rooms can be used for back-up and contingency storage if cabinets break down.

Temperature Monitoring Systems

Two of the supermarkets were observed to have a temperature alarm system. One of these was linked to the burglar alarm. There were sensors in each of the individual cabinets which would cause a signal to be sent to the security alarm company if the temperature of any of the cabinets rose above a pre-determined temperature outside opening hours. The alarm company would then notify one of the managers who could then deal with the problem. The system in the other supermarket was similar, but required the direct notification of the refrigeration company (responsible for all refrigeration in the store). Both systems had a unit which could enable the temperatures of any of the cabinets to be checked and would also give a printout for temperatures for the past 24 hours.

This can only be beneficial, especially as it usually involves the replacement of old cabinets with new ones. The alarm must be set to go off at a reasonably low temperature to be useful e.g. 8°C or less. At the same time, the unavoidable temperature rise during defrost cycles must be taken into account as it would not be desirable to have the alarm sound every time the cabinet goes on defrost. The function whereby the current temperatures of any cabinet can be checked and a printout can be obtained for the temperatures of the past 24 hours is highly useful and should be used in all cases. The temperature displayed by the monitoring unit is said to be an average of the "air off" and the "air on" and should be identical to the air temperature on the shelves of the cabinet. The printouts should still be supplemented by regular direct monitoring of the air temperatures using a portable thermometer and this will show how the temperature displayed by the alarm unit is indicative of the air temperature in the cabinet.

It was noted that very few cabinets were overloaded and in fact some were quite empty. Therefore overloading of cabinets would not be likely to be responsible for any high readings. However the visits to supermarkets were generally carried out between Monday and Thursday (to co-operate with the store management and also to facilitate easier freedom of movement around the store, without being hampered by large numbers of customers) when stock volumes are not as high as on Friday or Saturday.

Temperature control was generally good in the cold rooms. However, some of the supermarkets were visited early in the week, when there would not be the maximum amount of stock in the supermarket and further deliveries would be expected.

4.9 COMPARISON OF OBSERVATIONS AND TEMPERATURES WITH RECOMMENDATIONS OF REFRIGERATION COMPANY

The refrigeration company representative stated that, except for the most modern cabinets, the gauge only gives an approximate indication of the air temperature in the cabinet. It seems that the supermarket companies' policy of taking regular readings from the gauge and only occasional independent measurements is somewhat misguided. Staff resources would be better used on taking regular temperature measurements using a separate thermometer. The refrigeration company recommended that temperature measurements should be recorded in a log book. Company Q record measurements on a chart. However, a separate sheet is required for each day, so there is a possibility of past results being lost or discarded and it is also more difficult to get an overall picture of the results for the past few weeks. Company R stated that temperatures were recorded, but did not stipulate how they were recorded. It would be most effective to have all results recorded in a special log book, whereby all the results of the past few days or so can be viewed together and an overall impression of how the cabinets are performing can be obtained.

The refrigeration company recommends that the air grilles in the cabinets should not be blocked and the stock should not be stacked up to the level of the shelf above. Overstacking or blocking of air grilles were not observed, except in a couple of cabinets. However, visits were not carried out at times when there was a maximum amount of stock in the cabinet.

CHAPTER 5:
CONCLUSIONS AND SUGGESTED CODE OF PRACTICE FOR THE HANDLING OF CHILLED FOODS

5.1 CONCLUSIONS

The most important conclusions reached were:

1. that a Code of Practice is necessary to provide explicit information for companies involved in the handling of chilled foods; and

2. that legislation should be amended to require companies to carry out monitoring and recording of temperatures of chilled food at the distribution and retail stages of the chilled food chain.
   Such legislation should also include a requirement for companies to take specified appropriate action if temperatures are found to be outside certain specified ranges.

There were also certain more specific conclusions reached in relation to the distribution companies and the supermarket companies which were studied.

5.1.1 Distribution Companies

1. The distribution companies studied are all different, but a basic pattern is evident. At one end of the scale is the large company which is run similar to a large industrial operation and may have a number of large companies as clients or customers. These companies would have a large annual turnover. Such companies are the most likely to have an efficient policy and the best temperature control and handling practices. At the other end of this scale is the smaller company who would have a smaller number of staff, a smaller premises and a lesser number of vehicles. Resources available to such a company would be less and it appears from the companies studied that a smaller company is less likely to have a well-organized policy. There were also some companies seen which did not fit into either of

these categories but were intermediate and may have had a certain amount of efficient practices and a reasonable overall understanding of chilled foods, but no organized policy.

2. The temperature results from the distribution companies' depots show that products held in these cold stores were being held at satisfactory temperatures.

3. The general handling of chilled foods in the larger distribution companies was satisfactory and the maintenance of temperature control appears to be a priority for the larger companies, but not as important for smaller companies, who engage in (and admit to) some undesirable practices.

4. The level of staff training appears satisfactory for the larger companies but is minimal or non-existent for the smaller companies.

5.1.2 Supermarket Temperature Control

1. The different values of temperature evident in the cabinets and the high temperatures (both air and product/between-pack) found would be influenced by all of the factors discussed previously but the most important factors are the following:

    blocked air grilles;
    incorrectly adjusted or inaccurate thermostats;
    draughts;
    cabinets too old and too infrequently serviced; and
    warm product being loaded into cabinets.

2. There was a large proportion of meat being stored at temperatures above 3°C, which is unsatisfactory. There were also some cases of meat being stored at temperatures

slightly below the recommended range, but these were less significant than the prevalence of high temperatures.

3. All fish display units were observed to be operating at too high a temperature.

4. The milk cabinets were not as efficient at maintaining low temperatures as the multi-shelf cabinets and some of the milk in these cabinets was held at temperatures much higher than the recommended temperature for milk. In fact, none of the milk cabinets studied had all of the temperatures within the cabinet under 5°C.

5. The overall results for dairy products were reasonable compared to the other foods, but there were still some instances of high temperatures and some supermarkets had quite a high proportion of measurements above the recommended 5°C maximum temperature.

6. The air temperature measurements showed that the island cabinets studied were very effective at maintaining low temperatures.

7. Fruit and vegetables held in refrigerated display cabinets were widely held at the correct temperature.

8. Over half of the measurements for deli-type serve-over cabinets were above 3°C so that at least half of the food held in these cabinets was held at unsatisfactory temperatures.

9. All of the salad bars studied had temperatures too high. Also the design of these means that the food at the top of the container is exposed to contamination and is also exposed to the ambient air in the supermarket.

10. The overall pattern was that the two supermarkets (Supermarkets D and F) which had installed new display cabinets in the previous two years had the best overall temperature control as compared to Supermarket E which was due to replace its old cabinets and had poor temperature values. This leads to the conclusion that new cabinets are more effective at maintaining low temperatures. This could be due to the fact that cabinets (particularly when infrequently serviced) decrease in efficiency with age or it could also be due to the fact that specifications for refrigerated cabinets are becoming stricter with time.

11. It appeared that the larger a cabinet, the greater the range of temperature variations within the cabinet is likely to be.

12. The cold rooms in the supermarkets had satisfactory temperatures.

13. A very high proportion of cabinets had all of the between-pack temperatures greater than 3°C. The proportion of between-pack temperatures above 3°C was higher than for the air temperatures, even though the maximum between-pack temperatures were not always higher than the maximum air temperatures.

14. The loading of warm product into the cabinets was a problem and was probably responsible for some of the high between-pack temperatures.

15. It was concluded that the cabinet gauge reading on the cabinet was not a good indication of the air temperatures in the cabinet and should only be used as a rough guide.

16. It was common to see food left out at room temperature for too long, especially in some areas such as behind the delicatessen counter or in the goods inwards department.

17. None of the supermarket chains had policies which were well documented and communicated to staff.

18. All of the supermarket companies studied carried out staff training but it seems that this training could be improved for some staff, with a greater emphasis on the importance of temperature control at all times.

Relative Humidity in Supermarkets

1. The relative humidity was almost exclusively too low in all of the supermarkets studied. Some of the values were so low that dessication of unpackaged foods would be expected.

5.2 SUGGESTED CODE OF PRACTICE FOR THE HANDLING OF CHILLED FOODS DURING THE DISTRIBUTION AND RETAIL STAGES

The unsatisfactory temperatures and practices encountered in this study together with relevant published literature highlight the need for a Code of Practice to provide explicit information on the various areas involved in the handling of chilled foods. A Code of Practice has been drawn up with separate sections applying to the distribution sector and the retail sector. It covers areas such as temperature monitoring, transport and loading procedures, deliveries and refrigerated display cabinets. It has relevance for any individual or company involved in the manufacture, distribution or retail sale of chilled foods. It also contains information useful to consumers. Many of the principles relating to the handling of chilled foods contained in this Code of Practice also apply to frozen foods.

5.2.1 Distribution Stage

1. All distribution companies should have a well-documented policy for the handling of chilled foods. This policy should be drawn up in consultation with staff and with the help of an experienced or qualified expert, if possible. It should be as detailed as possible and should cover procedures for loading and unloading, temperatures, stock rotation, rejection procedures, etc.

2. Regular temperature monitoring (with a reliable, regularly calibrated thermometer) should be carried out in the cold store, in the transport vehicles and on incoming deliveries. The results of this monitoring should be recorded in a log book. The temperature should be taken in the warmest part of the cold store, if this is known, to show the highest temperatures foods are being stored at.

3. All staff who handle food should receive training and should be conversant with the company's policy document. This

training should be done by a suitably qualified person or senior staff member with extensive experience in dealing with chilled food.

4. Transport vehicles should be dual-powered to ensure maintenance of low temperature at all times.

5. Food to be loaded into a vehicle should be checked to ensure that it is at the correct temperature. It should not be loaded until it is at a sufficiently low temperature.

6. The vehicle should be pre-cooled before loading, unless the ambient temperature outside is below 8°C.

7. It is preferable to have a temperature-controlled loading bay. If this facility is not present, orders should be made up in the cold store and held there until loading.

8. The loading procedure should be carried out as quickly as possible, especially if there is no temperature-controlled loading area.

9. The doors of the vehicle should be closed immediately on completion of the loading/unloading procedure.

10. The food should be loaded so that air can circulate freely around the load i.e. it should not be stocked up to the level of the roof and air spaces should be left around the load. If product is in contact with the sides of the vehicle, it can rise in temperature due to heat conduction through the walls of the vehicle.

11. The vehicles used should be refrigerated and should be capable of maintaining products at the desired temperature. Unrefrigerated vehicles should never be used.

12. The refrigeration unit should not be switched off while there is stock in the vehicle or while the vehicle is being pre-

cooled. It should, however be switched off while the doors are open during the loading/unloading process to prevent warm air being drawn into the vehicle and the evaporator coils becoming iced up.

13. The refrigeration unit should be defrosted and serviced regularly.

14. Deliveries should be timed so that they only arrive when there is someone to receive them and place the stock immediately in cold storage. They should not arrive on public holidays or during the night if there is no staff present at the retail outlet.

5.2.2 Retail Stage

1. All major retail companies should have a well-documented, detailed policy covering every possible aspect of the handling of chilled foods. This policy could be drawn up by company staff, if suitably qualified personnel are available. Otherwise, outside expert advice may be necessary. The policy should be drawn up in consultation with representatives of the various areas of the company business, for example, staff from the meat department, delicatessen department and goods inwards.

Deliveries

1. The company's policy should specify temperature limits, outside which deliveries will not be accepted. It should also specify the action to be taken if a delivery is to be rejected. There should be clear procedures for verifying the temperature measurement to ensure that deliveries are not rejected mistakenly.
The temperature records relating to the delivery journey, for example, driver's log book or printout from temperature recorder, if present, should be checked at the time of receipt

to ensure that the low temperatures were consistent for the entire journey.

2. The company's policy should also cover standards of hygiene for delivery personnel and vehicles.

3. Deliveries should be placed in a back-up cold room if they are not to be loaded into a display cabinet immediately. If there is no back-up cold room, the stock should be placed into the display cabinet without delay.
   Deliveries found to be above 3°C should also be placed into a cold room until the temperature reaches 3°C.

Refrigerated Display Cabinets

1. The recommendations of the refrigeration company should be followed at all times in relation to cabinets.

2. Cabinets should be located as far away from sources of draughts such as doors and air conditioning vents as is possible.

3. The recommended operating temperature of the various cabinets should be specified in the policy document. This should be broken down according to the different foods which have separate temperature requirements. Staff should be made fully aware of these temperatures and they should be displayed in a prominent position so that staff taking temperature measurements can compare the actual and recommended temperatures.

4. Stock should not be placed above the recommended load line and should not obstruct the air inlets.

5. Cabinets should be regularly defrosted according to the manufacturer's instructions.

6. If the defrost time is known, it is informative for staff and customers if it is printed on the cabinet.

7. The gauge on the cabinet should be read at least twice daily. A separate measurement of the air temperature in the cabinet should also be taken at the same time using a separate thermometer. Regular comparison of the two temperatures will indicate how accurate the cabinet gauge is. Measurements should be taken from the top, middle and bottom of the cabinet. The number of measurements necessary will depend on the size of the cabinet, but larger cabinets will require a number of different measurements from various points along the length of the cabinet.
The thermometer should be calibrated at least annually or as often as the manufacturer recommends. Both the cabinet gauge temperature and the air temperature should be recorded in a log book which should be regularly checked by management.

8. Cabinets should be serviced regularly, as often as the manufacturer recommends.

9. Stock should be strictly rotated so that the oldest stock is sold first. Any stock which has exceeded its date of minimum durability should be removed from sale. If out-of-date stock is kept in the retail outlet for return to the manufacturer, it should be segregated from sale stock.

10. Cabinets which are seen to be poor at maintaining low temperatures should be serviced by a refrigeration engineer or representative of the refrigeration company.

11. If cabinets are emptied and turned off over the weekend, new stock should not be placed into the cabinet until after it has been turned on and the required temperature reached.

Cold Rooms

1. Separate cold rooms should be used for cooked and uncooked foods, if possible. If there is only one cold room, cooked and uncooked foods should be segregated.

2. The door of the cold room should be kept closed unless it is absolutely necessary to leave it open.

3. The capacity of the cold room should be sufficient to allow temporary storage of deliveries until loading into a cabinet as well as the normal storage volume.

Areas behind counters

1. Staff should ensure that all stock spends only the minimum time at room temperature, by only dealing with a small amount of stock at a time.
   This is especially important for staff cutting bulk foods such as cheese, as the temperature of the smaller portions can rise substantially during the cutting and packaging process.

2. It is imperative that stock which staff are not directly dealing with is not left out at room temperature for longer than is necessary, as was observed in this study.

3. Staff dealing with unwrapped foods in delicatessen-type cabinets should ensure that stock is rotated properly, as the statutory requirement to display a date of minimum durability requirement does not apply to unwrapped foods.

Salad Bars

1. The salad bars in modern supermarkets are unhygienic by design and expose the food to contamination and ambient temperatures. It is imperative, then, that they are all fitted with plastic "sneeze guards" and all reasonable precautions are taken to protect the food from contamination.

2. It would be preferable to have a staff member (who has undergone hygiene training) dispensing portions of salad to customers. However, this might meet some resistance from customers who would prefer to choose the exact amount of salad that is required. If the supermarket must operate salad bars on a self-service basis, it is imperative that signs are displayed advising customers on the correct manner to handle the salads, for example, to only use the serving utensils provided and not to transfer utensils from one salad container to another. Paper towels should also be provided.

3. It is necessary to discard all unused salads at the end of each day as the nature of the salad bars leaves the food exposed to contamination.

Relative Humidity

1. The relative humidity in cabinets containing unpackaged foods (which are more sensitive to air of low relative humidity) should be in the range of 85-95%.

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