2007-01-01

Time-temperature and Relative Humidity Profiles of Chilled and Frozen Foods in Retail Outlets Nationwide, and Evaluation of Related Practices

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Time-Temperature and Relative Humidity Profiles of Chilled and Frozen Foods in Retail Outlets Nationwide, and Evaluation of Related Practices.

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Submitted to the School of Food Science and

Environmental Health for

MPhil.

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April 2007

ABSTRACT

Temperature abuse combined with poor operational practices are the dominant factors in the mishandling of food products which can result in outbreaks of food borne disease. The objective of this work was to determine efficacy of temperature and relative humidity control using recorded data and to assess the food safety management systems in operation in retail outlets in the Republic of Ireland. This study also aims to examine food safety risk to consumers as a result of inadequate temperature control and poor food hygiene practices using microbial analysis and predictive modelling. External air temperature, core temperature and relative humidity of various chilled and frozen food products were recorded at 5 minute intervals over a 7.5 hour period in butcher, delicatessen and supermarket outlets in each county of Ireland, amounting to 85 commercial establishments. A questionnaire was discussed with employees regarding food safety management systems including hygiene protocol and staff training strategies. Microbial analysis was carried out for *Staphylococcus aureus* and *Listeria moncyotogenes* in three ready-to-eat chilled foods in 10 retail premises in Dublin city centre to investigate food safety practices. Predictive modelling for growth of both pathogens in chilled foods was done using results from the microbial analysis and temperature data recorded during the nationwide survey. Results showed that in 37% of premises surveyed, temperatures in chill cabinets exceeded 5°C. Frozen food was incorrectly stored in 52% of outlets surveyed. Readings for relative humidity were satisfactory in 36% of premises. There was compliance for the 3 elements of HACCP in 51% of outlets surveyed, with temperature control being the element of HACCP with least compliance. Provision of knowledge alone will not lead to changes in attitude and food handling behaviour, and management motivation is critical to the success of hygiene training. Low hygiene standards and poor temperature control detected in retail outlets suggest that there is a potential risk of foodborne disease as a result of consumption of chilled 'ready-to-eat' foods.

I certify that this thesis which I now submit for examination for the award of MPhil, 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.

This thesis was prepared according to the regulations for postgraduate study by research of the Dublin Institute of Technology and has not been submitted in whole or in part for an award in any other Institute or University.

The work reported on in this thesis conforms to the principles and requirements of the Institute's guidelines for ethics in research.

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Signature________________________ Date 18/1/08

Acknowledgements

My sincere thanks to my two supervisors, Dr. Nissreen Abu-Ghannam and Dr. Jesús Frías, for all their work, help, and constructive criticism with regard to this thesis.

I would like to thank the Food Safety Promotion Board of Ireland for providing the funding to enable me to carry out this research.

Thanks to my fellow colleagues in room 2.02 for their good humour and support during this thesis. Thanks are also due to Plunkett Clarke in the microbiology laboratory for his help with the microbial analysis, and to my internal reader Ms. Phil Nicholl who took the time to read and suggest corrections to my finished thesis.

A special mention for my family, Catherine and Brendan, my parents, Robert and David, my brothers and Rhoda my sister-in-law for their continuous encouragement and support. Finally, a very special thanks to my treasures, Dylan, Zach and Emily, my children and my greatest teachers, who never fail to inspire and entertain me.

Do Billy, m'anam chara

List of Abbreviations

BSE	Bovine Spongiform Encephalopathy
BS	British Standard
°C	Degrees celsius
CCP	Critical Control Point
CDC	Centres for Disease Control and Prevention
cfu/g	colony forming units per gram
cfu/cm^2	colony forming units per centimetre squared
EC	European Commision
E. coli	*Escherichia coli*
e.g.	for example
EFSA	European Food Safety Authority
EHEC	Enterohaemhorrhagic *Esherichia coli*
eur	euro
EN 441	European Standard 441
EU-RAIN	European Union Risk Analysis Information Network
et al.	and others
Fig.	Figure
FSAI	Food Safety Authority of Ireland
FSPB	Food Safety Promotion Board
g	gram
g/l	gram per litre
GHP	Good Hygiene Practice
GMP	Good Manufacturing Practice

HACCP	Hazard Analysis Critical Control Point
HPA	Health Protection Authority
HPS	Health Protection Service
HPSC	Health Protection Surveillance Centre
i.e.	that is
I.S. 341	Irish Standard 341
ISO	International Organization for Standardization
L. monocytogenes	*Listeria monocytogenes*
ml	millilitre
m/s	metres per second
MRD	Maximum Recovery Diluent
n	sample number
N/A	Not Applicable
N/D	Not Determined
NSAI	National Standards Authority of Ireland
PALCAM	Polymixin Acriflavine Lithium Chloride Ceftazidine Mannitol
PHLS	Public Health Laboratory Service
RH	Relative Humidity
S. aureus	*Staphylococcus aureus*
S.I.	Irish Statute
SOP	Standard Operating Procedure
spp.	species
TTT	Time Tolerance Temperature
UK	United Kingdom

WHO	World Health Organisation
%	Percentage
>	Greater than
≥	Greater than or equal to
<	less than

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CHAPTER ONE: LITERATURE REVIEW

1.1 FOODBORNE DISEASE

1.1.1 Introduction

There has been a major upsurge in the popularity of frozen and chilled foods in recent years in this country. Changes in lifestyle have added to the appeal of frozen and chilled foods in particular, with considerable attention being focused on quality and safety of practices associated with these products. Food borne illness is at best unpleasant and at worst can be fatal. But there are also other consequences; outbreaks of food borne illness can damage trade and tourism, and lead to loss of earnings, unemployment and litigation. Food spoilage is wasteful, costly and can adversely affect trade and consumer confidence. Effective food hygiene control, is vital to avoid the adverse human health and economic consequences (Codex Alimentarius Commission, 2003).

Despite improvements in food safety and quality, the number of outbreaks of foodborne disease has remained high. Foodborne disease has emerged as an important public health and economic problem in many countries during the last two decades (WHO, 2002). Frequent outbreaks caused by new pathogens, the use of antibiotics in animal husbandry and the transfer of antibiotic resistance to humans as well as the ongoing concerns about bovine spongiform encephalopathy (BSE) are just a few examples. The global incidence of foodborne disease is difficult to estimate but it has been reported that in the year 2000 alone 2.1 million people died from diarrhoeal diseases (WHO, 2002).

Control of the cold chain is of vital importance in the area of food safety. Food safety is of prime importance and is expected by the consumer. Consumers are worried about the safety of food products. These increasing concerns relate to the high number of food safety incidents reported in the last decade (Sun and Ockerman, 2005; Nel *et al.*, 2004 ; Blaha, 1999).

Foodborne disease is defined as disease, usually either infectious or toxic in nature, caused by agents that enter the body through the ingestion of food (WHO, 2002). Food may be intrinsically toxic or may be contaminated with toxic chemicals such as pesticides, or pathogenic organisms. The infectious dose varies between organisms and individuals. Every person is at risk of foodborne illness, and estimations of the burden of foodborne disease are complicated by the fact that very few illnesses can be definitively linked to food (Flint *et al.*, 2005).

Foodborne diseases are common and comprise a broad group of illnesses. Although most of these infections cause mild illness, severe infections and serious complications including death do occur. Gastro-enterits is the most frequent clinical syndrome which can be attributed to a wide range of microorganisms, including bacteria, viruses and parasites. Usually, the incubation period is short, from 1-2 days to 7 days. However, in the case of foodborne disease caused by chemicals or toxins, because the period of time between exposure to chemicals and effect is usually long, it is difficult to attribute disease caused by long term exposure to chemicals in food to the actual food in question.

Different degrees of severity are observed, from a mild disease which does not require medical treatment to the more serious illness requiring hospitalization, long term disability and/or death. In the USA, hospitalization rates due to foodborne disease vary from 0.6% to 29% and case fatality rates of up to 2.5% have been recorded (Mead *et al.*,1999). Foodborne disease can have particularly damaging effects on individuals, particularly young children, and on society as a whole. Foodborne diseases represent a significant health problem with important economic consequences. It is estimated that that foodborne disease in the U.S. costs almost US$7 billion annually (WHO, 2005).

1.1.2 Epidemiology of foodborne disease

The increased incidence of foodborne disease due to microbiological hazards is the result of a multiplicity of factors, all associated with a fast-changing world. The sources of food supply in a global economy have become increasingly complex; rapid transport of perishable goods and consumer preferences for new types and sources of food has led to exposure to foodborne pathogens from distant parts of the world. Many of the outbreaks of foodborne disease that were once contained within a small community may now take on global dimensions due to the increase in international trade.

Increased demand for ready-to-eat and minimally processed foods has also contributed to the new epidemiology of food borne disease (Angulo *et al.*, 1998). Changes in lifestyle mean that greater numbers of people go out and eat meals prepared in restaurants, canteens, fast food outlets, and by street vendors. Changes in eating patterns such as a preference for fresh and minimally processed foods, and the increasingly longer interval between processing and consumption of foods all contribute to the increased incidences of foodborne illness ascribed to microbiological organisms (WHO, 2006). Unhygienic preparation of food provides ample opportunities for contamination, growth, or survival of foodborne pathogens. In many countries the boom in the food service industry is not matched by effective food safety education and control.

Increased incidence of foodborne disease can occur for a number of other reasons:

- Increase in travel
- Urbanization
- The inadvertent introduction of pathogens into new geographic areas
- Changes in microrganisms
- Altered demographic profiles
- Changes in food production
- Changes in agronomic process
- Changes in food technology

However, the most common human action that results in foodborne disease is the avoidable lack of, or failure to use effective prevention and control measures. That failure is why the majority of all outbreaks are traceable, about equally, to mishandling in homes or in food service establishments. A rapid turnover of staff poses a considerable food safety risk and there is ample epidiological, microbiological and environmental evidence linking infected food handlers with causation in a significant number of outbreaks in the Republic of Ireland (Health Protection Surveillance Centre, 2004).

1.1.3 Magnitude of foodborne disease worldwide

Foodborne disease is a widespread and growing health problem, both in developed and developing countries. Routine surveillance systems vary widely between diseases and countries, a higher number of reported cases can be the result of a well performing surveillance system and not necessarily that people are more often sick from contaminated food. Countries with reporting systems have documented significant increases in the incidences of foodborne disease during the last two decades.

It is estimated that each year foodborne disease causes approximately 76 million illnesses, resulting in 325,000 hospitalizations and 5000 deaths in the United States and 2,366,000 cases, 21,138 hospitalisations and 718 deaths in England and Wales (Adak *et* al., 2002; Mead *et al.*, 1999).

The high prevalence of diarrhoeal diseases in many developing countries suggests major food safety problems. The enormity of the problem is evident, however from estimates of acute gastro-enteritis during childhood, for which an important proportion of cases are caused by food borne pathogens (Kosek *et al.*,2003). An estimated 1.8 million children under the age of five died of diarrhoeal diseases in 1999 and a large proportion of this illness is thought to originate in food and drinking water (WHO, 2000).

While most foodborne diseases are sporadic and not reported, foodborne outbreaks where two or more people are affected may take on massive proportions. For example, in 1994, an outbreak of salmonellosis due to ice-cream occurred in the U.S., affecting an estimated 224,000 persons. In 1998, an outbreak of hepatitis A, resulting from the consumption of contaminated clams, affected some 300,000 people in China. In 1996, an outbreak of *Esherichia coli* O157:H7 in Japan affected over 6,300 school children and resulted in 2 deaths. Also in Japan, a total of 13,809 cases of food poisoning occurred due to contamination of 3 different kinds of milk with *Staphyloccus aureus* (WHO, 2002).

There are only limited data on the economic consequences of food contamination and foodborne disease. It was estimated that the annual cost of the 3.3-12 million cases of foodborne illness caused by seven pathogens in the USA in 1995 was US $6.5-35 billion. The medical costs and value of the lives lost during 5 foodborne outbreaks in England and Wales in 1996 were estimated at UK£ 300-700 million. The cost of the estimated 11,500 daily cases of food poisoning in Australia was calculated at AU$ 2.6 billion annually (WHO, 2006).

According to data published by the World Health Organisation non-typhoidal salmonellosis is the only foodborne disease reported in all OECD countries, with an annual reported incidence ranging from 6.2 to 137 cases per 100,000 population.

Campylobacteriosis, when under routine surveillance, appears to be the most frequent bacterial foodborne disease in many countries with reported annual incidence rates up to 95 cases per 100,000 population.

For other bacterial foodborne disease, reported annual incidence rates are lower: between 0.2 and 19.9 cases per 100,000 population for shigellosis, 0.01 and 14 cases per 100,000 population for yersiniosis, between 0.03 and 10.4 cases per 100,000 population for VTEC *E.coli* infections, between 0.01 and 0.5 per 100,000 for listeriosis and between 0.01 and 1.6 cases per 100,000 population for botulism. For various reasons, most viral and parasitic foodborne disease are inconstantly recorded, except hepatitis A whose annual incidence rates vary from 1.2 to 22.3 cases per 100,000 population (WHO, 2002).

The number of foodborne disease outbreaks in the US in 1997 was highest in the deli/cafeteria/restaurant sector at 216 outbreaks whereas private residences accounted for 113 outbreaks. Fish was the food type which caused the highest number of outbreaks in the U.S. in 1997 (5.2%), meat, salads and Mexican foods caused the highest number of foodborne cases and fruit and vegetables were the food type which caused the highest number of deaths (Olsen, *et al.*, 2000).

Foodborne disease surveillance in the U.K. found that the confirmed food poisoning notifications were 94,925 in 1996 and increased to 105,596 in 1997, however according to figures published by the Health Protection Authority (HPA) in 2006 as shown in figure (1.1), there has been a continued decline since 2003, with a figure of 79,283 recorded in 2005.

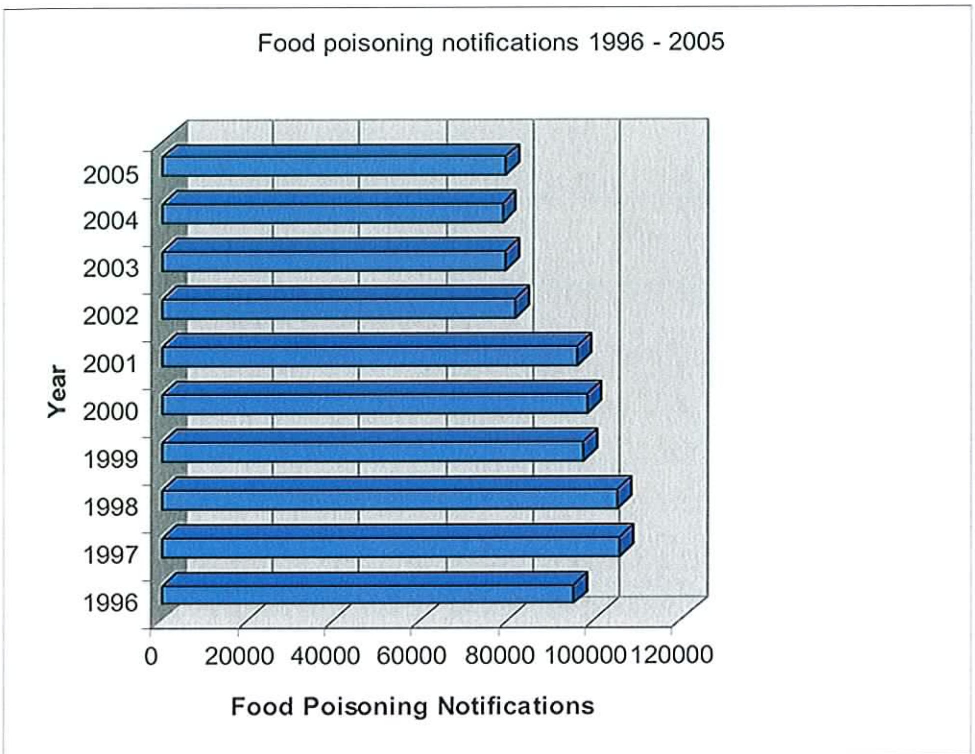


Figure (1.1): Food poisoning annual notifications 1996 to 2005 in U.K. (HPA, 2006)

The importance of food safety in Ireland has risen in the public consciousness due in part, to high profile awareness campaigns run by governmental agencies such as the Food Safety Promotion Board (FSPB) and the Food Safety Authority of Ireland (FSAI), and in part to a series of well publicised food scares.

It was reported that in Ireland, there were 5,956 notifications of food borne or waterborne infectious disease in 2004 (FSAI, 2005), which is more than double the level reported in 1999 (FSAI, 2000). There was a rise in the overall number of outbreaks of infectious intestinal disease in 2004 to 169, of which 12 outbreaks were attributed to food causes which is a 100% increase in the number of food related outbreaks compared to 2003 (HPSC, 2005). Norovirus was identified as the cause or suspected cause of 137 of the 169 outbreaks, it was identified as the causal agent in 1,128 cases of foodborne infectious disease (FSAI, 2004a).

In Ireland in 2004, there were 1711 cases of campylobacteriosis notified (four times the number of salmonellosis cases reported) with the highest burden in children under 5 years old (HPSC, 2005). There were 63 cases of enteroheamorrhagic *E.coli* reported in 2004. Serogroup O157 received the most reported cases, down from 86 in 2003 to 52 in 2004. *Listeria* was the causal agent in 11 cases of foodborne disease (FSAI, 2004a).

Staphlococcal food poisoning is listed as a notifiable disease since Jan 1st 2004, data on outbreaks of infectious disease has been collected by the HPSC since July 2001. Between July 2001 and the end of December 2003 there were 3 outbreaks of Staphloccocal food poisoning reported, one in 2001 (5 people ill), one in 2002 (7 people ill) and one in 2003 (4 people ill). However, there were 3 cases notified in 2004 and 6 in 2005 suggesting a steady increase in foodborne disease caused by *Staphyloccocus aureus* in Ireland (HPSC, 2006).

1.1.4 Aetiology of foodborne disease

The agents responsible for foodborne illness encompass a spectrum of foodborne pathogens including a variety of enteric bacteria, aerobes and anaerobes, viral pathogens, and parasites, as well as marine dinoflagellates, bacteria that produce biotoxins in fish and shellfish, and self-inducing prions of transmissible encephalopathies (Tauxe, 2002).

Most countries with systems for reporting cases of foodborne illness have documented significant increases over the past few decades in the incidence of diseases caused by microorganisms in food, including pathogens such as *Salmonella*, *Campylobacter jejuni* and enterohaemorrhagic *Escherichia coli*, and parasites such as cryptosporidium, cryptospora and trematodes (WHO, 2006).

Viruses are the most common pathogens transmitted via food, for example they are estimated to cause 66.6% of food-related illnesses in the United States, compared to 9.7% and 14.2% for *Salmonella* and *Campylobacter*, respectively (Meade *et al.*, 1999). Among outbreaks for which aetiology was determined, bacterial pathogens caused the largest percentage of outbreaks (75%) (Olsen *et al.*, 2000).

According to data from 10 surveillance systems of the Foodborne Viruses in Europe network, norovirus is found to be responsible for more than 85% of all nonbacterial outbreaks of gastroenteritis reported from 1995 to 2000 in Europe (Lopman *et al.*, 2003).

The very low infective dose of norovirus allows for extensive transmission by means of contaminated food, and subsequent person to person spread. It is estimated that more than 56% of foodborne norovirus outbreaks were associated with eating salads, sandwiches, or fresh produce which confirms that contamination of foods requiring handling but no subsequent heating is an important source of norovirus infection (Widdowson *et al.*, 2005). Most documented foodborne viral outbreaks can be traced to food manually handled by an infected foodhandler, rather than to industrially processed foods (Koopmans and Duizer, 2004).

Human listeriosis is one of the most serious human food borne infections. In the United States it was estimated that listeriosis accounted for over a quarter of all deaths due to food borne infections (Mead *et al*, 1999). In Ireland while the number of cases of listeriosis is small in comparison with other bacterial causes of food poisoning, the high morbidity and mortality associated with this infection make it of high public health concern. Contamination of ready-to-eat meat and poultry was less than 1% at retail and processing level according to the report on Zoonoses in Ireland in 2004 (FSAI, 2006d). Table (1.1) below lists the causal agents of foodborne disease in the Republic of Ireland.

Table (1.1): Causal agents of foodborne disease in Rep. of Ireland (FSAI, 2004a)

Pathogen Implicated and Number of Foodborne Outbreaks, 2004 ***Pathogen***	*Number of outbreaks*
Salmonella spp.	6
Clostridium perfringens	1
Suspected norovirus	2
Enterohaemorrhagic *E. coli*	2
Staphylococcus aureus	2
Campylobacter spp.	1
Not identified	2
Total	**18**

Despite *Salmonella* spp. being implicated in the highest number of foodborne disease outbreaks, *Campylobacter* remains the commonest cause of gastroenteritis of bacterial aetiology in Ireland, and rates of infection by *Campylobacter* continue to rise since 2000 (FSAI, 2006b). More than half of the poultry meat and 21% of the poultry meat products tested at processing level were found to be contaminated with *Campylobacter,* while at retail level relatively low levels of contamination were evident in meat products.

Salmonellosis was the pathogen implicated in 6 outbreaks of foodborne disease although the number of reported cases was only a quarter of those for *Campylobacter*. More than 50% of the food samples tested for *Salmonella enterica* in 2004 were meat and meat products. *Salmonella enterica* was identified at relatively low levels in poultry meat products at retail level, where only two of 22 samples tested positive. A low percentage (0.2%) of beef and veal samples tested at processing level were found to be contaminated with *Salmonella enterica,* while none of the fish products tested were contaminated. Only one out of 911 egg products (0.1%) sampled at processing level in 2004 was found to be contaminated with *Salmonella* spp., while it was identified in 2.3% of raw pork and 0.7% of pork products (FSAI, 2006b).

Enterohaemhorrhagic *E. coli* (EHEC) was a significant problem in 2002 when 26% of unpasteurised cow's milk at processing level and 14% of milk based products sampled at processing level were contaminated. EHEC was not identified in any dairy sample in 2004, and a relatively low level of contamination was detected generally with all positive samples being of meat and meat products (FSAI, 2006b).

1.2 FOOD SAFETY

Food safety is defined as protection of the food supply from microbial, chemical and physical hazards, so as to ensure that when consumed orally, the foodstuff does not cause a health risk to the consumer. Food safety requires the implementation of a food safety management system which can demonstrate its ability to control food safety hazards in order to ensure that food is safe at the time of consumption. The primary responsibility for food safety rests with the food business operator

1.2.1 Food safety management

Food safety is an increasingly important public health issue. Control of the cold chain is of vital importance in the area of food safety. Governments all over the world are intensifying their efforts to improve food safety. Food safety is related to the presence of foodborne hazards at the point of consumption (ISO:22,000, 2005). Food safety is vital to all sectors of the community, and is a shared responsibility.

Regulation (EC) No. 178/2002 assigns primary responsibility for ensuring food safety as follows: "a food business operator is best placed to devise a safe system for supplying food and ensuring that the food it supplies is safe; thus it should have primary legal responsibility for ensuring food safety". A high level of public health protection is one of the fundamental objectives of EC food law (Gomes-Neves, *et al.*, 2007).

Everyone involved in the food chain from farm to fork must take responsibility for safeguarding the food supply (FSAI, 2001a). Control of food safety requires a concerted effort on the part of the three principal partners, namely governments, the food industry and consumers (WHO, 2002).

According to a recent survey carried out by the Directorate-General Health and Consumer Protection as well as the European Food Safety Authority (EFSA), Food safety influences 8% of European consumers when shopping for food (EFSA, 2006). Food safety is a result of several factors: legislation should lay down minimum hygiene requirements; official controls should be in place to check food business operators' compliance and food business operators should establish and operate food safety programmes.

Food safety is ensured mainly by preventative measures, such as the implementation of good hygiene practice and application of procedures based on Hazard Analysis Critical Control Point (HACCP) principles, and other hygiene control measures (Sun & Ockerman, 2005). The implementation of a food safety management system based on the principles of HACCP, and the provision of food hygiene training, are recognised as fundamental steps towards assured food safety. Since 1998 it has been a legal requirement for all food businesses to have a food safety management system based on the principles of HACCP and to ensure that their food handlers are trained and/or supervised in a manner appropriate to their duties.

Both Good Manufacturing Practice (GMP), and Good Hygiene Practice (GHP) are considered as prerequisites that must be in place prior to the implementation of HACCP. Other tools of more general application are quality assurance methods and systems such as, the ISO 9000 series of standards and the Total Quality Management approach (Jouve *et al.*, 1999).

Regulation (EC) No 852/2004, underlining the need of all food businesses to identify the steps of the production process in order to secure food safety, has been implemented since January 2006. This regulation emphasizes the importance of the cold chain throughout the food safety management system for all foodstuffs that require a cooling or freezing regime. The legislation has been put in place to ensure a high level of consumer protection with regard to food safety.

Food business operators are legally obliged to ensure that all stages of production, processing and distribution of food under their control satisfy the relevant hygiene requirements (European Parliament and Council, 2004).

Since July 2006, the European Standard EN ISO 9001 has been aligned with EN ISO 22,000. The aim of these standards are to harmonize on a global level the requirements for food safety management. ISO 22,000 specifies the requirements for a food safety management system that combines the following key elements to ensure food safety along the food chain:

- Interactive communication
- System management
- Prerequisite programmes
- HACCP principles.

1.2.2 HACCP

1.2.2.1 Introduction to HACCP

Hazard Analysis and Critical Control Points (HACCP) is a systematic, science based approach to identifying and controlling hazards (i.e. microbiological, chemical or physical) that could pose a danger to the preparation of safe food. Globalization and free trade means that for production and trade in food, the introduction of a HACCP system has become a necessity.

Since 1998 it has been a legal requirement for all businesses to have a food safety management system based on the principles of HACCP. The HACCP system is an instrument to help food business operators attain a higher standard of food safety. Hazard analysis is the key to an effective food safety management system, since conducting a hazard analysis assists in organizing the knowledge required to establish an effective combination of control measures (ISO: 22,000, 2005).

Combining the principles of food microbiology, quality control and risk assessment, an approach incorporating HACCP is recommended by many regulatory bodies to assure food safety and demonstrate 'due diligence' in accordance with food safety legislation. Good hygiene practice and application of the HACCP principles are essential in outlets selling high risk foods to prevent cross contamination between raw meat and ready-to-eat foods.

1.2.2.2 Principles of HACCP

The HACCP system consists of seven principles which outline how to establish, implement and maintain a HACCP plan (Corlett, 1998). Food business operators shall put in place, implement and maintain a permanent procedure or procedures based on the HACCP principles under article 5 of Regulation 852/2004 on the Hygiene of Foodstuffs.

The principles, as outlined by the European Commission Guidance Document (2006), consist of the following:

1. Identifying any hazards that must be prevented, eliminated or reduced to acceptable levels (hazard analysis)
2. Identifying the critical control points at the step or steps at which control is essential to prevent or eliminate a hazard or reduce it to acceptable levels
3. Establishing critical limits which must be met at each identified critical control points so as to prevent or eliminate a hazard or reduce it to acceptable levels
4. Establishing and implementing effective monitoring procedures at critical control points
5. Establishing corrective actions when monitoring indicates that a critical point is not under control
6. Establishing procedures to verify that the measures outlined in points 1 to 5 are working effectively

7. Establishing documentation commensurate with the nature and size of the business to demonstrate the effective application of measures outlined in subparagraphs 1 to 6

1.2.2.3 Steps of a HACCP plan

Implementation of HACCP involves 14 steps (European Commission, 2006) which consist of the following:

Pre-HACCP

1. Define scope of the plan
2. Assemble the HACCP team
3. Assemble product data
4. Identify intended use of product
5. Construct flow diagram
6. On-site confirmation of flow diagram
7. List all hazards associated with each step and any preventative measures to control them
8. Determine CCPs by applying HACCP decision tree to each step
9. Establish critical limits for each CCP
10. Establish a monitoring system for each CCP
11. Establish a corrective action plan
12. Establish review procedures
13. Establish documentation and record keeping
14. Staff training

The food business operator is responsible for the development, implementation and maintenance of HACCP food safety management systems to ensure compliance with health and safety regulations and trade agreements.

1.2.2.4 Advantages of HACCP

A HACCP system is one which identifies, evaluates and controls hazards which are significant for food safety (Codex Alimentarius, 2003). When properly applied, it provides a management tool aimed at complete commitment to product quality and safety. Implementation of HACCP means cost effective control of foodborne hazards. Consumer confidence in product safety is increased by the knowledge that a HACCP system is in operation, and there is documented evidence of process control to allow for traceability should any problems occur.

The HACCP system focuses on prevention rather than relying mainly on end-product testing and is applicable to the entire food chain. HACCP is an important element in the control of safety and quality in food production.

1.2.2.5 Prerequisites to HACCP

To ensure successful implementation of a food safety management system good management techniques are required. Good Manufacturing Practice (GMP) and Good Hygiene Practice (GHP) are the major components of good management techniques.

(a) GMP

Through GMP the management demonstrates its commitment to retailing safe food. Under the principles of GMP, personnel receive appropriate training for their jobs. The design of the premises should be appropriate for safe food production, and equipment used in a premises adhering to GMP must be designed, installed and maintained in a condition that is suitable for its intended use. Other aspects of GMP include ensuring that there is an adequate supply of potable water, and electricity for refrigeration.

(b) GHP

Good Hygiene Practice is also a very important component of good management techniques. GHP highlights the need for staff training as well as emphasizing the importance of maintaining a clean work environment. Management should have a sanitation programme in operation in their premises that ensures food safety.

(1) Sanitation

It has been shown that over 50% of all contamination problems in processed foods, either pathogens or spoilage organisms, are related to improper cleaning and sanitizing of equipment and a major problem associated with proper cleaning and sanitizing is related to the proper design of the equipment (Floyd, 2000).

A good equipment-swabbing program after wash-up will help detect problem areas, particularly after the sanitizer has dissipated, allowing the bacteria to grow (Floyd, 2000). Research has shown that swabbing using a coarse pre-moistened swab is more effective than ATP bioluminesce as a means for monitoring surface cleanliness (Moore and Griffith, 2002).

An assessment of cleaning regimes and standards in butchers' shops in the UK concluded that the extent of surface soiling was generally underestimated when assessed visually, which is the technique most commonly used by the food retail trade and inspection authorities in that jurisdiction (Worsfold and Griffith, 2001).

A study of cleaning standards and practices in retail and catering premises in the U.K. found that cleaning cloths were more heavily contaminated with bacteria (Aerobic colony count (ACC), Enterobacteriaceae, *E. coli* and *S. aureus*) compared to surfaces sampled. Campylobacter *spp.* were detected in two (0.2%) and Salmonella *spp.* in one (0.01%) of the cleaning cloths (Sagoo *et al.*, 2003).

In the aforementioned study, most managers (89%) had received some form of food hygiene training. Documented cleaning schedules and cleaning records were only present in approximately half (55% and 44%, respectively) of the premises. Most did not have separate implements for cleaning raw and ready-to-eat food areas (67%), and deficiencies in the correct use of cleaning products such as the minimum contact time were identified. Surface samples (chopping/cutting boards, worktops and food containers) and cleaning cloths with ACC levels in excess of 10^3 cfu/cm^2, swab or ml were associated with premises that did not have management food hygiene training, hazard analysis, cleaning schedules or cleaning records in place (Sagoo *et al.*, 2003).

Research done on sanitation programmes in operation in butcher shops in the UK found that despite having separate equipment, surfaces and utensils for raw and cooked products, the same staff were handling both types of products (Worsfold, 2001). Therefore, work routines appear to provide many opportunities for contamination of hand and food contact surfaces.

(2) Cross Contamination

Cross contamination has previously been identified as an important contributory factor in 39% of food poisoning outbreaks (Evans *et* al., 1998). An evaluation of staff food safety behaviour in 91 butcher shops carried out in the UK showed that work routines appeared to provide many opportunities for contamination of hand and food contact surfaces (Worsfold, 2001). Cross contamination between raw meats and ready-to-eat foods is a constant possibility, unless there is sufficent separation of these products to adequately safeguard the public from infection through cross contamination (Worsfold and Griffith, 2001).

The main focus of the Pennington Group Report (1997) which investigated the *E. coli* O157 outbreak in Central Scotland was on the lack of separation of raw and cooked products during storage, production, sale and display, as well as staff handling both products without adhering to appropriate food hygiene and food handling practices. Another critical report on the butcher's shop (Cox, 1998) at the centre of the outbreak of *E. coli* O157, identified a failure to devise or enforce separate cleaning schedules and equipment for the shop as one of the many defects in their system.

The main defects in unsatisfactory cleaning procedures observed at butcher outlets in the UK, have been inadequate cleaning frequency, incorrect use of wiping cloths, improper use of cleaning chemicals and neglect of hand contact surfaces (Worsfold, 2001).

1.2.2.6 Auditing HACCP

The HACCP system must include a review procedure to ensure that the HACCP plan is being complied with on a day to day basis. An audit is a systematic, independent and documented process for obtaining audit evidence and evaluating it objectively to determine the extent to which the audit criteria are fulfilled (Brennan and Langan, 2004). An audit can be used to review the HACCP plan. An internal audit is conducted by or on behalf of a food business for internal purposes. An external audit is conducted by external independent organisations such as those having a commercial interest in the performance of a business or an authority verifying regulatory compliance.

An audit encompasses a review of the HACCP plan to verify that the HACCP plan has been implemented as it was planned, and thereby also validating the HACCP system in terms of ensuring food safety. Verification procedures include:

1. Audits of HACCP and its records,
2. Inspection of operations
3. Confirmation that CCP's are kept under control,
4. Validation of critical limits,
5. Review of deviations and product dispositions,

6. Corrective action taken in case of deviations

1.2.2.7 HACCP compliance

HACCP procedures, under whatever form they are applied, must be developed by and under the responsibility of the food business operators. Under Regulation (EC) No 852/2004, food business operators have the clear obligation to respect the maintenance of the cold chain. This obligation is therefore part of the prerequisite requirements and must be implemented even when simplified HACCP procedures are applied for example in the case of small businesses. Regulatory assessment should be carried out taking into account the means that have been chosen by food businesses for ensuring compliance with the HACCP requirement (European Commission, 2006).

Under legislation, assessment of compliance with the HACCP based element of the legislation requires implementation of three sections of HACCP:

(a) Hazard analysis

(b) Control of CCPs

(c) Review of HACCP system

However it should be mentioned that the new hygiene legislation which came into force in January 2006 allows for sufficient flexibility in all situations with regard to HACCP compliance, particularly in the case of small businesses where good hygiene practice may be all that is required. Article 5 of Regulation (EC) No 852/2004 on the hygiene of foodstuffs allows for businesses to follow sector specific guides to good practice in which the principles of HACCP have been applied.

A recent survey done in the Republic of Ireland in 2005 assessing HACCP compliance as required at the time by S.I. No. 165 of 2000 in butcher shops and supermarket butcher's counters, found that 48% of businesses were compliant for controlling CCPs and hazard analysis, with 36% being compliant in the element of verification (FSAI, 2006). A previous survey carried out 14 months earlier on the same outlet types found 28% of businesses compliant for controlling CCPs, 25% compliant for hazard analysis and 19% compliant for carrying out verification procedures. Results from these found a statistically significant ($p<0.001$) difference between the two surveys, with an improvement in HACCP compliance among butchers and supermarkets with butcher's counters (FSAI, 2006a).

A poor level of compliance with verification of procedures in comparison to the two other elements has been observed in all sections of the food industry from manufacturers to retailers. This appears to be due to lack of clarity on what the verification element of HACCP actually involves.

Research done on hospital, hotel and nursing home premises in Ireland found only 20% of businesses considered to be in full compliance (FSAI, 2004c). Results of this research done in 2003 showed that 88% of businesses assessed were controlling, or had commenced controlling the critical control points. However it appeared that over 10% of businesses were controlling CCPs without ever having conducted a hazard analysis, with verification procedures not being carried out in

40% of premises surveyed (FSAI, 2004c). Internationally it is recognised that this element of the HACCP system is least well understood and therefore rarely implemented properly if at all (FSAI, 2004c).

1.2.2.8 Barriers to HACCP compliance

The main barriers to HACCP compliance mentioned in the literature are poor understanding of HACCP system, lack of management commitment, cost and time commitment as well as lack of prerequisites.

Lack of in-house HACCP skills was identified as the principal barrier to compliance in two assessments of butcher outlets in Ireland (FSAI, 2006a). Lack of management/owner commitment was the next most frequently recorded barrier followed by lack of hygiene prerequisites. Lack of time was identified approximately half as often as the principal barrier. The three least frequently reported barriers were staff turn-over, cost and inappropriately designed HACCP plan (FSAI, 2006a). As part of this survey environmental health officers identified three additional barriers in butcher outlets:

(1) Butchers nearing retirement were more resistant to HACPP compliance

(2) Staff commitment was weaker where management was absent

(3) Smaller premises were less likely to devote time and resources to HACCP

Research done in Ireland in 2003 focusing on hospitals, hotels and nursing homes identified lack of prerequisites as the main barrier to HACCP compliance for hospitals, whereas lack of in-house skills was the key barrier for both nursing homes and hotels (FSAI, 2004c).

Research done in 2000 with regard to Irish food businesses found also that a lack of understanding of HACCP was identified as one of the main barriers to its implementation with 46% of respondents saying they didn't really know what HACCP was, while 14% said it was too complicated. A minority of respondents identified time (6%), language (4%) and cost (6%) as barriers. A small number of respondents mentioned other barriers including consultants charges, the need for simple guidelines and the volume of paperwork (FSAI, 2001b).

Research done in Spain also had similar findings with results suggesting that lack of understanding and negative guideline factors lead to HACCP implementation being difficult and slow (Vela and Fernández, 2003).

1.2.2 Food safety training

Food safety training is an essential component of every food business in ensuring a food safety culture. Education of food handlers is recognised as a crucial line of defence in the prevention of food borne illnesses (Sun and Ockerman, 2005, Legnani *et al.*, 2004, Worsfold, 2001 and Martínez-Tomé *et* al., 2000). The successful implementation of procedures in a food safety management system requires the full cooperation and commitment of all staff, which have been trained appropriately.

It is a legal requirement that staff working in a food environment are adequately trained and/or supervised commensurate with their work activity. The responsibility for training and supervision of staff lies clearly with the proprietor of every food business. This is the case for all staff whether they are part-time, full-time or casual.

Managers and supervisors should have the necessary knowledge to judge potential risks and take the necessary action to remedy deficiencies. Supervisors and managers can undermine the effectiveness of staff training if they are not adequately trained themselves (FSAI, 2001c).

Careful planning and efficiently provided education of employees is of great importance (Jevsnik *et* al., 2006).The pathogens found to be most frequently linked to foodhandler transmission have been norovirus, *Salmonella* and hepatitis A (HPSC, 2005). The viral contamination of food can occur anywhere in the process "from farm to fork", but most foodborne viral infections can be traced back to infected persons who handle food that is not heated or otherwise treated afterwards (Vasickova *et al.*, 2005).

Therefore, emphasis should be on stringent personal hygiene during food handling. Accumulated data obtained over the last 20 years on the microbial status and survival of pathogens on coins and currency notes indicates that this could represent a potential cause of sporadic cases of foodborne illness. Failure to adequately sanitize hands, or use food handling tools (tongs, spoons, utensils or bakery/serving papers) between handling money and serving food, could put consumers at risk (Michaels, 2002).

A training plan should address the training needs of all food handlers and non-food handlers, and should also identify the stages of employment when specific hygiene training should be carried out. Previous research has shown that the basic lack of hygiene knowledge and understanding could prove to be a major barrier to the effective implementation of HACCP in small food businesses (Walker *et al.*, 2003).

Recent survey studies conducted in Portugal, Turkey, South Africa and Italy pinpoint the need for training and education of food handlers in public hygiene measures and revealed a general lack of knowledge of microbiologic food hazards, refrigerator temperature ranges, cross contamination and personal hygiene (Gomes-Neves *et al.*, 2007; Bas, Ersun, & Kivanç, 2006; Nel, Lues, Buys, & Venter, 2004; Angelillo, Viggiani, Rizzo and Bianco, 2000).

With regard to the situation in Ireland, previous research has shown that 5% of 710 Irish food businesses surveyed in 2000 admitted that none of their food handlers had been trained or instructed. The most common form of training received was on the job instruction, 30% of businesses said that none of their food handlers had received more than formal training. Basic food hygiene training is the training needed by the majority of food businesses (61%). It was also identified as the main training priority followed by HACCP training (FSAI, 2001b).

It is suggested by the FSAI that all employees in retail outlets should receive induction training covering food safety skills before commencing work, and be closely supervised in the first month of employment. It is also recommended that food handlers involved in high-risk activity should receive further supplementary training within 3-6 months of employment followed by a reduced level of supervision. Food handlers involved in low-risk activity and non food handlers should receive further training following induction within 6-12 months of employment, followed by reduced levels of supervision.

At the induction stage, the food safety training skills should include (FSAI, 2001c):

(1) Wearing and maintaining uniform/corrective clothing hygienically

(2) Maintaining a high standard of hand-washing and personal hygiene

(3) Correct hygienic practice if suffering from an illness that may affect food safety

(4) Safe food handling practice

(5) Maintaining work area clean by applying correct and appropriate cleaning procedures

(6) Awareness of and compliance with food safety signs

It is recommended that additional training following the induction course should address the following skills:

(1) Recognition of how food safety can be put at risk by chemical, physical and biological hazards

(2) Understanding of cross contamination and the hygiene practice necessary to prevent it

(3) Ability to correctly record the temperature of foods as required in a hygienic manner and to keep appropriate food safety record

(4) Pest control

(5) Ability to implement the HACCP procedures in place

Food safety skills for management should include those previously mentioned under induction and additional training but should also include the following:

(1) Knowledge of bacteria of relevance in the food operation

(2) Understanding of the methods of food storage

(3) Commitment to good food hygiene practice

(4) Understanding of the implications of foodborne illness for the business

(5) Ensuring food workers suffering from foodborne disease do not work in contact with open food

(6) Ability to oversee all structural hygiene

(7) Ability to implement and review the food safety management system

Competence of staff and effectiveness of training can be assessed through observing and interviewing staff to ensure that the knowledge and instruction delivered in training is actually applied and practised consistently to the required standards.

For effective cold chain maintaining in retail outlets it is essential to be familiar with cooling and freezing units (Jevsnik *et al.*, 2006). The food business operator should be familiar with the operation of the cooling units in use in their premises. An informed decision should be made when storing foodstuffs according to their temperature declaration and temperature regime of the cooling unit.

The food business operator is obliged to make sure that all employees are aware of the hazards identified, the critical control points in the storage, and display of products and the corrective measures, preventive measures and documentation procedures applicable in his/her business (European Commission, 2006).

It is also vital that food safety training is supported within the business through provision of adequate resources and support from colleagues, as traditional assumptions that the provision of knowledge alone will lead to changes in attitudes and thus performance have been shown to be ill founded (Seaman and Eves, 2007).

1.3 TEMPERATURE MONITORING

Temperature is a key parameter ensuring food safety and quality. Temperature control is incorporated into food safety management systems based on the principles of HACCP as a critical control point. The most commonly reported problem which contributes to foodborne disease in the U.S. is poor preparation practices and improper holding temperatures (Olsen *et al.*, 2000).

Storage temperature is paramount in maintaining the quality of foodstuffs while ensuring that the integrity of the food remains intact (Jol *et* al., 2006). According to the legislation, food business operators have an obligation to withdraw unsafe food from the market. Control of temperature is one of the measures required to be taken by the food business operators in order to ensure compliance with food safety legislation.

Several different types of equipment are available for temperature monitoring, such as sensors, thermocouples, sensor housing and probes, read-out and recording systems, portable data and logging systems and time-temperature indicators. Temperature data loggers provide a hard copy of the temperature profile in real time and thus evidence of temperature abuse and the source of the abuse (McMeekin, *et al.*, 1997).

1.3.1 Chilled food

The chill chain is a vital part of modern global trade as it impacts on all food commodities. More than 50% of foodstuffs in developed countries (1.2 billion inhabitants) are retailed under refrigerated conditions, in developing countries (5 billion inhabitants) only a small proportion of food is chilled or frozen (Billiard and Viard, 2002).

In today's modern society, refrigerated storage is one of the most widely practised methods of preserving perishable foods. Improper use of this process increases the potential risk that microbial hazards will advance, thus increasing the risk of foodborne illness. Control of food temperature is vital in maintaining the quality and safety of refrigerated foods throughout the continuum from 'farm to fork' (Jol *et al.*, 2006). The retail link appears to be one of the weakest links of the professional part of the cold chain (Guilpart *et al.*, 2006).

Ensuring the microbial safety and shelf life of foods depends on minimizing the initial level of microbial contamination, preventing or limiting the rate of microbial growth or destroying microbial populations. Regulation (EC) No 852/2004 emphasizes the importance of the cold chain throughout the HACCP system for all foodstuffs that require a cooling or freezing regime.

Two principles dominate control of quality and safety in chilled foods: PPP (product-process-package) and TTT (time-temperature tolerance). TTT concepts refer to the relationship between storage temperature and storage life. Maintaining food temperatures below critical values is the key to maximising the high quality display life of chilled foods (Foster *et* al., 2005). In the United Kingdom, sales of chilled and frozen food in retail outlets was £83.68 billion in 2002 (Supermarkets & Superstores: Market Report, 2003) and most is sold from refrigerated display cabinets.

Current recommendations are that chilled foods should be displayed between the appropriate temperature range of -1 and +5°C (NSAI, 1998). It has been shown that mean food temperatures between chilled multi-deck cabinets can range from -1°C to +16°C (James and Evans, 1990).

Previous research has cited that in chill cabinet displaying food in retail outlets:

(1) Introducing warm products into chilled food cabinets can cause a general temperature increase as cabinets are intended only for holding previously chilled food and not for cooling food

(2) Poor cabinet stocking and stacking arrangements and inadequate servicing cause significant problems with maintaining low temperatures

(3) Iced-up cooling coils in cabinets indicate the need for proper defrosting regimes and correct setting of thermostats

(4) Interference with cabinet design can disrupt the flow of cool air through the cabinet and cause a rise in temperature (Gormley, 1989b)

Almost all cabinets sold in Europe are tested to determine their temperature performance. Until recently the test standard has been EN441 (this has recently been superceded by BS EN ISO 23953:2003 Parts 1 and 2, and that has broadly similar tests but slightly more stringent test room requirements) (Evans *et al.*, 2007). Within EN441-6, chilled cabinets are described as M1 if all temperatures of test packs are maintained between -1 and 5°C, M2 if between –1 and 7°C or H if between 1 and 10°C. A further, more stringent temperature classification, M0 is often used for cabinets that maintain the temperature of all the test packs between –1 and 4°C. The M0 classification was introduced exclusively for cabinets that display meat.

Most refrigerated systems function by circulating cold air over the system's evaporator and then passing this cold air over the food load to remove heat from the food. With open systems such as display cabinets, their operation is more sensitive to environmental conditions and location. For example ambient air temperature within the outlet can change the temperature distribution and the effect of radiant heat from lighting or sunlight can be more pronounced with serve-over cabinets and can effect food temperature significantly (Gormley, 1989b).

There is a wide range of models of chill cabinets, however during this research, the two main designs encountered in the retail outlets surveyed were serve-over and multi-deck display cabinets, both of which are "open" display cabinets.

(1) Serve-over display cabinets are used for displaying meat, delicatessen products, patisserie and ready-to-eat products in retail outlets. Typical serve-over cabinets found in retail premises use fan-assisted air where air emerges from the back grille, cascades over the food and returns via a front grille.

(2) Multi-deck cabinets commonly used to display dairy products, also fruit and vegetables, have a similar air flow pattern with an air curtain forming at the front of the cabinet. The temperature near the front of the cabinet will usually be indicative of the warmest locations and hence warmest foods within the cabinet (Denis and Stringer, 1992).

In the case of open display cabinets, the only barrier between the refrigerated load and the ambient air is represented by a forced air curtain, whose effectiveness is constrained by irregularities in air flow, which may cause a slight entrainment of ambient air. Such operating conditions can lead to poor food temperature control. Food in open display cabinets is also subject to direct radiative heating, further highlighting the influence of ambient conditions.

Large temperature differences have been found in most open display cabinets. Technical problems in the supply of air from the evaporator and the design of the air curtain can result in uneven temperature across the cabinet and too much entrapment of ambient air at the front of the cabinet. To engineer a cabinet that performs to the M0 specification requires optimal air flow design to reduce air entrapment at the front of the cabinet, whilst ensuring that air leaving the rear duct grille is as close to -1°C as possible (Foster *et al.*, 2005).

According to I.S. 341, in the event of a chill cabinet breaking down, the food shall be disposed of if the core temperature reaches 10°C. Ready-to-eat high risk food whose temperature has exceeded 5°C for more than 2 hours but less than 4 hours must be used immediately, if the time period above 5°C exceeds 4 hours the food should be disposed of. Ready-to-eat high risk food that has been kept above 5°C for less than 2 hours should be refrigerated at temperatures below 5°C immediately.

1.3.2 Microbiology of chilled foods

Chilling of food results in effective short-term preservation of food by retarding many of the microbial, physical, chemical and biochemical reactions associated with food spoilage and deterioration. At chill temperatures (between -1°C and +5°C) the growth of microrganisms occurs only slowly and food spoilage and deterioration reactions are inhibited to such an extent that food safety and quality is preserved for extended periods, often for a few days, sometimes a few weeks longer than the fresh counterpart (EFSA, 2006).

However, chilled foods are perishable and they deteriorate progressively throughout their shelf life. The growth and activity of microrganisms, which may be present in the food ingredients or may be introduced when the food is handled or processed, may cause deterioration. Safe and high quality chilled foods require minimal contamination during manufacture, rapid chilling and low temperatures during storage, handling, distribution, retail display and consumer storage.

Temperatures of meat on retail display may fluctuate above and below the minimum temperatures for growth of mesophilic organisms (Olsson, 1990). Although the proliferation of pathogens may be slow at temperatures near their minimum for growth, any increase in the numbers of pathogens with very low infectious doses such as *E. coli* O157:H7 (Willshaw *et* al., 1994), may increase risks to consumers' health. There is the need to maintain awareness for potential growth of psychrotrophic microrganisms such as *Listeria monocytogenes, Yersinia enterocolitica, Aeromonas hydrophila, Bacillus cereus* and *Clostridium botulinum* at chill temperatures, due to their ability to grow at refrigeration temperatures.

With many chilled foods, handling and product preparation steps are usually involved. Coughing and sneezing of food handlers may result in contamination of chilled foods by *S. aureus*. *Staphylococcus aureus* can be found as a commensal on the skin and in the anterior nares of the nose of humans. It is usually transmitted to food by a human source or cross contamination from utensils or food preparation surfaces previously contaminated by humans (FSAI, 2003b).

The presence of small numbers of *S. aureus* on food is common. It occurs as a normal part of the microflora on poultry skin for example, and as such may pose a risk of cross contamination to other foods which are already cooked or will be consumed without further cooking. Ensuring minimal handling and keeping foods refrigerated prior to cooking or serving will reduce significantly the risk to the consumer (Phillips, 1998).

Raw salad vegetables have been implicated as vehicles of infection in many outbreaks of foodborne illness (Sivapalasingam, 2004, Long *et al.*, 2002, Ministry of Health and Welfare Japan, 1997). Contaminated raw salads are of particular concern in salads containing cooked ingredients. These products have a high nutrient and moisture content and if temperature abused, salads can readily support microbial growth.

1.3.3 Microbiological surveillance

According to Article 4 of Regulation (EC) No 852/2004 food business operators must comply with the microbiological criteria for foodstuffs. This includes testing against the values set through the taking of samples in accordance with Regulation (EC) No 2073/2005. Food business operators must decide themselves the necessary sampling and testing frequencies, unless specific sampling frequencies are detailed in legislation, as part of their procedures based on HACCP principles and other hygiene control procedures

The microbiological criteria are based on formal risk assessment and internationally approved principles. The concentration of *Listeria monocytogenes* in food is to be kept below 100 (cfu/g), whereas it was concluded that applying an end-product microbiological standard for VTEC O157 was unlikely to deliver meaningful reductions. Similarly, currently available scientific data does not support setting specific criteria for pathogenic *Vibrio vulnificus* and *V. parahaemolyticus* in seafood.

The surveillance of potential contamination of foods is an important aspect of the food inspection service. The national microbiological surveillance program is carried out under the auspices of the FSAI in the Republic of Ireland. Test results of ready-to-eat food samples in these surveys have been classified as 'satisfactory', 'acceptable', 'unsatisfactory' and 'unacceptable/potentially hazardous' based on criteria specified in the Authority's Guidance Note No.3: *Guidelines for the interpretation of results of microbiological analysis of some ready-to-eat foods sampled at point of sale.* Guidelines for the Microbiological Quality of some ready-to-eat foods are shown in Table (1.2).

Table (1.2): Guidelines for the Microbiological Quality (cfu per gram) of some Ready-To-Eat Foods at point of sale (FSAI, 2001d)

	Satisfactory	Acceptable	Unsatisfactory	Unacceptable
Staphylococcus aureus	< 20 cfu/g	20 - <100cfu/g	100 - <10^4 cfu/g	≥ 10^4 cfu/g
Escherichia coli	Not detected in 25g	N/A	N/A	Detected in 25g
***Salmonella* spp.**	Not detected in 25g	N/A	N/A	Detected in 25g
***Campylobacter* spp.**	Not detected in 25g	N/A	N/A	Detected in 25g

N/A-Not Applicable

Results of a national microbiological surveillance survey done by the FSAI in 2005 is detailed below in Table (1.3). This survey looked at the presence of *L. monocytogenes* in mixed salads, and results are compared to previous research done on salads in other countries.

Table (1.3): Prevalence of *L. monocytogenes in mixed salads (*FSAI, 2006b)

Location of study	Year of study	Type of product	Qualitative test		Quantitative test
			No. of samples	No. positive for *Listeria monocytogenes*	No. of samples with *Listeria monoyctogenes* count>100cfu/g
UK	2005	Mixed salad with meat	1268	76(6.0%)	2(0.16%)
		Mixed salad with seafood	1418	54(3.8%)	0(0%)
		Overall	2686	130(4.8%)	2(0.07%)
Wales	1995-2003	Prepared mixed salads	224	0	N/A
United States	2003	Deli salads	8459	202(2.4%)	1(0.01%)
		Seafood salads	2446	115(4.7%)	2(0.08%)
England & Wales	1993	Mixed salads	923	18(2.0%)	N/D
Ireland	2005	Mixed salads	715	19(2.7%)	2(0.28%)

N/A: Not Applicable

N/D: Not determined

In the FSAI 2005 study *L. monocytogenes* was detected in 2.7% (19/715) of samples and was present at levels >100cfu/g in 0.3% (2/715) of samples. A statistical comparison of the results of this study with the UK study showed that there was no significant difference in the prevalence of positive samples; however there was a significant difference in the number of samples with *L. monocytogenes*, with significantly higher numbers in the UK (FSAI, 2006). *Salmonella* spp. was not detected in any of the samples (n=714) tested, similarly in a UK study undertaken in 1993, salmonellae were not detected in any prepared mixed salads (n=923).

Both *Staphylococcus aureus* and *Escherichia coli* are commonly used in the microbiological evaluation of foodstuffs as indicators of poor hygiene and poor food handling practices. A study done by FSAI in 2001 investigated the microbiological quality of cakes and pastries with perishable fillings and toppings. A total of 527 samples were analysed for *Staphylococcus aureus* and *Escherichia coli*. One sample of a cream doughnut (0.19%) was found to be unacceptable and potentially hazardous for *S.* aureus, while 9 samples (1.71%) were found to unsatisfactory for *S. aureus*. 11 different samples (2.09%) were unsatisfactory for *E. coli* (FSAI, 2002a).

In recent years it has been recognised, as previously mentioned, that in Ireland *Campylobacter* is the leading cause of foodborne illness, with a high prevalence of this pathogen in raw poultry. A study was done in 2001 by the FSAI to test for *Campylobacter* and *Salmonella* in ready-to-eat chicken pieces. *Campylobacter* and *Salmonella* were not detected in any of the samples tested (FSAI, 2002b). Presence of these pathogens would be indicative of either under cooking or cross contamination from raw to ready-to-eat foods. This study also tested for the presence of *Staphylococcus aureus*. It found using the Irish microbiological guidelines (detailed in their Guidance note 3), that 2.8% (n=12) of all chicken samples tested to be unsatisfactory or unacceptable / potentially hazardous for *S. aureus* (FSAI, 2002b).

In the UK, a LACOTS (Local Authorities Coordinating Body on Food and Trading Standards)/PHLS (Public Health Laboratory Service) surveillance project on the rate of contamination of ready-to-eat take-away chicken pieces (n=4055) with *Salmonella* and *Campylobacter* reported the absence of *Salmonella*, but *Campylobacter* was isolated in one sample which was found to be undercooked. Another UK study undertaken by the Joint Food Safety and Standards Group on ready-to-eat meats and meat products reported that *S. typhimurium* was detected in 2 samples and that *Campylobacter* was not detected in any of the samples tested (n=758) .

A study done by the FSAI in 2002 investigated the microbiological safety of pre-packed sandwiches (n=475) with respect to *S. aureus* and *L. monocytogenes*. Table (1.4) details how the results for *S. aureus* in the FSAI survey compare with other studies.

Table (1.4): Incidence of *S. aureus* in sandwiches at levels >100cfu/g (FSAI,2003b)

Origin	Sampling period	Sample Description	No. of samples enumerated	No. of samples >100cfu/g
Australia	1998	Sandwiches and rolls	62	7(11%)
UK	1989	Sandwiches with various fillings	91	0(0%)
UK	1993	Sandwiches with different fillings	324	2(0.5%)
UK	2001	Chicken sandwiches and rolls(without salad)	449	10(2%)
Ireland	2002	Sandwiches with various fillings	475	3(0.6%)

As shown in table above, the incidence of *S. aureus* at unsatisfactory levels (0.6%) is similar ($p<0.05$) to that of a UK study which was undertaken as part of the 1993 EC coordinated food control programme (FSAI, 2003b).

Quantitative and qualitative analysis for *L. moncytogenes* in prepacked sandwiches as found in the 2002 survey are shown in Table (1.5) as well as comparisons with other studies.

Table (1.5): Incidence of *Listeria monoctyogenes* in sandwiches (FSAI, 2003b)

			Qualitative tests		Quantitative tests	
Origin	**Year of study**	**Sample description**	**No. analysed**	***L. moncytogenes***	**No. enumerated**	**Count**
Australia	1998	Sandwiches and rolls	44	1(2.3%)	ND	N
UK	1993	Sandwiches with different fillings	324	6(2%)	ND	NA
UK	1989	Prepacked sandwiches	91	16(17%)	16	>100
NI	1996	Prepacked sandwiches	725	113(15.59%)	725	>100
Ireland	2002	Prepacked sandwiches	475	52(10.9%)	323	>100

NA-Not Applicable

ND- Not determined

L. monocytogenes was detected in 11% of samples taken by the FSAI. The qualitative results presented in Table (1.5) show the variability in the incidence of *L. monocytogenes* between the studies conducted in Ireland, U.K. and Australia, ranging from 2% to 17%.

1.3.4 Frozen foods

The sales of frozen foods in the Republic of Ireland were worth in excess of €382.5 million in 2003 and continues to grow annually (Frozen Foods in Ireland, 2004).

The ice cream market in Ireland is worth €143 million and is considered to have the third highest consumption of ice cream per capita in Europe, with ten litres per head consumed every year (Checkout, 2006).

Temperature abuse of frozen foods could adversely affect sensory and nutritive quality. It occurs when frozen products are held at temperatures too high or if temperature is allowed to fluctuate. Current recommendations are that frozen foods should be displayed at -18°C, except in the case of ice-cream which should be held at -23°C (NSAI, 1998).

A major difference between chilled and frozen foods is that the latter have a safety factor in that thawing requires both ambient and latent heat. Therefore, temperature abused frozen foods remain at 0°C for some time because of the latent effect. While this may influence quality and sensory properties due to partial thawing. The microbiological status usually does not deteriorate until thawing is complete and the temperature begins to rise above 5°C (Gormley, 1989b).

Freezing preserves the storage life of foods by making them more inert and slowing down the detrimental reactions that promote food spoilage and limit quality shelf life. However, a number of physical and biochemical reactions can still occur and many of these will be accentuated when recommended conditions of handling, production and storage are not maintained. Although few microorganisms grow below -10°C, freezing and frozen food is not a reliable biocide.

Freeze damage occurs by a number of mechanisms that result in loss of quality in a product after thawing. Loss of quality may be seen in the frozen product, e.g. freezer burn, discoloration, mechanical damage, but in many cases the loss of quality is not noticeable until after thawing. Most of the mechanisms of quality loss are determined by storage temperature and are accelerated with time spent above the recommended value. They are also promoted by temperature fluctuations.

1.4 RELATIVE HUMIDITY

During display in refrigerated cabinet, evaporation of water from produce represents a direct loss of saleable product through reduced weight. It also limits display life through dehydration and perceived deterioration of quality. Humidification reduces the vapour pressure difference between water at the surface of the produce and in the air, thus reducing the driving force for evaporation (Brown *at al.*, 2004). Optimum relative humidity for display of most produce is 80-95%, with fruit and vegetables requiring a RH at the higher end of the scale.

Relative humidity (RH) is the main factor controlling weight loss and the display life of delicatessen products. Large differences in average relative humidities and air velocities from 41 to 73% and 0·1 to 0·5m/s respectively have been measured (Gormley, 1989a).

At an RH of 40% the effect of surface drying became apparent after approximately 100 minutes. At 85% RH the products could be displayed for between 4 and 6 hours before surface drying could be noted. The overall weight loss at 40% RH was approximately three times that at an RH of 85% (Brown *et* al., 2004). Chill cabinet manufacturers are addressing this issue and newer models guarantee low product temperatures combined with extremely low levels of dehydration (0.73% per day in some cases due to new humidification systems) through control of air velocity.

It is a concern with fruit and vegetable products, which carry high initial numbers of bacteria, that the increased availability of water may have a detrimental effect on bacterial growth and multiplication. However Brown *et al.*, (2004) cited no adverse effects on microbial quality due to humidification of chill cabinets.

1.5 PREDICTIVE MICROBIOLOGY

Predictive microbiology involves the development of mathematical models of microbial population changes in food. It is based on the premise that the responses of populations of microorganisms to environmental factors are reproducible and that, by characterising environments in terms of those factors that most affect microbial growth and survival, it is possible from past observations to predict responses of those microorganisms in other, similar environments (M^{c}Meekin *et al.*, 2006).

Classical predictive microbiology is based on the assumption that the rate of growth or death of a given microorganism in the exponential phase is characteristic of its environment. Predictive microbiology is a description of the responses of microorganisms to particular environmental conditions, the most important environmental parameters are temperature, pH and water activity (Baranyi and Tamplin, 2004).

Laboratory based microbiological tests are typically used to make critical decisions regarding food safety and product shelf-life. However the growth, survival and inactivation of microorganisms in foods are reproducible responses. Predictive microbiology models which quantitatively describe the combined effect of specific environmental conditions can be used to predict growth, survival or inactivation of microrganisms (Baranyi and Tamplin, 2004).

Membré and Bénézech (2003) cited that the significant applications of predictive microbiology include:

(1) Prediction of the shelf life of foodstuffs

(2) Food Quality and safety-HACCP

(3) Research and Development technology (development of new products)

(4) Quantitative Risk Analysis

(5) Pedagogy (knowledge on microbial growing)

Knowledge of microorganisms and the behaviour of microbial populations in foods for the purpose of developing effective food safety management strategies is required at the population level, the cellular level and the molecular level (M^{c}Meekin, 2003).

1.5.1 Databases

Databases contain information on microbial population behaviour. These information systems are concerned with data capture, storage, analysis and retrieval. Databases with information on microorganisms pertinent to the identification of food borne pathogens, response of microbial populations to the environment and characteristics of foods and processing conditions are the cornerstone of food safety management systems (M^{c}Meekin *et al.*, 2006). In the context of food safety management, databases in conjunction with predictive modeling software are vital to assist the practical application of HACCP, risk assessment and decision tress to bring logical sequences to establishing and modifying food safety practices

ComBase, a web-based software accessible via ComBase Browser (www.combase.cc/predictor.html), is a common database on microbial responses to food environments, it encompasses observations of bacterial responses to food environments. The information in ComBase is referred to as 'quantitative microbiological' data since it describes how levels of microorganisms, both spoilage organisms and pathogens, change over the course of time.

The data included in ComBase were obtained from cooperating research institutes and from the literature (Baranyi and Tamplin, 2004). The ComBase Initiative is a collaboration between the Food Standards Agency and the Institute of Food Research from the U.K, the USDA Agricultural Research Service and its Eastern Regional Research Centre, USA and the Australian Food Safety Centre of Excellence.

The database consists of thousands of microbial growth and survival curves that have been collated in research establishments and from publications. They form the basis for numerous microbial models presented in *ComBase Predictor*. The maximum rates of growth or death of microorganisms for the same values of temperature, pH and water activity can be different depending on the nature of the food and other environmental factors that are not necessarily recorded. The measurements recorded in ComBase database are in both food and laboratory media.

1.5.2 Growth Models

Development of models to predict growth survival or inactivation of micr0organisms in foods has been a most active area of food microbiology within the last 20 years and a considerable number of models to predict responses or growth limits in foods are available (M^{c}Meekin, 2006). Predictive microbiology models are important tools for food safety management as they provide a scientific basis to underpin key aspects of HACCP and quantitative microbial risk assessment.

Growth limit models in particular help identify potential microbial hazards in specific foods. Growth and inactivation models provide a quantitative link between measurements used to monitor processes (e.g. time, temperature, pH and salt) and potential responses of specific pathogens (M^{c}Meekin *et al.*, 2006).

Growth or inactivation of pathogens along the 'farm to fork' chain is fundamental to microbial risk assessment. Therefore predictive models are key components in estimating consumer exposure to pathogens in foods at the time of consumption (M^{c}Meekin *et al.*, 2006).

To model responses in foods a two step approach has been used widely:

(1) 'Primary ' models are used to express changes in concentration of organisms over time using a limited number of kinetic parameters e.g. lag time, rates of growth or inactivation, maximum population reached, that together describe the change in the population size

(2) 'Secondary' models that express the effect of environmental parameters (e.g. temperature, NaCl, pH, etc) on the kinetic parameters (Ross *et al.,* 2000).

ComBase Predictor comprises a set of twenty three growth models and six thermal death models for predicting the response of many important food borne pathogenic or spoilage microorganisms to environmental factors, including temperature, pH and salt concentration. Some models also include an additional fourth environmental factor, such as the concentration of carbon dioxide or acetic acid.

ComBase Predictor can be used to make predictions at either a static temperature or under non-constant temperature conditions. The predicted rates from *ComBase Predictor* are from models of kinetics in laboratory media. Therefore these models usually predict faster growth rate or slower death rate than would be observed in vivo.

1.5.3 Validation and limitation of models

Mathematical models must undergo validation before they are used to aid food safety decisions (FSAI, 2007). Validation involves comparing model predictions to experimental observations not used in model development. Models can be validated by reference to published literature (Sutherland *et al.*, 1994), or by performing challenge studies of organisms in foods or both.

Predictive microbiological responses are normally developed assuming microbial responses are consistent. While predictive models can provide a cost effective means to minimise microbiological testing in determining shelf life of foodstuffs, there may be occasions when the model's predictions may not be accurate, due to inconsistent microbial responses and variations in the growth media.

Models are normally developed under static conditions (growth rates and lag times are measured at a series of set temperatures, water activity values and pH levels), and the results are combined to describe the effects of each factor or a combination of factors on population development. Subsequently, models must be validated in foods under conditions that mimic situations encountered in normal practice, e.g. decreasing temperature and water activity during distribution and storage of many food commodities.

A common theme of problems in predictive microbiology is that of uncertainty due to variability in terms of the starting conditions (e.g. initial microbial numbers and types) and the microbial response in a given or changing environment. Also when using the growth models at the growth limits the 'no growth' conditions are usually omitted from the model fitting. Therefore, conditions close to the no growth/ growth boundary, which are often of industrial interest, may lie outside of the interpolation area. Attempts to include 'no growth' data in the building of a secondary growth model have been made but this inclusion may bias the resulting equation (Buchanan and Philips, 1990).

1.6 OBJECTIVES

The primary objective of this research was to investigate temperature and relative humidity control of chilled and frozen foods on sale in 3 types of retail outlets, in the Republic of Ireland.

A further objective was to evaluate the food safety management systems in operation in supermarket, delicatessen and butcher retail outlets, in the Republic of Ireland through:

a) Analysis of air and food core temperature control in chilled and freezer display cabinets, as well as air relative humidity within the chill cabinets.

b) Administration of a questionnaire to employees in the retail outlets visited on food safety practices, and observations, on food safety management including food hygiene and staff training practices.

c) Assessment of HACCP compliance within the outlets surveyed.

d) Assessment of the microbiological safety of 'ready to eat' high risk foods on sale in retail outlets with respect to *Staphylococcus aureus* and *Listeria monocytogenes.*

A final objective was to examine food safety risks to consumers as a result of inadequate temperature control and poor food hygiene practices using microbial analysis and predictive modelling.

CHAPTER TWO: METHODOLOGY

The methodology used for this research consisted of:

(i) Time-temperature and relative humidity monitoring of chilled and frozen foods in open and closed display cabinets throughout a commercial day in 85 premises spread throughout the 26 counties of the Republic of Ireland.

(ii) A survey of employee food safety practices in the retail outlets that are part of the food safety management system in operation, using a questionnaire and visual audit.

(iii) Microbiological study of 'high risk' chilled foods

2.1 SELECTION AND GENERAL DESCRIPTION OF OUTLETS SURVEYED

This survey was conducted throughout the twenty six counties of the Republic of Ireland, three outlets in each county except for the capital where ten premises were surveyed. This research was targeted at retail outlets handling "high risk" ready-to-eat and/or raw foods such as sliced meats or salads. The premises targeted for this research were supermarket, delicatessen and butcher outlets. For the purpose of this study the term delicatessen refers to sandwich bars and coffee shops. A supermarket, delicatessen and butcher outlet were selected in each county of the

Republic of Ireland, except for Dublin, where ten premises were visited comprising of three butchers, three delicatessen and four supermarket outlets. The outlets were selected randomly, with initial contact being made by telephone to discuss the nature of the research, outlining the scope of the survey and the specific objectives pertaining to it.

Following agreement from the proprietor a date was scheduled for each visit. It was agreed that store names would be treated confidentially, resulting in code names to ensure anonymity. The size of the outlets varied, with the premises being classified as small (less than 10 employees), medium (greater than 10 and less than 40 employees) or large (40 or more employees). Table (2.1) details the number of outlets included in the temperature and relative humidity monitoring survey. Three of the butcher outlets surveyed in three counties were butcher counters within a supermarket premises.

Table (2.1): Scope of the temperature and relative humidity monitoring survey

Size of Outlet	Large	Medium	Small
Butcher	0	2	23
Butcher*	0	0	3
Deli	0	7	21
SM	10	12	7
Total	10	21	54

Butcher * denotes a butcher counter within a supermarket outlet

2.2 TEMPERATURE AND RELATIVE HUMIDITY MONITORING

Temperature readings of various chilled and frozen foods were recorded in each outlet as part of this research. A range of chilled and frozen foods were selected for monitoring including dairy, fresh meat and the ready meal sector. The range of chilled foods to be investigated were

(a) Refrigerated, processed ready-to-eat foods

(b) Raw or partially prepared products intended to be cooked by the consumer

(c) Raw meats intended to be cooked

The final list of products that were investigated included:

- Fresh meat and meat products, game and poultry
- Fresh fish,
- Salads for example coleslaw, sliced tomatoes
- Fruit and vegetables
- Dairy products for example milk, yoghurt
- Sliced meats for example ham, chicken
- Soups
- Patisserie
- Prepared dishes for example lasagne, pizza
- Frozen foods for example fish, pizza, vegetables

The air relative humidity in the open display cabinets containing chilled foods was also monitored.

Temperatures and air relative humidity were measured with calibrated dataloggers (Testostor 175 and 175-H2, Eurolec Instrumentation Ltd., Dundalk, Ireland) and a water-tight penetration probe (IP65, Eurolec Instrumentation Ltd., Dundalk, Ireland) with a measurement range from -50 to +150°C. The dataloggers were programmed to measure and record external air temperature (with an accuracy of +/- 0.5°C), product core temperature (with an accuracy of +/- 0.5°C) and air relative humidity (with an accuracy of +/- 3% relative humidity) at 5 minute intervals for a typical commercial day which added up to a 7 ½ hour period.

Dataloggers were placed in different positions in chill cabinets and freezers beside the various food products where they were left in situ for the period of a typical commercial day. The postioning of the dataloggers depended on the cabinet design, but the same positions were used in cabinets of the same design, for the purpose of consistency. Three dataloggers were used in each outlet, two which measured air and or core temperature, and one which measured the air relative humidity. All temperature readings were downloaded using Testo Comsoft software.

2.3 QUESTIONNAIRE

A questionnaire on operational practices with regard to the hygiene and food safety protocols was used for this study. The objective of the questionnaire was to extract critical information that would support the analysis. The questionnaire was divided into 4 sections and used both open-ended and closed questions. The questionnaire was discussed directly with the manager, assistant manager or quality control manager, this allowed for any ambiguities in the questions to be addressed. The complete text of the questionnaire is provided in Appendix 1 to give dimension to the field of analysis. The questionnaire comprised of 40 questions, divided into 4 sections which covered topics including:

(1) Respondents' profile

(2) Awareness and understanding of HACCP

(3) Operation of in-store food safety management system

(4) Compliance with statutory legislation

(5) Food safety training offered to employees

The questionnaire was used to examine the interviewees' knowledge and understanding of food safety management, as well as getting their opinions on relevant industry issues in this area. All outlets, except those in the Dublin area, were visited in the period from August to November 2005. The premises in the Dublin area were visited in June, July and August of 2006. HACCP compliance, as required at the time of the survey by the European Communities (Hygiene of foodstuffs) Regulations, 2000 (S.I. No 165 of 2000) was assessed. HACCP compliance was assessed by examining the three major elements of a HACCP system: a) hazard analysis; b) controlling critical points; c) verification.

2.4 OBSERVATIONS

On completion of the questionnaire, staff work practices were observed. Observations were noted with regard to staff work practices in the area of hygiene, in particular food handling protocols were observed whilst present in the store.

Cabinet make and model were recorded and their condition was examined visually and checked for cleanliness.

Positioning of open and sealed display cabinets within the store as well as stacking arrangements, stocking levels and stock rotation were also checked. Seals on doors were checked and temperature as shown on digital display was compared to reading recorded by dataloggers to check for accuracy. The complete text of the observations recorded is in Appendix 2.

2.5 ANALYSIS OF NATIONWIDE SURVEY DATA

2.5.1 Temperature and relative humidity readings

The temperature and relative humidity readings were analysed to determine the mean, median, maximum and minimum values for the recorded readings with regard to each product surveyed.

Further analysis of the temperature and relative humidity readings were done using analysis of variance (ANOVA) tests and multiple comparisons if a significant result was found using ANOVA. Analysis of the following variables was carried out using ANOVA and multiple comparisons:

(a) outlet type

(b) outlet size

(c) cabinet design

(d) cabinet make

(e) position of dataloggers within the cabinets

The Pearson Chi-Square test was also used where appropriate. All statistical tests were generated at a 95% Confidence Interval.

2.5.2 Questionnaire & observations

All completed questionnaires were analysed, the critical data extracted, manually collated and then inputted. The Statistical Package for the Social Sciences (SPSS) software version 13.1 was used as the method of analysing the resulting data from the questionnaire. Following data entry, the data file was subject to a number of data validation procedures, including both inter and intra variable validation checks.

In addition to simple frequencies, bi-variate statistical tests were applied to identify significant variations in response to key background variables. The test result used most frequently was the Pearson Chi-Square. All statistical tests were generated at a significance level of 5%. Fishers Exact Test was used in cases where there was a small number of observations. Graphical presentations were produced using Excel software. The data acquired from observations recorded was interpreted without using statistical analysis.

2.6 MICROBIOLOGICAL STUDY OF 'HIGH RISK' CHILLED FOODS

2.6.1 Selection and general description of outlets surveyed

This study focused on ten outlets in Dublin city centre, each having a high food turnover. Five of the outlets were sandwich bars, three of the outlets were cafés, and two were supermarkets with sandwich counters.

The sandwich bars and cafés had seating to accommodate approximately 15-20 people, and the majority of business in these outlets was carried out between 12-3pm. The supermarkets had no seating, and longer opening hours than the other 2 types of retail outlets, but the majority of business would have been visited between 12-3pm and 4.30-6.30pm.

2.6.2 Description of food type

Microbiological analysis focused on popular chilled foods, which are not subject to further heat treatment prior to consumption. Samples surveyed were pre-cooked chicken pieces, coleslaw and cream doughnuts. The chicken pieces, coleslaw and cream doughnuts arrived in the outlets in refrigerated vans and were immediately placed into chilled storage.

The chicken pieces arrived as vacuum packed chicken breasts. The vacuum packed chicken breasts were opened in the morning at 9am and the chicken was prepared for use as a sandwich or salad filler. Food handlers at each outlet wore gloves while handling the food. Preparation varied from outlet to outlet and included cutting the chicken breast with a sharp knife or chopping them in a blender. The chicken pieces were then placed into a bowl in the salad bar display unit, which was refilled as required. All the chicken was handled at least twice; once when opening the vacuum pack and chopping the chicken, and again while making the sandwich.

The coleslaw and cream doughnuts arrived ready made. The coleslaw was stored in a chiller and put into a stainless steel container in the salad bar. The coleslaw was never handled directly instead a serving spoon was used to put it into the serving bowl as required.

The cream doughnuts were also kept in a cold store in the outlets prior to being displayed in serve-over cabinets. The cream doughnuts were handled at least twice, once when being put into the cold store and again when being transferred to the serve-over display cabinet.

2.6.3 Sample collection

A 75g or more sample of each food type was taken at three set times during a commercial day. A sample of each food type was taken at 9am, 1pm and 4pm of the same day. The sampling took place during June, July and August 2006, and one outlet was sampled per week.

2.6.4 Microbial analysis

2.6.4.1 *Microorganisms studied*

The microbiological safety of the chicken pieces, coleslaw and cream doughnuts was assessed with respect to *Staphylococcus aureus* and *Listeria monocytogenes*. The microbiological status of the samples was determined according to the microbiological criteria in Commission Regulation (EC) No 2073/2005 and the FSAI Guidance note no. 3. The food samples were analysed both qualitatively, and quantitatively if applicable, for both pathogens. All microbiological analysis conducted in this research were taken from the analytical reference methods in Commission Regulation (EC) No 2073/2005.

2.6.4.2 *Preparation of chilled food samples*

The samples of chicken pieces, coleslaw and cream doughnut reached the laboratory in a condition virtually microbiologically unchanged from that existing at the time of sampling in the retail outlet. Contamination of the samples and microbial growth or death during transport and storage was avoided by adopting the following procedures:

(i) <u>Containers for transporting chicken samples</u>

Insulated cooler bags (Thermos, 34498) were used to hold and transport the chilled chicken samples from each outlet to the laboratory. These containers and all sampling instruments were pre-sterilised.

(ii) <u>Transportation and storage</u>

All food samples were transported and stored under conditions which inhibit changes in microbial numbers. Samples were delivered to the laboratory within 5-10 minutes of sampling.

The maximum recovery diluent (MRD) which was used to suspend the sample was Tryptone Phosphate Water (Scharlau, 02-277), which was composed of peptone 10.0g/L, sodium chloride 5.0g/L, disodium phosphate 9.0g/L and potassium phosphate 1.5g/L. Tryptone phosphate water powder (25.5g) was dissolved in 1 litre of distilled water, this solution was put into a Duran bottle and sterilized at 121°C for 15 minutes.

The food samples were rendered into a liquid suspension in order to apply counting and culturing techniques. Weighed samples of each food type (25g) (Sartorius weighing scales, LC2200P) were homogenised in a measured volume of diluent (225mL) to give a 10^{-1} homogenate. The samples and diluent were aseptically placed in the appropriately sized stomacher bag (Seward, Filter bag BA604/STR). The machine was switched on and operated for 120 seconds at high speed, and the contents of the bag were poured into a sterile 250mL bottle. This 10^{-1} homogenate, or a decimal dilution of this homogenate, was used for the counting and culturing techniques.

Duplicate plating was carried out for each sample taken, and two decimal dilutions were made for each sample tested. Dilutions of 10^{-2} were made up from the 10^{-1} sample homogenate of each food type sampled, prepared as described in section

2.6.4.3, using (MRD) as diluent. Two agar plates using the appropriate selective culture media for *S. aureus* (Baird Parker, Merck 432 with egg yolk tellurite sterile emulsion supplement, Scharlau 14172) and *L. monocytogenes* (Palcam, Merck OC528123) were prepared for each dilution of the two dilutions of food sample to be tested, as well as a control culture for each pathogen.

Starting with the highest dilution, the test dilution was taken up into a 0.1 mL pipette with a disposable tip (Jencons pipette, 200-1000), and dispensed from the pipette onto each of the dried agar plates. The inoculum was spread evenly over the entire surface of the plate using a sterile hockey stick. All plates were incubated (Gallenkamp Incubator) at 37°C for up to 48 hours.

2.6.4.3 *Enumeration of microrganisms*

After incubation all confirmed colonies on plates containing 150 or fewer colonies per plate were counted (Stuart colony counter, 6994). The number of colony forming units (CFU) per gram of test sample (N) was calculated as follows:

$$N=C/V(n1+0.1n2)d$$

where: C is the sum of colonies on the plate

V is volume of the inoculum on each dish in mLs

n1 is the number of plates counted at first dilution

n2 is the number of plates counted at second dilution

d is the dilution from which first count was obtained.

Results were rounded down to two significant figures and expressed as a number between 1.0 and 9.9 multiplied by 10^X where x is the appropriate power of 10.

2.6.4.4 *Staphylococcus aureus*

Direct enumeration on Baird-Parker (Merck, 432) is selective and produces characteristic colonies of *S. aureus*. Plates were examined for the presence of typical colonies, which on Baird-Parker medium appear as grey-black, shiney and convex, with a diameter of 1-1.5mm (18h incubation) or up to 3mm (48h incubation), with a narrow white margin surrounded by a zone of clearing. The cell morphology was examined using a GRAM stain, after which the number of cells were counted on a colony counter (Stuart, 6994).

The identity of an organism may be confirmed by demonstrating its ability to perform biochemical reactions, each species conforming to a recognisable result pattern. The identity of the colony types were confirmed by using the Agglutination test, and the proportion of colonies confirmed as *S. aureus* was used to calculate the count per gram.

Agglutination test

The rapid latex agglutination test is used for the detection of Staphylococci which produce clumping factor and/or Protein A from those species of Staphylococci which do not. The agglutination test was carried out as follows:

- The test reagents were allowed to reach room temperature
- One drop of isotonic saline was placed onto one of the test circles
- Using a sterile loop, 2-4 colonies of the suspected Staphylococcus bacteria were picked and emulsified in the isotonic saline on the test circle.

- One drop of latex reagent (AVIPATH®STAPH, OD044) was added to the test circle.
- The reagent and culture emulsion were mixed using a disposable stirrer.
- The slide was gently and evenly rocked for 1 minute whilst slide was examined for agglutination.
- A positive result is indicated by the agglutination pattern of the latex in a clear solution. A negative result is indicated by no change in the latex suspension.

2.4.6.5 *Listeria monocytogenes*

Direct enumeration on PALCAM *Listeria* Selective-Supplement agar (Merck, OC528123) is selective and produces colonies of *L. monocytogenes*. Plates were examined for the presence of typical colonies, which on PALCAM medium appear as green-blue colonies surrounded by an opaque halo. Confirmation of presumptive colonies is carried out by using tests described in ISO 11290-2:1998, however as no growth was found in this analysis this was not necessary.

2.7 MICROBIAL PREDICTIVE MODELLING

Microbial predictive modelling was used as a tool to assess the food safety management systems in operation in some of the retail outlets visited. Temperature readings recorded during the nationwide survey of supermarket and delicatessen outlets were used in conjunction with results of microbial analysis of cooked chicken pieces, coleslaw and cream doughnuts to estimate consumer exposure to *Staphylococcus aureus* through consumption of these foods.

In the case of butcher outlets, the result of microbial analysis of a survey done by the FSAI on the microbiological safety of loose cooked ham were used in conjunction with temperature readings recorded in the butcher outlets visited on the nationwide survey. *ComBase Predictor* was the computer software used for the predictive modelling in this research to predict the microbial load in the foodstuffs analysed under actual conditions. In relation to deli outlets, the microbial results of analysis for *S. aureus* load in chicken pieces, coleslaw and cream cakes were used from premises (n=6) in conjunction with temperature readings recorded from deli outlets with chill cabinets displaying these foodstuffs.

The results of microbial analysis for *S. aureus* levels in cooked chicken pieces, and coleslaw in premises (n=3) were used in combination with temperature readings from a supermarket outlet with poor temperature control. The temperature readings in the chill cabinet containing patisserie in this supermarket, were used with the results for *S. aureus* levels found in cream doughnuts analysed from premises (n=4), also a supermarket.

To predict the growth rate of *S.aureus* using the Growth Predictor model, values for other environmental factors are required. The values for the pH and Aw of coleslaw and cream doughnuts were measured using a pH meter and a water availability machine ('Aqualab', LABCELL Ltd., Four Marks Alton, Hampshire GU34 5PZ, UK). The same values for cooked chicken pieces and sliced ham were taken from the ComBase database.

Predictive modelling was also done with regard to *Listeria monocytogenes* count in smoked salmon which is a chilled product that has increased in popularity due to emphasis being placed on increasing dietary intake of omega 9 fatty acids. Temperature readings recorded in a supermarket outlet were replicated over a 30 hour period using an acceptable level of *L. monocytogenes* to demonstrate the importance of temperature control. To predict the growth rate of *L. monocytogenes* using the Growth Predictor model a pH value of 6.3 and an Aw of 0.959 were used. The values for pH and Aw of smoked salmon were taken from the ComBase database.

CHAPTER 3: RESULTS AND DISCUSSION

3.1 ANALYSIS OF TEMPERATURE MONITORING DATA

Analysis of the data recorded by the dataloggers indicates that temperature abuse of both chilled and frozen foods products is occurring in the three types of retail outlets included in this nationwide survey.

3.1.1 External Air Temperature in chill cabinets

The results of external air temperature analysis show 33% of chilled products are not held at the correct temperature. The variation in standards of temperature control in the chill cabinets examined in this research is detailed below in Figure (3.1). The boxplot displays the median air temperature for each of the chilled products included in this survey. Fruit and vegetables are not considered chilled food but do have to be stored in the temperature range 5°C to 10°C, they are also included in the boxplot in Figure (3.1).

The median value is the one that divides the lower half from the higher half, therefore it is less sensitive, in comparison to mean values, to extreme values outside the overall pattern of a distribution which are referred to as outliers. The thick black bar in the boxplots represents the median value, and the error bars represent the range of values recorded.

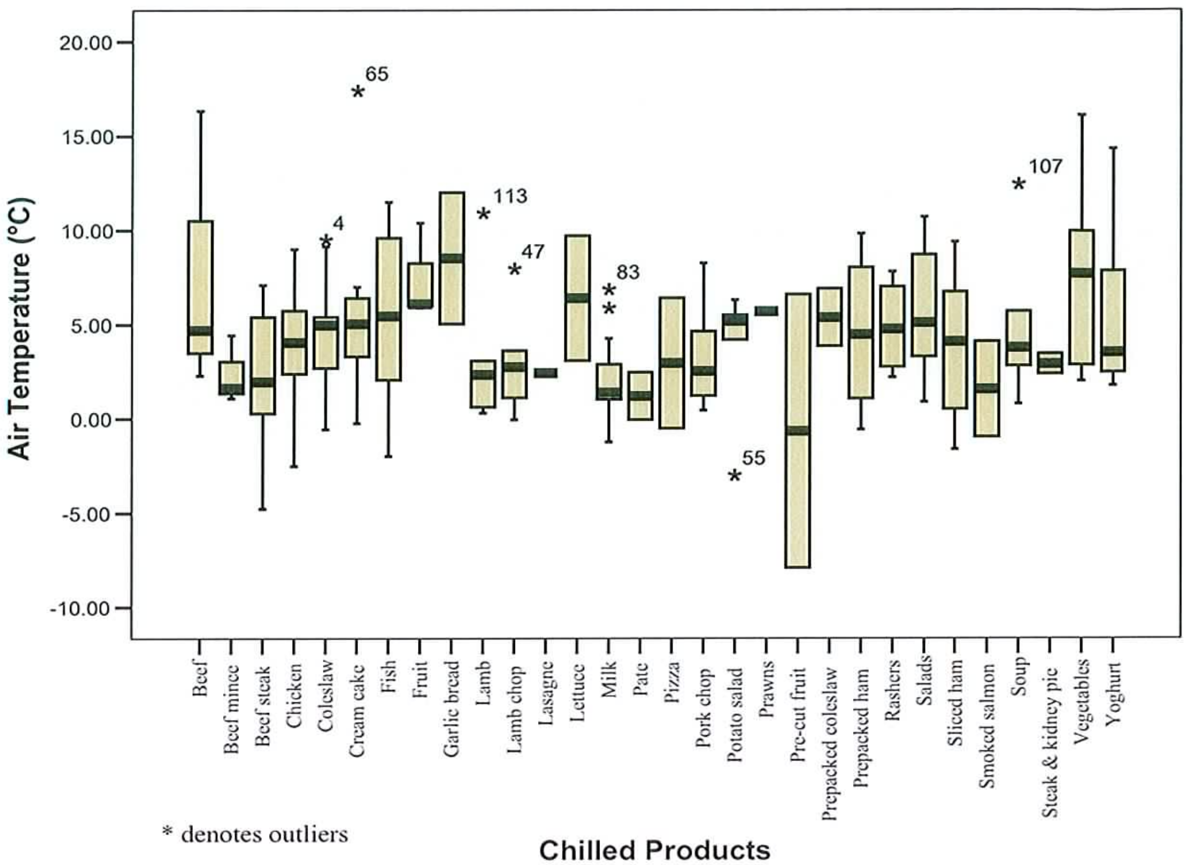


Figure (3.1): External air temperature of chilled products

The mean cabinet air temperature for 191 chilled products was 3.94°C, individual readings for each product including mean, median, maximum and minimum air temperature is detailed in appendix 3. Appendix 3 shows that despite having an overall mean cabinet air temperature of 3.94°C which is well within the acceptable range for chilled foods (-1 to 5°C), it does not mean that temperature abuse is not occurring in some outlets.

The dairy wall was found to maintain the external air and core temperature of products such as milk and yoghurt within the correct range outside of the defrost cycle, where readings such as those shown in Figure (3.2) were recorded.

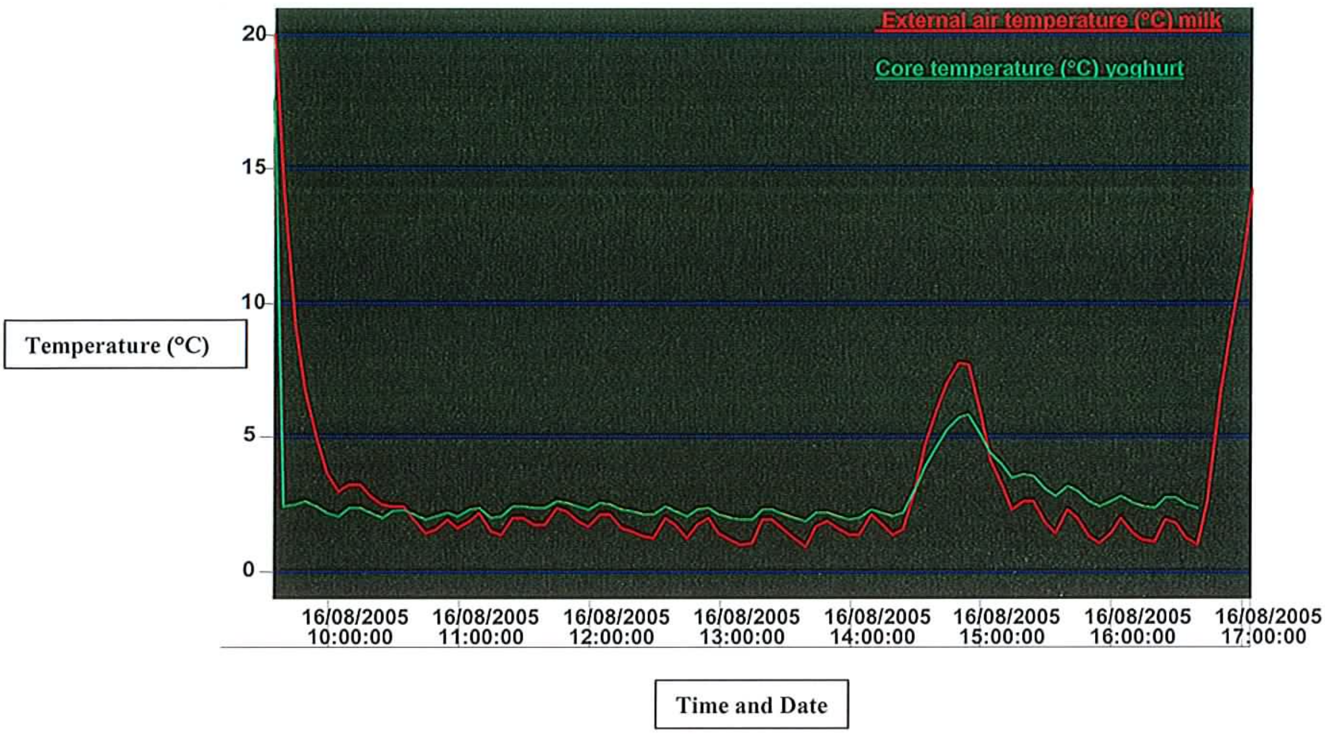


Figure (3.2): External air and core temperature in dairy wall

Figure (3.2) shows the temperature readings taken from a chill cabinet in a supermarket displaying milk and yoghurt. The products stay below 5°C for the duration of the recording period except at the beginning where the dataloggers were adapting from ambient air temperature to the temperature within the cabinet. The defrost cycle occurred for approximately 40 minutes with temperatures never exceeding 6.03°C. A defrost cycle occurs when frost has accumulated on the evaporator coil of the cabinet refrigeration system. During a defrost cycle a defrost heater melts any accumulated frost, and whilst this is occurring the air temperature within the cabinet rises.

The mean air temperature for beef steak in 17 outlets was 1.97°C, however in at least one outlet the cabinet air temperature was -4.76°C. Storing meat at an excessively low temperature does not pose a food safety problem however it would affect meat quality due to the effect of the freeze thaw cycle on the muscle fibres. Appendix 3 also shows that in at least one outlet the air temperature in the chill cabinet storing the meat reached 7.10°C.

Due to the defrost cycle occurring during the temperature monitoring it would be expected to see maximum temperatures exceeding 5°C usually for 30-60 minutes. However, temperatures above 10°C would be considered excessive even if occurring during the defrost cycle. The median value, as opposed to the mean, has been used for most of the analysis of results to compare temperatures as it is considered to give a more accurate value for air temperature in the cabinets where defrost cycles are occurring at different times and for different time periods.

The products that were stored in cabinets where the air temperature was above 5°C for at least a 2 hour period were fish, prawns, coleslaw, potato salad, lettuce, mixed salad, cream cake and garlic bread. Of particular concern in this list would be the products such as any of the salads or the cream cake which are not subject to further heat treatment. Figure (3.3) shows the temperature of the display cabinet displaying cream cakes in one supermarket.

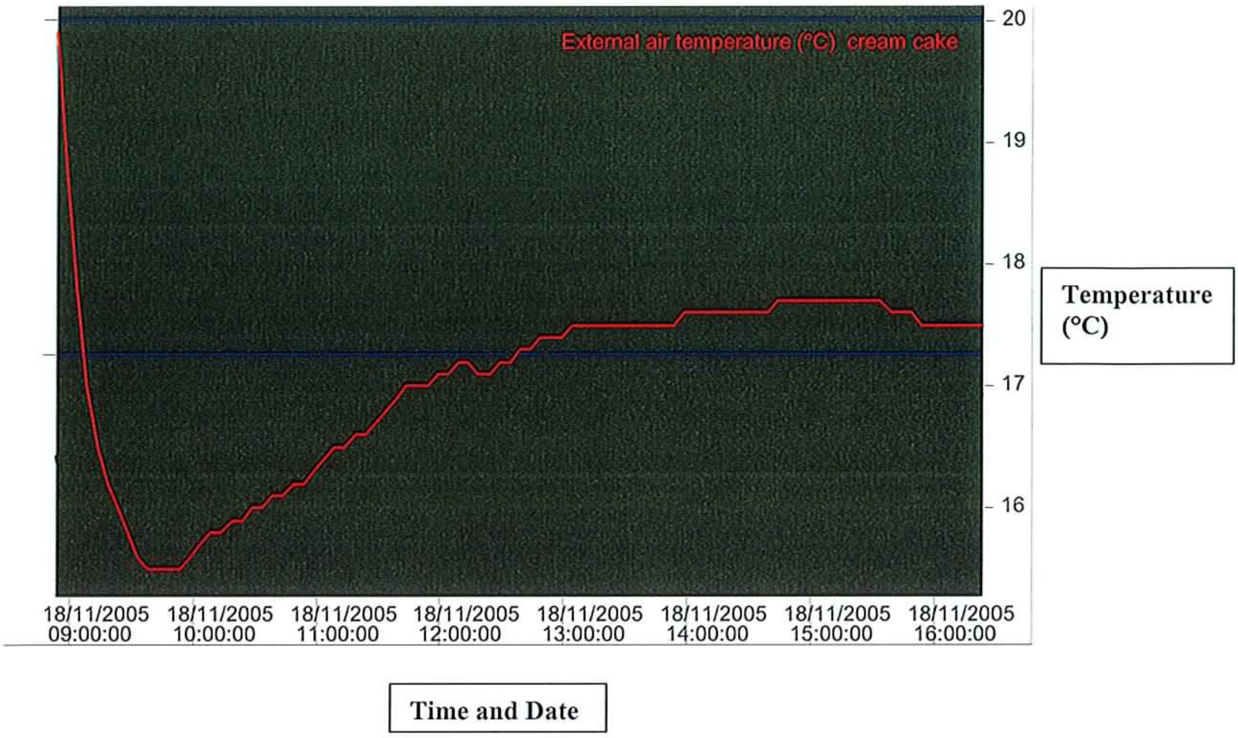


Figure (3.3): External air temperature in chill cabinet displaying patisserie

Figure (3.3) shows the chill cabinet that was displaying cream cake at temperatures no lower than 14°C throughout the entire 7½ hour monitoring period. A previous survey done by the FSAI investigating the microbiological quality of cakes and pastries from catering establishments and shops in Ireland found that 3.99% (n=21) of all samples were either unsatisfactory (10^2-<10^4 cfu/g) for *Staphyloccus aureus* or *Escherichia coli,* or were unacceptable / potentially hazardous for *E. coli* (>10^4 cfu/g) (FSAI, 2002a).

The results from the FSAI study done in 2001 highlight the necessity to maintain good hygiene practices, and further emphasizes the importance of chill cabinet temperature control if pathogens are present. Temperature abuse of products as shown in figure (3.3), combined with unhygienic practices leading to contamination of the product with pathogens represents a serious risk to public health.

Further analysis of results found that in 37% of premises, temperatures in chill cabinets exceeded 5°C for more than a minimum of two hours. Fresh meat including beef, lamb and chicken were all recorded at temperatures over 5°C outside of the defrost cycle in 40% of the counties visited. Temperature abuse of fresh chicken is shown below in figure (3.4).

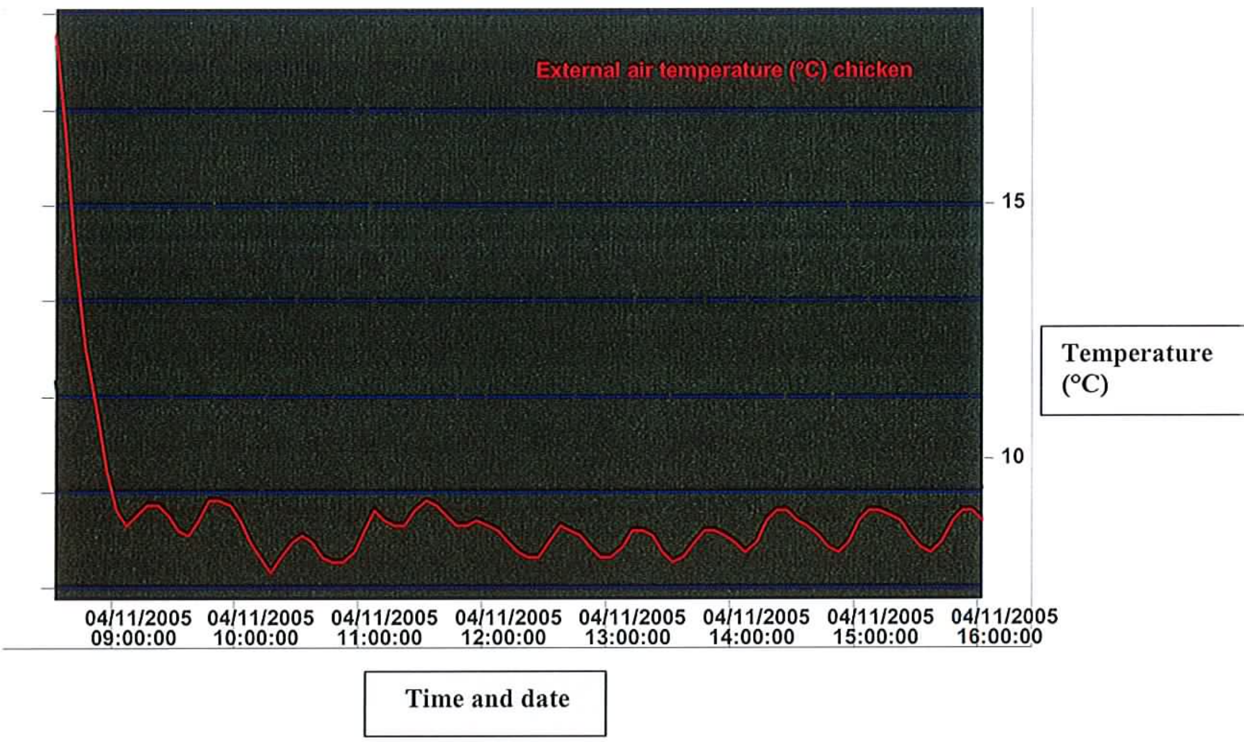


Figure (3.4) External air temperature in chill cabinet displaying meat

Figure (3.4) shows the external air temperature surrounding chicken fillets on display in a chill cabinet in a butcher outlet. The external air temperature was never lower than 7.8°C throughout the recording period, however this product will be subject to heat treatment prior to consumption. In comparison to meat, fresh fish was inappropriately stored in a smaller number of cases (16%), where for example in one supermarket it was kept at temperatures of 9°C or greater throughout the entire period of temperature recording.

Consumption of salads has increased greatly, particularly as a result of their use as sandwich fillers. Only 30% of supermarkets and delicatessens stored salads at the correct temperature range. Frequently temperatures of 10°C and above were recorded throughout the logging period, in particular with coleslaw as shown below in figure (3.5).

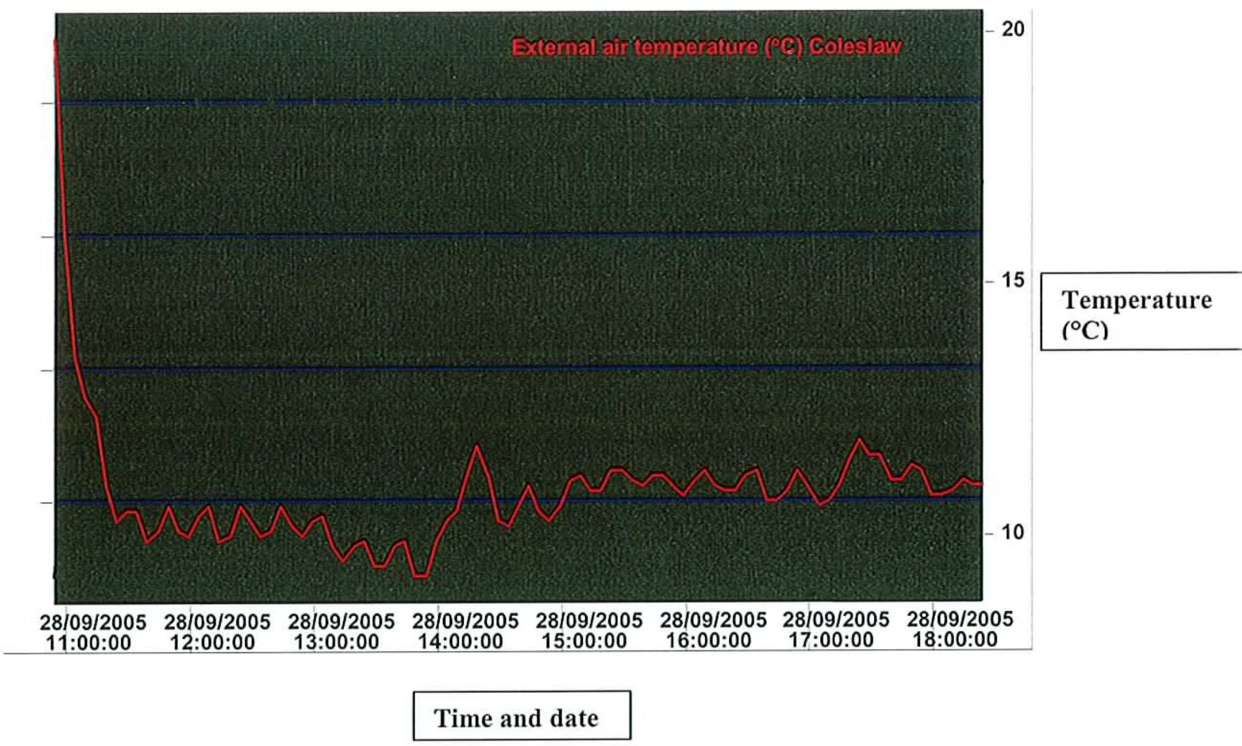


Figure (3.5): External air temperature in salad bar displaying coleslaw

In figure (3.5) there is evidence that the cold chain is broken at the retail level, as in this delicatessen outlet the salads were being stored in a chill cabinet with an average external air temperature of 10.12°C through out the commercial day. Pathogenic pyschrotrophs such as *Listeria monocytogenes* and *Yersinia enterocolitica* are not inhibited at the temperatures recorded in figure (3.5), and coleslaw will readily support the growth of these pathogens.

If these pathogens are already present in coleslaw due to contamination prior to display in the salad bar, or if contamination occurs whilst in the salad bar, the lack of temperature control observed in the salad bar shown in figure (3.5) significantly increases the risk of an outbreak of listeriosis due to consumption of this coleslaw. Previous research done by the FSAI found that 23.8% (131/550) of pre-packaged salads samples taken from retail outlets similar to those surveyed for this research were stored in cabinets whose external air temperature exceeded 5°C (FSAI,2006b).

Sliced meats, in particular ham used in sandwiches, showed inadequate temperature control in 25% of outlets surveyed. As previously mentioned, temperature control is essential to ensure that pathogens such as *Listeria monocytogenes* (if present) do not exceed their critical limit in terms of food safety, at the point of consumption. Figure (3.6) shows evidence of temperature abuse of sliced ham in a supermarket outlet.

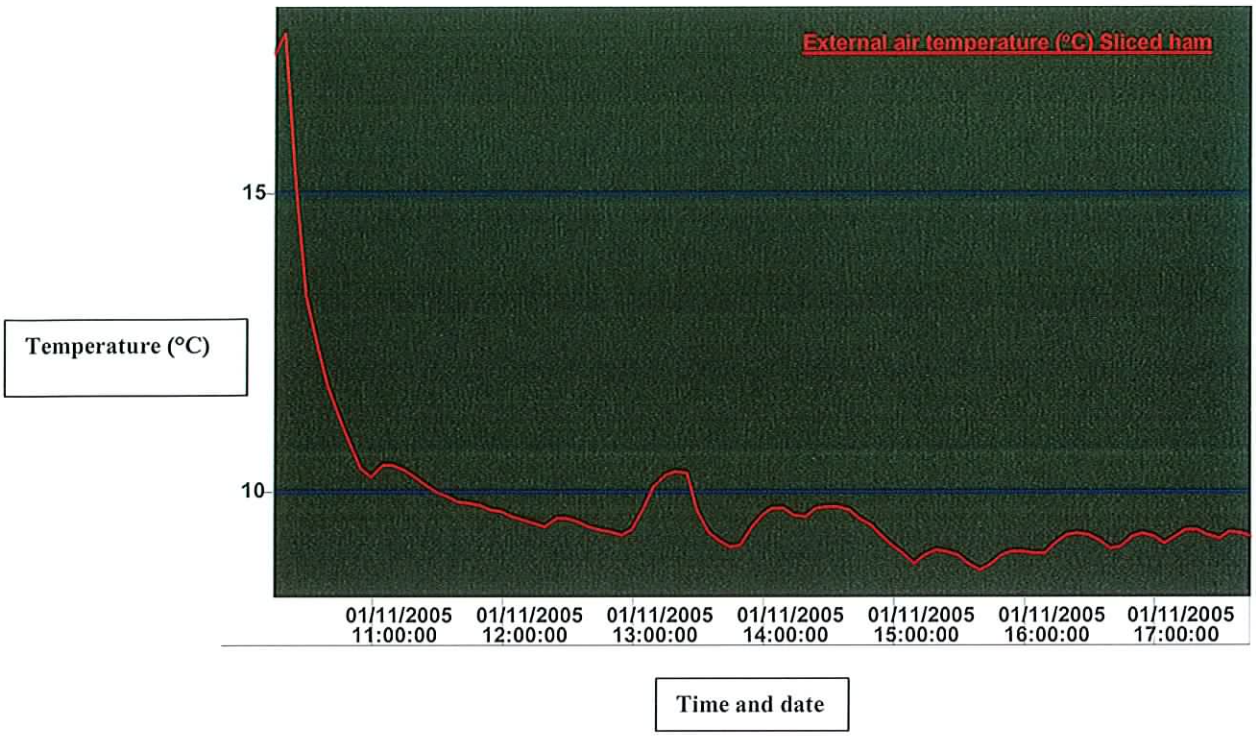


Figure (3.6): External air temperature in chill cabinet displaying sliced ham

In figure (3.6) the external air temperature is never lower than 8.7°C, which is not acceptable in terms of maintaining microbiological safety of the foodstuff. In terms of microbiological safety; *Salmonella* spp., *Listeria monocytogenes* and *Staphyloccocus aureus* are pathogens which have been associated with ham.

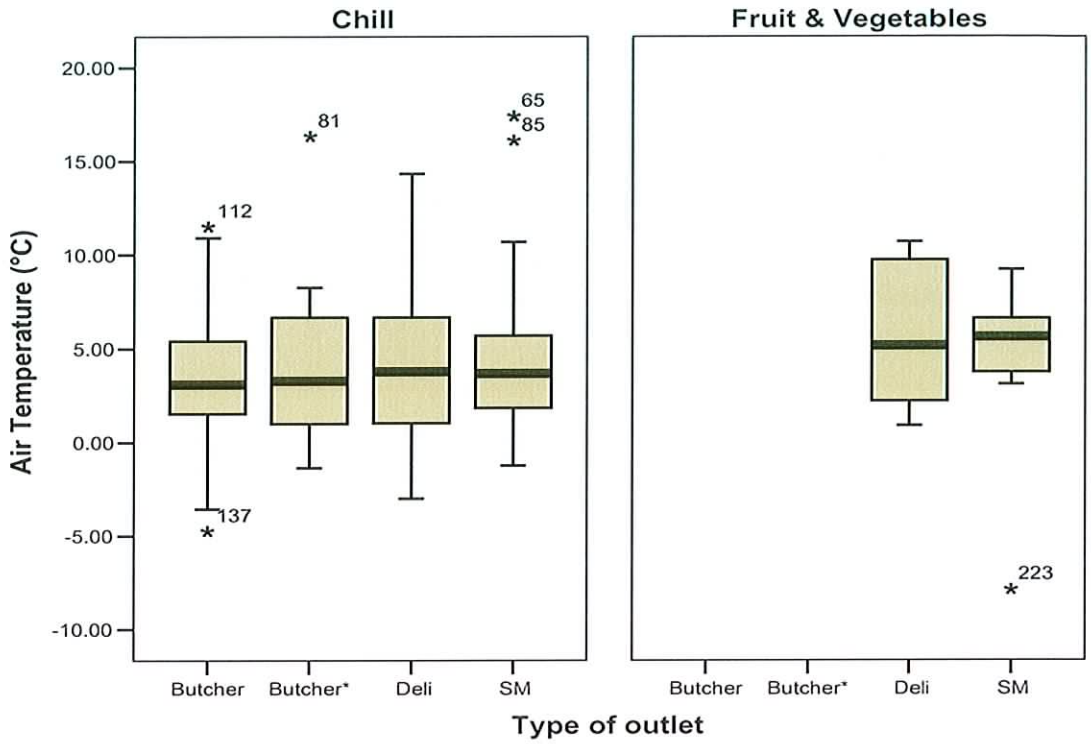
A survey done by the FSAI in 2005 found all samples of cooked sliced ham were satisfactory for *L. monocytogenes* (n=919) and *Salmonella* spp. (n=923). In relation to *S. aureus,* 99.1% (915/923) were satisfactory while 0.6% (5/923) and 0.3% (3/923) of samples were classified as acceptable and unsatisfactory respectively, according to the guidelines in the legislation (FSAI, 2006c). A previous survey done by the FSAI on pre-packed cooked ham found 13% and 4% of samples were unsatisfactory for Aerobic Colony Count (ACC) and *Enterobacteriaceae* respectively (FSAI, 2004d). The research done by the FSAI did not examine temperature control, it concluded that more emphasis must be placed on appropriate hygiene and handling practices.

Patisserie was stored at the correct temperature in 25% of the outlets surveyed, all other outlets had temperature readings above 10°C for a minimum of 2 hours. Prepared meals were generally correctly stored, however fresh garlic bread spent 3 hours in an air temperature of 12°C in a delicatessen.

Storage of dairy products such as milk and yoghurt has improved since the last survey done by the Irish National Food Centre in 1987. Previous research showed that at no stage during a 48 hour period did milk temperatures fall back to their starting values (Gormley, 1989b). However this survey showed that the average external air temperature in the milk chill cabinet was 2.1°C, and in only 2 of the 25 outlets surveyed did temperatures exceed 5°C. In both cases the maximum temperature reached was 6.86°C and this occurred during a defrost cycle.

With regard to fruit and vegetables, the overall mean external air temperature (n=12) was 5.32°C. In the 12 outlets where the temperature of fruit and vegetables were monitored the external air temperature was found to be in the correct range.

The results of temperature monitoring were analysed to determine if temperature control was dependant on the type of outlet storing the product, as shown in figure (3.7).



* represents outliers

Butcher* represents butcher counters in supermarkets

Deli represents delicatessens

SM represents supermarkets

Figure (3.7): External air temperature in chill cabinets in different outlet types

It can be seen from figure (3.7) that there was no great variation in external air temperature control between the different outlet types, for either chilled products or fruit and vegetables in supermarket and deli outlets. Analysis of the variables using ANOVA also found no significant difference between outlet type and temperature control at a 5% confidence level. Therefore, the standard of temperature control for chilled and fruit and vegetable products were not significantly better in any one of the outlet types surveyed. The median air temperature in all the outlets types for chilled products was approximately 3°C, and was approximately 5.5°C for fruit and vegetables, both values are considered satisfactory.

The effect of outlet size on temperature control with respect to products investigated was also examined as shown in figure (3.8). There was no significant difference between outlet size and the standard of temperature control in chill cabinets ($p>0.05$).

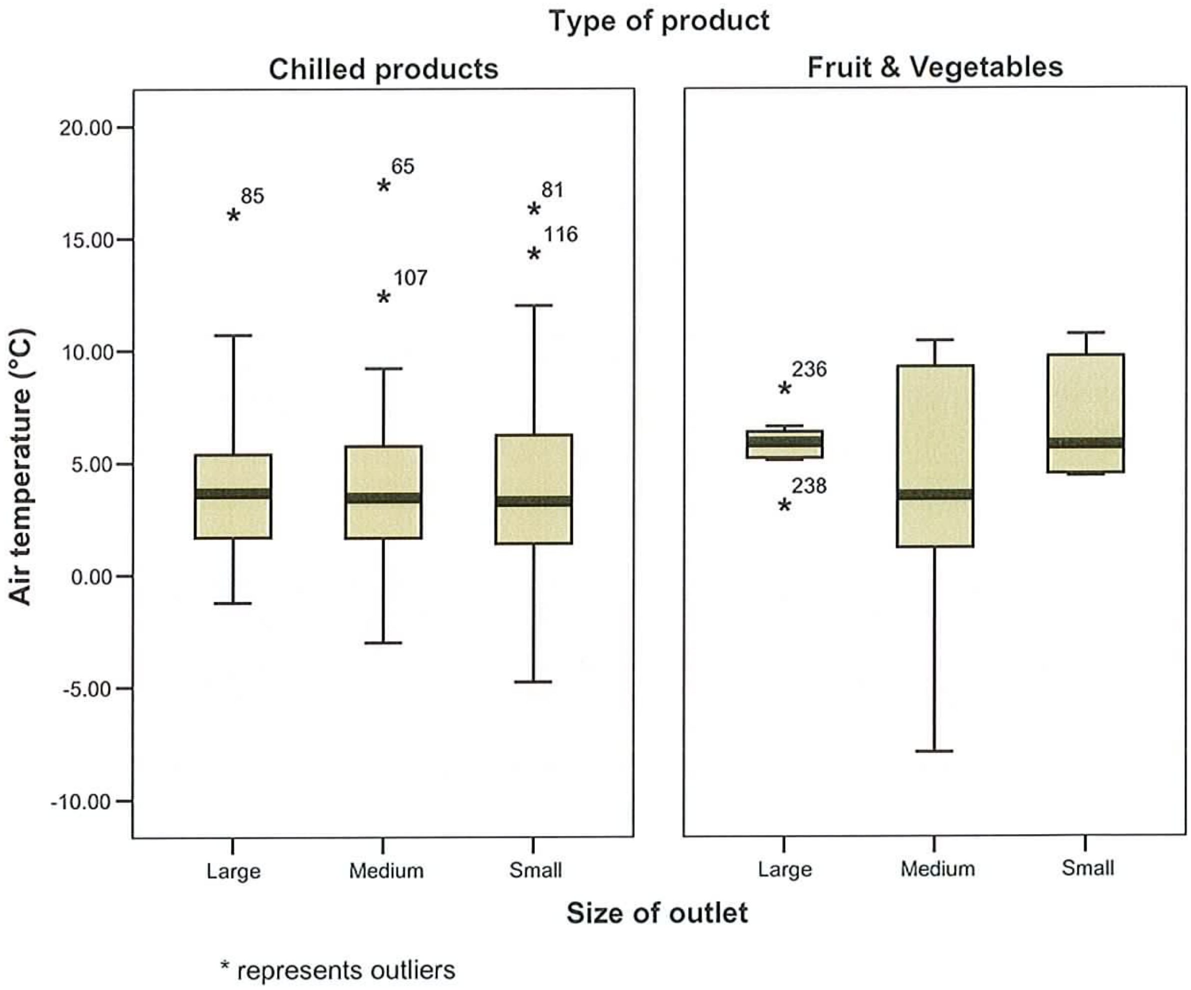
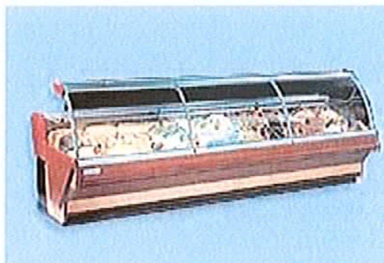


Figure (3.8): Cabinet air temperature in outlets of different size

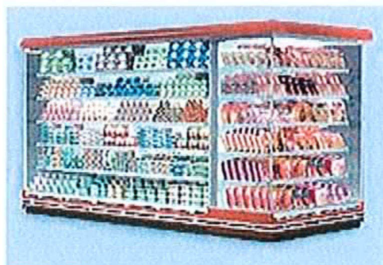
The outlets were grouped into the 3 categories small, medium and large depending on the number of employees in each outlet as mentioned earlier. The median cabinet air temperature for chilled products in the three different sizes of outlets visited was approximately 3.5°C. In the case of fruit and vegetables the outlet size was not significant with regard to temperature control ($p>0.05$) despite the median air temperature in medium sized outlets being 3.52°C in comparison to 5.92°C and 5.8°C in large and small premises respectively. Therefore the number of employees in a premises does not have a significant effect on the standard compliance of external air temperature in the chill cabinets.

Five designs of cabinets were encountered during the course of this research, and these designs are shown in figure (3.9) below.

(i) Workstation salad bar



(ii) Serve-over



(iii) Multi-deck

(iv) Circular salad bar

(v) Ice-counter

Figure (3.9): Designs of chill cabinets in outlets surveyed

Both workstation and rear feed cabinets were used as salad bars in supermarkets and delicatessens. Both cabinets allowed customers to serve themselves, the rear feed design consisted of two rows of different salads, whereas the circular cabinet had the salads arranged in two rows in a circular fashion. Serve-overs were commonly used at the deli counter to display meats and sandwich fillings behind a glass front. Serve-over cabinets were used in all the butcher outlets surveyed. Multi-deck cabinets were typically used for the dairy wall as they had an open front and several rows of shelves which were convenient for the display of products and also very easily accessible for customers. Ice-counters were used to keep the fresh fish chilled, and were covered in ice onto which the fish was placed.

Table (3.1): Design of chill cabinet types encountered in this study

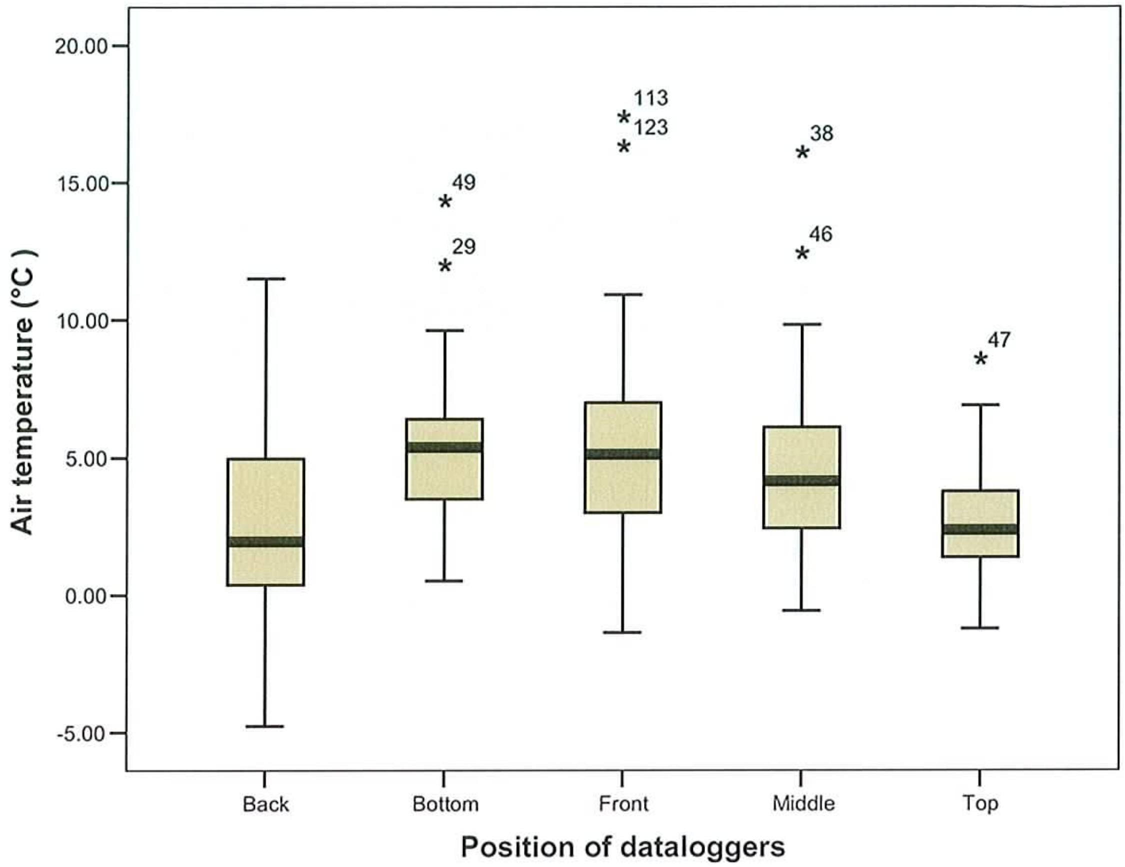
Cabinet Design	Number	External Air Temperature	
		-1 to 5°C	> 5°C
Serve-over	99	60%	40%
Multi-deck	59	64%	36%
Circular	8	38%	62%
Ice-counter	6	40%	60%
Workstation	3	67%	33%

Cabinet design was examined for efficacy of temperature control. With regard to Table (3.1), all cabinets examined seem inefficient at maintaining external air temperature below 5°C. Table (3.1) suggests that the ice counter and circular salad bars are not as effective as the other designs in maintaining the correct chill temperature, however statistical analysis does not support this theory. Using

ANOVA testing on the recorded results there was no significant difference between the cabinet design types with regard to temperature control.

During the course of this research 24 different makes of chill cabinet were monitored for efficacy of external air temperature control. Using ANOVA testing it was found that the cabinet make has a significant effect on air temperature. However it was not possible to do post hoc testing due to small numbers of some makes encountered during the survey.

The final variable analysed with regard to chill cabinets was the position of the datalogger within the cabinet. This was done to determine if air temperature varies within the cabinet and also to investigate if cabinets were functioning correctly. The external air temperature in the chill cabinet should be at the lowest temperature at the air outlet and warmest at the air inlet. Figure (3.10) shows the air temperature variation in the chill cabinets according to the different position of the datalogger.



* represents outliers

Figure (3.10): Air temperature in different positions within the chill cabinet

Large temperature differences have been found in most cabinets (Foster *et al.,* 2005), and open display cabinets are thought to be one of the weakest links in the food chain (Cortella and D'Agaro, 2002). These temperature differences are a result of technical differences between the lowest and highest temperature products. All chill cabinet designs work on the principle that an air curtain is generated which creates a non-physical barrier between the cold air in the cabinet and the ambient air outside. Due to air from the curtain being colder than the surrounding air it will also fall due to buoyancy. As the air curtain falls from the cabinet air-off duct, the curtain entrains cold air from inside the cabinet (entered through the rear grille) and warm air from the rest of the room. The entrainment of warm air from outside the chill cabinet causes the air curtain to become warmer as it falls down the cabinet (Foster *et al.,* 2005).

Although several surveys have presented data on food temperatures in supermarkets, the data on temperature variation within individual cabinets have been quite general and often contradictory. Magnusssen (1993), Dennis and Rose (1984) and Rogers and Althen (1980) all reported that product temperatures were higher in the top layer of food in open display cases. Gormley (1987) found that product temperatures tended to be higher in the top decks rather than the lower decks of multi-deck retail cabinets, whereas Faramarzi *et al.*, (2003) found the opposite. Gill *et al.,* (2003) found the lowest temperatures to be on intermediate shelves. Brimelow (1987) reported temperatures at the rear of upright cabinets to be colder than temperatures at the front shelves, and this was corroborated by Greer *et al.,*(1994) and Gill *et al.*,(2003) for a chilled meat case.

None of the previous research detailed in the paragraph above continuously monitored the food temperatures over a typical commercial day at intervals as frequent as 5 minutes. Instead, the methodology usually involved several temperature checks throughout one or more days. This research found that the lowest temperature produce is usually sited at the rear of the cabinet in the case of salad bars and serve-over chill cabinets. In the majority of multi-deck display cabinets air enters the display area through holes or slots in the cabinet rear grilles, or a honeycomb grille placed at the front of the cabinet canopy. Therefore, it is expected that the products situated at the top of the multi-deck cabinet would be at a lower temperature that those located at the bottom. The findings in fig. (3.10) in relation to multi-deck chill cabinets corroborates those of Evans *et al.*,(2007) who found, under test conditions, that the majority of maximum temperature packs (97%) were located at the front of open fronted cabinets, the largest number (60%) being at the front of the base of the cabinet.

The boxplot in Figure (3.10) shows that dataloggers at the back of horizontal chill cabinets recorded lower temperatures than those in the middle or front. This is what would be expected if the cabinet was functioning correctly as the air outlet is located at the back of the cabinet. Product temperature does increase with distance from the cold air outlet. Cycles of surface freezing followed by thawing were often found in product situated in the incoming air stream. The front of the cabinet is beside the air inlet and as shown above in the boxplot the air temperature is highest there. The findings in this research confirm previous findings that surfaces temperatures are influenced by both the horizontal and vertical location of each item within the retail case (Greer *et* al., 1994).This also means that temperature readings recorded at the front or bottom of cabinet depending on design would be a better conservative measure when examining cabinet efficacy with regard to temperature control.

The air temperature recorded in the middle of cabinets is higher than readings recorded at the back or top of cabinets which is explained by the gradual warming of the air as it travels through the cabinet due to entrainment of ambient air. The positions of top and bottom would relate to the multi-deck vertical cabinets, and again the dataloggers at the air outlet at the top of the cabinet recorded lower temperatures than those located at the air inlet found at the bottom of vertical cabinets.

Figure (3.10) shows that in general the cabinets are functioning correctly with regard to temperature except for the few outliers shown above. The outliers were identified as lamb chops and coleslaw at a butcher and deli outlet which were situated in the middle of a chill cabinet, and also potato salad and patisserie both in separate delicatessens situated at the front of the respective chill cabinet. The other outliers were chicken and beef, both found in separate butchers in the middle of serve-over cabinets, and also yoghurt located at the top of a multi-deck cabinet in a supermarket.

3.1.2 Core temperature of chilled foods

It was not possible to monitor the core temperature of chilled products in all premises surveyed as retailers felt it was not aesthetically pleasing to customers to have a metal probe left inserted into products. The mean core temperature for 27 chilled products monitored was 3.4°C. This research found that generally the core temperature of products was higher than the external air temperature, except in the case of 60% of meat and fish products sampled. This anomaly can be explained by the temperature history of the product as discussed later.

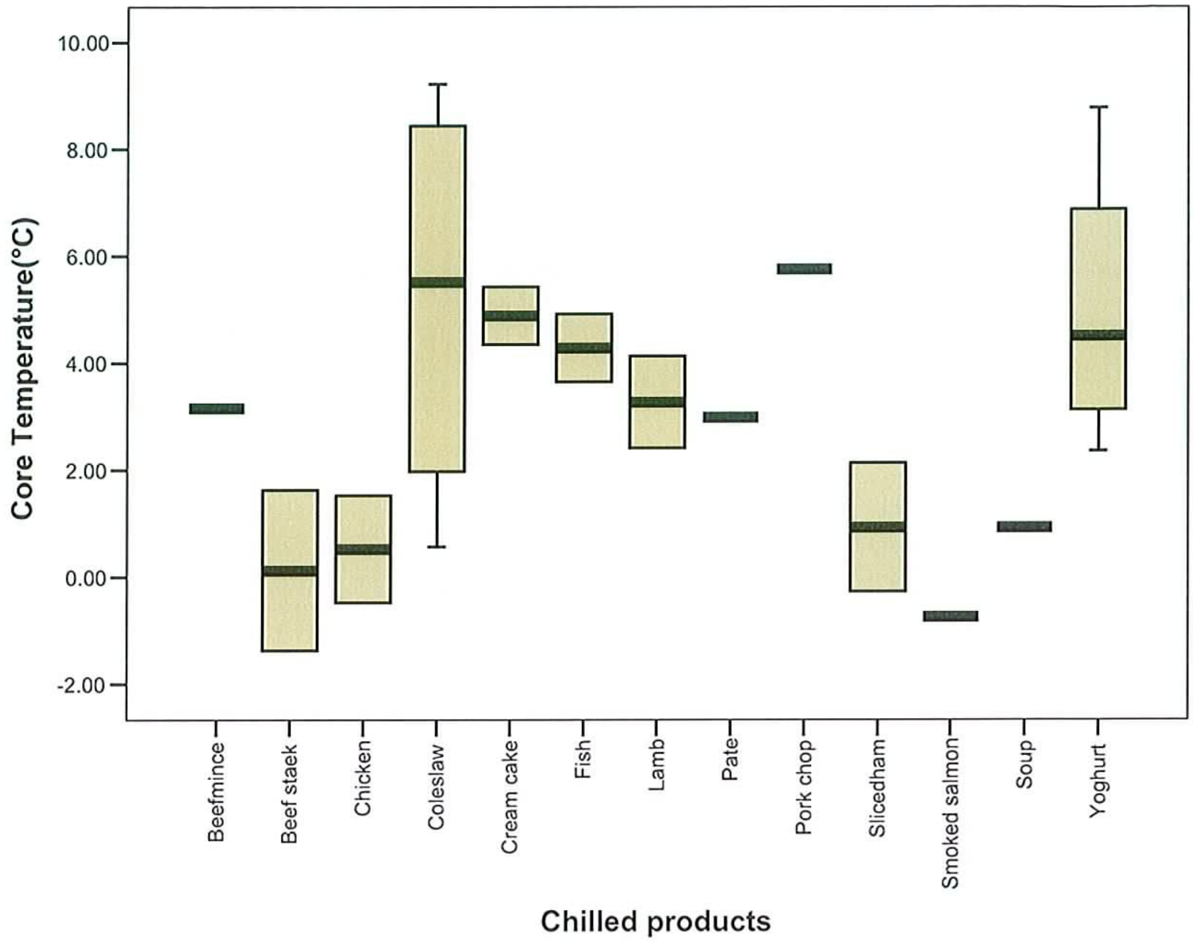


Figure (3.11): Core temperature of chilled products surveyed

As shown in Figure (3.11) above, 75% of chilled products surveyed were found to have median core temperatures between -1 and 5°C. With regard to coleslaw and pork chops, both were found to have median core temperatures exceeding 5°C. It is of particular concern in relation to coleslaw whereby, the core temperature reached was 13.98°C (see appendix 4). In the case of cream cakes monitored, although the median core temperature was within the acceptable range, the maximum core temperature recorded in one outlet was 17.30°C as shown in appendix 4, which is indicative that temperature abuse of the product is occurring at some stage of the 7½ hour monitoring period.

In the case of dairy products and salads in 66% of outlets, the recorded data showed that the core temperature was always at least 0.5°C and in some outlets as much as 2°C higher than external air temperature. Figure (3.12) shows core and external air temperature readings for coleslaw in delicatessen outlet.

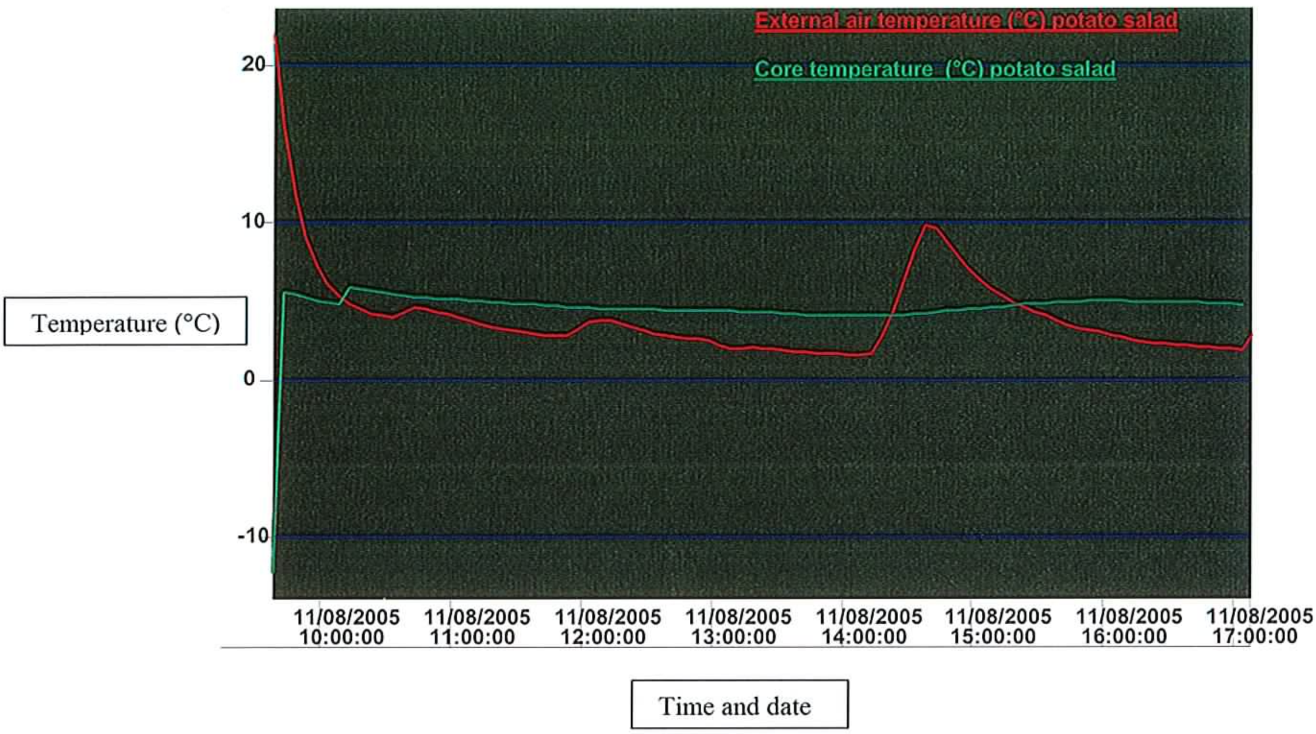
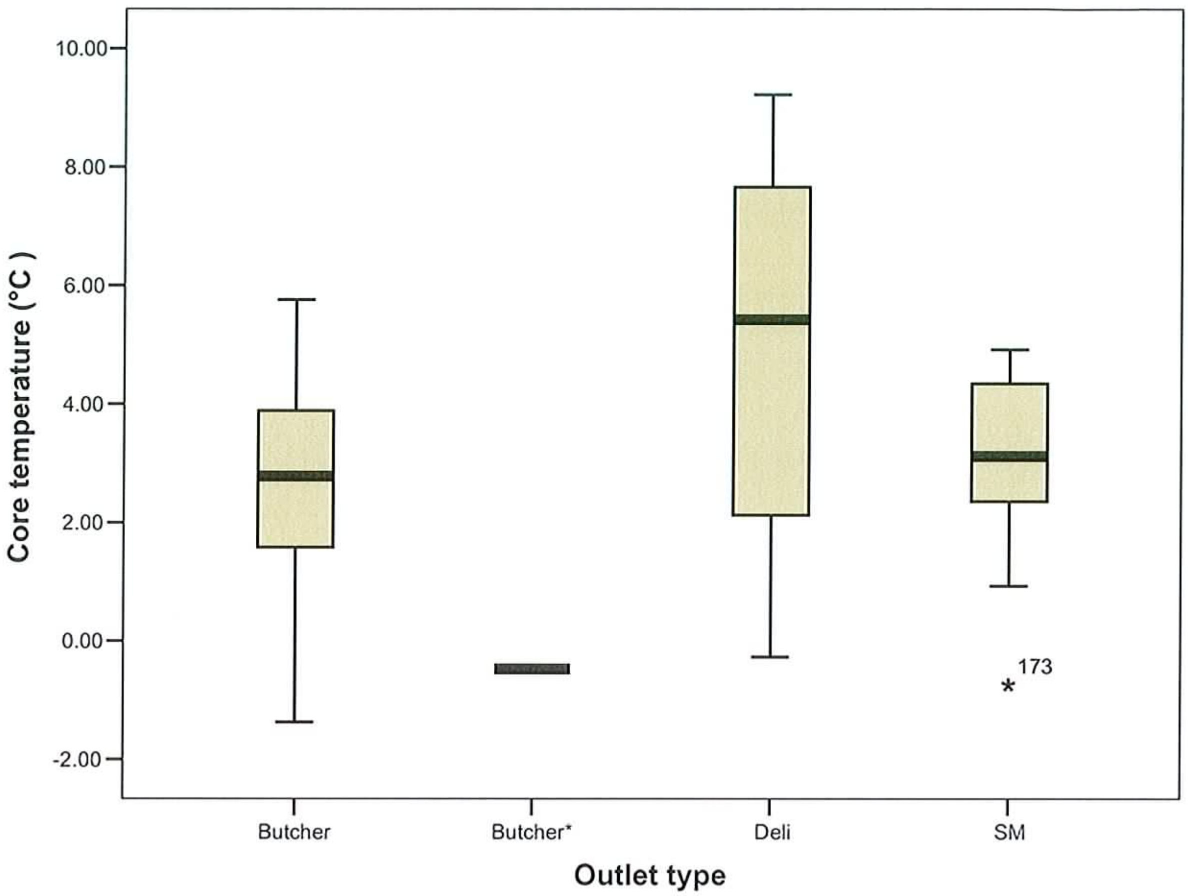


Figure (3.12): Core and external air temperature of potato salad

Figure (3.12) shows the temperatures within a salad bar in a deli outlet displaying potato salad over a 7 ½ hour recording period. The median external air temperature was 3.3°C, however the median core temperature was 5.2°C. The defrost cycle lasted 40 minutes and did not effect the core temperature in this case. Previous research on loose cooked sliced ham by the FSAI found that 30.5% (185/606) of refrigerated samples had core temperatures >5°C (FSAI, 2006c). This research found that the core temperatures of all samples of sliced ham were within the correct temperature range. With regard to raw meat, in 60% of the cases where an internal probe was inserted into the meat the core temperature was 1-2°C lower than the external air temperature within the chill cabinet.

In the butcher outlets where the core temperature recorded was lower than the external air temperature, the products were stored overnight in a cold store which was maintained at 0°C, and the external air temperature at the air outlets of the display chill cabinets in these outlets was below zero. This was discussed with one owner since it was possible that a freeze thaw cycle could be occurring in the meat which would have a deleterious effect on meat quality. However, due to rapid product turnover this did not seem to be an issue and there had been no complaints from customers. The core air temperature of fish was always 1-2°C lower than external air temperature in all cases where it was possible to insert a probe. This would be expected as the fish were always displayed on ice. Figure (3.13) shows the core temperature for different products in terms of outlet type.



* represents outliers
Butcher* represents Butcher counter in a Supermarket
Deli represents delicatessen
SM represents supermarket

Figure (3.13): Core temperature of chilled products in different outlet types

The core temperature of chilled products was within the satisfactory range in butcher and supermarket outlets, however, the median core temperature in deli outlets was greater than 5°C with maximum temperature of 13.98°C being recorded for a salad bar containing coleslaw. It was found using ANOVA tests that the outlet type was not significant with regard to control of chilled product core temperature ($p>0.05$). Statistical analysis also found that the outlet size did not significantly influence core temperature control of chilled products, even though medium sized outlets had a higher median core temperature value than the two other categories as shown in Figure (3.14).

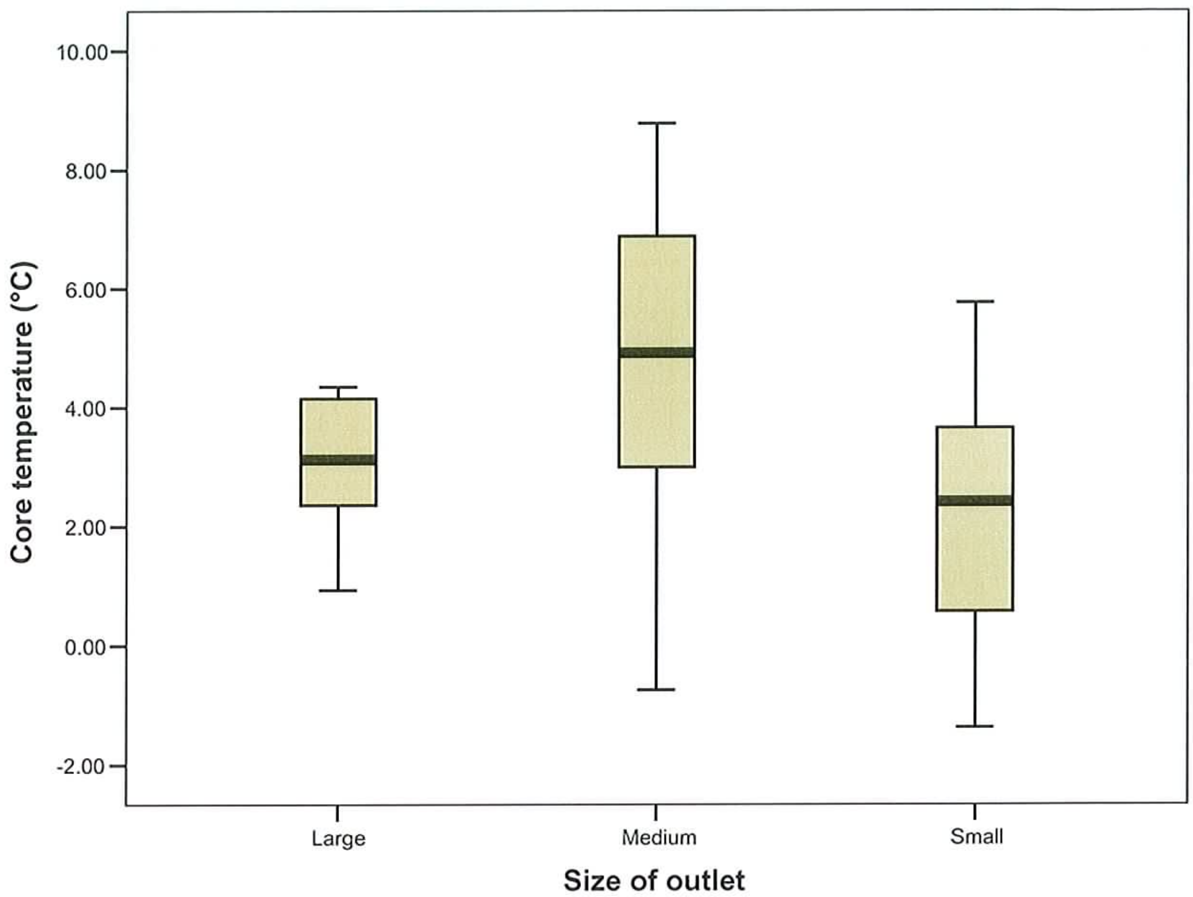


Figure (3.14): Core temperature of chilled products in outlets of different size

Crosstabulation of core temperature and outlet size showed that 23% of small outlets and 44% of medium sized outlets did not maintain chilled product core temperatures in the correct range. It was also found that the core temperature of chilled products in 25% of butchers and 56% of delicatessens exceeded 5°C.

The chill cabinet designs mentioned previously in section (3.1.1) were monitored in terms of efficacy of maintaining core temperature, it was found that 20% of multi-deck cabinets did not maintain chilled product core temperatures below 5°C. The mean core temperature was 3.8°C and 2.8°C for multi-deck and serve-over cabinets respectively. With regard to salad bars it was found that the rear feed design maintained the core temperature in the correct range but the mean core temperature for the workstation design was 7.8°C. The cabinet make was not significant with regard to maintenance of chilled product core temperature at a 5% confidence interval.

3.1.3 Air temperature in freezer cabinets

It is recommended that frozen foods are displayed at or below -18°C (I.S. 341, 1998). This research found that frozen foods were incorrectly stored in 52% of outlets visited, with cabinets monitored in these outlets showing air temperatures above -18°C. In one supermarket outlet, a ready meal (steak and kidney pie) was being stored in an external air temperature of approximately -7°C throughout the recording period. The mean external air temperature in the 33 freezer cabinets monitored was -17.2°C.

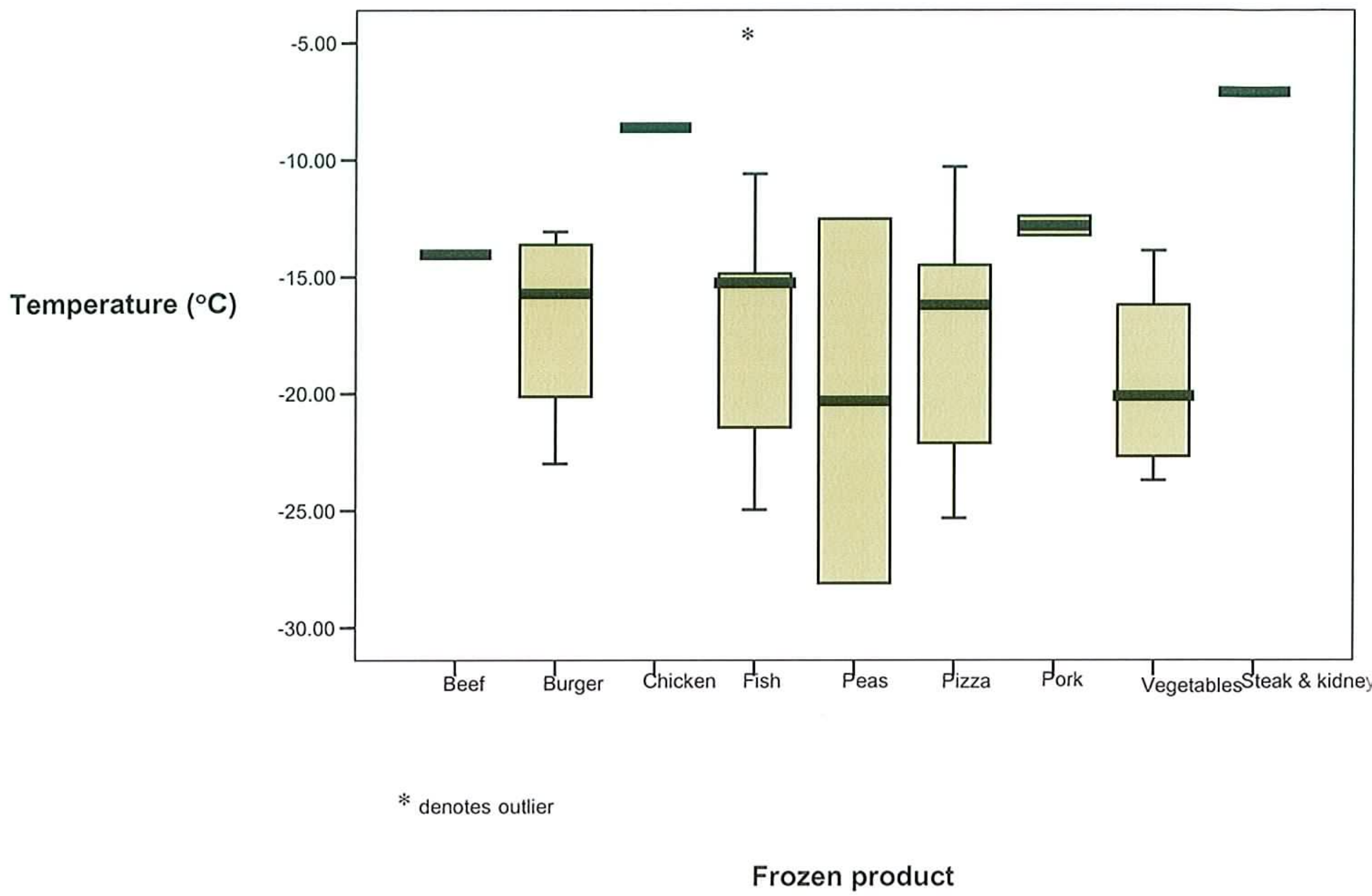


Figure (3.15): External air temperature of freezer products surveyed

The boxplot in figure (3.15) shows that despite statistical analysis showing an overall mean of -17.2°C, the median external air temperature for many products was higher than this. Appendix 5 gives a more detailed break down of temperatures recorded in different freezer cabinets in different premises.

Storage temperatures above -18°C in freezer cabinets have been shown to effect sensory properties of certain frozen foods, such as strawberries stored at -12°C (Singh and Wells, 2003). However Gebczunski (2006) contradicts this by finding that frozen carrots stored at -30°C, had a higher sensory quality than those stored at

-20°C. In terms of economical storage, the recommended temperature is generally considered to be -18 to -20°C. It was found in the case of green beans, storage temperatures below -18°C had a detrimental effect on sensory and nutritional quality, whereas -6 and -12°C were found to be optimal storage temperatures (Martins and Silva, 2004), so type of product stored may be an influential factor when storing frozen food. Fluctuations in external air temperatures in freezer cabinets commonly occur during the defrost cycle as shown below in Figure (3.16).

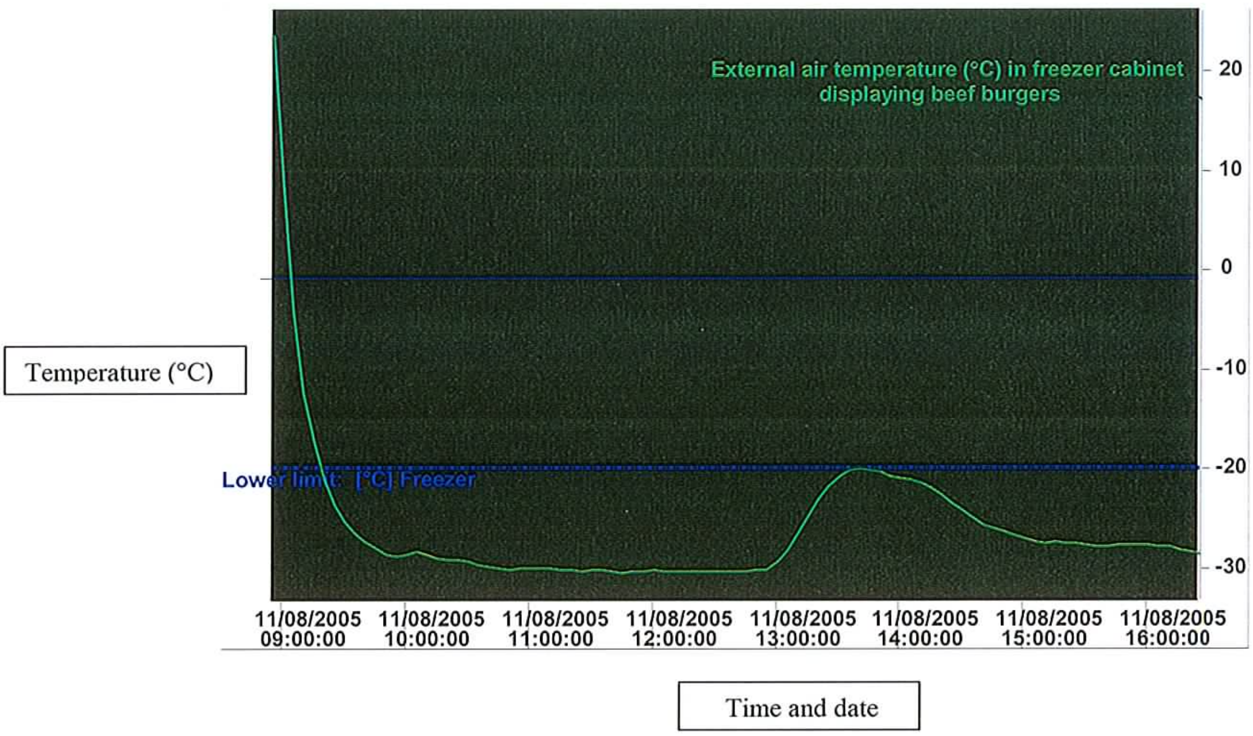


Figure (3.16): Air temperature in freezer cabinet displaying beef burgers

The temperature fluctuation seen in Figure (3.16) from -30.5°C to -20.2°C lasted approximately 2 hours, however defrost cycles have been shown to have minimal effect on product sensory quality. Previous research carried out on samples of raw salmon, smoked mackerel, beef pieces, pizza and broccoli found that temperature fluctuations from -30°C to -10°C had minimal effect on quality parameters such as texture, colour, water-holding capacity and drip loss on thawing, in these products (Gormley *et al.,* 2002).

Freezing is known to reduce viable cell counts of microbes by 1-2 log units, with extended storage causing additional, time dependent reductions (Yammamoto and Harris, 2001). However, previous research has indicated that *L. monocytogenes* is capable of survival but not growth on the surface of frozen strawberries for periods of at least 2 weeks (Flessa *et al*., 2005). Therefore, it is important that temperature abuse does not occur in the freezer cabinet to allow product temperature to exceed zero, which would facilitate food-borne pathogen growth, particularly in the case of psychrotrophs. Figure (3.17) below shows extreme temperature fluctuations occurring within a freezer unit holding frozen fish in a supermarket.

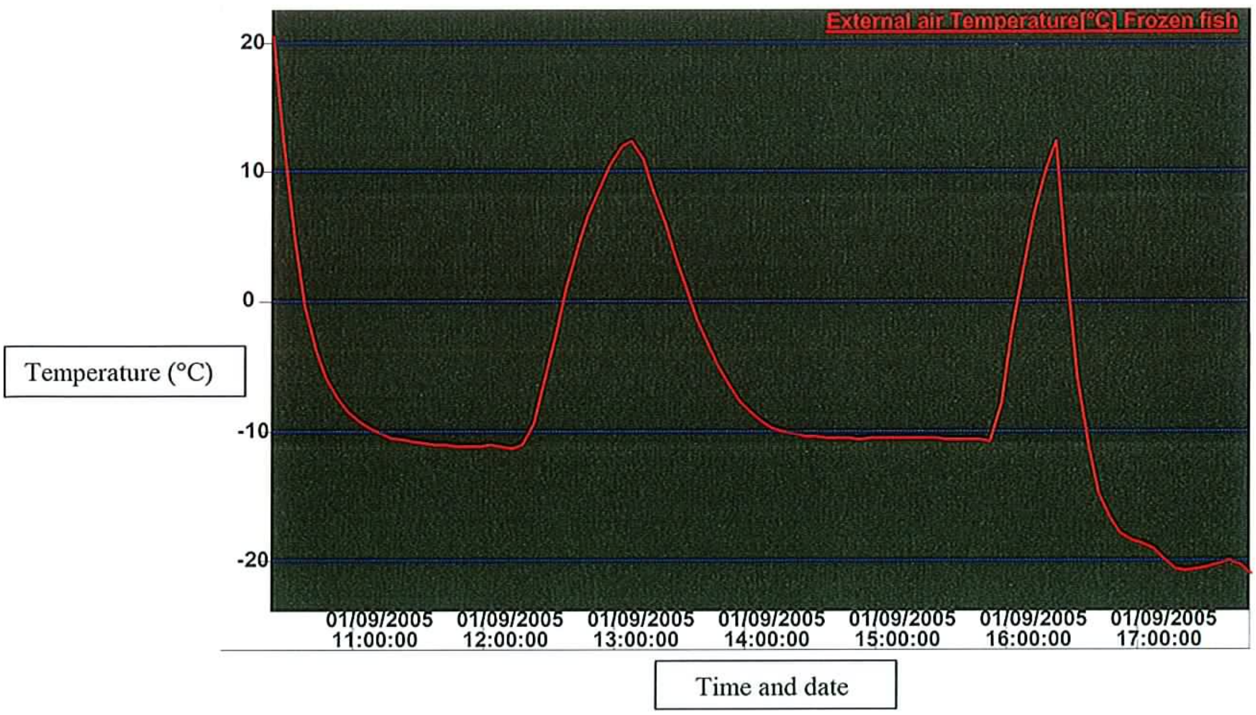
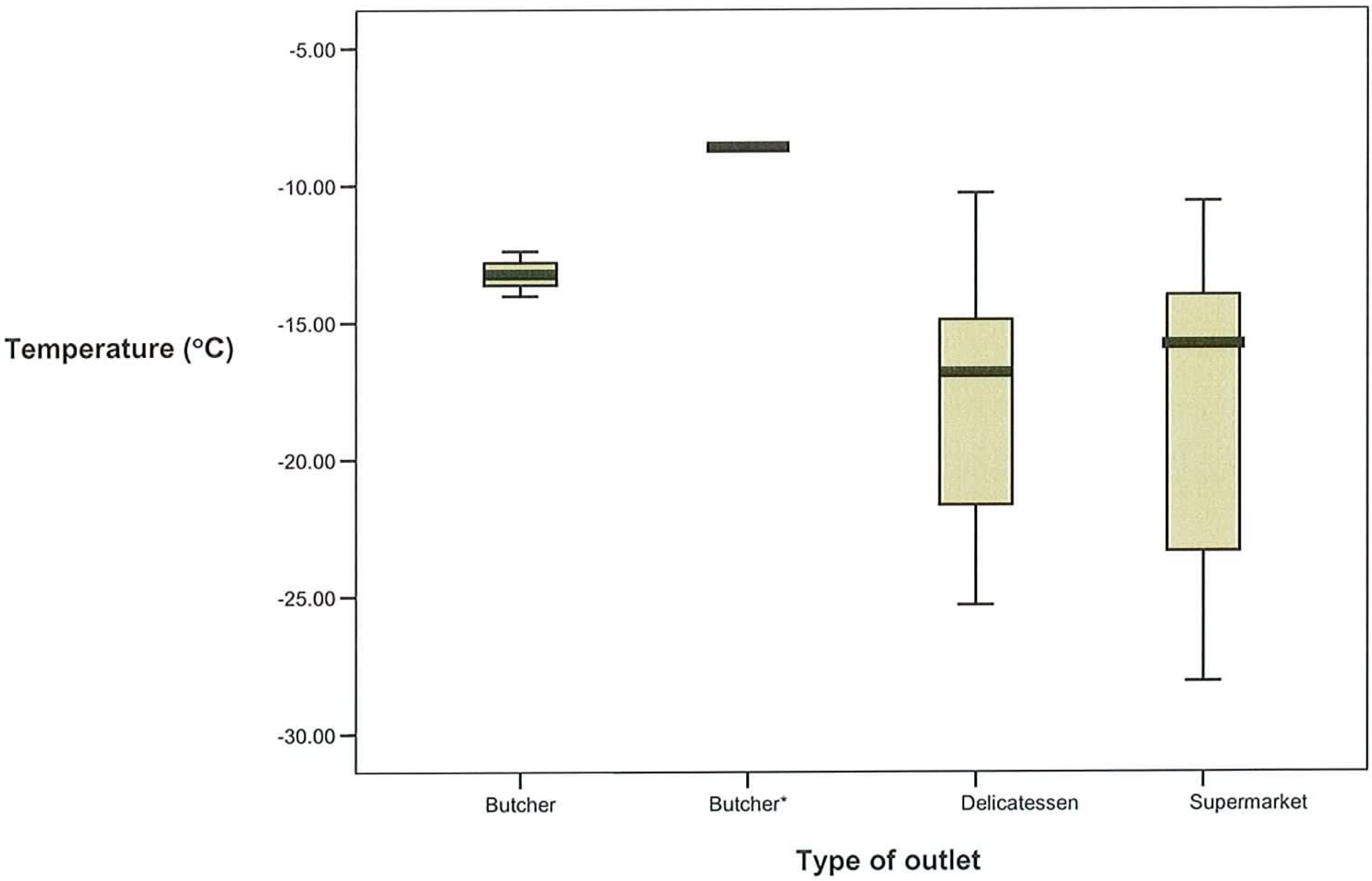


Figure (3.17): Air temperature in freezer displaying fish

Two defrost cycles occurred in the freezer in Figure (3.17) in a 7½ hour period, the first cycle lasted 110 minutes and the second 50 minutes. Freezing and defrosting may make some foods more susceptible to microbiological attack, but defrosted foods do not spoil more readily than those that have not been frozen (Adams and Moss, 2000). Injuctions against refreezing are motivated by the loss of textural and other sensory properties. Figure (3.18) shows the influence of the type of outlet on the efficacy of temperature control.



Butcher * denotes butcher counter in a supermarket

Figure (3.18) Air temperature in freezer cabinets in different outlet types

Using ANOVA testing it was found that the type of outlet was not significant with regard to freezer temperature control. For the purpose of this survey only freezer cabinets in supermarket and delicatessen outlets were examined, butcher outlets usually used freezer cabinets for storage of meat.

Despite the outlet type not being found to be significant, ANOVA testing did find the size of outlet to be significant ($p<0.05$). Using bivariate analysis it was found that small stores, i.e., those with less than 10 employees were holding products at higher temperatures than medium or large stores as shown in Table (3.2).

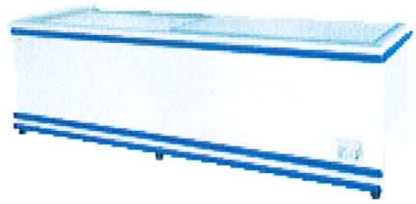
Table (3.2): Air temperature of freezer cabinets in outlets of different size

Size of Outlet	**Number of Outlets**	**Mean Temperature °C**	**Minimum Temperature °C**	**Maximum Temperature °C**
Large	12	-19.2	-28.1	-13.06
Medium	15	-17.5	-25.3	-10.6
Small	6	-12.7	-20.8	-8.6

It was not possible to perform post hoc testing for difference in temperature control of frozen foods between medium and large sized retail outlets.

Frozen food is most commonly stored in either open well cabinets or in freezers with glass doors (Evans *et al.*, 2007). In this survey, there were three designs of freezer cabinet used to display the frozen foods, which are shown in Figure (3.19).

(i) Wall



(ii) Island

(iii) Well

Figure (3.19): Designs of freezer cabinets in survey

Wall freezers are vertical upright cabinets with glass doors on the front that may open outwards or slide across. The wall freezers analysed were divided between integral units (33%) and remotely operated (refrigeration system separate from cabinet) units (64%). Island freezers are horizontal chest freezers with glass lids, all island freezers analysed were integral (refrigeration system part of cabinet) units without an internal lighting. Well freezers consist of an open horizontal chest cabinet, in some cases, though not included in this research, the well freezer may be attached to a vertical wall cabinet. The well freezers analysed were divided between integral units (33%) and remote units (66%). The three cabinet designs were analysed in terms of their temperature control with mean, maximum and minimum temperatures shown below in Table (3.3). From these results it was shown that island freezers analysed had the lowest mean temperature, and island and well freezers were found to have the largest range in temperature. Both of these results corroborate previous findings by Evans *et al.*, (2007).

Table (3.3): Air temperature in different designs of freezer cabinets

Design of Freezer	Number of Freezers	Mean Temperature °C	Minimum Temperature °C	Maximum Temperature °C
Island	12	-19.1	-25.3	-10.6
Wall	9	-13.8	-15.4	-10.3
Well	6	-18.9	-28.1	-10.7

The design of cabinet was significant at a 95% confidence interval in relation to temperature control. It was found using multiple comparison testing that there was a significant difference between island and wall freezers, with island freezers being significantly better in maintaining frozen foods at the correct temperature. Although when analysing the results in Table (3.3) it would appear that well freezers operate better than wall freezer cabinets with regard to temperature control, it was not possible to prove this statistically. Evans *et al.*, (2007) had similar findings, in that using ANOVA testing no significant difference ($p>0.05$) was found between mean temperatures in well and wall freezer cabinets.

Finally, the variation in air temperature within the freezer cabinets was analysed and it was found that overall the middle area of the three cabinet designs surveyed had the lowest external air temperatures, as shown in Figure (3.20).

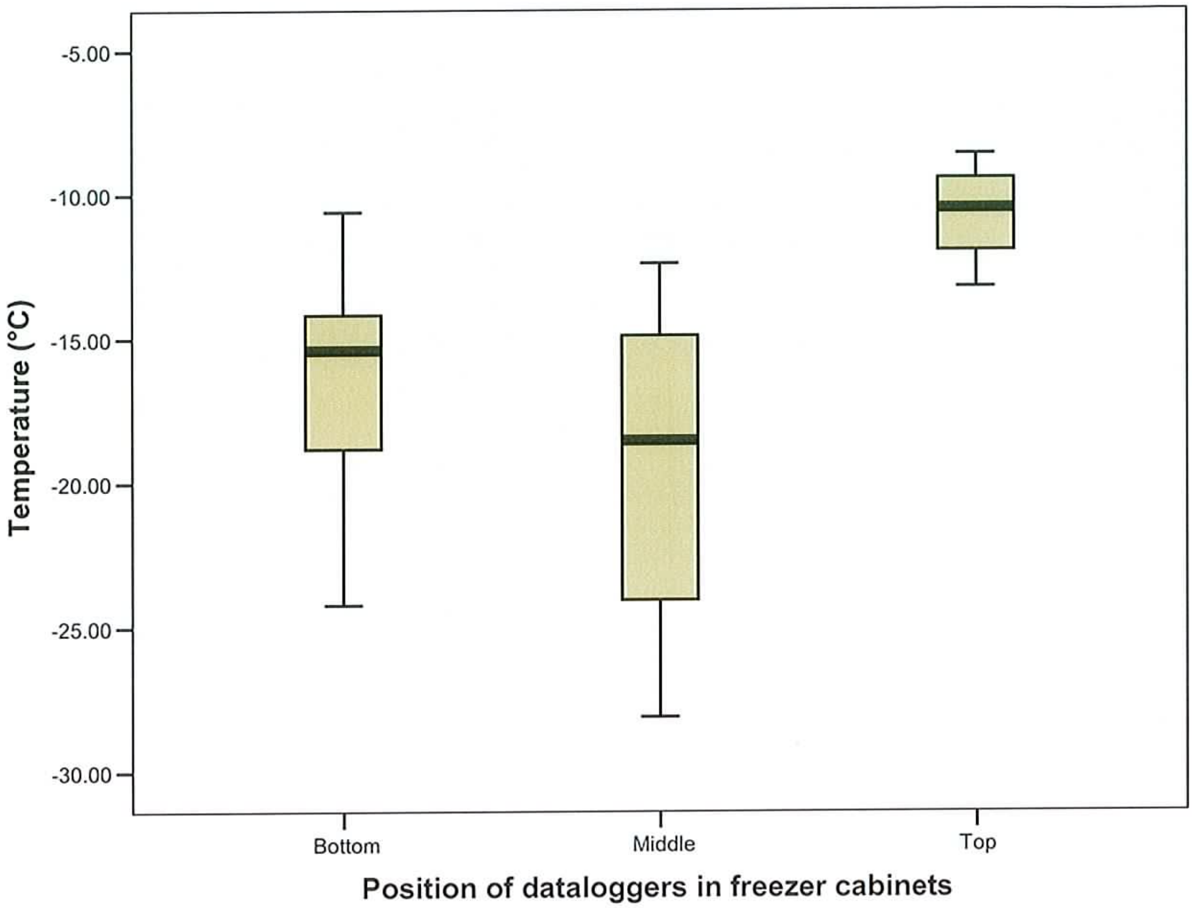


Figure (3.20): Air temperature in different positions within the freezer cabinets surveyed

When each design was looked at on an individual basis, the following results were found. In the case of island freezers, the lowest temperatures (85%) were recorded in the middle layers of the cabinet, with the highest temperatures (90%) being found at the top layer. With regard to wall cabinets, there was no significant difference ($p>0.05$) between position of highest and lowest temperature in integral and remote cabinets. In the wall cabinets, the lowest temperatures were recorded on the bottom shelf (55%), and the highest temperature (79%) was recorded on the top shelf.

No significant difference ($p>0.05$) was found between positions of highest and lowest temperatures in integral and remote well cabinets. The majority of well cabinets (91%) recorded highest temperatures in the top layer of the cabinet. This is to be expected, given the fact that the only barrier between the refrigerated load and the ambient air is a forced air curtain, and there is also the influence of radiative heat. The findings in this survey corroborate previous research done by Evans *et al.*, (2007) on the performance of the same designs of freezer cabinets in terms of location of maximum and minimum temperatures under EN441 test conditions.

3.1.4 Air temperature in ice-cream cabinets

The recommended external air temperature for the storage of ice-cream is -23°C. This research found that ice-cream was stored in air temperatures higher than -18°C in 29% of outlets, and below -30°C in 21% of the 14 outlets surveyed. The mean external air temperature in the freezer cabinets displaying ice-cream was -24.6°C. The storage of ice-cream at the incorrect temperature can lead to sensory problems, as crystallisation of dairy proteins can occur at temperatures higher than -15°C. Maintaining an excessively low external air temperature is unnecessary in terms of product quality and safety, as well as being uneconomical.

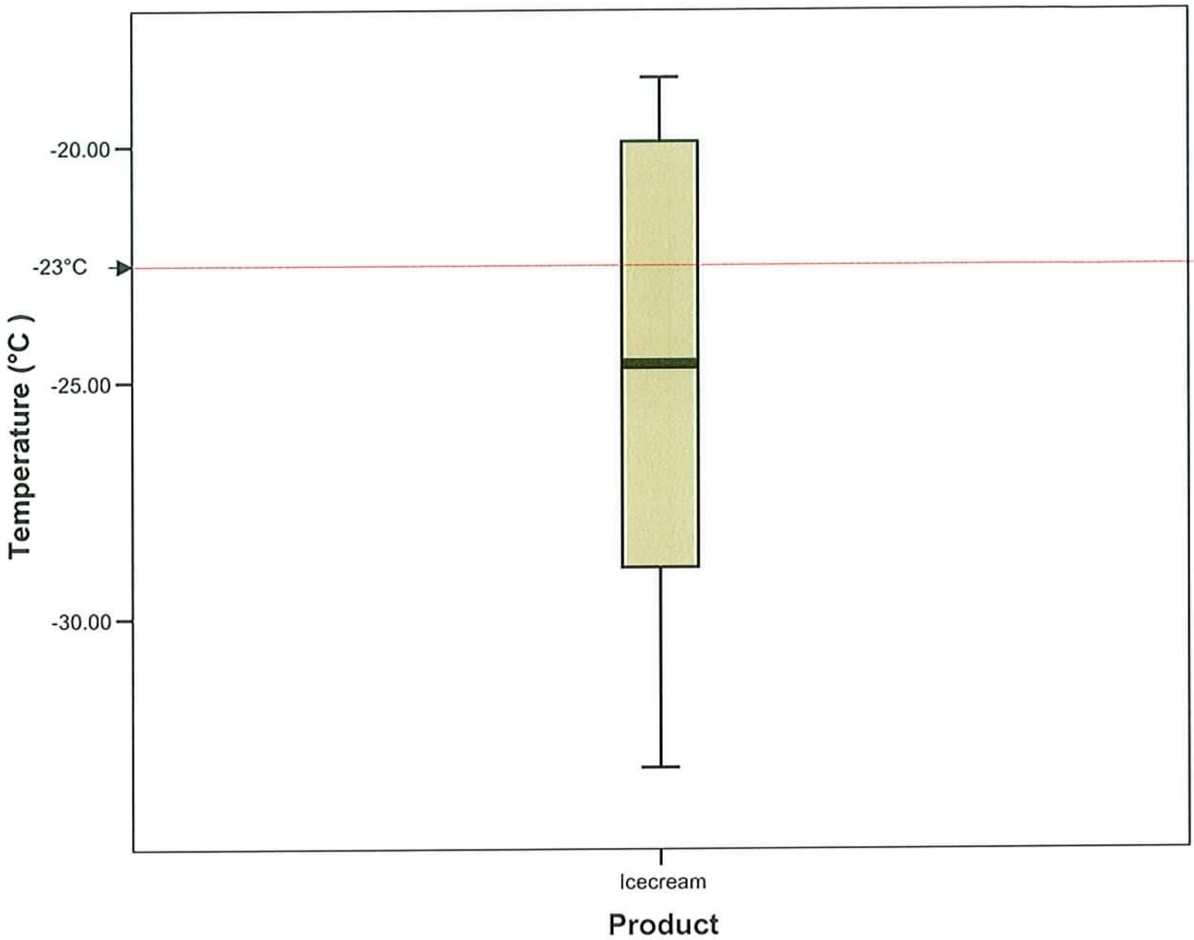


Figure (3.21): Air temperature in ice-cream cabinets surveyed

Figure (3.21) shows that the median external air temperature in the ice-cream freezer cabinets was -25°C, with a minimum air temperature of -33°C and a maximum of -17°C being recorded in some outlets. Data was recorded in 10 deli-type outlets and 4 supermarket outlets, statistical analysis using ANOVA testing found that the type of outlet was not significant in terms of temperature control in freezer cabinets holding ice-cream.

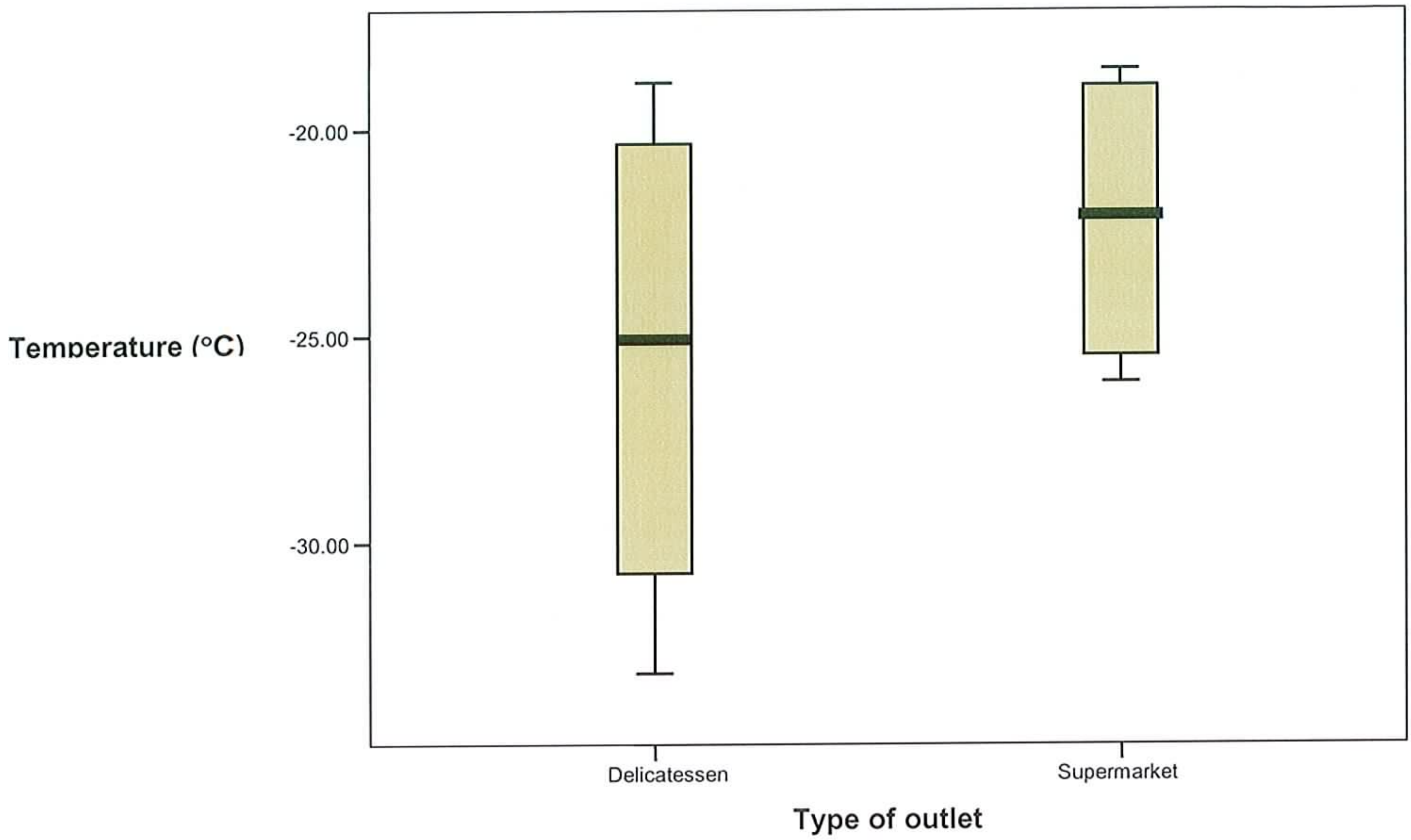


Figure (3.22): Air temperature of ice-cream cabinets in 2 outlet types surveyed

As shown above in Figure (3.22), the median air temperature of ice cream freezer cabinets in deli outlets is lower than in supermarkets, but outlet type was not found to be significant (p>0.05) with regard to temperature control of ice-cream freezers. Neither was the outlet size found to be significant (p>0.05) following statistical analysis of recorded readings. The boxplot in Figure (3.23) shows the air temperature of ice-cream cabinets in outlets of different size.

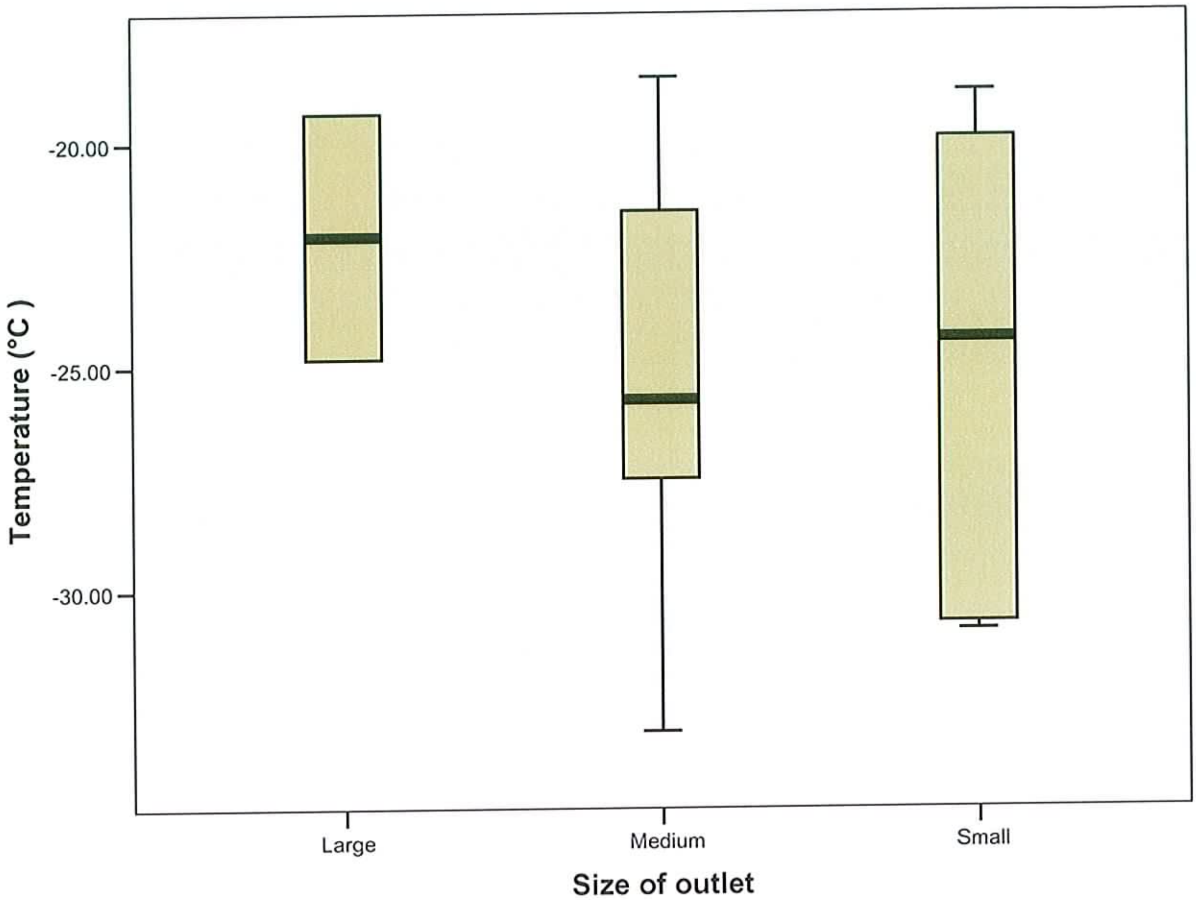


Figure (3.23): Air temperature of ice-cream cabinets in outlets of different size

Figure (3.23) above shows that the median external air temperature was highest (-22.1°C) in the large premises (n=2), however this was closer to the correct temperature than the median temperature recorded in either the medium (n=7) or small (n=5) premises which had readings of -25.1°C and -24.9°C, respectively.

The two designs of cabinet used were previously mentioned, island freezers with sliding lids, vertical standing wall freezers with a glass door and smaller specifically made horizontal freezers also with sliding lids. It was found using statistical analysis that neither the design nor make were significant with regard to control of air temperature within the cabinet. The position of the dataloggers within the cabinets showed that there was variation in air temperature through the cabinets, as shown in Figure (3.24).

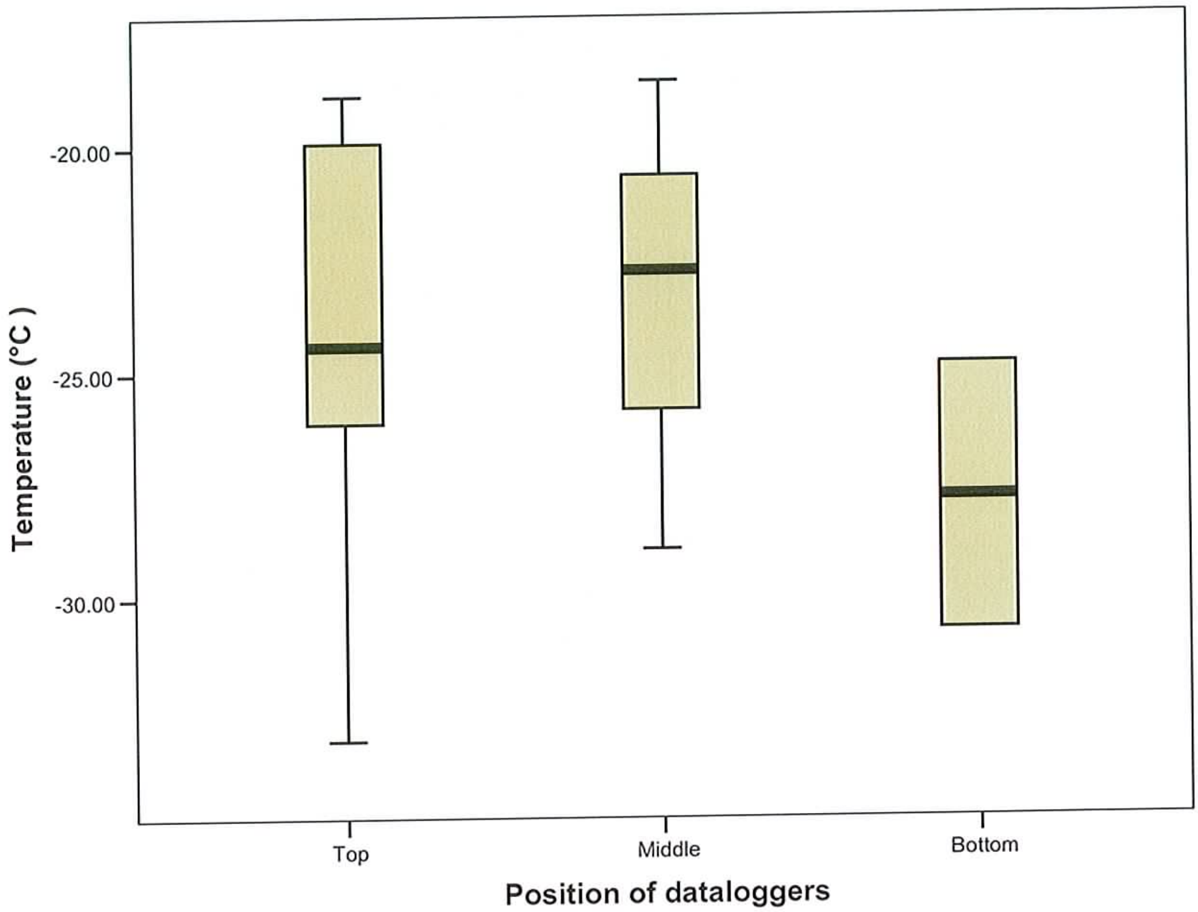


Figure (3.24): Position of dataloggers in cabinets displaying ice-cream

The results in Figure (3.24) show that the lowest air temperatures were at the bottom of the cabinet, and the temperatures in the middle of the cabinet were slightly higher than those at the top. These findings contradict those with regard to island freezers used for standard frozen foods. This could be explained by the fact that the survey was done during the summer and the cabinet was being opened on a regular basis and frequently not closed properly. The opening of the cabinet allowed entrainment of hot air into the cabinet and warming of the air curtain at the top of the cabinet. This would have subsequently affected the middle layer of the cabinet also.

3.2 ANALYSIS OF RELATIVE HUMIDITY DATA

Control of cabinet air relative humidity results in reduced weight loss with all products and a reduction in the rate of deterioration in the appearance of the produce on display (Brown *et al.*, 2004).

There are no recommended guidelines in the legislation with regard to air relative humidity in this country, however the USDA guidelines suggest readings between 70 and 95% to be appropriate for chilled foods, including fruit and vegetables. The mean air relative humidity of chilled products throughout 56 outlets surveyed was 71%, and for fruit and vegetables in 22 outlets it was 77% as shown in Figure (3.25).

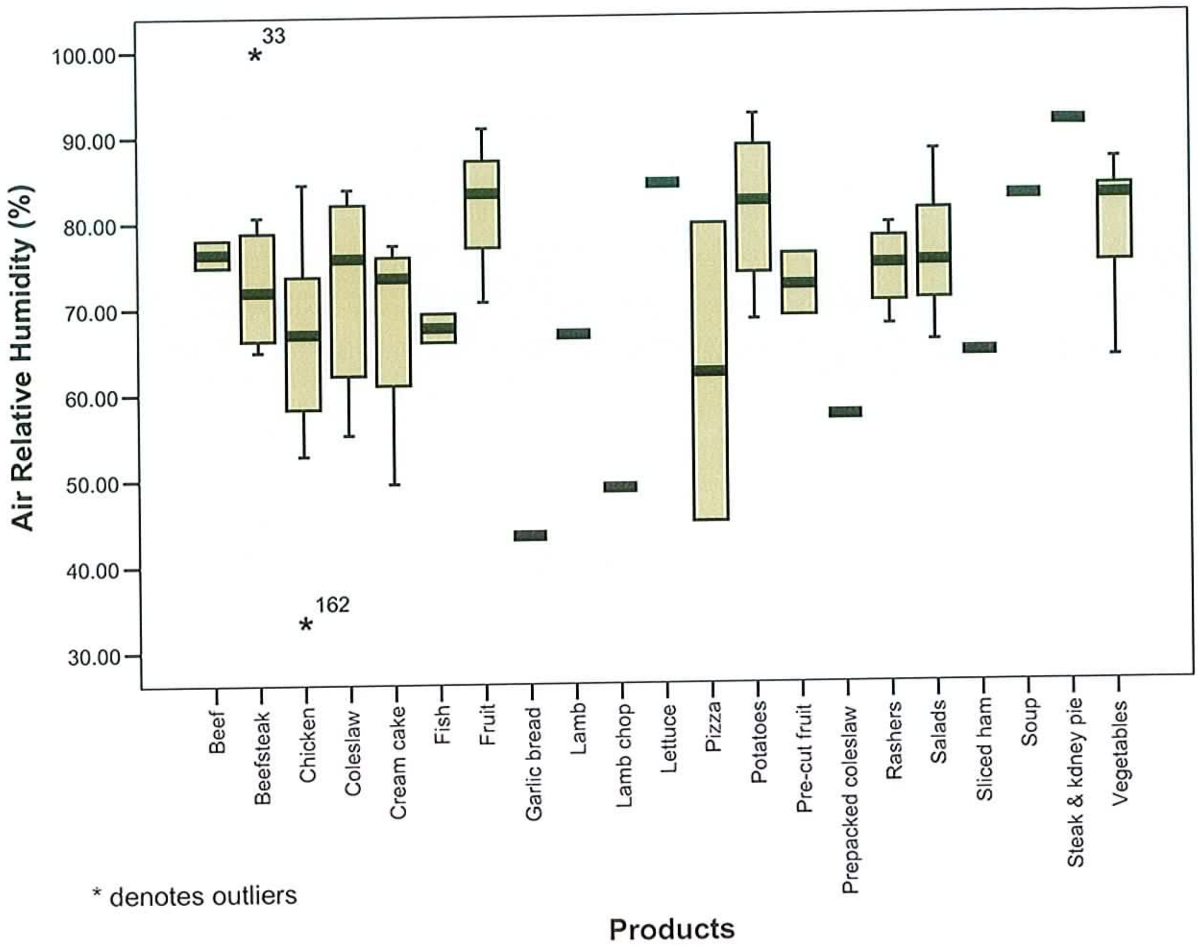


Figure (3.25): Air relative humidity of chilled, fruit and vegetable products

In 39% of 56 outlets surveyed, chilled products shown above in Figure (3.25) were held in a mean air relative humidity less than 70%, and in 2% of those outlets the mean air relative humidity in chill cabinets was greater than 95%. In the case of fruit and vegetables, all of the 12 cabinets surveyed showed mean air relative humidity greater then 70%, however only 14% of cabinets recorded RH above 80%. The recommended air relative humidity according to USDA guidelines for fruit and vegetables is 85-95%, and none of the cabinets recorded readings in this range, this suggests it is likely that dehydration and increased rate of spoilage of this produce is occurring due to excessively low air RH. Appendix 6 details individual product readings for relative humidity including mean, median, maximum and minimum values.

Results showed that 36% of all products surveyed were being held in the recommended range of air relative humidity. Air humidity is not subject to fluctuations due to defrost cycles. Garlic bread was held at a low air relative humidity which would result in desiccation of the product. Similarly pork chops would be prone to drying out and colour change due to loss of water through evaporation. Chicken, although having a median relative humidity of 67%, in one outlet the air relative humidity within the cabinet was 33.5% resulting in the product surface was noticeably dull and dry in appearance. A decrease in moisture content of meat products also leads to economic loss due to weight reduction of the meat prior to sale. Brown *et al.*, (2004) found that overall weight loss at 40% RH was approximately 3 times that at an RH of 85%.

Excessive air relative humidity was only recorded in one outlet, a butcher shop, and the cabinet was displaying beef steak. The air relative humidity in the chill cabinet was 98-99%, resulting in excessive moisture deposition on the meat surface. An increase in moisture content causes an increased rate of product deterioration due to microbial proliferation. Therefore excessive air relative humidity can reduce product shelf-life, and subsequently effect outlet turnover. Figure (3.26) shows the relative humidity recorded in cabinets in terms of the four outlet types surveyed.

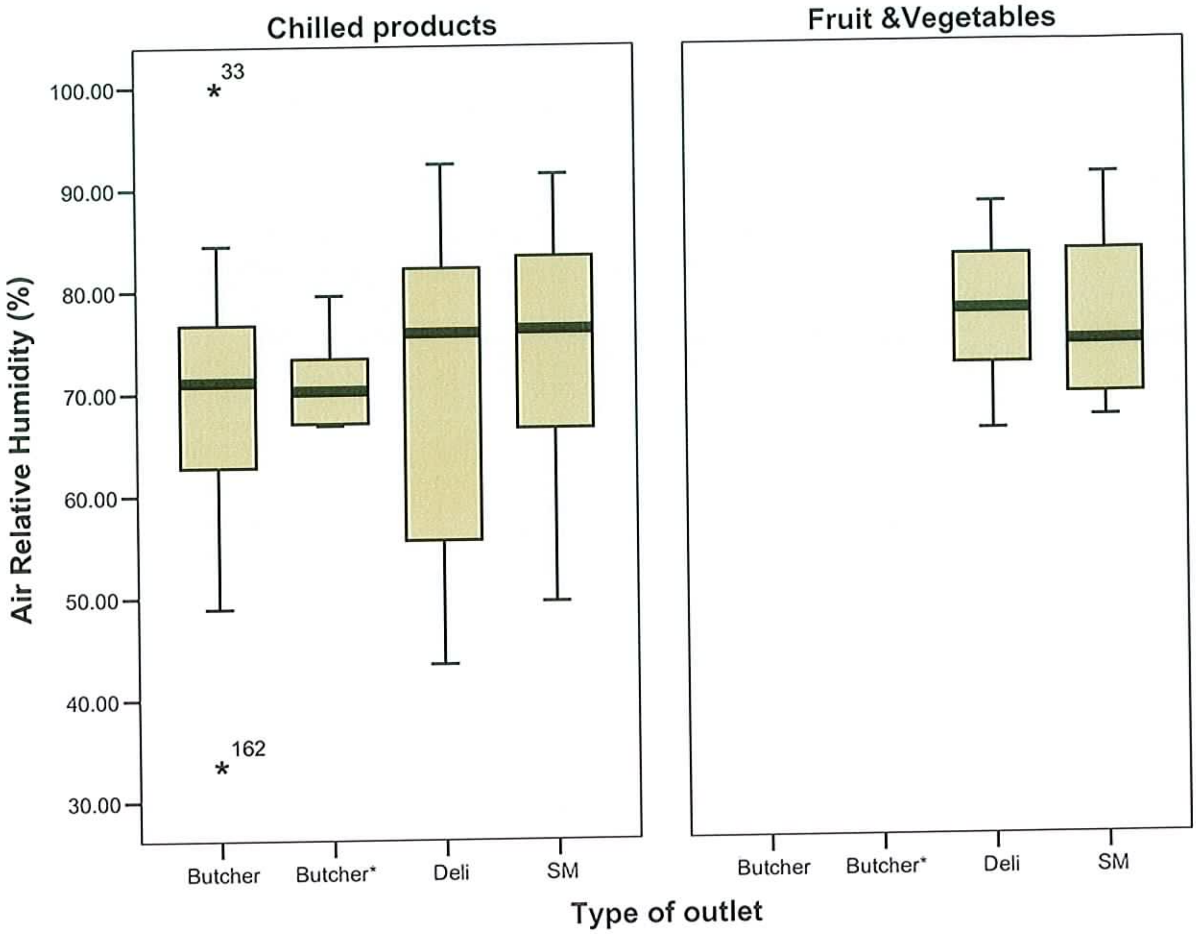


Figure (3.26): Air relative humidity in different outlet types surveyed

Using ANOVA testing, there was no significant difference in air relative humidity in cabinets holding chilled foods or fruit and vegetables between the four outlet types surveyed in this research. The size of the outlet was not found to be significant at a 5% confidence interval, in terms of air relative humidity in cabinets displaying chilled foods and fruit and vegetables.

The chill cabinet makes and designs were the same as mentioned in section (3.1.1), and results were examined in relation to significance of make or design with regard to the control of the level of air relative humidity. Previous research had reported that serve-over cabinets used in delicatessen outlets had a poor reputation for the preservation of food quality due to surface drying (Maidment *et al.*, 2000). Maidment *et al.*, (2000) found that this evaporation led to a large commercial loss for the retailer, as much as 5% of the total mass of food retailed. Crosstabulation of the results of this research showed that 30% of multi-deck cabinets maintained the air relative humidity of chilled, fruit and vegetable products in the recommended range. In contrast, 40% of circular and 50% of workstation salad bars were maintaining air relative humidity at a satisfactory level. The serve-over chill cabinet was found to be the most effective design, with 68% of cabinets controlling air relative humidity effectively.

In terms of variation of air relative humidity within the cabinets, results showed that air relative humidity at different positions within the cabinet varied depending on the design of cabinet and products displayed. Figure (3.27) shows the variation in air relative humidity as recorded by dataloggers at different positions within the chill cabinet.

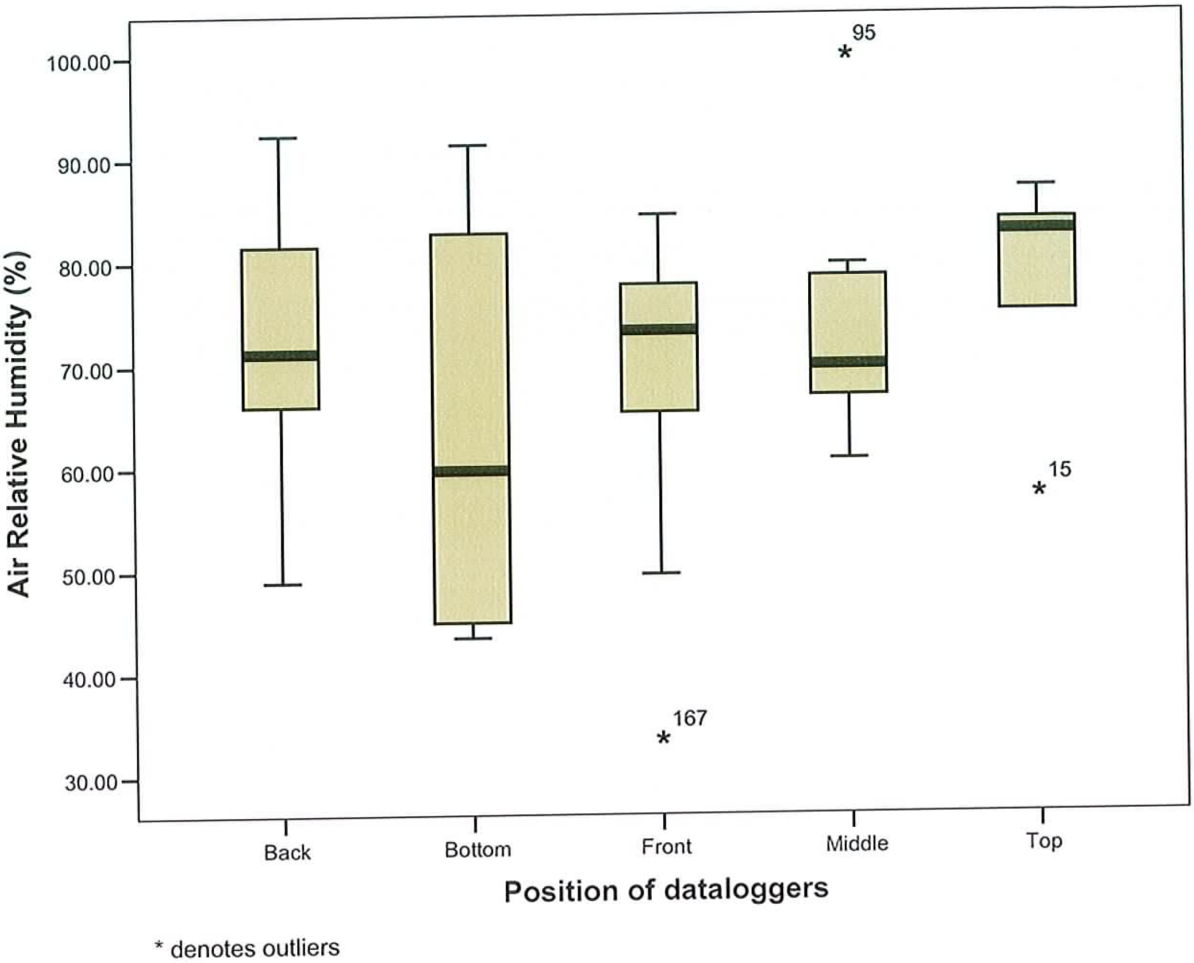


Figure (3.27): Air relative humidity at different positions within the multi-deck, serve-over and salad bar cabinets displaying chilled foods

Figure (3.27) shows that the dataloggers located at the bottom of vertical multi-deck cabinets recorded the lowest air relative humidity. The air relative humidity was seen to drop as the air travelled from the top of the cabinet to the middle and bottom areas. In the case of serve-over and salad bar cabinets, there was no difference found in the air relative humidity at the back compared to the front of the cabinet. However statistical analysis of results found that neither cabinet design or make was significant with regard to the control of air relative humidity.

With regard to multi-deck cabinets displaying fruit and vegetables, Figure (3.28) shows the changes recorded in air relative humidity as air travels from the outlet to the inlet of the display cabinet.

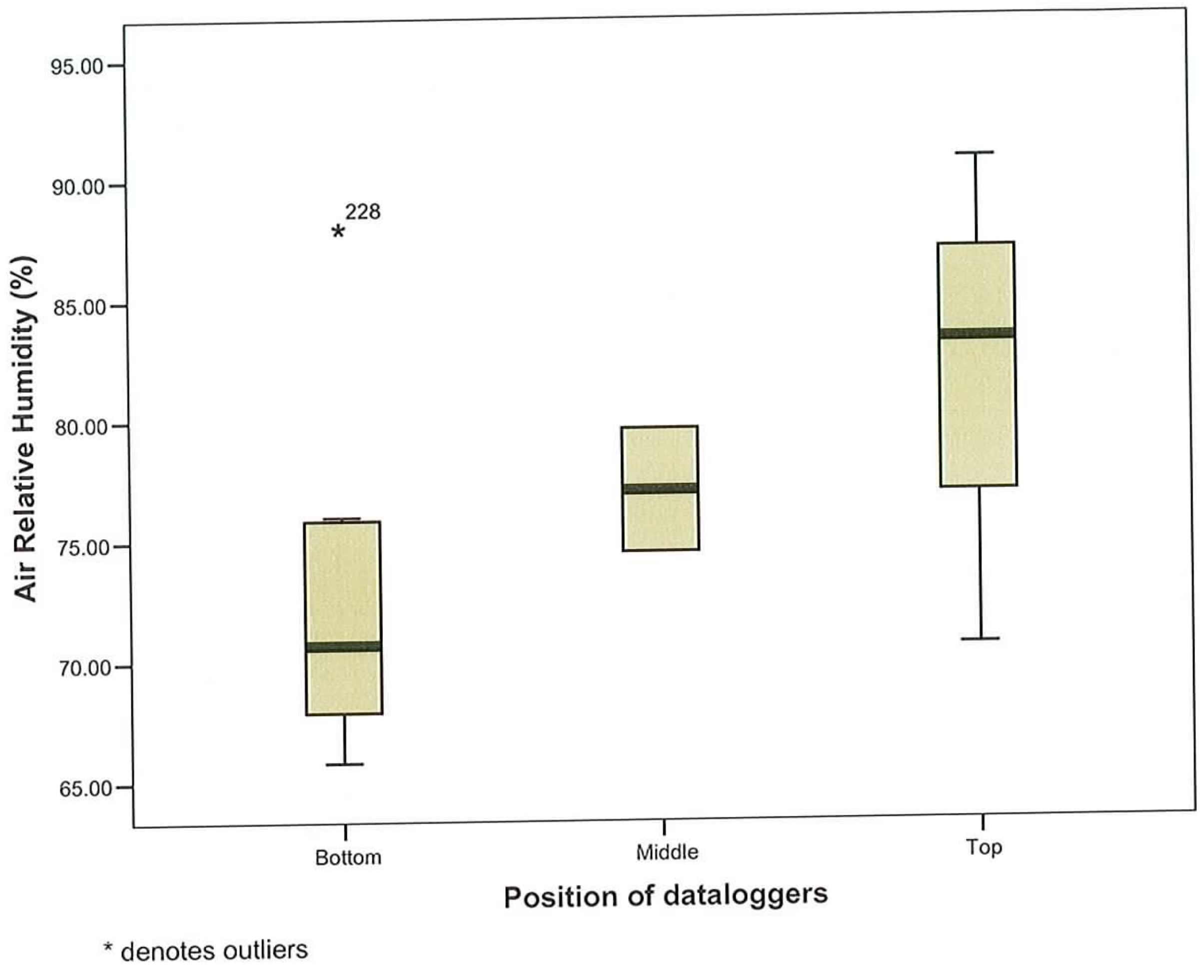


Figure (3.28): Air relative humidity at different positions within the multi-deck cabinets displaying fruit and vegetables

The boxplot in Figure (3.28) with data from chill cabinets displaying fruit and vegetables shows the air relative humidity starts to decrease with distance from the air outlet. The highest values for air relative humidity were recorded at the top of the cabinet, with the lowest values recorded at the bottom close to the air inlet. This suggests that products displayed on the lower levels of the multi-deck cabinet are more likely to loose moisture, and thereby have a shorter shelf life. The air moisture content drops as it travels from the air outlet to the air inlet in the multi-deck cabinets since the air curtain is in contact with ambient air with as lower relative humidity.

3.3 QUESTIONNAIRE ANALYSIS

The questionnaire was discussed with either the manager, assistant manager or quality control manager in each outlet. Questionnaires were returned for all outlets, there was a 100% response rate. The outlets were ranked in size according to number of employees. Figure (3.29) below shows a breakdown of the number of employees in the various outlets visited. Over half of the outlets (56%) had less than 10 employees, with 18% having between 10 and 20 staff. The majority of outlets would be classified as small to medium business enterprises, having less than 40 employees, with only 12% of premises having more than 40 employees.

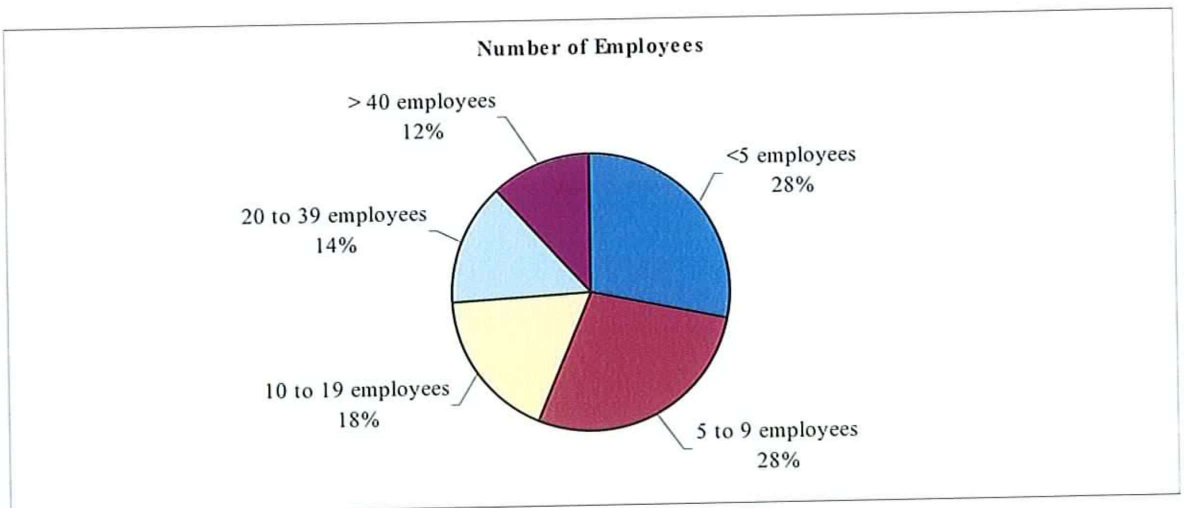


Figure 3.29: Distribution of business size surveyed

3.3.1 Food Safety Awareness

General issues of food safety awareness were discussed with the interviewees. Industry issues of most concern amongst the retailers in butcher, delicatessen and supermarket outlets were similar. The primary issues were food safety, cost of labour and staff shortages with most butchers mentioning increasing competition from supermarkets as a cause of closure of a substantial number of outlets. In relation to food safety, respondents in all outlets considered food hygiene and food poisoning as their principle concerns as retailers, from a list that included pesticide and herbicide residues, genetically modified foods and Bovine Spongiform Encephalopathy. Table (3.4) summaries the issues of concern to the customer with respect to food safety in the opinion of the staff interviewed in the retail outlets.

Table (3.4): Consumer's greatest Food Safety Concern

Outlet Type	Freshness	Food Hygiene	Traceability	Value for money	No concerns
Butcher	14%	7%	75%	4%	0%
Delicatessen	57%	29%	7%	7%	0%
Supermarket	41%	31%	22%	22%	3%

When staff were asked about what they considered to be the consumer's greatest food safety concern the replies varied depending on the type of outlet. Butchers felt that 75% of consumers were very anxious to know the country of origin of the meat they were purchasing. Employees (57%) in delicatessens felt that customers were most concerned about the freshness of the product and would regularly check sell-by dates before purchasing foodstuffs. Food hygiene in terms of food handling and store cleanliness was also an issue of concern for consumers with some degree of importance was attached to value for money and origin of foodstuffs.

In the supermarkets surveyed the staff felt that freshness, food hygiene and traceability of products were all food safety issues of concern for the general public. The cost of the product was also a determining factor when choosing a product, for instance some consumers mentioned the fact that they preferred to buy organic food but cost was an influencing factor. Respondents in 3% of supermarket outlets were of the opinion that consumers had no concerns about the safety of the food that they were purchasing.

As it is now mandatory to have a food safety management system in place at these retail outlets surveyed based on the principles of HACCP, a clear understanding of what HACCP is necessary for successful implementation. In order to determine the level of understanding HACCP, respondents were asked to explain the term HACCP. Their responses were categorised as excellent, good or poor.

A poor understanding of HACCP implies the respondent was only able to explain what HACCP stood for. Whereas as a good understanding meant that the respondent understood HACCP to be part of a food safety management system. In cases where the respondent was able to explain how HACCP worked to control food hazards and why certain steps were critical to prevent food borne disease in consumers, this reply was categorised as excellent.

It was found that the level of understanding of the term HACCP was not dependant on the job description of the person interviewed ($p<0.05$). In Table (3.5), the level of understanding of HACCP was related to the average external air temperature recorded in the chill cabinets in the outlets. There was a significant relationship ($p<0.05$) between the level of understanding of HACCP and the efficacy of temperature control.

Table (3.5): Significance of understanding of term HACCP

Understanding of term HACCP		**Chill Temperature (°C)**		**Total**
		-1 to +5	**> +5**	
Excellent	Number of outlets	16	1	17
	% within group	94.1%	5.9%	100%
Good	Number of outlets	30	23	53
	% within group	56.6%	43.4%	100%
Poor	Number of outlets	7	8	15
	% within group	46.7%	53.3%	100%
Total Number of outlets		53	32	85
% of Total		62.4%	37.6%	100%

The results show that the outlets with a poor understanding of HACCP exhibited poor temperature control and this suggests that a clear understanding of the HACCP results in superior food safety management. This finding correlates with the findings of an assessment of HACCP compliance in butcher shops and supermarket butcher's counter done by the Food Safety Authority of Ireland (FSAI) in 2004 and 2005.

The baseline assessment of HACCP compliance surveyed 961 premises and revealed that the principle barrier to HACCP compliance reported was lack of in-house skills (FSAI, 2006a). The assessment done by the FSAI found that staff in some outlets did not fully understand the concept of HACCP and the protocol required for an effective food safety management system based on the principles of HACCP. Similarly this research found that control of temperature in chill cabinets was related to understanding of HACCP.

The FSAI assessment of butcher outlets mentioned previously also showed that slightly more premises appeared to be controlling Critical Control Points (CCPs) than had actually conducted a hazard analysis. A possible explanation is that the butcher premises were following a generic industry guide to steps that needed to be controlled without actually conducting a hazard analysis. The danger with this situation is that businesses may not identify all the hazards in their operation and the steps at which these hazards need to be controlled. In addition, businesses may be treating steps as CCPs that are not genuine CCPs, thereby potentially wasting resources on excessive monitoring. Therefore, a lack of understanding of HACCP has a detrimental effect on implementation of food safety management systems.

In terms of the advantages of having a food safety management system in operation based on the principles of HACCP, the majority (53%) of outlets mentioned the fact that it reassured customers that a food safety management protocol was in place. The views of the employees with respect to the advantages of operating a food safety management system based on the principles of HACCP in the premises surveyed are summarised in Figure (3.30).

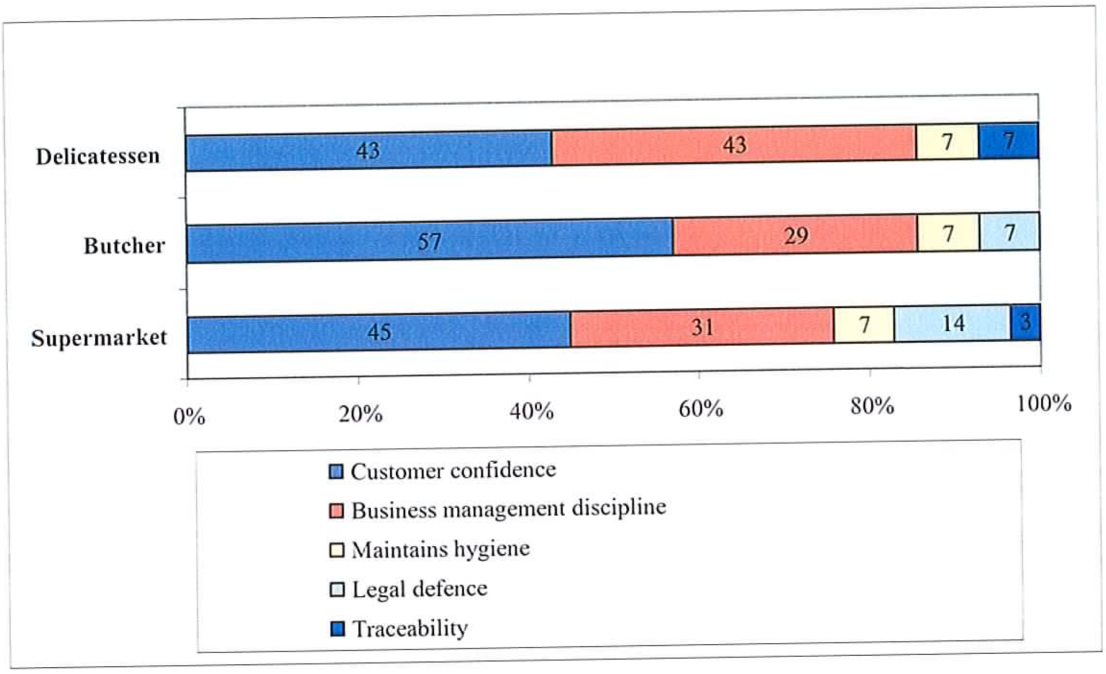


Figure (3.30): Advantages associated with a HACCP based food safety management system as expressed by respondents from the premises surveyed

In the case of delicatessens, 43% of staff expressed the view that having a HACCP system reassured the consumer's food safety concerns and equally provided step by step guidelines for other employees to follow to ensure food quality and safety. Staff interviewed in 7% of deli outlets indicated that a HACCP system facilitated cleanliness and made it easier to investigate and determine the cause of any problems with foodstuffs in relation to food safety.

In the case of butcher outlets, as well as reassuring customers of their commitment to food safety, employees in 29% of outlets surveyed were of the opinion that a HACCP system provided guidelines for employees to assist in maintaining food safety. It also assisted in-store standards of hygiene according to 7% of respondents and was evidence of 'due diligence'.

The managerial staff in supermarkets considered an increase in customer satisfaction as the most important benefit of an in-store food safety management system (45%). The advantage of providing food safety protocol for staff was mentioned in 31% of premises. Compliance with the legislation was mentioned as a benefit in 14% of outlets with 7% stating it maintained hygiene and 3% it facilitated finding the cause of any breaches in food safety.

Figure (3.31) examines the opinions of staff with regard to what they perceive as disadvantages associated with implementation of a food safety management system.

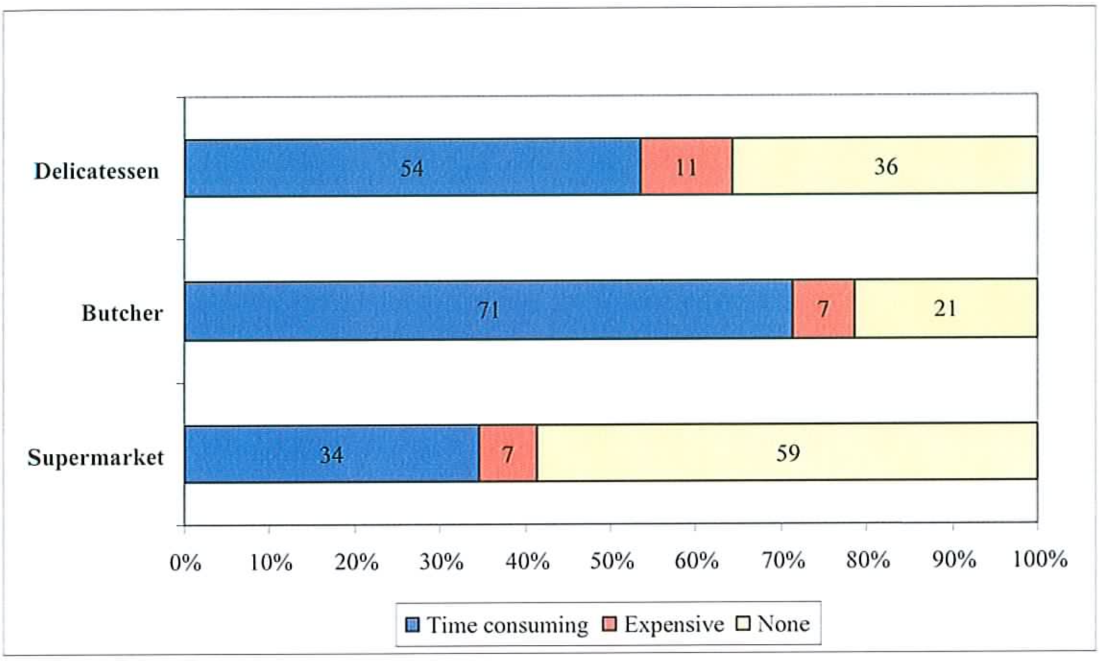


Figure (3.31): Disadvantages associated with a HACCP based food safety management system as expressed by managers of the retail outlets in this survey

When asked to discuss the disadvantages inherent in having a HACCP system staff in 54% of deli outlets said the procedures involved took up a lot of time, 11% found it expensive to install and maintain but in 36% of the deli premises surveyed it was felt there was no adverse effect of using a HACCP based food safety management system. Nearly 75% of butchers surveyed found having a food safety management system that followed HACCP principles very time consuming particularly as 64% of outlets had less than 5 employees, which would also account for the fact that 7% found it costly to maintain. However, 21% of staff in the butcher outlets expressed the opinion that there were no perceivable disadvantages.

With regard to supermarket outlets over half (59%) of respondents said there was no disadvantage to having a HACCP system, with 34% saying the time involved in maintaining the system was a deterrent and 7% said cost of adhering to the system was an issue. The fact that a majority of supermarkets felt there was no perceivable disadvantages, was to be expected given the fact that they have larger staff numbers than butchers and deli outlets, so it is not as great a drain on human resources when procedures required by the HACCP system are being followed. It also should be mentioned that many of the supermarkets that participated in this survey were supported by a food safety department within the particular chain of supermarkets. This meant that installing the system and addressing any problems would have been less expensive.

The rationale behind temperature control was then discussed with the respondents in relation to why it is necessary to control food temperature. The reasons given for controlling food temperature are detailed in Figure (3.32).

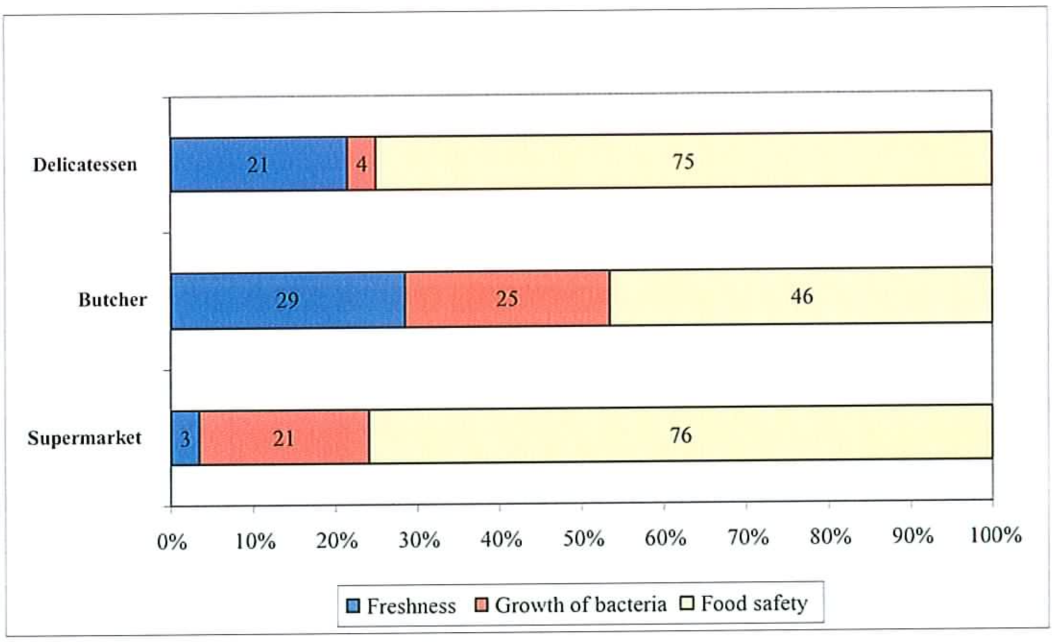


Figure (3.32): Reasons for Controlling Food Temperature as obtained from respondents

Food safety was the reason for controlling the temperature of food cited by the majority of outlets, with approximately 75% of deli and supermarket outlets, and 46% of butcher premises giving this as an answer. Growth of bacteria was mentioned in the case of 25% of butcher outlets, 21% of supermarket outlets and only 4% of deli outlets. The other reason mentioned for controlling food safety was the freshness of the foodstuff, over a fifth of butchers (29%) and delicatessens (21%) considered this was the main rationale behind temperature control, whereas it was only cited by 3% of supermarkets surveyed.

It was considered worthwhile to determine levels of food safety knowledge and understanding amongst managers as part of an evaluation of the food safety management system. Figure (3.33) addresses high risk foods.

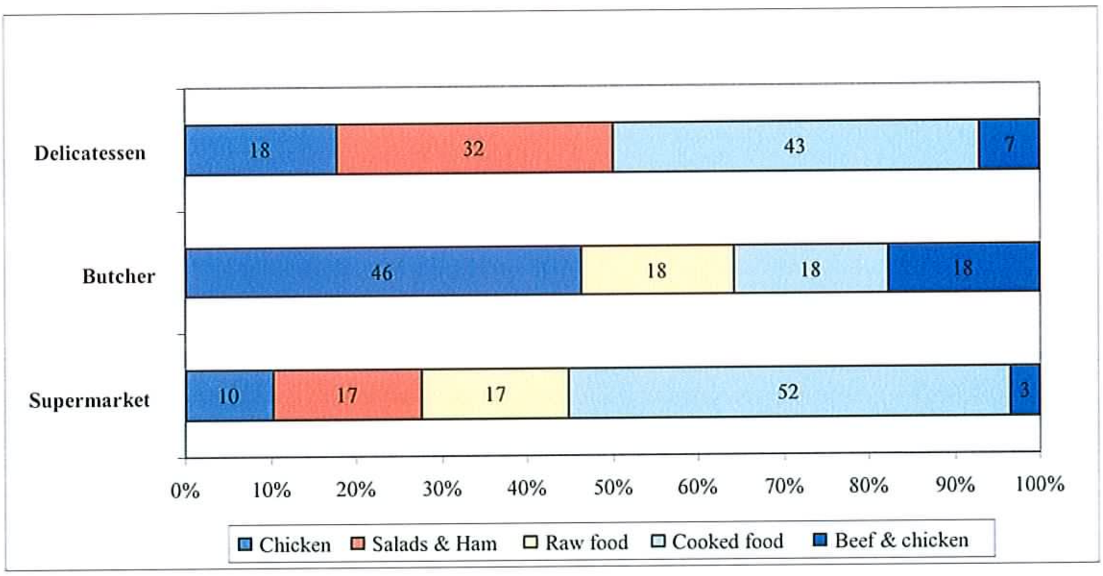


Figure (3.33): Classification of high risk foods according to survey respondents

When asked what foodstuffs they considered as having a high potential to cause food-borne disease in customers, cooked food was the most common reply. Both staff in 43% (12 outlets) of deli outlets surveyed and 52% (15 outlets) of supermarkets surveyed selected hot foods such as cooked chickens as posing a significant risk. Given the nature of the foodstuffs they sell, it was not surprising that salads such as coleslaw, and sliced ham were mentioned in 32% of deli outlets surveyed, chicken was also mentioned in 18% of deli premises as was beef in 7% of shops visited.

In the case of 17% of the supermarket outlets surveyed employees considered that prepared salads and cold meat slices such as ham as well as raw meat were in the high risk category in terms of food safety. Beef was only considered a significant risk in 3 % of outlets. Chicken was considered the highest risk food by butchers with 46% voicing a concern in terms of its potential as a causal agent of gastroenteritis. Beef, raw meat and cooked food were each cited as high risk foods in 18% of the total butcher premises visited.

As previously mentioned, some of the questions in the survey aim to determine levels of food safety knowledge amongst managers and its relevance to food safety management and control. As part of this objective the interviewees were asked if they were aware of any pathogens of significance in the area of food safety control. The pathogens mentioned were *Salmonella* spp., *E. coli* and *Staphylococcus aureus*.

There was no mention of *Campylobacter* by any employee interviewed even though in 2004 there were 1,711 cases of *Campylobacter* infections reported, four times the number of reported cases of salmonellosis making it the most common cause of bacterial human gastroenteritis illness in Ireland (FSAI, 2004a). Using the

Pearson Chi-Square test at a 5% Confidence Interval, it was found that the knowledge of pathogens was not dependant on the job description of people interviewed. In other words, the managers were not any more informed than assistant managers or quality control managers.

The knowledge of food borne pathogens by managers in the retail outlets was compared to the mean temperature in their chill cabinets and results of this analysis are shown in Table (3.6).

Table (3.6): Influence of knowledge of pathogens by store managers on temperature control

	Chill Temperature (°C)		**Total**
	-1 to +5	>+5	
Aware of any pathogens	31	12	43
% within group	72%	28%	100%
Not aware	22	20	42
% within group	52%	48%	100%
Total	53 62%	32 38%	85 100%

From this table it can be concluded using the Pearson Chi-Square test at 5% Confidence Interval that pathogen knowledge is not significant in terms of temperature control. It would be expected that an increased knowledge of food borne pathogen hazards would influence the standard of temperature control. Awareness of the health risks associated with consumption of food contaminated with pathogens should act to improve the standard of temperature control and ultimately food safety management. Previous research has concluded that the level of food science knowledge was rather low, whilst food safety knowledge levels were high, amongst the Irish population (McCarthy *et al.*, 2005).

3.3.2 Food safety compliance with regulations

The next section of the questionnaire focused on the food safety management system in operation in the outlets surveyed. The questions were used to determine the level of compliance with the statutory regulations in place at the time. When asked what the acceptable temperature of chilled foods on arrival at their premises was, all respondents replied that a food temperature in the range between -1 and 5°C was acceptable. All respondents also said that the temperature of the cold store was always between 0 and 5°C, with external air temperatures in display chill cabinets being between -1 and 5°C outside of the defrost cycle.

When questioned regarding frozen foods, replies suggested that all frozen foods were stored at temperatures of -18°C except for ice-cream which was held at -23°C. However, again the readings downloaded from the dataloggers left in-situ indicated in-correct storage in 78% of outlets, with 52% of outlets never going below -15°C.

This research found that ice-cream was stored in mean external air temperatures above -20°C in 29% of outlets, and below -25°C in 36% of outlets. This is again related to the previous discussion on temperature distribution and the role of the temperature sensor in the chamber. It is particularly important that 29% of the cases the temperature sensor was giving a compliant temperature in the freezing chamber while the results of this survey showed that the cabinet was over the recommended limit. This anomaly also suggests inaccurate monitoring of freezer temperature and failure to detect unsatisfactory freezer temperature control by both the freezer unit itself and the in-store HACCP system. It is also possible that freezer chambers containing ice-cream are not being accurately checked in retail outlets, and that there is over reliance on the appliances digital temperature display. No other research could be found in the literature on this aspect of temperature control in retail outlets.

In terms of compliance with the legislation, the respondents were asked about the main sources of information on food regulations. Figure (3.34) shows the various sources for food business operators.

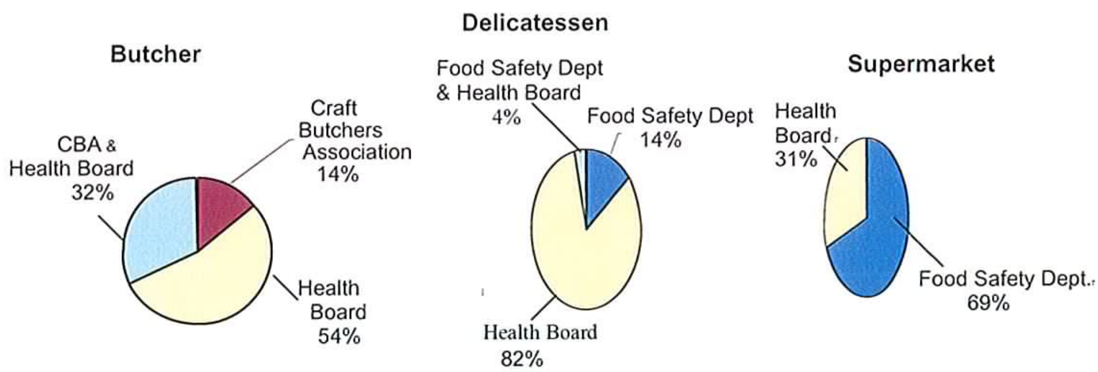


Figure (3.34): Sources of Information on food legislation for participants in this survey

Most information on operation and maintenance of food safety management system was obtained from the local health board. Retail outlets that were franchises of large chains, (e.g. Musgraves), were instructed by the food safety department at head office and were subjected to annual internal audits from personnel at head office. In the case of supermarkets, 31% got information from the environmental health officer but the vast majority (69%) were reliant on the food safety department of the particular franchise.

Butchers were more reliant on environmental health officers for information with 54% saying they relied solely on the health board and 32% relying on the health board and the Craft butchers Association. The Craft Butchers Association was the only source of information for 14% of outlets. Deli outlets were most reliant on the health board (82%) with 14% reliant on a food safety department at head office in the case of franchises and 4% using both the health board and a designated food safety department within the chain of outlets.

None of the respondents were familiar with the codes of practice such as I.S. 341-Hygiene for the Retailing Sector or I.S. 343-Food Safety Management incorporating HACCP. None of the respondents were aware of any legislation that was relevant to their business, yet all felt that they were compliant with current legislation. None of the respondents were familiar with the Food Safety Promotion Board of Ireland, a few had heard of the Food Safety Authority but all were familiar with the Health Boards, Bord Bia and Bord Iascaigh Mharaigh.

The respondents were asked for their opinions on the regulation of the food industry, with emphasis on food safety, their opinions are detailed in Figure (3.35).

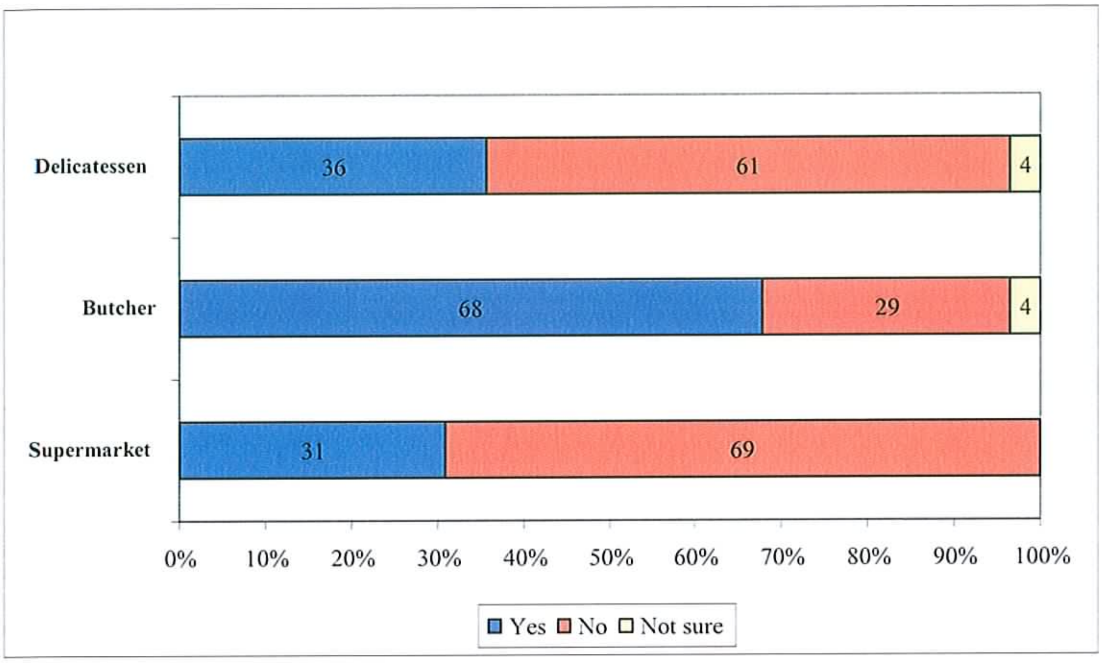


Figure (3.35): Respondents opinion as to whether food safety is over-regulated

When asked about the controls in place regarding food safety such as legislation, inspections and audits, the vast majority of butchers (68%) felt that there was over regulation. However, the opposite was the case with regard to supermarket and delicatessen outlets, with over 60% feeling that the level of regulation was necessary. Similar findings were encountered in a previous survey done by the FSAI which found that 41% of Irish food businesses called for more food safety checks by the authorities (FSAI, 2001b).

In the FSAI food business survey mentioned in the paragraph above, 27% of respondents were retailers. The FSAI finding in relation to stating the need for more checks was not a surprise in the context of the high percentage of overall respondents (42%) who had previously said they thought that the health board should be responsible for developing their food safety management system (FSAI, 2001b).

The cabinets in use in the outlets visited were also studied during this research. As previously mentioned, some outlets had cabinets with computerised continuous temperature monitoring. These cabinets had a temperature probe located at the air outlet which was programmed to record the temperature at fixed time intervals, and the readings recorded were displayed on a computerised print-out usually located in an office. The majority of supermarket outlets surveyed (90%) had cabinets where the external air temperature was being recorded automatically at pre-set intervals, 82% of deli outlets and 64% of butchers also used this design of cabinet.

With regard to having a digital temperature display, 97% of supermarkets, 89% of delicatessens and 79% of butchers had one on each of their cabinets. However only 46% of butcher outlets compared to 85% of delicatessens and 86% of supermarkets had chill cabinets fitted with alarms. These alarms were programmed to alert staff once external air temperature within cabinets exceeded limits set by the retailers. The limits set were those recommended in guidelines, and by environmental health board inspectors. The presence of an alarm system as part of temperature monitoring within the outlets should allow for immediate notification of staff when temperatures within cabinets exceed critical limits.

The external air temperature in the cabinets was set by the cabinet supplier during installation under instruction from the retailer in 69% of the outlets visited, and once set the temperature was expected to be maintained continuously by the cabinet. In 31% of outlets the external air temperature was set daily by the owner before placing produce into the cabinets, in these cases the product would have been kept in a cold store overnight. The manual setting of temperature was done more in butcher outlets than either of the other two outlet types, butcher outlets tended to have older chill cabinets as shown in Figure (3.36).

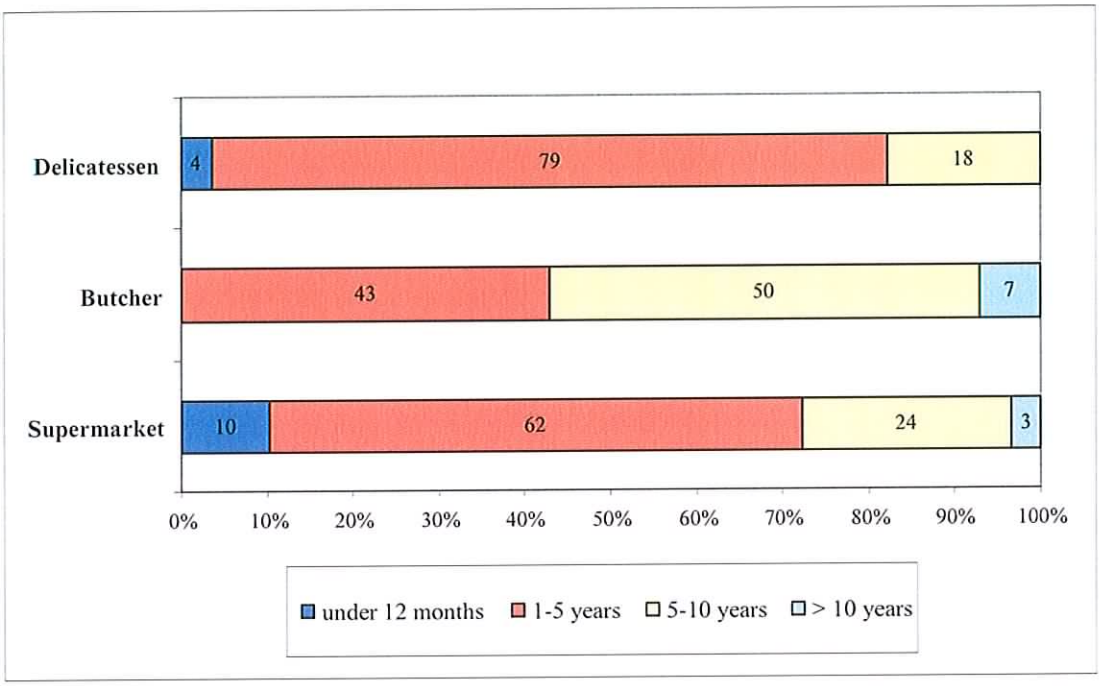


Figure (3.36): Age of chill cabinets in three types of retail outlets surveyed

The age of the cabinet did depend on the type of business ($p<0.05$). In 83% of delicatessen outlets the cabinets were less than 5 years old, which is probably related to the recent introduction of this kind of business in Ireland. In the case of supermarkets, 27% of outlets had cabinets older than 5 years old. The butcher outlets, a more traditional business, had on average older cabinets, with over half of the cabinets being older than 5 years and 7% between 10 and 15 years old.

However, although butchers may use older cabinets not quite as sophisticated as those used by supermarkets and deli outlets, the standard of temperature control does not suffer as will be shown in Figure (3.44). Chill temperature control was found to be in the correct range in 75% of butcher outlets as opposed to 62% of supermarkets and 50% of delicatessens in Figure (3.44). This may be related to the fact that in butcher outlets consumers do not have direct access to fridges, whereas delicatessens and supermarkets have generally unsupervised installations available directly to consumers. This results in an increased rate of door opening, with the risk of increasing the temperature. Also, due to the age of the cabinets being older in butcher outlets, daily manual setting was more prevalent in butchers which may also have increased the efficiency of temperature control.

It is recommended that cabinets be serviced at least every two years and condensing coils should be cleaned of dust and debris every two months in order to keep the unit performance at its best. The defrost water outlets must be kept clean and free running to avoid malfunction.

Evans *et al.*, (2004) has found bacteria present on evaporator cooling coils in all chill rooms of processing plants in a survey of 15 factories. Further trials with an experimental evaporator indicated that bacteria could be transferred from the surface of an evaporator to the air within a cold room (Evans *et al.*,2004). These trials also indicated that little microbial growth occurred on a clean evaporator. Braun (1986) found that if dirt was not removed from a cooling coil promptly, cleaning was ineffective and the coil required replacement. In addition, he found that it was impossible to determine the cleanliness of the coil simply by looking at the surface. Often external surfaces look clean whereas central areas hidden from view were extremely dirty.

Therefore it is important that evaporators should be cleaned regularly and thoroughly as part of a maintenance regime to prevent build up of contamination. Figure (3.37) gives details of the maintenance frequency of cabinets in the outlets surveyed.

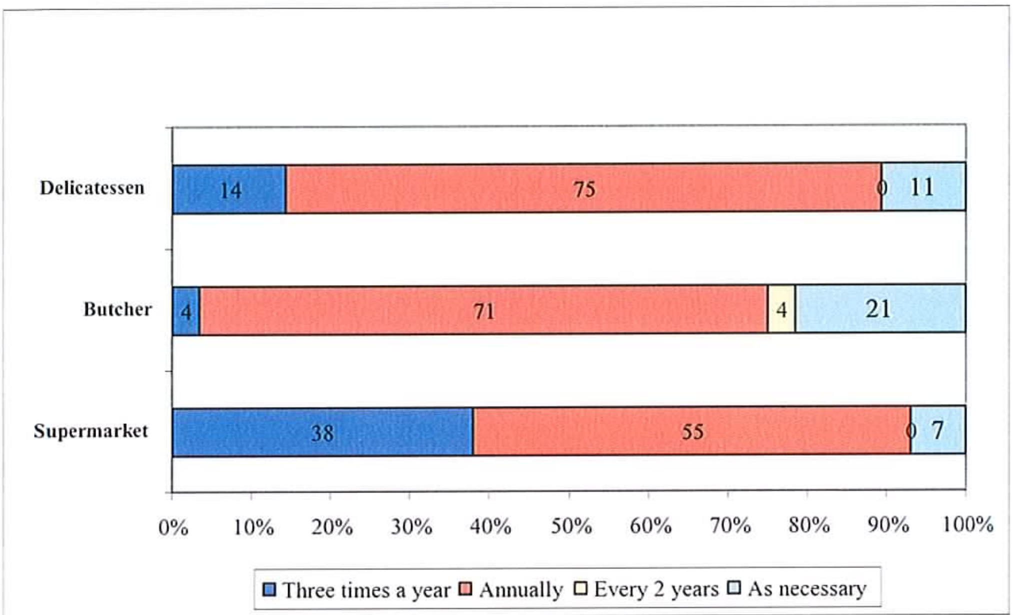


Figure (3.37): Maintenance frequency of cabinets in retail outlets surveyed

Most outlets had their cabinets maintained annually, however, 38% of supermarkets, 14% of delis and 4% of butchers had their cabinets function checked three times a year. In 21% of butchers, 11% of delicatessens and 7% of supermarket outlets the cabinets only were serviced when a problem was noticed, a regular cabinet maintenance was considered time consuming and an unnecessary expense by these retailers.

Temperature of products was regarded as a critical control point in all outlets visited and regular temperature monitoring was an integral part of the food safety management system. Checks of food and air temperature were done in all cases using a digital probe. The checks were done twice daily, morning and evening in 98% of outlets visited, a temperature check was done once daily in 2% of outlets.

Calibration of probes was done yearly in 96% of outlets. All of the probes which were calibrated were done using an external company, except in one case, where the butcher calibrated the probe himself. In the case of three butcher outlets visited the probes were never calibrated. Extreme temperature abuse was recorded in one of these outlets with temperatures at the back of one chill cabinet displaying beef never going below 15°C throughout a typical commercial day. These readings are shown in Figure (3.38).

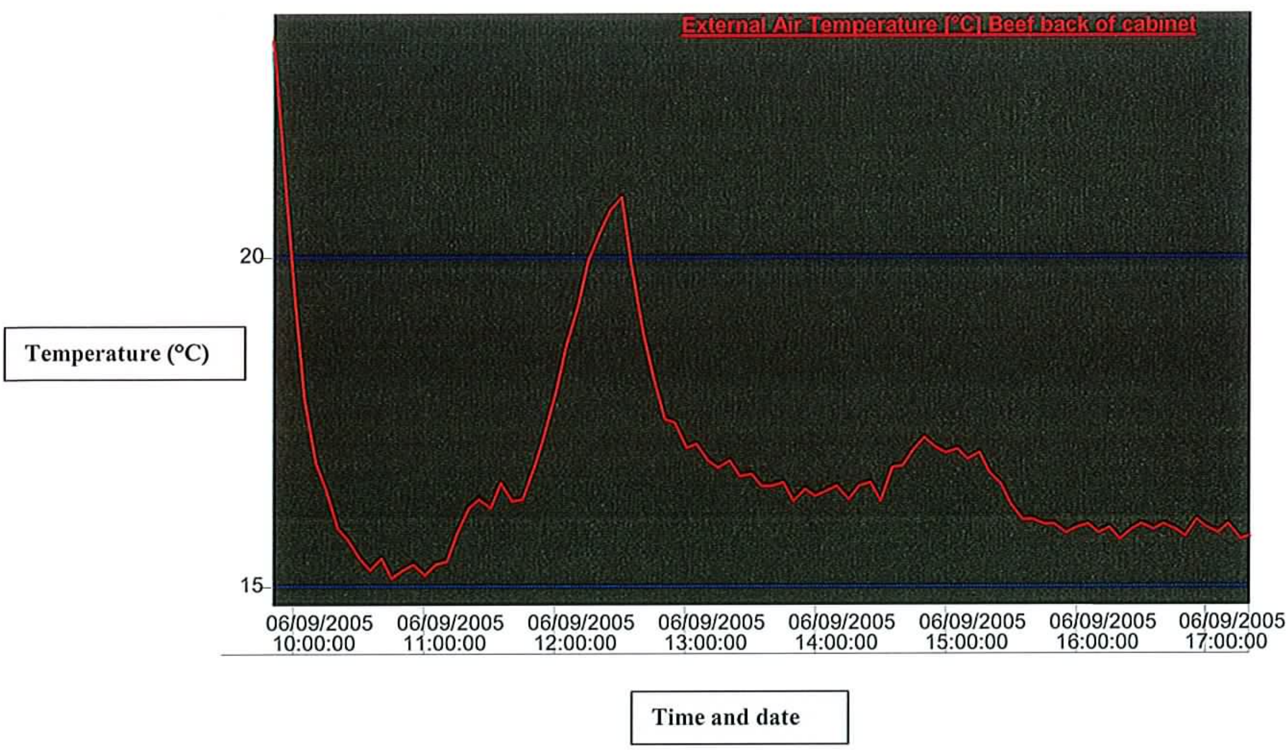


Figure (3.38): External Air temperature at back of cabinet displaying raw beef steak

Figure (3.38) clearly shows the extent of the temperature abuse occurring in this outlet, where the external air temperature reaches 20.9°C during the defrost cycle. The lack of temperature control in this cabinet means that growth of any mesophilic pathogens possibly present on the product surface, for example *E. coli*, are not inhibited. The chill cabinet in this outlet was manually set each day and was only serviced when a problem was detected. The manager in this outlet was unaware of the lack of temperature control due to inaccuracies in readings taken with the digital probe and inaccuracies in the temperature sensor of the cabinet. The lack of temperature control at this outlet is a real and serious risk to public health.

A 12 month study commenced in March 2001, on the incidence of *E. coli* O157:H7 in minced beef and beef burgers done by the National Food Centre in Ireland detected the pathogen in 2.8% (43) of samples taken (Cagney *et al.*, 2004). The minimum temperature for E. coli O157:H7 growth is 7°C, it will grow well at room temperatures and has an infectious dose of only 10-100 cells. The study also found that *E. coli* O157:H7 was present in Irish minced beef and beef burgers at unacceptable and potentially hazardous levels in 2.8% of samples.

A previous survey carried out in Ireland (Walsh *et al.*, 1997) found a much lower prevalence (0.2%), of *E. coli* O157:H7 in retail and wholesale beef. A similar study with similar results, where a prevalence of 0.3% was found, was done in the UK in 2000 (De Boer and Hauvelink, 2001). Therefore, research highlights an increase in prevalence of this hazardous pathogen and further emphasizes the importance of accurate temperature control within the retail outlets selling this foodstuff.

Apart from maintaining temperature control and hygienic handling practices, there is little more that retailers can do to reduce the prevalence of *E. coli* O157:H7 in the products they sell, provided they prevent cross contamination at the mincing stage if this is carried out at the retail premises. The current prevalence of *E. coli* O157:H7 in minced beef and beef burgers coupled with the emergence of occasional gross contamination of comminuted beef products at retail level presents a real risk to public health. It is likely that this risk is only being controlled by the cooking process to which the meat is subjected in the consumers' home (FSAI, 2003a).

In the two other butcher outlets surveyed, where the probe was not calibrated, the chill cabinets maintained a satisfactory chill temperature but the chill cabinets were less than 5 years old and there was computerised monitoring of temperature. Therefore, it was less likely that temperature abuse would be undetected in these butcher outlets. Records of temperature readings were kept in all outlets surveyed and these records were kept for one year in 70% of outlets and for two years in 30% of outlets.

Guidelines in I.S. 341 suggest that any food product that exceeds 10°C should be disposed of (NSAI, 1998). Figure (3.39) indicates respondents reply when asked at what temperature they would consider food unfit for human consumption.

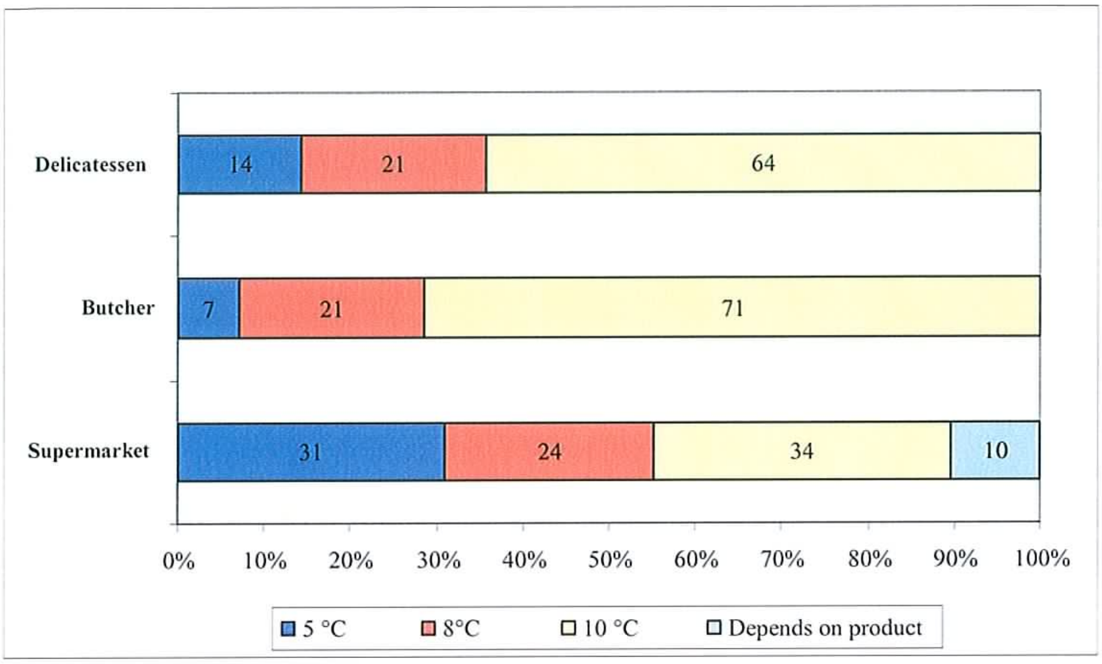


Figure (3.39): Core temperature at which food is disposed of according to managers in retail outlets surveyed

In the case of delicatessens, 14% of respondents said food with a core temperature above 5°C would be disposed of, 21% of deli managers selected 8°C as their cut off point, compared to 64% of deli managers agreeing on 10°C as the temperature above which food would present a health hazard to customers.

The vast majority of butcher outlets (71%) considered products with a core temperature exceeding 10°C as hazardous, with 21% and 7% of butchers agreeing on 8°C and 5°C respectively. In supermarkets 31% of managers said food with a core temperature higher than 5°C would be disposed of, whereas 24% of supermarket managers said food with a core temperature higher than 8°C would be disposed of.

Over one third of managers in supermarket (34%) said it was store policy to dispose of products once their core temperature exceeded 10°C, whilst 3 outlets said the core temperature at which they disposed of food depended on the type of product as they would dispose of high risk ready-to-eat products at a lower temperature than those which were subjected to further heat treatment.

All outlets had a written sanitation programme. All chill cabinets were surface cleaned with a sanitiser and also in some cases with a degreaser. The frequency of cleaning was daily in all outlets except one delicatessen which felt that every 2 or 3 days was sufficient given time and labour restraints. However, the sanitation schedules did not have information on products used for cleaning such as dilution rates, or details on rinsing, contact times, or drying.

Worsfold, (2001) recommends that in order to demonstrate that adequate sanitation procedures are in place and monitored, managers should construct comprehensive programmes that indicate cleaning frequency and provide information on:

- the type and concentration of chemicals
- the use and treatment of cleaning equipment
- a detailed cleaning method, including the requirement to allow an appropriate contact time, and to rinse and dry where necessary

All hygiene checks done on chill and freezer cabinets both internally or externally by inspectors are visual, but there is evidence that visual assessment is a poor indicator of cleaning efficiency (Griffith *et al.,* 2000). No swabs are taken from the cabinet surfaces, but samples of foodstuffs are sometimes taken for microbiological analysis by Health Board inspectors. All the chill cabinets in the outlets surveyed were subjected to a deep clean which involves dismantling the cabinets to allow a more thorough cleaning. This was done at different frequencies as seen in Figure (3.40) below.

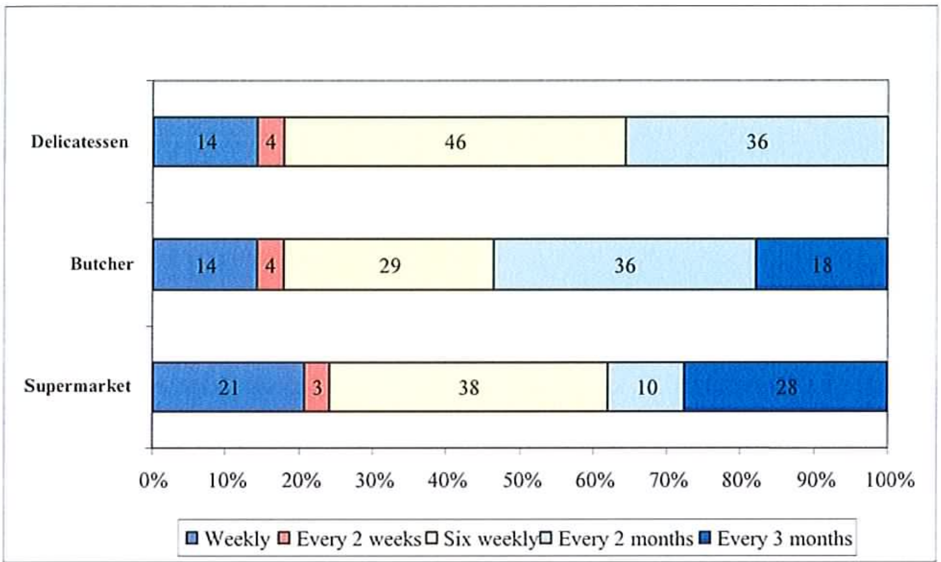


Figure (3.40): Deep cleaning frequency of chill cabinets in outlets surveyed

A deep clean was done in most outlets every six weeks. In the case of delicatessens, 36% of outlets carried out a deep clean every two months, 4% of outlets did a deep cleaning every two weeks and 14% of outlets said they managed to do a weekly thorough cleaning of their chill cabinets. In the butcher premises surveyed 36% did a deep clean every 2 months, 18% of butcher outlets carried out a deep clean of cabinets every 3 months, while 14% of butcher outlets did a deep clean of cabinets weekly and fortnightly.

Supermarkets managed to do a deep clean once a week in 21% of outlets visited, possibly due to the fact that these outlets had higher numbers of employees.

However, 28% of outlets carried out a deep clean of chill cabinets every 3 months and felt this was adequate. A deep clean was carried out every 2 months in 10% of outlets and fortnightly in 3% of premises but the majority of the supermarket outlets (38%) did a deep clean every 6 weeks. The type of business was not significant in terms of deep cleaning frequency ($p>0.05$).

3.3.3 Food safety training

When questioned on training given to employees, 88% of outlets replied that all staff were given formal training prior to commencing work, the remaining 12% were given on the spot instruction. The type of business was not found to be significant with regard to the type of training given, the three outlet types surveyed provided similar food safety training.

All outlets emphasised that no staff were permitted to handle food without prior training. It is a legal requirement that staff involved in a food environment are adequately trained and/or supervised commensurate with their work activity. The responsibility for training and supervision of staff lies clearly with the proprietor of the business. The various subjects discussed as part of induction training are shown in Table (3.7).

Table (3.7): Topics covered under induction training given at outlets surveyed

	Personal Hygiene	Hygienic Practice	Food Handling	Food Safety	HACCP	Sanitation
Example	Handwashing	In case of illness	Food storage temperature	Temperature checks	Steps to ensure food safety	Cleaning of the work area

All employees in each outlet type had been given an induction training which covered topics such as basic food hygiene, management of food safety and HACCP training. All staff training in any of the outlets that were franchises was overseen by head office. Previous research has cited the main problem identified with food handlers to be the fact that they receive no specific training, and need no qualification certificate to work with food (Gomes-Neves *et al.*, 2007).

Mortlock *et* al. (2000) has highlighted the need to develop training methods that are proven to change workplace behaviour as well as imparting knowledge. The topics covered under both training regimes ensure the employee is adequately informed on food safety management but this does not guarantee compliance with in-store protocol in relation to food safety.

Experience has shown that food-poisoning outbreaks can still occur even when comprehensive training programmes have been implemented (Luby *et al.,* 1993). Previous research cites that in one instance despite previous sanctions and intensive staff training, a large salmonellosis outbreak occurred affecting 824 people at a convention due to inappropriate hygiene practice where cooked meat was unrefrigerated for several hours and incompletely reheated (Luby *et al.*, 1993). Furthermore, despite undisputed improvements in attendance at food hygiene training courses, the 1990s have seen significant increases in the reported incidence of food poisoning in the UK (Ehiri and Morris, 1996). The apparent contradiction of increasing food-poisoning incidences and improved rates of training can in the opinion of researchers be explained by the methodologies adopted by most training programmes. Traditional approaches to food hygiene training tend to follow the Knowledge Attitudes Practices model (KAP), assuming that the provision of education and knowledge will stimulate changes in work practices (Rennie, 1994).

The managers in the outlets were then asked if they were satisfied with the training given and their opinions on the adequacy of training given to staff is outlined in Figure (3.41).

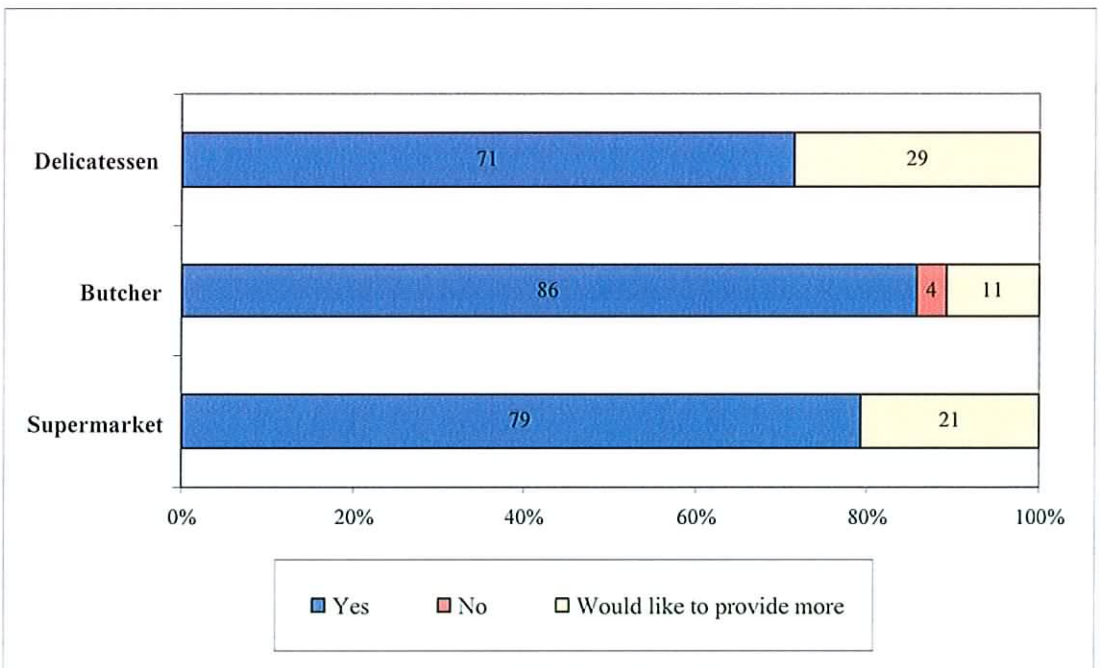


Figure (3.41): Managers opinions on adequacy of training given to employees

When questioned regarding the level of training given to employees the majority of outlets (79%) considered it adequate. It was the opinion of 64% of managers that HACCP training was necessary to successfully implement a food safety management system based on the principles of HACCP. However, some managers (20%) said they would like to provide more training. One butcher did feel it was appropriate to offer more training but was not in a position to do so due to financial and staffing constraints.

In the UK, the vast majority (over 90%) of retailers are in ‘micro’ businesses, employing fewer than 10 food handlers (Mortlock *et al.*, 1999), and the scenario would be similar in this country with regard to butcher and deli outlets. Therefore, training costs are likely to be of greater concerns for smaller enterprises than for larger businesses with larger turnovers.

Respondents were then asked if they felt that the government backing for employee training was adequate, and satisfaction levels to this question are shown in Figure (3.42).

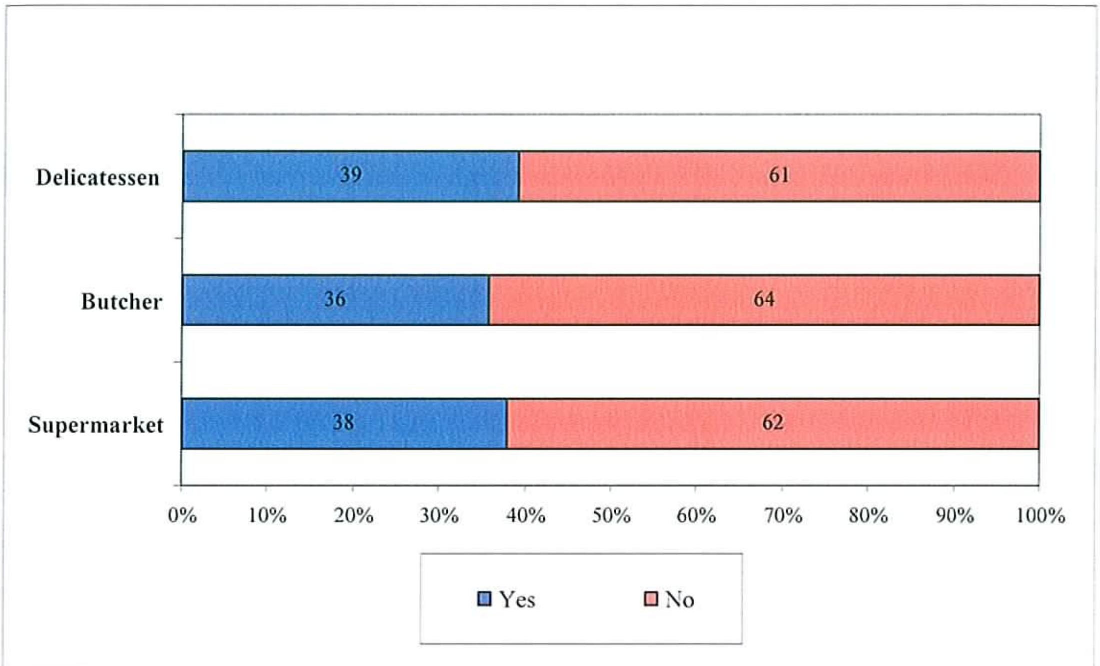


Figure (3.42): Managers satisfaction with government support for employee food safety training

When asked whether they felt there was adequate support from the government for training over 60% of respondents in all three outlet types felt there was unsatisfactory government funding for training. The lack of government financial support was felt to be the most significant obstacle to improving training levels and standards as shown in Table (3.8).

Table (3.8): Current barriers to training

Barriers to Training	Percentage
High cost of training	54
Lack of staff cover	38
Distance from training venue	2
Lack of suitable course	6

All businesses mentioned the same barriers to staff training, mainly the expense involved including the cost of the course, as well as finding and paying staff to cover the absent employee. In some outlets (6%) it was felt there was a lack of appropriate courses available or in the case of two outlets distance from the training centre was a problem.

One way of overcoming the costs of training, and by doing so improve managerial commitment to training, is to follow a managerial certification approach (Mortlock *et al.,* 2000). Managers would be able to provide the more basic levels of food safety training to employees, on the spot if necessary, if they themselves were trained to an advanced level. Evidence suggests that it is management who hold the key to the delivery of food hygiene training as well as the implementation of the food hygiene practices recommended by such training (West, 1992).

Managers need training to help them understand the principles of HACCP and to ensure that the food safety management system is implemented effectively, as was discussed previously (Table 3.4) where the managers level of understanding of HACCP was significant in relation to the efficacy of temperature control. Unless managers can fully appreciate the inherent risks involved in their food-handling practices, they are unlikely to recognise either the need to train or the contribution that training can make to the food industry (Mortlock *et al.,* 2000).

Managers in food outlets require a background knowledge and awareness of food hygiene in general, as this is integral to effective implementation of a food safety management system. As shown previously in Table (3.5), 49% of managers interviewed in this survey were unaware of any pathogens of relevance to food safety. Although pathogen knowledge was not found to be significant in terms of temperature control in this survey, it would be expected that pathogen knowledge influences other aspects of food safety management such as sanitation.

In view of the fact that the majority of respondents were satisfied with the standard of training given as shown in Figure (3.43), the effect of the type of training given on the standard of temperature control was investigated. The type of training given was divided into two categories as shown in Table (3.9) since based on replies from managers in the outlets surveyed, similar topics were covered in all training procedures.

Table (3.9): Effect of type of training on temperature control

Type of training given		**Chill Temperature**	
		-1 to 5°C	**>5°C**
Formal instruction	Number of outlets	48	27
On the spot instruction	Number of outlets	5	5

There was no significant difference between the type of training given and the standard of temperature control ($p>0.05$), therefore there is insignificant evidence from this survey to say that the type of training influences control of temperature in the chill cabinets.

This finding is contradictory to previous UK studies which highlighted significant relationships between training and levels of knowledge and the degree of risk to food safety (Tebbutt 1992, Kitchner 1994, West and Hancock 1994). The importance of training food handlers has been acknowledged as critical to effective food hygiene however, there have been limited studies on the effectiveness of such training (Egan *et al.,* 2006).

Results from this survey correlate with more recent research, where studies have found little evidence that food hygiene training has any impact on hygiene standards in general (Mathias *et al,* 1994, Riben *et al.,*1994, Powell, 1997, Seaman and Eves, 2006, Ackiel *et al.,*2007). These studies used a similar methodology as this survey involving a questionnaire to evaluate level of employee knowledge and behaviour as well as observations, Ackiel *et al.,* also analysed the bacteria density on the left hand as a quantitative indicator of the subjects' self-reported behaviours on food and personal hygiene, however using this method extensively will not be practical both from the application and financial points of view (Ackiel *et al.*, 2007).

The retail outlet managers were asked for their opinion on the effectiveness of the food safety management system in operation in their outlets. The majority of retailers were satisfied with their food safety management system as shown in Figure (3.43).

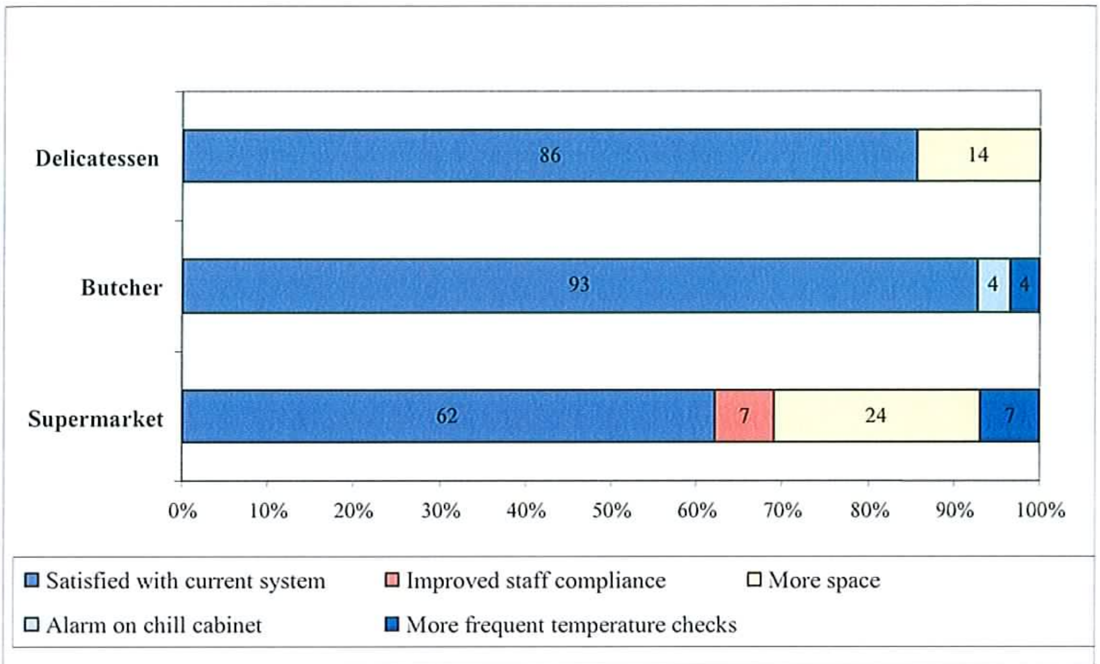


Figure (3.43): Opinions of managers in outlets surveyed on current food safety management system

As shown in fig. (3.43), most respondents (80%) expressed satisfaction with their current system. In the case of butchers, an overwhelming 93% of outlets were happy with their food safety management system. However, 4% said they felt if there was an alarm on their chill cabinets it would improve their food temperature control, however, an alarm might have a negative effect if it resulted in reduction of visual monitoring or was faulty. In the case of 4% of outlets, it was suggested that increased frequency of temperature checks would be of benefit.

In the case of deli outlets 86% of outlets considered their food safety management system satisfactory, but 14% felt lack of space affected the efficacy of temperature control. Space constraints meant that often the deli salad bar was directly beside the hot food counter. Lack of floor space was also an issue for 24% of supermarket surveyed as well as staff compliance with procedures detailed in the HACCP system. Managers in supermarkets mentioned that despite correct food handling procedures being explained to employees there was still problems with adherence to these procedures. Respondents in 7% of supermarkets also expressed the view that more than two temperature checks a day would increase the efficacy of the store food safety management system.

3.4 ANALYSIS OF OBSERVATIONS

Whilst in the store, various observations were recorded in the 85 outlets surveyed, including make and model of the chill cabinets and freezers in use. The most common makes of chill and freezer cabinets were Arneg, Costan, Criosbanc, Euro'cryor, ISA and Linde. Nuttalls were the manufacturers of the salad bars, with different models encountered. AHT Nucab supplied the freezer cabinets for HB icecream. The designs of chill cabinets were similar in all makes, the most common designs were open display-multi-deck, serve-over, ice fish counters, workstation and circular salad bars. In the case of freezers, well and wall, island (open top cabinets) and vertical multi-deck with glass doors were the common models.

The digital display reading of the cabinets was incorrect in 75% of outlets visited with regard to freezer temperature. It was incorrect in 35% of outlets with regard to chill cabinets. Previous studies (Jevšnik *et al.*,2006, Gormley, 1989b) have shown a large distribution of temperatures in different locations within refrigeration equipment. Generally the temperature sensor should show the "worst case" scenario, which was not found in most of the surveyed installations. Jevšnik *et al.*

(2006), also found that the supervision system of cool air temperature in cooling units is not always reliable because of temperature oscillation on cabinet digital displays.

Stacking arrangements of products in outlets were not observed to interfere with cabinet design. Stocking levels were always seen to be adequate to prevent disruption of air flow through the cabinets, and products were not placed too close to lights on the cabinets which might have caused partial warming of the product. Most of the cabinets appeared visually clean, however some of the dairy walls had old milk residues on their surfaces.

In the larger outlets, cabinet positioning was usually appropriate, however in the smaller outlets with space constraints frequently the chill cabinet was directly beside the hot food counter. Since the ends of the cabinet are where air flow is usually lowest, it implies that heat transfer through the side walls is greatest so positioning beside hot food counters will adversely affect temperature control of chilled foods. Previous research has shown that medium and large stores had better conditions for cooling and refrigerating foodstuffs compared to small stores where units were on average smaller and mostly overfilled which thereby inhibited movement of air around them (Jevšnik *et al.*, 2006).

Staff, when handling unwrapped food, did not wash hands or change gloves between serving customers. Staff in all delicatessens would serve many customers with the same pair of gloves on, thus handling many different food types and facilitating cross contamination. In two outlets visited, the staff making the sandwiches were also handling the money and then returning to make more sandwiches without washing hands, this practice was also observed in butcher outlets surveyed in the UK (Worsfold, 2001).

Cross contamination is a major concern in outlets where both raw and cooked food are being sold. Cross contamination has been identified as an important contributory factor in 39% of food poisoning outbreaks (Evans *et al.*, 1998).

In the case of butcher outlets surveyed, in over 50% of premises the butcher did not wash his hands after serving each customer and in three outlets it was noticed that the soap dispenser was empty. It was also noticed that a lot of butchers would wipe their hands on their aprons instead of washing them after serving each customer, thus leading to a build up of meat and residue on their aprons. The butchers cutting block, usually wooden, was not cleaned very frequently and was usually cleaned using a spray gun which would suggest the possibility of aerosol contamination of the meat on display. Research done in the UK in 91 butcher outlets also found that 75% of butchers surveyed infrequently cleaned hand contact surfaces (Worsfold, 2001), and similarly this research in the UK found that 42% of outlets were not aware of the importance of sanitizing hand contact surfaces or the potential for cross contamination due to inadequate cleaning protocols.

Research on food safety behaviour in 91 butchers' shops in the UK observed unsatisfactory cleaning procedures, the main defects being inadequate cleaning frequency, incorrect use of wiping cloths and neglect of hand contact surfaces (Worsfold, 2001). From observations made during this Irish research, similar unsatisfactory practices are carried on in this country, in the three outlet types surveyed.

3.5 ANALYSIS OF FOOD SAFETY MANAGEMENT SYSTEM

All food business operators are now bound to have a food safety management system compliant with HACCP principles. According to the Food Safety Authority of Ireland for the purposes of assessment, HACCP compliance in line with regulation 4.2 of S.I. No. 165 of 2000 may be broadly divided into three sections (FSAI, 2004b). Compliance can be achieved by identifying points critical to food safety, identifying and implementing safety procedures and finally reviewing these procedures.

All premises surveyed claimed to have carried out a hazard analysis and were satisfied that they had effective controls in place at each critical control point (CCP). All premises were using a digital probe for temperature checks of cabinet air temperature and food core temperature. These checks were being carried out twice daily in all cases.

In Guidance note 11 published by the FSAI, to be classified as HACCP compliant, a business has to review the procedures in place, and reviewing includes both verification and validation (FSAI, 2004b). Verification and validation are generally considered to be the elements of HACCP implementation that is least understood. Verification is defined as looking for evidence that the HACCP system has been implemented as it was planned and refers to management checking at regular intervals that necessary protocol is being followed by employees, for example twice daily temperature checks.

Verification has been shown to be the element of HACCP with the smallest level of compliance as shown in research done by the FSAI in 2006. Previous research shows that although there was a significant improvement in compliance with regard to verification from the baseline assessment done in 2004, the level of compliance in 2005 amongst butchers was still only 36.4%.

Results from this research suggested that 68% of butcher premises surveyed were verifying their food safety management system. Results also showed that 78% of delicatessens and 97% of supermarkets were carrying out verification procedures. So results from this research suggest that there has been a further significant improvement in compliance with regard to verification of food safety management systems in operation in the type of retail outlets surveyed.

Validation involves checking by the management (respondents), that the system as designed, will be effective in ensuring the safety of food. As part of this research respondents were questioned on the frequency of review or validation of their HACCP system, and Table (3.10) details the frequency in the outlets surveyed.

Table (3.10): Validation of HACCP system in surveyed premises

	Monthly	Every 3 months	Every 6 months	Annually	Never
Frequency of review of HACCP system	1%	20%	38%	22%	19%

As shown in Table (3.10), 19% of outlets never reviewed their food safety management system, 22% reviewed it annually, 38% reviewed it twice a year, 20% validated the system every 3 months and one outlet claimed to review HACCP protocol once a month. Previous surveys done by FSAI have not included validation as a necessary element of HACCP compliance and have checked solely for verification. However since as part of this research dataloggers were used to monitor temperature control throughout a 7½ hour period it is also possible to validate the food safety management systems in operation in the premises visited and to include this aspect of HACCP in the final assessment of HACCP compliance.

The correct temperature range for chilled products is from -1 to 5°C, however, the results from the dataloggers used in this survey showed that in 37% of premises mean external air temperatures in chill cabinets exceeded 5°C. Figure (3.44) shows the temperature variation of the chill cabinets amongst the premises visited.

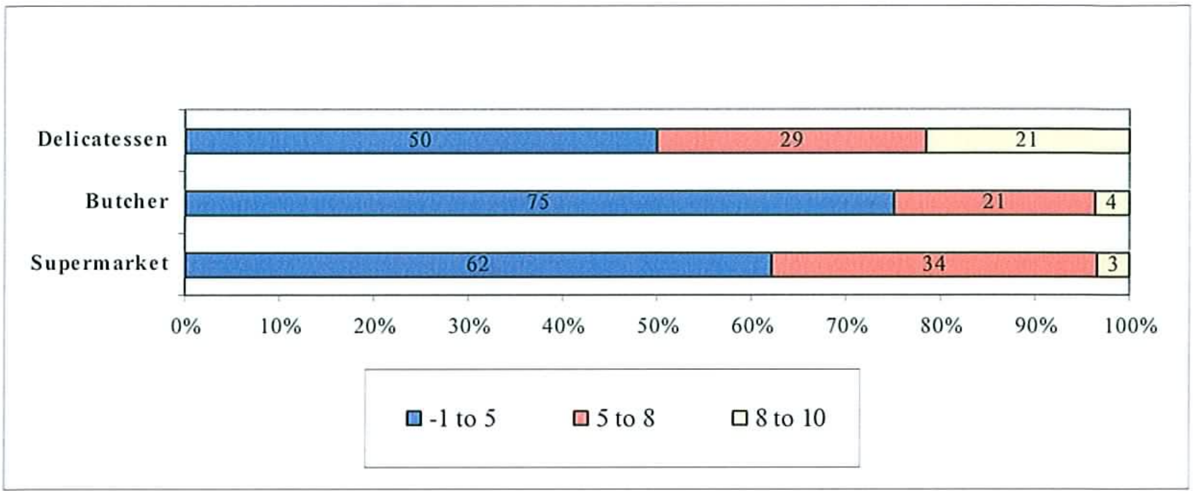


Figure (3.44): Chill temperature control in premises surveyed

Results shown in figure (3.44) indicate that 25% of butchers, 37% of supermarkets and 50% of deli outlets had temperatures in their chill cabinets that exceeded the normal acceptable range of -1 to 5°C for a minimum of 2 hours. Butchers were shown to have the highest number of outlets with external air temperature and product core temperature in the correct temperature range, and delicatessens exhibited the poorest temperature control.

However, the analysis of results using Pearson Chi-Square test at 5% Confidence Interval showed that the type of outlet was not significant in terms of chill temperature control. Similarly, the number of employees in the business did not significantly influence the standard of temperature control in the chill cabinets ($p>0.05$). These findings indicate that the smaller outlets with small staff numbers are just as effective as the larger outlets at controlling temperature of chilled products and managing a food safety system. A possible reason for this would be that the employees in smaller outlets may be long term employees which would commonly be the case in butcher outlets. As a result of this they are potentially more motivated and possibly more aware of the implications of deficiencies in a food safety management system on their business.

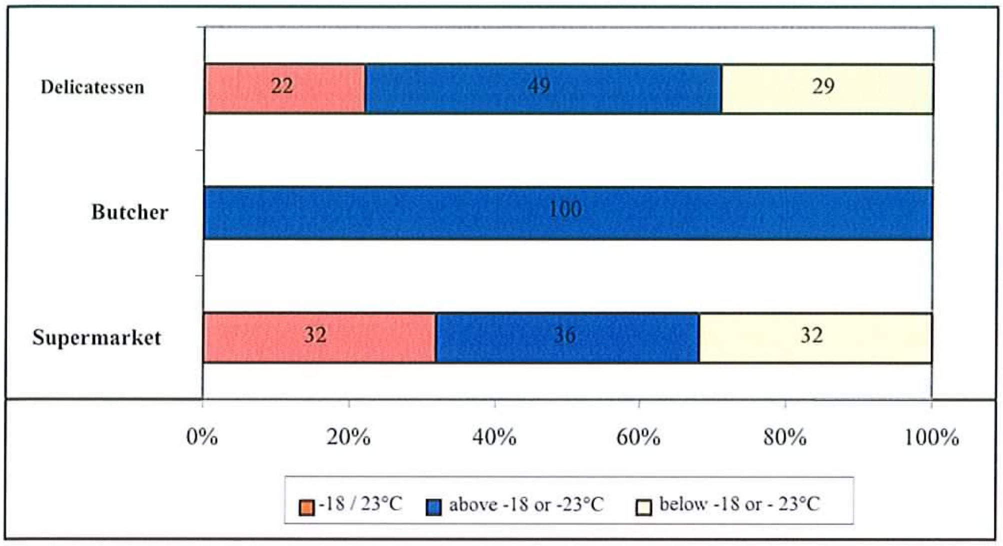


Figure (3.45): Temperature control of freezer cabinet in outlets surveyed

As previously mentioned the temperature at which frozen food is held is generally a quality issue rather than one of safety. Figure (3.45) above shows the temperature control recorded in the outlets surveyed. Only four of the butcher outlets visited had freezer cabinets and in all cases the temperature readings throughout the day were higher than the recommended guidelines. In the case of delicatessens, 5 of the 28 outlets visited did not have freezers. The results for the remaining 23 deli outlets show that only 22% of these outlets were storing frozen foods correctly. In 49% of deli outlets the freezer temperature was too high, in 29% of premises the freezers were maintaining products unnecessarily low.

With regard to freezer temperature in the supermarket outlets visited, the temperature was monitored in 24 of the premises visited. On a comparative basis with the other outlet types, the supermarkets exhibited the best compliance with the guidelines for freezer temperature with nearly a third (32%) of outlets with freezer temperatures of -18°C for food products and -23°C for ice-cream. However, over a third (36%) of outlets recorded temperatures above -18 and -23°C, and similarly 32% of premises monitored had freezers with excessively low temperatures below -20°C and -25°C for frozen foods and ice-cream respectively.

At an international level it is well recognised that HACCP is an enormously useful tool to ensure the safety of food. HACCP is an integral part of every food safety management system. To evaluate the food safety management system in the premises surveyed an assessment of HACCP compliance was done. Using the recorded results of the cabinet temperature monitoring it was possible to assess compliance for the 3 elements of HACCP as shown in Figure (3.46).

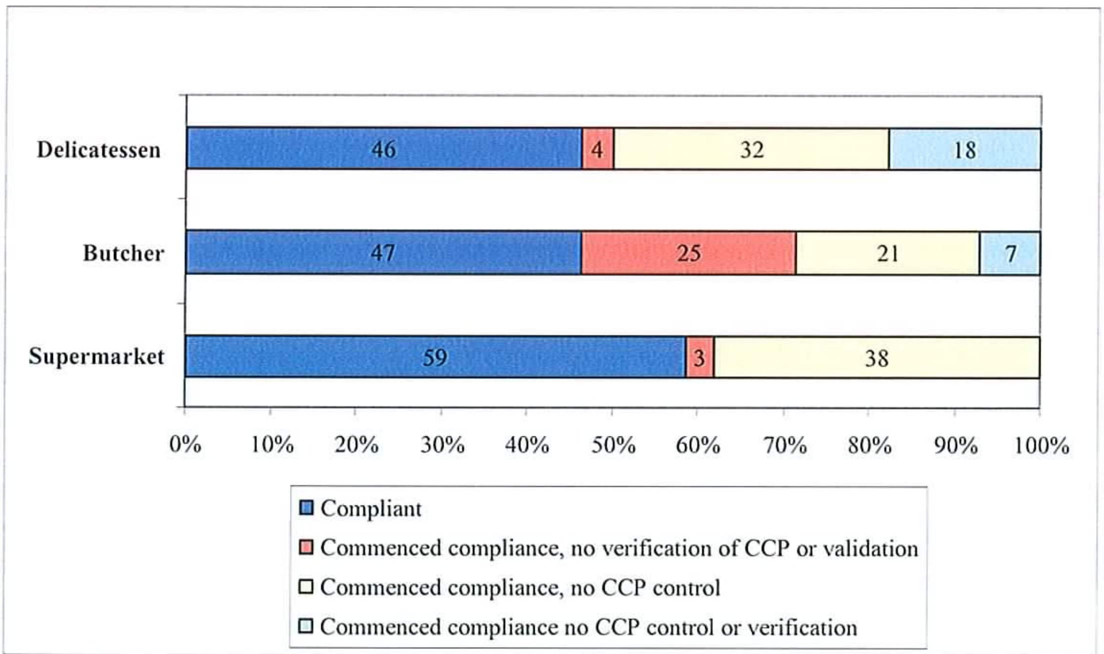


Figure (3.46): Assessment of HACCP compliance in surveyed premises

The results of the survey showed that there was compliance for the three elements of HACCP in 51% of outlets surveyed. When the level of compliance is examined in terms of outlet type, the results in Figure (3.46) show that HACCP compliance is greatest in supermarket outlets (59%), with butcher and delicatessen outlets showing compliance levels of 47% and 46% respectively in the outlets visited. Previous research showed that 36% of butcher outlets surveyed were HACCP compliant (FSAI, 2006a), however this research did not include validation of the food safety management system.

The study done by the FSAI checked for verification of the HACCP system through management checks on employee protocol. Due to use of temperature monitoring as part of this current research, it was possible to validate the critical control point of temperature control. Since the readings were recorded every 5 minutes it was possible to get a much more accurate representation of what was happening to temperatures in the cabinets instead of relying on twice daily temperature checks.

It should be mentioned that in 79% of the outlets, mainly supermarkets and delicatessens there was continuous computerised monitoring of the temperature. However there were discrepancies between the readings recorded by the dataloggers used in this research and what the computerised readings were showing. The temperature in these cabinets was set to the correct range and an alarm was automatically detonated if temperatures exceeded these limits. However, this was not happening in all cases as the dataloggers showed a breach in temperature control on 12% of the outlets that had continuous monitoring and yet the retailers were unaware of this problem. One Quality Control manager did remark that she frequently noticed a difference in what the computerised readout was showing and what temperature her calibrated digital probe was reading.

Temperature control as opposed to verification appears to be the element of HACCP with least compliance. Lack of temperature control was demonstrated in 38% of supermarkets, 32% of delicatessens and 21% of butchers and all of these premises claimed they were carrying out verification procedures. Therefore, despite claims to the contrary, temperature control was found to be satisfactory in 63% of outlets, and not 100% of premises as would be expected based on respondents replies in the survey.

3.6 MICROBIAL ANALYSIS OF CHILLED FOODS IN 10 OUTLETS

Microbial sampling was carried out on chilled foods focusing on *Staphyloccocus aureus* and *Listeria monocytogenes*. *S. aureus* was used in the microbiological evaluation of foodstuffs as an indicator of poor hygiene and poor food handling practices. *Listeria monocytogenes* was chosen for analysis due to the high morbidity and mortality associated with listeriosis infection and its ability to survive at refrigeration temperatures.

Microbial counts of *S. aureus* and *L. monocytogenes* were carried out on cooked chicken pieces, coleslaw and cream cakes (cream doughnuts) at the outlets surveyed according to the sampling plan in Table (3.11). The foodstuffs examined would be considered 'high risk' chilled foods as they are not subjected to further heat treatment prior to consumption by the consumer.

Table (3.11): Microbial analysis sampling plan carried out at each retail outlet on three food types

Outlet type	No. of outlets	Total no. of samples per day (n=3 for each outlet)	Times of sampling
Sandwich bar	5	15	9am, 1pm, 4pm
Delicatessen	3	9	9am, 1pm, 4pm
Supermarket	2	6	9am, 1pm, 4pm

The three retail outlet types selected for the sampling plan were sandwich bars, delicatessens and supermarkets. Sandwich bars have dramatically increased in number in the past few years and sell mainly 'high risk' ready-to-eat foods. The outlets are usually small in size with a high staff turnover rate, these factors and given the nature of the work suggest that there is potential for food safety issues.

Delicatessens, unlike supermarkets tend to be smaller premises with staffing of a more transient nature. Staff in all outlets surveyed are obliged to adhere to food safety management protocol, and microbial analysis of these popular foodstuffs allowed further examination of the food safety management systems in operation in the different outlets. Sampling was carried out in 10 premises as these were located in close proximity to the analytical laboratory, enabling prompt transport of samples to the laboratory for analysis.

3.6.1 *Staphylococcus aureus*

3.6.1.1 *Cooked chicken pieces*

Results of microbial analysis on cooked chicken pieces at each outlet are shown in fig. (3.47), which shows the level of *Staphyloccocus aureus* in a sample of cooked chicken pieces taken at three different times throughout a commercial day.

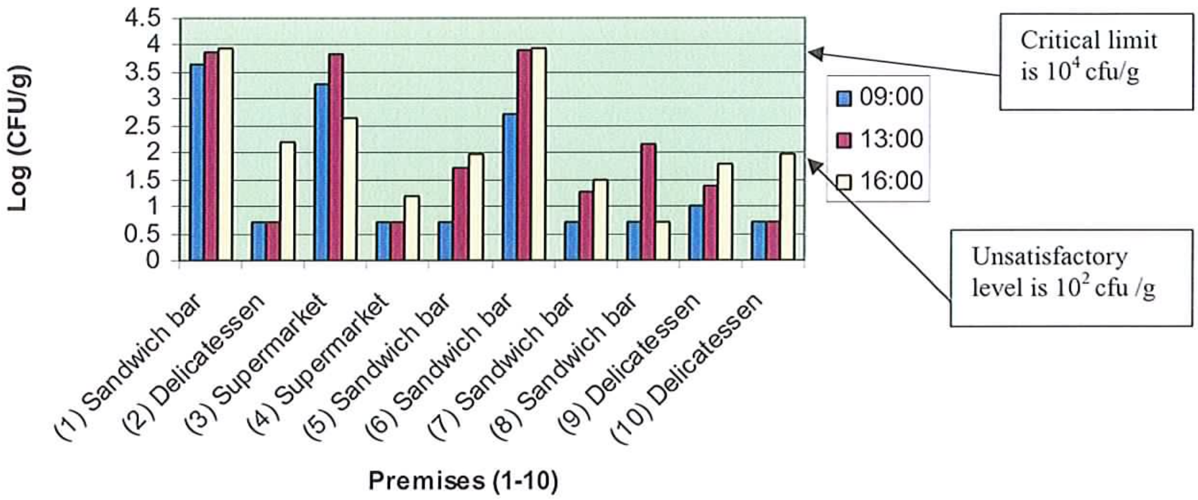


Figure (3.47): Microbial analysis of *S. aureus* growth in refrigerated cooked chicken pieces sampled in 10 outlets

As seen in figure (3.47), none of the levels of this pathogen exceeded the critical limit at the time sampled in any of the premises surveyed. However, in 3 outlets levels were unsatisfactory according to FSAI guidelines (FSAI 2001d), and in one outlet levels were unsatisfactory in the sample taken at 1pm based on the Irish standards. If the level is already unsatisfactory at this point this is significant as there is still potential for temperature abuse by the consumer, which could result in food poisoning.

In premises (1), a sandwich bar, the initial level of *S. aureus* in samples of cooked chicken pieces taken was unsatisfactory at 9am. An unsatisfactory level at this time of day suggests improper storage and or handling occurred previously Sampling of cooked chicken pieces at 1pm and 4pm also found unsatisfactory levels of *S. aureus,* with levels increasing as the day progressed but remaining below the hazardous level.

In premises (2), a deli outlet, the levels of *S. aureus* found in the cooked chicken pieces at the 9am and 1pm sampling period remained at the satisfactory level, however there were unsatisfactory levels of *S. aureus* in samples taken at 4pm. This could be attributed to cross contamination by food handlers and lack of food handling hygiene.

In premises (3), a supermarket, levels of *S. aureus* in samples of cooked chicken pieces at 9am and 1pm were unsatisfactory; the level at 4pm was also unsatisfactory but was at a lower level than 9am or 1pm. This could be explained by the fact that a new batch of chicken pieces may have been sampled at 4pm as the previous batch was used up during the busy lunch time period. All samples taken in premises (4), a supermarket, showed satisfactory levels of *S. aureus,* with an increase in levels at 4pm.

In premises (5), a sandwich bar, the initial level of *S. aureus* was satisfactory, levels increased at both later sampling periods but remained at acceptable levels. Premises (6), a sandwich bar, had unsatisfactory levels of *S. aureus* at 9am, and levels continued to increase during the day, with levels at 4pm being just below the unacceptable level. The level of *S. aureus* in cooked chicken pieces in premises (7), a sandwich bar was initially satisfactory, but increased at both 1pm and 4pm to acceptable levels.

In premises (8), a sandwich bar, the level of *S. aureus* in a sample of cooked chicken pieces taken at 9am was satisfactory, at 1pm *S. aureus* was found at unsatisfactory levels, possibly due to cross contamination from a food handler. However, at 4pm the levels of *S. aureus* in the cooked chicken pieces had dropped to satisfactory levels, the same level as found at 9am. This drop in levels of *S. aureus* is most likely due to a new batch of cooked chicken pieces being sampled as explained in relation to premises (3).

In premises (9), a deli outlet, the numbers of *S. aureus* in the sample of cooked chicken pieces started at a satisfactory level, however by 1pm numbers had increased to an acceptable level. There was a continued increase in numbers of *S. aureus* found in the sample of cooked chicken pieces taken at 4pm, however levels remained at an acceptable level. Finally, premises (10), also a deli-outlet, initial levels of *S. aureus* in the cooked chicken pieces sampled were at a satisfactory level both at 9am and 1pm. However, levels of the pathogen in the sample of cooked chicken pieces taken at 4pm showed an increase in numbers of *S. aureus* present to a satisfactory level.

S. aureus is an ubiquitous pathogen found in animals. It occurs naturally in a variety of foods including raw meat, but does not compete well with indigenous microbes. In addition, food handlers are commonly implicated in the transmission of this pathogen to food (Aycicek *et al.*,2005). Staphylococcal food poisoning is caused by ingestion of a toxin formed by *S. aureus* in the food. *S. aureus* produces 7 protein exotoxins, of which types A to D are most frequently implicated in food poisoning. Levels of *S. aureus* must grow to $>10^6$ cells/g before producing sufficient quantities of the heat-stable staphylococcal toxin to cause illness, and toxin will only be produced at temperatures above 4°C, so contamination is necessary but is not alone sufficient for an outbreak to occur (Adams and Moss, 2000).

The critical limit cited in the literature is 10^4 cfu/g, levels above this are considered unacceptable or potentially hazardous (FSAI, 2001d). The results of the analysis of microbiological quality of the samples of coleslaw based on sample source are shown in Table (3.12).

Table (3.12): Microbiological quality of samples of cooked chicken pieces based on sample source according to FSAI guidelines (FSAI, 2001d)

Type of premises	No. of samples tested	No. (%) of samples with the following microbial quality		
		Satisfactory < 20 cfu/g (%)	Acceptable 20-$<$ 100 cfu/g (%)	Unsatisfactory 100-$<10^4$ cfu/g (%)
Sandwich bar	15	5 (33%)	4 (27%)	6 (40%)
Delicatessen	9	5 (56%)	4 (44%)	0
Supermarket	6	3 (50%)	0	3 (50%)

The results showed that 40% of samples from sandwich bars and 50% of samples from supermarkets were unsatisfactory in relation to levels of *S. aureus*. In the case of deli outlets, all samples were within the satisfactory (56%) or acceptable (44%) range. A previous study by the FSAI involving 432 samples found 2.6% (n=11) of samples of refrigerated chicken pieces to be unsatisfactory and 0.2% (n=1) to be potentially hazardous (FSAI, 2002b). This research found that overall 30% (n=9) of samples had unsatisfactory *S. aureus* levels. Using ANOVA testing it was found that the pathogen population in the product increased with time ($p<0.05$).

The continued increase in levels of *S. aureus* found in the samples of cooked chicken pieces as the day progressed is to be expected if staff handling this product are not adhering to proper hygiene practices, and thereby increasing the possibility of cross contamination. Storage temperature and display temperature also play an important role in inhibiting microbial growth. Time and temperature conditions must also be suitable for growth of the organism. *S. aureus* is a typical mesophile with a growth temperature range between 7 and 48°C, toxin is produced between 10 and 43°C. The range over which enterotoxin is produced is narrower by a few degrees and has an optimum at 35-40°C under otherwise optimal conditions of pH, NaCl, water activity and atmosphere (Adams and Moss, 2000).

Both temperature control and food handler hygiene are vital components of a food safety management system in the retail outlet. It is also the responsibility of the retailer to ensure that the foodstuff is arriving at the outlet with minimal pathogen contamination, so a reliable supplier is vital to maintain food safety standards along the food chain.

3.6.1.2 Coleslaw

Raw salad vegetables have been implicated as vehicles of infection in many outbreaks of foodborne illness (Sivapalasingham *et al.,* 2004, Long *et al.*, 2002). Contaminated raw salad vegetables are of particular concern as these products have a high nutrient and moisture content and if temperature abused can readily support microbial growth. Results of microbial analysis on coleslaw sampled at 10 outlets at three different times throughout one commercial day are shown in Figure (3.48).

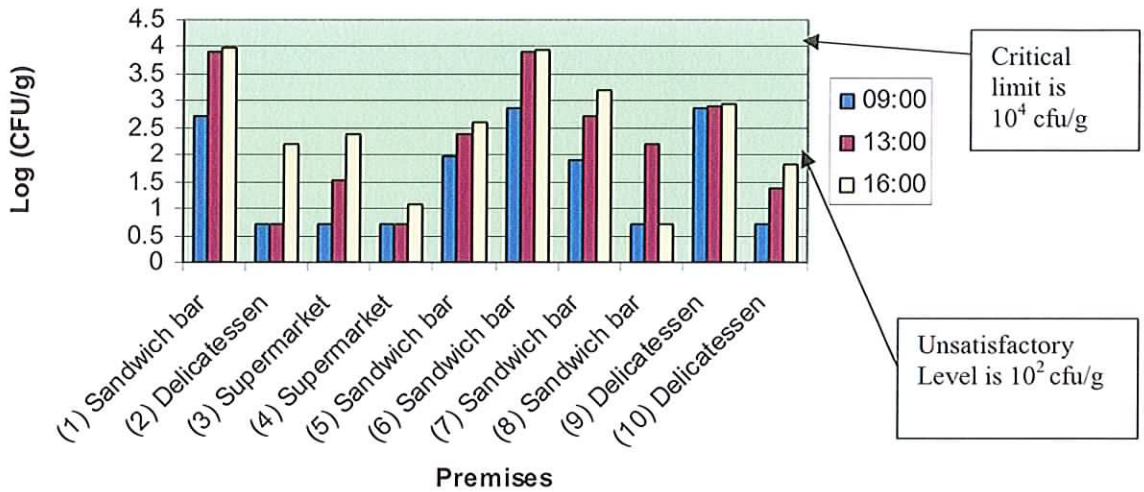


Figure (3.48): Microbial analysis of *S. aureus* growth in coleslaw sampled from 10 premises

Figure (3.48) shows the level of *Staphylococcus aureus* found in coleslaw samples taken from the 10 outlets surveyed. None of the levels of this pathogen exceeded the critical limit at the time sampled in any of the premises surveyed, despite the 4 pm sample being close to log 4 cfu/g in premises (1) and (6), in both salad bars. However 8 outlets had unsatisfactory levels at one or more sampling periods.

In premises (1), a sandwich bar, the initial level of *S. aureus* was unsatisfactory in the sample taken at 9am. This sample was taken from a batch that had been on display in the outlet the previous day and then stored overnight in a cold store. Since the levels of *S. aureus* are unsatisfactory, this suggests that the coleslaw had been previously contaminated and subjected to temperature abuse and or improper handling practices. The level of *S. aureus* continued to increase in the subsequent samples taken at 1pm and 4pm, with both results being just below the critical limit of log 4 (cfu/g).

In premises (2), a delicatessen, *S. aureus* levels in coleslaw taken at 9am and 1pm were satisfactory, however results showed unsatisfactory levels at 4pm. The 4pm sample was taken after the busy lunchtime period where the product was subjected to a lot of handling by foodservice personnel who were not wearing gloves, and the serving spoon was frequently left on the cutting board used for making the sandwiches instead of being replaced back into the coleslaw bowl in the chill cabinet display unit. It was also noticed that the hot food counter was directly adjacent to the serve-over cabinet displaying the ready-to-eat chilled foods. It is possible that this cabinet positioning would have an adverse effect on temperature control in both cabinets, however it was not possible to record any temperatures in either cabinet due to lack of manager permission. In premises (3), a supermarket outlet, the 9am sample of coleslaw was satisfactory, however similar to outlet (2), the levels of *S. aureus* increased as the day progressed. In this case, the 1pm sample was acceptable and the 4pm sample was unsatisfactory.

Premises (4) was also a supermarket outlet, this outlet showed satisfactory levels of *S. aureus* at all times of sampling, with a slight increase in levels of the pathogen in the 4pm sample of coleslaw taken. This outlet was visually very bright and clean, and staff were observed to follow appropriate hygiene protocol when handling ready-to-eat chilled foods. In premises (5), the 9am sample of coleslaw showed acceptable levels of *S. aureus*, as the day progressed the level of *S. aureus* at both 1 and 4pm, was unsatisfactory, indicating a steady growth of microbial numbers.

Premises (6), a sandwich bar showed similar results to outlet (1), since the initial sample showed unsatisfactory levels of *S. aureus* and pathogen levels continued to increase at 1 and 4 pm, to levels just below those considered hazardous to consumer. Staff in this outlet changed before lunchtime, and the staff working during the busiest period of the day were not observed adhering to hygiene protocol.

In premises (7), another sandwich bar, the 9am coleslaw sample had acceptable levels of *S. aureus* present in the sample. The 1 and 4pm samples both had unsatisfactory levels of *S. aureus*, which increased as the day progressed. Premises (8), also a sandwich bar had initial levels of *S. aureus* in the acceptable satisfactory range at 9am, which rose to unsatisfactory according to results of analysis of coleslaw sample taken at 1pm. However, the sample taken at 4pm showed a significant drop in the level of *S. aureus* to satisfactory levels. On enquiry it was explained by food handling staff that the coleslaw had all been used up over the lunchtime period, and the sample taken at 4pm was from a fresh batch of coleslaw recently taken from the cold store in the outlet. Therefore, if correctly stored and handled prior to being put in the chilled display cabinet it would be expected to have lower levels than sample taken at 1pm.

In outlet (9), a delicatessen outlet, initial levels of *S. aureus* in the sample of coleslaw taken at 9am were unsatisfactory, as were subsequent samples taken at 1 and 4pm. The increase in *S. aureus* levels as the day progressed was slight, and it was noticed that the digital display on the front of the chill cabinet displaying the coleslaw was never above 1°C at times of sampling. This suggests that the initial level of contamination was due to prior contamination at a previous stage in the supply chain.

In outlet (10), a delicatessen outlet, the *S. aureus* level at 9am was satisfactory but levels continued to increase as time progressed to show acceptable levels at both 1 and 4pm. Poor food handling hygiene is a possible contributory factor to the unsatisfactory levels of *S. aureus* found in some of the coleslaw samples taken from the various outlets, particularly given the inappropriate handling practices observed such as lack of hand-washing.

As previously stated, the unsatisfactory levels of *S. aureus* are indicative of insufficient hygiene and inappropriate food handling practices. Ready-to-eat salads such as coleslaw have been shown to be significantly more likely ($p<0.05$) to contain *S. aureus* at higher levels than foods which require less food matrix handling (Aycicek *et al.*, 2005). The results of the analysis of microbiological quality of the samples of coleslaw based on sample source is shown in Table (3.13).

Table (3.13): Microbiological quality of samples of coleslaw based on sample source according to FSAI guidelines (FSAI 2001d)

Type of premises	No. of samples tested	No. (%) of samples with the following microbial quality		
		Satisfactory < 20 cfu/g (%)	Acceptable 20-< 100 cfu/g (%)	Unsatisfactory 100-<10^4 cfu/g (%)
Sandwich bar	15	4 (27%)	0	11 (73%)
Delicatessen	9	3 (33%)	2 (22%)	4(45%)
Supermarket	6	3 (50%)	2 (33%)	1 (17%)

The results in Table (3.13) show that all of the three outlets surveyed had coleslaw samples with unsatisfactory levels of *S. aureus*. In the case of sandwich bars, 73% of samples were unsatisfactory, with 13% of these samples having levels very close to 10^4cfu/g. The remaining 27% of coleslaw samples taken from sandwich bars were all satisfactory. In the case of delicatessens, 45% of coleslaw samples were unsatisfactory, with 22% being acceptable and 33% being satisfactory. In this survey the supermarket outlets had the lowest number of coleslaw samples (17%) that had unsatisfactory levels of *S. aureus*. Results showed that 33% of coleslaw samples taken from the supermarket outlets in this survey were acceptable, and 50% of samples were satisfactory.

The levels of *S. aureus* detected in the coleslaw samples taken from the 10 outlets raise concern as the results show that coleslaw may contain pathogenic bacteria and thereby present a risk to the consumers in regard to food borne disease. The microbial safety of salads has been previously cited in the literature as a concern due to extensive handling during preparation by foodservice personnel and potential abusive temperatures during storage (Bornemeier, *et al.*, 1997).

This survey on 10 outlets in the Dublin area found that overall 30% of outlets had satisfactory levels of *S. aureus*, with 13% having acceptable and 57% having unsatisfactory levels of this pathogen which is a cause for concern in terms of food borne disease. It was found using ANOVA analysis that time was a significant factor in the growth and increase in pathogen numbers ($p<0.05$).

3.6.1.3 Cream cake

Cakes with perishable fillings and toppings were analysed for S*taphylococcus aureus*. The fillings of cream cakes provide suitable conditions for multiplication of *S. aureus* to dangerous levels. Both the food handler and the non-food handler (whose duties and responsibilities can impinge on food safety) have a significant role to play in ensuring microbiologically safe products reach the consumer. The type of cream cake chosen for analysis for S*taphylococcus aureus* was a cream doughnut as this was on sale in all outlets surveyed. Figure (3.49) shows the results of this analysis of *S. aureus* levels in doughnuts sampled in the 10 outlets surveyed.

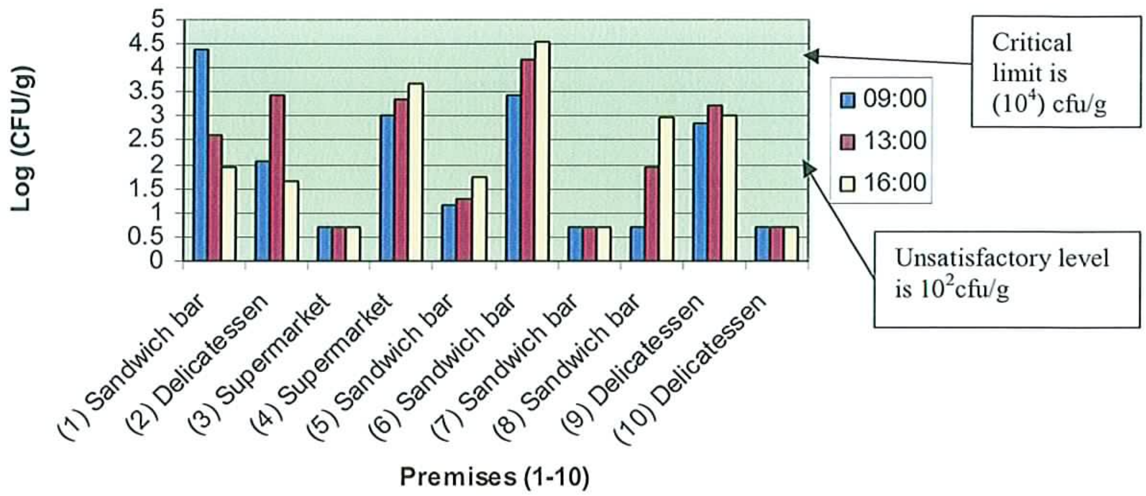


Figure (3.49): ***S. aureus*** **growth in cream cake sampled from 10 premises**

Figure (3.49) shows the level of *S. aureus* found in the cream cakes sampled at the 10 outlets surveyed. At each time of sampling an entire cream doughnut was purchased. The results show that in 2 outlets, premises (1) and (6), the *S. aureus* count in 3 of the cream doughnuts sampled indicated that the foodstuff was potentially hazardous.

In both outlets (1) and (6), poor hygiene and poor food handling practices were observed. The staff in both outlets were not wearing gloves and were never seen to wash their hands between customers. There was no hand washing facilities visible close to serving counter in premises (6) and there was no soap visible in premises (1). Also products were removed from the chill cabinets and left on counters for prolonged periods of time. Unsatisfactory levels of *S. aureus* were detected in cakes sampled from 6 premises, and there would be potential for levels to rise further if product was subjected to further temperature abuse from the purchaser prior to consumption.

In the case of premises (1), a sandwich bar, the cream doughnut sampled at 9am had hazardous levels of *S. aureus*. This cream doughnut had been in the outlet 48 hours so it possibly had been subjected to temperature abuse and inappropriate handling. The cream doughnut sampled at 1pm had unsatisfactory levels of *S. aureus,* the sample taken at 4pm had acceptable levels. Both of the later samples were delivered that morning and were fresher in comparison to the 9am sample. This would explain the lower levels of the pathogen. The chill cabinet displaying the cream doughnuts did not appear visually clean, and food handlers were not observed washing their hands between customers or when handling different foodstuffs.

In premises (2), a delicatessen outlet the cream doughnut sampled at 9am and the one sampled at 1pm both had unsatisfactory levels of *S. aureus,* whereas the level of *S. aureus* in the cream doughnut sampled at 4pm was within the acceptable limits. All these cream doughnuts were delivered to the delicatessen that morning so it is possible that contamination with *S. aureus* occurred prior to arrival at this premises, as this outlet appeared visually clean.

All 3 cream doughnuts sampled in premises (3), a supermarket outlet, had satisfactory levels of *S. aureus* at all times sampled. This supermarket outlet showed unsatisfactory levels of *S. aureus* in the chill cabinet displaying sliced and ready-to-eat meats including chicken pieces. The chill cabinet displaying the chilled cooked chicken pieces was over 10 years old, whereas the chill cabinet displaying the coleslaw was relatively new so the temperature of produce may not have been as effectively controlled in the older cabinet, resulting in higher levels of pathogen growth.

In premises (4), a supermarket, the 3 cream doughnuts sampled had unsatisfactory levels of *S. aureus,* which was in contrast to the levels found in both the cooked chicken pieces and the coleslaw samples taken from the same premises. This suggests that the cream doughnuts may have been contaminated prior to arrival at this premises as food handling practices observed followed a food safety management system based on the principles of HACCP.

The results of sampling cream doughnuts in premises (5), a sandwich bar shows that the level of *S. aureus* found in the samples increasing as the day progressed, but remaining within the acceptable level. This outlet also had acceptable levels of *S. aureus* in the chicken pieces sampled, however the coleslaw samples had unsatisfactory levels of *S. aureus*, possibly due to poor food handling practices of this product.

Premises (6), a sandwich bar was the second outlet that showed unacceptable or potentially hazardous levels of *S. aureus* in 2 cream doughnuts sampled at the outlet, the levels in the 9am morning sample were unsatisfactory. The staff in this outlet did not follow good hygiene practises, no gloves were worn and hands were not washed between customers or when handling different products. The chill cabinets were not visually clean, and one staff member appeared to have a respiratory infection. All these factors imply that appropriate hygiene standards were not being adhered to in this outlet, resulting in potentially hazardous level of *S. aureus* in some of the foodstuffs on sale to consumers.

The cream doughnuts sampled from premises (7), a sandwich bar, all showed satisfactory levels of *S. aureus*. The chill cabinet displaying patisserie appeared visually cleaner than the serve-over cabinet with the sandwich fillings which included the coleslaw and cooked chicken pieces samples. The samples taken from the serve over cabinet had higher levels of *S. aureus*, suggesting sanitation programme within the outlet was not effective or being implemented correctly.

In premises (8), a sandwich bar, the initial cream doughnut sampled had satisfactory levels of *S. aureus,* however levels increased to acceptable and unsatisfactory results for the subsequent samples taken. The levels of *S. aureus* in the cooked chicken pieces and coleslaw were initially satisfactory at 9am, however the level of *S. aureus* had risen to unsatisfactory levels at 1pm. The staff handling the foodstuffs appeared to be following appropriate hygiene procedures, but temperature control within the cabinets may not have been effective.

Premises (9), a delicatessen outlet, had unsatisfactory levels of *S. aureus* levels in all 3 cream doughnuts sampled which had arrived at the outlet that morning. The levels did not increase significantly during the day which suggests that the foodstuffs had arrived at the outlet already contaminated with *S. aureus*, and that temperature control within the chill cabinet was limiting growth levels of the pathogen.

In premises (10), a delicatessen outlet, all 3 samples taken of cream doughnuts were satisfactory, the chill cabinet appeared visually clean, and there was a sliding door at the back of the cabinet which ensured less interference with the air curtain from ambient air, thereby increasing the efficacy of temperature control within the cabinet.

The levels of *S. aureus* in premises (1) and (6), both sandwich bars, were consistently higher than the other premises in relation to the 3 foodstuffs sampled. In these outlets the food handlers did not follow appropriate hygiene procedures, such as frequent hand washing and no sink was observed near the sandwich making area. It was not possible to measure the chill cabinet temperatures in these outlets; however it was noticed that the digital display was reading 6°C in premises (1) and 7°C in premises (6). Non conformance to correct storage temperature (-1 to 5°C) could allow pathogen levels to reach potentially hazardous levels.

Table (3.14) shows the results of analysis of microbiological quality of the cream doughnuts based on sample source.

Table (3.14): Microbiological quality of cream doughnuts based on sample source

Type of premises	No. of samples tested	No. (%) of samples with the following microbial quality			
		Satisfactory < 20 cfu/g (%)	Acceptable 20- < 100 cfu/g (%)	Unsatisfactory 100-<10^4 cfu/g (%)	Unacceptable >10^4cfu/g (%)
Sandwich bar	15	6 (40%)	2 (13%)	4 (27%)	3 (20%)
Delicatessen	9	3 (33%)	1 (11%)	5 (56%)	0
Supermarket	6	3 (50%)	0	3 (50%)	0

The results in Table (3.14) show that 47% of cream doughnut samples taken from sandwich bars were unsatisfactory or unacceptable, in the case of both delicatessens and supermarkets between 50%-56% were unsatisfactory. A survey done by the FSAI on 527 samples found 1.7% (n=9) of cakes and pastries with perishable fillings and toppings to be unsatisfactory, and 0.2% (n=1) to be unacceptable (FSAI, 2002a). A similar study undertaken by the Public Health Laboratory Service (PHLS) in the UK on the microbiological quality of ready-made foods found a *S. aureus* count of > 100cfu/g in 0.5% of desserts and cakes tested (Nichols *et al.*, 1993).

With regard to overall levels of *S. aureus* in the cream doughnuts sampled, 37% were satisfactory, 10% were acceptable, 47% were unsatisfactory and 6% were unacceptable or potentially hazardous.

Since it was only possible to take samples from 10 premises in this research the unsatisfactory and unacceptable results may be slightly overestiamated than would be expected. However it does emphasize the importance of ensuring good hygiene practices throughout the food chain i.e. from manufacture to retail.

3.6.2 *Listeria monocytogenes*

L. monocytogenes is ubiquitous in the environment and is present in many raw foods including fruit and vegetables. The presence of this pathogen in ready-to-eat foods raises concern as it is capable of proliferating under refrigeration temperatures

(FSAI, 2006b). *L. monocytogenes* has been detected in many commercially prepared processed foods including ham (Frye *et al.*, 2002 ,de Valk *et al.*, 2000).

Levels of *Listeria monocytogenes* ≥100cfu/g at the point of consumption is considered to represent a risk to consumers (European Commission, 1999). *Listeria monocytogenes* was not detected in any of the samples tested from the 10 outlets included in this research, this finding is very encouraging.

Although raw materials, equipment and personnel have been identified as potential sources of contamination, (Gravani, (1999), Johansson *et al.*,(1999)); the environment has been identified as the primary source of post process contamination in commercially prepared processed foods (Tompkin, (2000); Kathariou, 2002)).

It is imperative that high levels of hygiene are achieved and then maintained at all stages through out the food chain. It is essential that food handlers, and the non-food handler (whose duties and responsibilities can impinge on food safety) are aware of their responsibilities in terms of food safety. It is also essential that they are adequately trained, are aware of their responsibilities in terms of food safety and ensure that good hygiene and food safety practices are followed at all times. All sectors of the food chain have a role to play in the control of *L. monocytogenes*.

Overall this study highlights the necessity for the food industry to maintain good hygiene practices at all stages throughout the food chain, i.e. from manufacture to retail. Such practices should form part of a food safety management system based on the principles of HACCP. Temperature control throughout the food chain is also essential to ensure that pathogens (if present) do not exceed their critical limits at the point of consumption to make them hazardous for consumers.

3.7 PREDICTIVE MICROBIOLOGY

An effective food safety management system incorporates temperature control and appropriate hygiene practices. Predictive microbiology can be used to show the consequences of an ineffective food safety management system.

3.7.1 *Staphylococcus aureus*

Since it was not possible to record temperatures in the outlets where the sampling was done for microbial load with regard to *S. aureus,* predictive growth modelling software in the *ComBase Predictor* was used, incorporating the temperature readings recorded during the nationwide survey, to predict microbial load under actual conditions. Environmental factors including pH and Aw, were inputted into the growth model for each foodstuff using measurements taken in the laboratory or values on the ComBase database.

Therefore the results of microbiological analysis of the three foodstuffs in section (3.6), combined with temperature readings recorded for these products during the nationwide survey further aid assessment of the efficacy of food safety management systems in place in retail outlets in Ireland. Both sets of data recorded in actual conditions allow prediction of the growth rate of *S. aureus* and *L. monocytogenes*, and assessment of the potential risk to the consumer of foodborne disease.

The ComBase growth model will only predict pathogen counts at temperatures of 7.5°C or above so in some cases the predictive period was less than 7 hours due to actual recorded temperatures not exceeding 7.5°C for the entire 7 hour recording period.

Figure (3.50) shows the predicted counts of *S. aureus* using *ComBase Predictor* and temperature data recorded in a deli outlet displaying cooked chicken pieces.

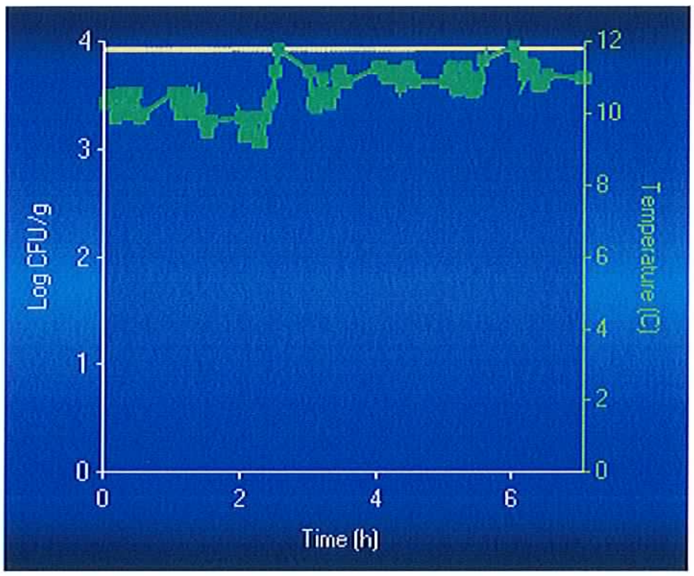


Figure (3.50): *ComBase Predictor* data for counts of *S. aureus* in cooked chicken pieces displayed in a fluctuating temperature in a deli outlet

The data in Figure (3.50) shows the external air temperature fluctuations within the chill cabinet in a deli outlet surveyed, displaying chicken pieces (pH 6.31 and Aw

0.971) during the recording period. The predicted level of *S. aureus* never exceeds the critical level of log 4 cfu/g. The count of S. aureus increases to log 3.95 cfu/g after 7 hours from the initial level of log 3.94 cfu/g.

In the case of coleslaw (pH 4.5 and Aw 0.967) being displayed in a salad bar in the same outlet, both the core and external air temperatures were used to predict the *S. aureus* count. Using both sets of temperature data, The ComBase growth model predicted that counts of the pathogen would increase from initial level of log 3.94 cfu/g to log 3.95 cfu/g of coleslaw within a 4 and a half hour period of fluctuating temperature.

It was not possible to estimate *S. aureus* levels over a 7 hour period for the coleslaw, as was done for cooked chicken pieces, since as previously mentioned, *ComBase Predictor* will only accept temperatures of 7.5°C or above. In this case, the remainder of the period recorded in the salad bar chill cabinet displaying the coleslaw recorded temperatures below 7.5°C. No external air temperatures were recorded for cream doughnuts in any of the deli outlets surveyed within the temperature range applicable to the use of *ComBase Predictor* growth model (7.5-30°C). Therefore it was not possible to predict the microbial load of *S. aureus* in this foodstuff in a deli outlet surveyed during this research.

In the case of a supermarket outlet, *S. aureus* growth was predicted in cooked chicken pieces and results using *ComBase Predictor* found over a 7 hour period the initial levels of log 2.62 cfu/g increased to log 2.63 cfu/g which is below the recommended critical limit for consumer safety. Figure (3.54) shows the predicted growth rate of *S. aureus* in coleslaw using temperature results recorded from a chill cabinet displaying coleslaw in the same supermarket outlet.

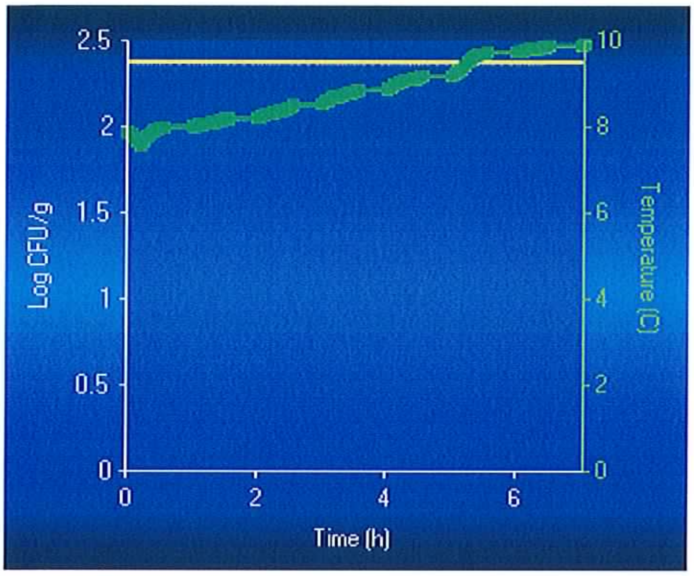


Figure (3.51): *ComBase Predictor* data for counts of *S. aureus* in coleslaw displayed in a fluctuating temperature in a supermarket outlet

The results in Figure (3.51) predict that the *S. aureus* levels in coleslaw would remain at the initial load of log 2.38 cfu/g throughout a 7 hour period despite external air temperature fluctuations.

With regard to cream doughnuts sampled in this supermarket, the microbial analysis found that levels of *S aureus* in two of the samples taken were above the critical level of log 4 cfu/g. The *S. aureus* level found in the 4pm sample (pH 6.12 and Aw 0.935) was used in conjunction with temperature data recorded in the same supermarket that previous data for cooked chicken pieces and coleslaw was used. Figure (3.52) shows the predicted levels of *S.aureus* in cream doughnuts using results from this research and the growth model in *ComBase Predictor*.

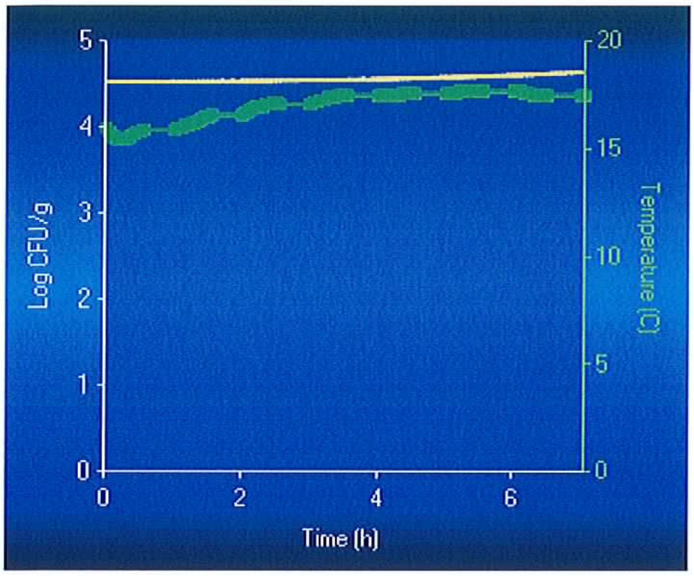


Figure (3.52): *ComBase Predictor* data for counts of *S. aureus* in a cream doughnut displayed in a fluctuating temperature in a supermarket outlet

The results in Figure (3.52) show a predicted growth level of *S. aureus* from an initial log 4.53 cfu/g to log 4.65 cfu/g after a 7 hour period in a chill cabinet that was maintaining external air temperature at a median air temperature of 16.05°C. The results predict a continued increase in *S. aureus* levels throughout the time in the chill cabinet and the predicted levels of *S. aureus* are considered hazardous making this foodstuffs a likely vector of food borne disease.

The end result of lack of temperature control combined with poor food hygiene either in the supermarket outlet, or at some stage along the food production chain, is a foodstuff on sale to the general public that has unacceptable levels of a pathogen implicated in food borne disease. The predicted result of growth level of *S. aureus* in a cream doughnut, sampled and displayed in a chill cabinet in a supermarket outlet, highlights the importance of an effective food safety management system in retail outlets.

To predict the growth of *S. aureus* levels in sliced ham displayed in a butcher outlet surveyed during this research, temperature readings recorded in a chill cabinet displaying sliced ham were used in conjunction with results from microbial analysis done by FSAI for *S. aureus* in cooked sliced ham in 2005. Figure (3.53) shows the predicted growth rate of *S. aureus* in cooked sliced ham (pH 6.22 and Aw 0.975) in a butcher outlet using the growth model in *ComBase Predictor.*

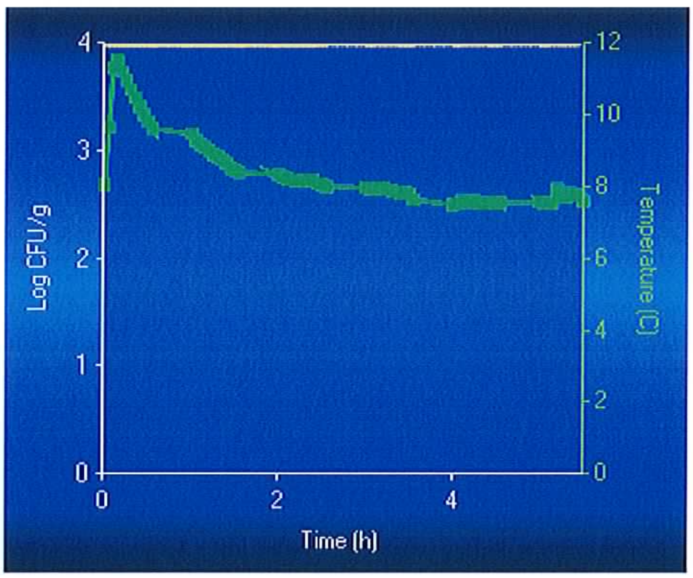


Figure (3.53): ***ComBase Predictor*** **data for counts of** ***S. aureus*** **in a cooked sliced ham displayed in a fluctuating temperature in a butcher outlet**

The initial level of *S. aureus* in the cooked sliced ham was log 3.9899 cfu/g, and using the growth model this level remained unchanged throughout the 6 hour period of fluctuating external air temperatures recorded in a butcher chill cabinet.
This predictive data shows that despite air temperatures being 7.5°C or above for a six hour period and *S. aureus* levels in the cooked sliced ham just below the critical level of log 4 cfu/g, the foodstuff would not contain sufficient levels of *S. aureus* to cause food borne disease after 6 hours of storage in an inappropriate temperature environment.

Given the fact that the air temperatures and core temperatures analysed previously using the growth model were all above 7.5°C, a further application of the growth model was used to predict the time required for the *S. aureus* load to reach an unacceptable level (i.e. > 10^4 cfu/g). The results of microbial analysis for *S. aureus* count for the cooked chicken pieces, coleslaw and cream doughnuts and sliced ham were used in conjunction with the median external air and core temperatures recorded in the chill cabinets displaying them. Table (3.15) shows the predicted time required for the *S. aureus* load in the four previously mentioned foodstuffs to reach hazardous levels under certain environmental conditions.

Table (3.15): Time required for *S. aureus* count in foodstuffs to exceed critical limit in four foodstuffs maintained at different temperatures

Type of outlet	Foodstuff	Environmental factors					ComBase Prediction
		S. aureus count Log cfu/g	Median external air temperature (°C)	Median core temperature (°C)	Aw	pH	Time to log 4 cfu/g (hrs)
Deli	Chicken pieces	3.934498	9.9	_	0.971	6.31	32
Supermarket	Chicken pieces	2.623249	7.6	_	0.971	6.31	260
Deli	Coleslaw	3.944483	10.58		0.967	4.5	92
Deli	Coleslaw	3.944483		11.44	0.967	4.5	74
Supermarket	Coleslaw	2.380211	8.06	_	0.967	4.5	940
Supermarket	Cream doughnut	3.432364	16.05	_	0.935	6.12	38.40
Butcher	Sliced ham	3.989999	8.75	_	0.975	6.22	6.6

The results in Table (3.15) show that sliced ham with an unsatisfactory level of *S. aureus* and stored at 8.75°C will have critical levels of this pathogen in 6.6 hours. This is in contrast to coleslaw which even with a higher core temperature of 11.44°C, it would not have hazardous levels of *S. aureus* for 74 hours.

Table (3.15) shows that as well as temperature and initial load, environmental factors such as pH and Aw are important influences on the growth rate of *S. aureus*. However the growth model used for these predictions does not take into account the presence of other pathogen growth inhibitors such as sodium nitrite which would be present in ham, and would increase the time required for *S. aureus* levels to reach log 4 cfu/g.

The results in Table (3.15) show that foods with a pH close to 7 and a higher Aw provide the best environment for the growth of *S. aureus,* and will have a shorter shelf life in terms of food safety if subjected to temperature abuse and poor food hygiene practices.

In terms of food safety management systems, temperature control and satisfactory food hygiene practices are the two variables that can be controlled and monitored by the retailer, and significantly affect the microbial safety of the food products.

Table (3.16): Time required for *S. aureus* count in foodstuffs to exceed critical limit in four foodstuffs all maintained at the same temperature

Type of outlet	Foodstuff	Environmental factors				ComBase Predictions
		S. aureus count Log cfu/g	Core temperature (°C)	Aw	pH	Time to log 4 cfu/g (hrs)
Deli	Chicken pieces	3.934498	7.5	0.971	6.31	64.4
Supermarket	Chicken pieces	2.623249	7.5	0.971	6.31	265
Deli	Coleslaw	3.944483	7.5	0.967	4.5	215.3
Supermarket	Coleslaw	2.380211	7.5	0.967	4.5	1140
Supermarket	Cream doughnut	3.432364	7.5	0.935	6.12	340
Butcher	Sliced ham	3.989999	7.5	0.975	6.22	16

In Table (3.15), when compared to table (3.14), it is shown that the time required for *S. aureus* levels in the coleslaw on display in a deli outlet to reach log 4 cfu/g has more than trebled by reduction in core temperature of approximately 4°C. This information is also of value to the retailer as the temperature value used to predict a shelf life of 215.28 hours or 3.6 days is still 2.5°C above the legislative guidelines of 5°C. Therefore a further reduction in food temperature not only reduces the risk of food borne disease, but also makes economic sense for retailers.

In the case of the 3 other foodstuffs in the various outlet types it can be seen from table (3.16) that temperature control even at levels above the recommended guidelines in the legislation greatly enhances the safety of the foods in terms of inhibiting growth of *S. aureus*.

3.7.2 *Listeria monocytogenes*

In the case of *Listeria monocytogenes*, temperature is a major inhibitory factor in the growth of this pathogen to hazardous levels. Due to the psychrotrophic nature of *L. monocytogenes*, temperatures above the recommended range such as those recorded during the nationwide survey of supermarket, delicatessen and butcher outlets would have very serious implications for the growth of *L. monocytogenes*.

Smoked salmon has been taken as an example to highlight the importance of temperature control in retail outlets in relation to *L. monocytogenes*. Figure (3.54) shows the predicted counts of *L. monocytogenes* using *Combase Predictor* and temperature data previously recorded during this study.

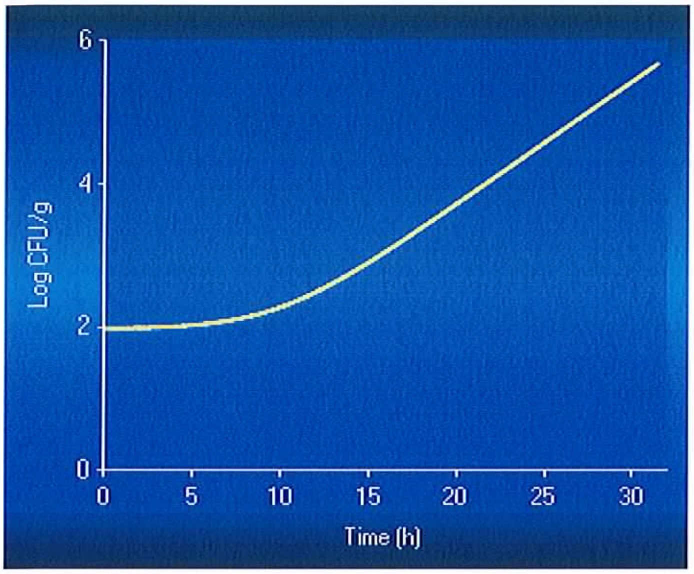


Figure (3.54): *Combase Predictor* data for counts of *L. monocytogenes* in smoked salmon displayed, with a median core temperature of 17.5°C

The initial level of *L. monocytogenes* was log 1.98 cfu/g, which is regarded as an acceptable level. However fig. (3.57) shows that within 3.2 hours at this temperature the levels of *L. monocytogenes* in this product were unacceptable and hazardous. This product would normally have a shelf life of several days, however fig. (3.57) shows that levels of *L. monocytogenes* in the smoked salmon would have risen to log 3 within 15.6 hours, and to log 4 within 21.76 hours.

These predicted levels highlight the importance of temperature control in relation to this pathogen, and can be starkly contrasted to Figure (3.55) which shows predicted levels in the same product kept within the legislative guidelines for temperature control of chilled foods.

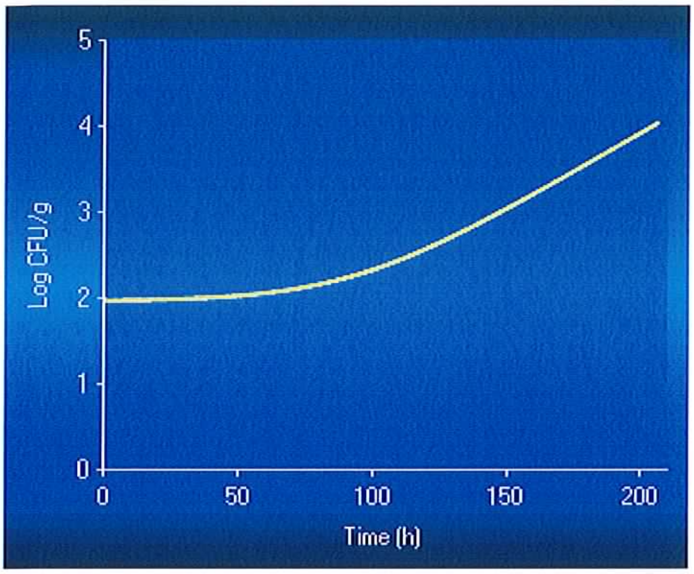


Figure (3.55): ***Combase Predictor*** **data for counts of L. monocytogenes in smoked salmon on display, with a median core temperature of 5°C.**

The initial level of *L. monocytogenes* was log 1.98 cfu/g, which was the same level as was used for predictive modelling in Figure (3.54). However, the reduction in core temperature of this product has had a marked effect on safety and shelf life of this product. Figure (3.55) shows that it would require 24.96 hours for levels of *L. monocytogenes* to reach log2 cfu/g, with 147.2 hours (6.1 days) and 204 hours (8.5 days) to reach log 3 and log 4 cfu/g respectively.

The difference in time required to reach hazardous levels of *L. monocytogenes* emphasizes the importance of temperature control in the area of food safety and why it is a critical control point in food safety management systems in operation in retail outlets.

CHAPTER FOUR: CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

- This research confirms that the cold chain is broken at the retail level in the case of 37% of premises surveyed with regard to chilled foods, of particular concern was the temperature abuse occurring in relation to chilled ready-to-eat foods, that are not subjected to further heat treatment prior to consumption.

- The mean external air temperature in chill cabinets was outside the correct range (-1 to 5°C) in the case of 33% (n=63) of chilled foods surveyed (n=191), with external air temperature ranging from -4.76 to +17.7°C.

- The core temperature of 19% (n=5) of chilled foods sampled (n=27) was above 5°C, the core temperature of the chilled food sampled ranged from -1.37-+13.98°C.

- Fruit and vegetables (n=12) were stored in the correct external air temperature range (0-10°C) in all outlets surveyed.

- In relation to supermarkets, butchers and delicatessens, which were the outlet types surveyed, there was no significant difference between outlet type or outlet size and standard of external air and core temperature control for chilled foods and fruit and vegetables. However butcher outlets were shown to have the highest number of outlets with external air temperature and product core temperature in the correct range, and delicatessens exhibited the poorest temperature control.

- Frozen foods, excluding ice-cream, were not stored at the recommended temperature (-18°C) in 52% of delicatessen and supermarket outlets surveyed (n=34).

- In terms of the efficacy of freezer temperature control, the type of outlet was not significant ($p>0.05$). The size of the outlet and number of employees were found to be significant factors in freezer cabinet temperature control ($p<0.05$). Smaller premises, i.e. those employing ten people or less were holding products at higher temperatures than outlets with higher staff numbers.

- There was no significant difference between chill cabinet design in relation to the efficacy of external air temperature control ($p>0.05$). The design of freezer cabinet was found to be significant, with island freezer cabinets found to be significantly better than wall freezers in maintaining frozen foods at the recommended temperature ($p<0.05$).

- In 67% of the premises surveyed (n=12), the ice-cream freezer cabinets were maintaining an excessively low external air temperature (<-23°C), which is both unnecessary in terms of product quality and safety, uneconomical and environmentally unfriendly.

- Efficacy of temperature control in ice-cream freezers was not dependant on the outlet type or size.

- Two ice-cream cabinet designs were examined, island freezers with sliding doors and vertical standing wall freezers with glass doors, the design not being significant with regard to control of air temperature within the cabinet ($p>0.05$).

- Air relative humidity within the cabinets surveyed varied, depending on cabinet design and the products contained therein, with 36% of all products surveyed being held in the recommended range. Neither cabinet design or make was significant ($p>0.05$) with regard to control of air relative humidity.

- There was compliance for the three elements of HACCP in 51% of the outlets surveyed, with HACCP compliance greatest in supermarket outlets (59%), with butcher and delicatessen outlets showing compliance levels of 47% and 46% respectively.

- In this study, temperature control was the element of HACCP with least compliance, and despite high levels of verification of food safety management systems in the outlets surveyed, ineffective temperature control was not being detected.

- To avoid undermining the effectiveness of staff food safety training, supervisors and managers should themselves be adequately trained, have a thorough understanding of HACCP, as the survey found a significant relationship ($p<0.05$)

between the level of understanding of HACCP and the efficacy of temperature control. Therefore, unless managers fully appreciate the inherent risks involved in their food-handling practices, they are unlikely to recognise the need to train or the contribution training can make to the food industry.

- Management motivation of staff is critical to the success of hygiene training and food safety management, as provision of knowledge alone will not lead to changes in attitude and food handling behaviour. It was observed that despite receiving food hygiene training, work practices did not adhere to training principles. In many outlets, staff did not wash hands frequently and handled many different food types with potential to facilitate cross contamination.

- A major disadvantage to training was cost and the risk of loss of investment if an employee left. The survey done found that the lack of government financial support was felt to be the most significant obstacle to improving training standards.

- Accurate monitoring of temperature is necessary but it is not taking place in all food retail outlets, therefore greater emphasis should be placed on temperature control procedures and their importance in all food hygiene courses.

- Unsatisfactory cleaning procedures were observed in some outlets surveyed, the main defects were inadequate cleaning frequency, incorrect use of wiping cloths, and neglect of hand contact surfaces.

- Food hygiene and food handling practices could be improved by increasing the awareness of staff to the opportunities for cross contamination and the importance of hand washing.

- In the context of a food safety management system, product temperature and food hygiene practices are the two variables that can be controlled by the retailer which significantly affect the microbial safety of the food products and the risk to the consumer of foodborne disease.

- Inappropriate food hygiene practices combined with temperature abuse will result in hazardous levels of pathogens in 'high risk' chilled foods, this highlights the importance of effective implementation of a food safety management system.

- In smaller outlets space constraints were a factor in inappropriate positioning of chill cabinets beside hot food cabinets.

- Cabinet digital displays were not found to show accurate measurements of external air temperature within cabinets in the outlets surveyed, possibly due to temperature distribution within the cabinet or inaccuracies in the cabinet temperature sensor.

- Based on observations in outlets surveyed, stacking and stocking rates of products were not seen to inhibit movement of air around them.

- The presence of *Staphylococcus aureus* at unsatisfactory (43%) and hazardous (0.02%) levels in samples (n=90) of chilled 'ready-to-eat' high risk foods on sale in retail outlets highlighted the necessity to maintain good food handling and food hygiene practices.

- Growth of *Staphylococcus aureus* is a function of low hygiene standards and temperature fluctuations above the recommended range, both of which were observed in retail outlets during this research. As a consequence, there is a potential risk of *Staphylococcus aureus* related food poisoning due to the consumption of ready-to-eat chilled foods.

- Using predictive modelling, incorporating recorded temperature readings and microbial analysis of 'high risk' chilled foods with unsatisfactory levels of *Staphylococcus aureus,* it was determined that prolonged exposure, greater than 24 hours, of the foodstuffs to temperatures above 7.5°C is required for levels of the pathogen to exceed the critical limit.

- Poor food hygiene practices along the food chain resulting in high levels of pathogen contamination of foodstuffs were a greater risk to the consumer than temperature abuse of the product in the case of foodborne disease due to *Staphylococcus aureus.* Results of this research show that significant levels of *S. aureus* contamination are required to be present initially for temperature abuse to have a consequence in terms of food safety.

- *Listeria monocytogenes* was not detected in any of the samples (n=90) tested during this research, and this finding is encouraging. However it is important not to become complacent, and to maintain continued awareness for the potential growth of all psychrotrophic microrganisms and to maintain effective temperature control.

- While temperature abuse might not pose an immediate or severe risk of food poisoning with respect to *Staphylococcus aureus*, there will be a significant risk of foodborne disease from *Listeria monocytogenes,* especially as there are a number of popular chilled products that are minimally processed.

4.2 RECOMMENDATIONS

- For effective maintenance of the cold chain in retail outlets, retailers should be familiar with operation of chill and freezer cabinets, in order to make an informed decision when storing foodstuffs according to their temperature declaration and temperature regime of the chill or freezer cabinet.

- When examining cabinet efficacy with regard to temperature control as part of a food safety management system, temperature checks on produce located at the front or bottom of the cabinet, depending on design, would be the best conservative approach.

- The core temperature of products should always be measured as opposed to relying on external air temperature as part of the temperature monitoring procedure since the core temperature of foods can vary by 0.5-2 °C from external air temperature.

- The food business operator should be familiar with the operation of cooling and freezing units in use in their premises, including time and duration of defrost cycles if relevant to cabinet particularly if only external air temperature is being monitored.

- Ice-cream freezer temperatures need to be checked so that they are run effectively and economically.

- Guidelines for % air relative humidity should be included in the legislation or in food industry standard guidelines to enable retailers to monitor air relative humidity and prolong shelf life.

- Cabinet digital displays should not be relied upon as the only indicator of external air temperature within the chill or freezer cabinet.

- The temperature sensor should be located at a position within the chill cabinet so that the digital display would show the 'worst case' scenario.

- To ensure a food safety management system is HACCP compliant and effective, both verification and validation procedures must be carried out.

- Food retailers should be aware of the difference between verification and validation of food safety management systems.

- Continuous temperature monitoring could be included in the food safety management system as part of the validation of temperature control within the chill and freezer cabinets.

- Review of both verification and validation procedures should be included as part of the protocol of each food safety management system.

- Both internal and external audits should include inspection of validation procedures.

- A licence to start a food retail business should not only be dependant on adhering to structural hygiene designs, but also require proof of some evidence of existing training and relevant food safety skills

- Food retail outlets must ensure that effective training is an on-going activity in their business.

- Safe food handling and effective implementation of training programmes depends essentially on well-trained, knowledgeably and positive minded managers within food retail outlets.

- If managers and supervisors were trained to advanced levels, then they would be able to provide the more basic levels of training and thereby reduce training costs, whilst also offering the additional benefit of making training more relevant to the individual needs of the staff.

- Attitudes of staff are an important factor as well as knowledge and enforcement of food safety training. To achieve behavioural change it is important that businesses see training as one part of a broader food hygiene control strategy.

- Visual, non-microbiological and microbiological methods should be combined, resulting in the production of an integrated cleaning monitoring strategy.

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Appenndix 1

Questionnaire

Section A: General Information

Q1. Type of Business:
Supermarket ☐ butcher ☐ delicatessen ☐

Q2. Position in Business:
Manager ☐ QC manager ☐ other.....................

Q3. Number employed in business?
(a) < 5 ☐
(b) 5 to 10 ☐
(c) 11 to 20 ☐
(d) 21 to 40 ☐
(e) >40 ☐

Section B: Food Safety Awareness

B1. What industry issues most concern you: (number in order of importance)
cost of labour ☐
threat of imports ☐
staff shortages ☐
food safety ☐
increasing competition ☐
other........................

B2. What specific food safety concerns, if any, do you have? eg additives, pesticide & herbicide residues, G.M., B.S.E., food hygiene, food poisoning,natural toxins,radiation levels..
....

B3. What do you perceive as the consumers greatest food safety concerns?..
....
....
....

B4. What is your understanding of the term HACCP ?..
....
....
....

B5 What are the main advantages associated with a HACCP based food safety management system ?..
....
....

B6 What are the main disadvantages associated with a HACCP based food safety management system? ....
....
....
....

B7 What are the reasons for controlling the temperature of foods?..
....
....

B8 What do you consider 'high risk' foods?..
....
....
....

B9 Are you aware of potential pathogens that may occur as a result of temperature abuse of foods? If yes list them....................................
....
....

Section C. Food Safety Compliance with Regulations

C1 What is the acceptable temperature of the chilled foods on arrival at the premises?

(a) 0 to 5°C ☐
(b) < 5°C ☐
(c) 1 to 4°C ☐
(d) 2°C ☐

C2 What is the temperature range of the cold store ?

(a) 0 to 5°C ☐
(b) < 5°C ☐
(c) 0°C ☐

C3 What temperature do you display chilled foods at?

(a) 0 to 4°C ☐
(b) 0 to 5°C ☐
(c) 0°C ☐

C4 Above what temperature is food disposed of?

(a) 5°C ☐
(b) 8°C ☐
(c) 10°C ☐
(d) 12°C ☐

C5 What are your main sources of information on food regulations and the implications of food regulations on your business?..............................
....
....

C6 Is there too much food safety regulation and enforcement of these regulations in your industry? Yes ☐ No ☐ Not sure ☐

C7 Have you carried out a hazard analysis? Yes ☐ No ☐

C8 Have you effective controls in place at each CCP? Yes ☐ No ☐

C9A How do you verify that CCPs are being controlled?.............................
....
....
....

C9B Is HACCP system reviewed and verified? Yes ☐ No ☐

C9C Frequency of review of verification:

(a) Monthly ☐
(b) Every 3 months ☐
(c) Every 6 months ☐
(d) Every year ☐
(e) No formal review ☐

C10 What age are the chill cabinets?..

C11 Are chill cabinets fitted with a temperature recorder? Yes ☐ No ☐

C12 Are chill cabinets fitted with a temperature display? Yes ☐ No ☐

C13 Are chill cabinets fitted with a temperature alarm? Yes ☐ No ☐

C14 Does the cabinet supplier control the cabinet temperature by computer or is control done on the premises?...
....

C15 How often are the temperatures of the chill cabinets checked:
- (a) once daily ☐
- (b) twice daily ☐
- (c) every second day ☐
- (d) other ....

C16 What type of thermometer is used:
- (a) digital probe ☐
- (b) infra-red thermometer ☐
- (c) digital display ☐
- (d) other, please specify.................

C17 How long are records of temperature kept for?..

C18 How often are thermometers calibrated?
- (a) every 6 months ☐
- (b) annually ☐
- (c) every 2 years ☐
- (d) other please specify...................

C19 Does equipment supplier also calibrate thermometers? Yes ☐ No ☐

C20 How often is maintenance carried out on chill cabinets?.............................
....
....

C21 Have you a written sanitation programme in place for the entire premises?
Yes ☐ No ☐

C22 How often are the chill cabinets cleaned?
(a) daily ☐
(b) every 2/3 days ☐
(c) weekly ☐

C23 How often are chill cabinets deep cleaned?
(a) weekly ☐
(b) monthly ☐
(c) 6 monthly ☐

C24 How could you improve the current system in the area of temperature control of chilled foods?..
....
....

Section D: Food Safety Training

D1 What type of training do you offer to employees?
(a) no training ☐
(b) on the spot instruction ☐
(c) formal instruction ☐

D2 Do you provide any of the following:
(a) induction training ☐
(b) basic food hygiene ☐
(c) management of food safety/hygiene ☐
(d) microbiology ☐
(e) food safety/hygiene auditing ☐
(f) HACCP training ☐
(g) Training the trainer ☐
(h) Weekly staff meetings for updating hygiene knowledge ☐
(i) Periodic updates ☐

D3 Do you consider the practical training given to staff adequate?
Yes ☐
No ☐
Would like to provide more ☐

D4 Do you consider that there is adequate support from government agencies eg: E.H.O., F.S.P.B., F.S.A.I.,.? Yes No

D5 What do you currently see as the barriers to training?

(a) lack of funding for training ☐
(b) high cost of training ☐
(c) lack of staff cover ☐
(d) other, please specify............................

Section E: Recorded results of Temperature monitoring in outlets

E1 Results of temp control in chill cabinet for outlet:

(1) -1 to + 5°C ☐
(2) +5 to +8°C ☐
(3) +8 to +10°C ☐
(4) above + 10°C ☐

E2 Results of temp control in freezer cabinet for outlet:

(1) -18 or -23 ☐
(2) >-18 or > -23 ☐
(3) <-18 or < -23 ☐

E3 Is business HACCP compliant based on 3 criteria necessary for compliance including validation by auditing and verification which should be done at least annually. The three elements of HACCP plan necessary are:

(a) Hazard analysis
(b) Control of CCPs
(c) Verification

Results are classed as follows:

1-Compliant ☐
2-Commenced compliance, no hazard analysis ☐
3-Commenced compliance, no verification ☐
4-Commenced compliance, no CCP control ☐
5- Commenced compliance, no CCP control or verification ☐

Appendix 2

Observations

1. Who is responsible for temperature monitoring?..

2. Is documentation in relation to temp. monitoring:
   (a) Supervised
   (b) signed and dated daily
   (c) signed and dated at regular intervals

3. Is documentation of temp. monitoring readily available? Yes No

4. Type of thermometer used?...

5. Type of chill cabinet used (name, brand and model) and condition................
   ....

6. Is there evidence of calibration of thermometers? Yes No if yes how often..
   ....

7. Are certificates of calibration & maintenance available on the premises? Yes No

8. Is location of chill cabinet suitable? Yes No

9. Temp. of chill cabinet-.....................
   Temp. from digital read out..............
   Is it working?..

10. Temp. of freezer..........
    Temp. on digital readout.........

11. Are chill cabinets overloaded? Yes No

12. Are freezer cabinets overloaded? Yes No

13. Is stacking arrangement interfering with air flow? Yes No

14. Are cabinets visually clean? Yes No

15. Are light fittings in display cabinet of safety type? Yes No

16. Is there an adequate sanitation programme in place with sufficent documentation ie: fridge cleaned at least once daily,floors & surfaces cleaned once daily...
....
....
....

17. Personnel hygiene practice at time of visit:
V. good good satisfactory poor unacceptable

18. Were correct operational practices observed at the time of visit?

Washing hands		Yes	No
Wearing gloves		Yes	No
Changing gloves		Yes	No
Clean protective clothing		Yes	No
Hair nets/hats		Yes	No
Wearing jewellery		Yes	No
Cuts/grazes covered		Yes	No

....

19. Do staff working with chilled foods have other duties? Yes No

Appendix 3

External air temperature of chilled products including fruit and vegetables

Product	Sample number	Mean (°C)	Median(°C)	Minimum(°C)	Maximum(°C)
Beef burger	3	6.78	4.70	2.3	16.33
Minced beef	3	2.39	1.63	1.09	4.44
Beef steak	17	1.94	1.93	-4.76	7.10
Chicken (raw)	23	3.87	3.06	-2.50	9.00
Coleslaw	13	5.35	5.27	-0.55	13.50
Cream cake	8	5.84	5.05	-0.24	17.70
Fish	9	5.45	5.43	-1.98	11.50
Fruit	3	7.47	6.10	5.90	10.40
Garlic bread	2	8.54	8.53	5.05	12.00
Lamb	6	3.27	2.35	0.31	10.91
Lamb chops	6	3.03	2.76	-0.4	7.96
Lasagne	2	2.46	2.44	2.42	2.48
Lettuce	2	6.45	6.41	3.10	9.72
Milk	17	2.1	1.39	-1.23	6.86
Pate	2	1.22	1.2	-0.04	6.86
Pizza	2	2.99	2.95	-0.50	6.40
Pork chops	7	3.28	2.54	0.44	8.26
Potato salad	5	5.64	5.18	-3.00	6.30
Prawns	2	5.69	5.65	5.43	5.70
Pre-cut fruit	2	-0.68	-0.65	-7.90	6.60
Pre-packed coleslaw	2	5.40	5.38	3.85	6.90
Pre-packed ham	4	4.54	4.46	-0.57	9.82
Rashers	4	4.88	4.75	2.20	7.80
Salads-mixed	17	5.51	5.10	0.89	12.00
Sliced ham	15	3.47	4.09	-1.63	12.06
Smoked salmon	2	1.57	1.56	-0.96	4.09
Soup	6	4.88	3.78	0.78	12.43
Steak & Kidney pie	2	2.92	2.94	2.38	3.45
Vegetables	7	7.34	7.70	2.00	16.10
Yoghurt	10	5.39	3.55	1.77	8.78

Appendix 4

Core temperature of chilled products surveyed

Product	Sample number	Mean (°C)	Median(°C)	Minimum(°C)	Maximum(°C)
Beef mince	1	3.16	3.16	3.14	3.18
Beef steak	2	0.13	0.13	-1.37	1.63
Chicken	2	0.53	0.53	-0.47	1.53
Coleslaw	4	5.21	5.22	-0.57	13.98
Cream cake	2	4.89	4.89	-0.24	17.30
Fish	2	4.29	4.29	3.65	4.92
Lamb	2	3.27	3.27	2.41	4.13
Pate	1	2.99	2.99	2.97	3.01
Pork chops	1	5.78	5.76	5.45	5.82
Sliced ham	2	0.93	0.93	-0.27	2.13
Smoked salmon	1	-0.74	-0.74	-0.42	1.14
Soup	1	0.93	0.93	0.88	0.96
Yoghurt	6	5.03	4.52	2.36	8.78

Appendix 5

Air temperature of frozen products

Product	Sample number	Mean (°C)	Median(°C)	Minimum(°C)	Maximum(°C)
Frozen beef	1	-14.03	-14.03	-15.15	-13.45
Frozen burgers	4	-16.87	-15.71	-22.99	-13.06
Frozen chicken	1	-8.61	-8.61	-8.42	-9.15
Frozen fish	12	-17.22	-15.26	-24.96	-10.60
Frozen peas	2	-20.31	-20.31	-28.10	-12.52
Frozen pizza	8	-17.66	-16.21	-25.32	-10.30
Frozen pork	2	-12.82	-12.82	-13.23	-12.40
Frozen vegetables	4	-19.45	-20.11	-23.71	-13.88
Frozen steak & Kidney pie	1	-7.1	-7.1	-6.90	-7.30

Appendix 6

Air relative humidity for chilled, fruit and vegetable products

Product	Sample number	Mean (°C)	Median(°C)	Minimum(°C)	Maximum(°C)
Beef burger	2	76.40	76.40	74.80	78.00
Beef steak	8	74.84	71.95	64.90	99.90
Chicken	11	64.69	67.00	33.50	84.40
Coleslaw	7	71.87	75.80	55.20	83.80
Creamcake	4	68.45	73.50	49.50	77.30
Fish	2	67.65	67.65	66.00	69.30
Fruit	3	81.57	83.30	70.60	90.80
Garlic bread	1	43.40	43.40	43.40	43.40
Lamb chops	1	48.90	48.90	48.90	48.90
Lettuce	1	84.30	84.30	84.30	84.30
Pizza	2	62.25	62.25	44.90	79.60
Potato salad	4	81.28	82.20	68.40	92.30
Pre-cut fruit	2	72.40	72.40	68.80	76.00
Prepacked coleslaw	1	57.20	57.20	57.20	57.20
Rashers	4	74.20	74.80	67.70	79.50
Mixed salads	16	76.16	75.10	65.80	88.00
Sliced ham	1	64.50	64.50	64.50	64.50
Soup	1	82.70	82.70	82.70	82.70
Steak and kidney pie	1	91.30	91.30	91.30	91.30
Vegetables	5	78.42	82.70	63.80	86.90

Publications

1: Garvan, C.B., Abu-Ghannam, N. and Frías, J.M. (2006). Temperature Analysis and Relative Humidity Profiles of Chilled and Frozen Foods in Retail Outlets in the Republic of Ireland, and Evaluation of the Food Safety Management Systems in place. Poster presented at the 9th World Environmental Congress on Environmental Health, Trinity College Dublin, Dublin, Ireland, 18th-23rd June 2006.

2: Garvan, C.B., Abu-Ghannam, N. and Frías, J.M. (2006). Temperature Analysis and Relative Humidity Profiles of Chilled and Frozen Foods in Retail Outlets in Ireland, and Evaluation of the Food Safety Management Systems in place. Paper presented at the 36th Annual Research Conference Food, Nutrition and Consumer Sciences, University College Cork, Cork, Ireland, 14th September 2006. Abstract published in Proceedings of the 36th Annual Research Conference Food, Nutrition and Consumer Sciences.