

A study of domestic fridges on the island of Ireland

Temperature control, design and consumer practices



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1 Executive Summary

Aim

This project aimed to survey consumer food safety knowledge and operating practices, and to identify barriers to safe practice, in relation to food storage and temperature control in domestic fridges on the Island of Ireland (IoI), by:

- assessing current consumer knowledge and practice in temperature control and food storage in domestic fridges
- determining the incidence, and efficiency of use, of fridge thermometers in households on IoI
- identifying barriers to the safe storage of food in domestic fridges
- identifying means of overcoming these barriers, to facilitate **safefood** in providing advice to consumers and fridge manufacturers.

Research Method

The researchers carried out a literature review to inform the design of a questionnaire on [a] consumer fridge safety and chilled food storage knowledge, and [b] the temperatures and contents of domestic fridges. One hundred study participants (50 in Northern Ireland (NI) and 50 in the Republic of Ireland (RoI)) were identified using quota sampling methods to ensure appropriate age, gender and social class representation. The participants were interviewed at home by field workers who used standard operating procedures (SOPs) in completing the questionnaire, and collecting fridge data including temperature (using calibrated digital thermometers), and the nature, location and “use by” status of food in participants fridges.

Results

Consumer knowledge

- only 1/3 of participants were able to identify the recommended operating fridge temperature range
- only 2/3 of participants knew the correct way to adjust their fridge thermostat to change fridge temperature

- only 1/3 of participants were able to identify the correct definition of a “use by date”, and only 50% were able to identify the correct definition for “best before” date. These results indicate significant confusion between “food safety” and “food quality” in relation to current labelling arrangements
- 3/4 of participants identified the bottom shelf as the safest place to store raw meat and poultry, but there was confusion in relation to what was the most suitable part of the fridge to store ready to eat foods, and the importance of separating raw and cooked foods to reduce cross contamination
- participants felt that fridge safety recommendations were important in the prevention of food poisoning from foods prepared at home, and lack of access to a fridge thermometer was identified as the only potential barrier to implementation of guidance on safe fridge/food storage practices
- comparison of these findings with previous studies established that although participant knowledge was increased slightly over the past 10 years, lack of understanding and lack of thermometers in most domestic fridges were identified as the main barriers to safe fridge practices
- 2% of participants reported that they had fridge thermometers (although thermometers were observed in 6% of the examined fridges; see below)

Fridge management

- The mean temperature of the sampled fridges (n=100) was 4.9°C, which is within the **safe** recommended (safe) range (0-5°C). However a very wide range of fridge temperatures (-4°C to +12.5°C) was observed, and more than 40% of the fridges had temperatures above 5°C, and in some cases well above, the recommended temperature for safe storage of food
- 10% of fridges contained high-risk ready-to-eat foods (cooked meats, cold salads, fish and dairy products) which were past their “use by” dates, and 8% of fridges contained foods beyond on pack storage instructions
- 6% of fridges contained thermometers, however, it is unclear how many participants were using these thermometers, as only 2% of participants knew that their fridges contained thermometers

The study observed some correlation between better knowledge and safer practice, for example most fridges belonging to participants who had more correct knowledge (and better general fridge behaviours) had temperatures within the recommended fridge temperature range (0-5°C), whereas

the fridges of participants with less knowledge (and poorer general fridge behaviours) were more operating at temperatures above the recommended range. The study also observed the potential value of thermal imaging technology in the design and operation of domestic refrigerators, although further development in terms of system sensitivity may be required to allow this technology to be calibrated against current digital thermometers.

Key Project Recommendations

Recommendation 1: Fridge thermometers should be promoted to consumers as a ‘best practice’ method for assessing fridge temperature e.g. given out with each new fridge sold. In addition fridge manufacturers should be encouraged to more widely include integrated (LED display) thermometers in fridge design.

Recommendation 2: Appropriate advertising campaigns and interventions (e.g. web or smart phone apps, and/or e-social media) should be developed to raise consumer awareness of the importance of regular checking fridge temperatures using integral or insertable thermometers.

Recommendation 3: Clear guidance should be provided to consumers on the correct way to adjust thermostat on the domestic fridges. The manufacturers could assist with this by designing a colour coded thermostat, i.e. blue to red to assist with consumer understanding of which way to turn the thermostat to make it colder.

Recommendation 4: There is a need to improve consumer understanding and behaviour in relation to “use-by” and “best before” labels.

Recommendations 5: There is a need to improve consumer understanding of the risks associated with incorrect storage of ready-to-eat cooked foods and a need to improve consumer behaviour in relation to safe storage of high risk foods in the fridge.

Recommendation 6: Further studies of consumer’s knowledge and practice in relation to safe fridge temperatures and practices, (perhaps involving a larger number of participants to enable identification of at risk subgroups within the wider IoI population), should be carried out to monitor the impact of current and future **safefood** campaigns and interventions on consumer fridge practice.

2 Introduction

Almost every household on the island of Ireland has a domestic fridge, yet a number of studies have shown that many consumers may not be using their fridge safely. *safefood* (2005, 2012) have reported a lack of awareness of safe practices in relation to food storage in the refrigerator amongst householders, such as the importance of correct refrigeration temperatures (0-5°C). International studies (Laguerre et al., 2002 and NZFSA, 2010) have reported comparable results. Many more consumers (65-66%) associate foodborne illnesses and inadequate food safety practice with food prepared outside of the home (i.e. in restaurants/food manufacture), than with domestic food preparation (16-17%) (Fein et al., 1995 and Williamson, 1992).

A number of studies have associated higher risk food preparation practices with younger males (<45 years old), and those with higher levels of educational attainment (Kennedy et al., 2005; McCarthy et al., 2007). These studies have also suggested that overconfidence, and a lack of interest in fridge safety behaviours, along with lifestyle and environmental factors (lack of facilities and time) contribute to failure to follow good food safety practice (Bolton et al., 2005; Brennan et al., 2007 and McCarthy et al., 2007). The development and delivery of a number of domestic food safety campaigns, and the introduction of new fridge designs and technologies, make it timely to carry out a new survey to update previous findings and gain new insights into consumer knowledge, behaviours and perceptions relating to fridge safety using a comprehensive and multidisciplinary approach.

3 Project Aims and Objectives

The main aim of this project was to conduct a detailed survey of temperature control, fridge design and consumer practices relating to domestic fridges across the Iol.

The objectives were as follows:

OBJECTIVE 1: To assess the current status with regards to temperature control and consumer practices in relation to storage of food in domestic fridges.

OBJECTIVE 2: To determine the incidence of fridge thermometers, and their use, in households on the Iol.

OBJECTIVE 3: To identify barriers to the correct storage of food in domestic fridges.

OBJECTIVE 4: Identify solutions to overcome these barriers, to facilitate **safefood** communications with consumers and fridge manufacturers.

4 Methods

Development and validation of questionnaire

This task involved the development of a consumer fridge safety questionnaire and standardised procedures for assessing fridge temperatures using a calibrated digital electronic thermometer and recording fridge and food data.

Development and validation of questionnaire and survey methods

A review of the current literature and fridge safety recommendations identified a number of key areas to be included in the questionnaire i.e. fridge safety, fridge temperature, storage and 'use by' dates for refrigerated foods, defrosting frozen foods, placement of foods within fridge, storage of leftovers and fridge cleanliness, along with a number of key observations/measurements to be carried out during the domestic visits. These areas along with collection of relevant participant demographic data were presented within a draft fridge safety questionnaire designed to explore current consumer knowledge, perceptions and behaviours relating to fridge temperature control and fridge related food safety on the Island of Ireland. A pilot study of the draft fridge safety questionnaire was conducted with a convenient sample of 20 participants, to assess face and content validity, structure and comprehensibility of the questions, and response scales. The information gained in this pilot study informed a number of refinements, including improved clarity of questions and possible responses. The final questionnaire and data collection protocol as agreed with **safefood** included 110 questions and/or observations within six sections:

Section A: "Food responsibility" - Participant responsibilities for food shopping; stocking the fridge; preparing and cooking food in the home; along with information on main shopping/top up shopping patterns.

Section B: "Fridge behaviours" - Participant practices in relation to temperature control; use of thermometers; temperature monitoring; and adjustment; frequency of fridge cleaning; placement of food; 'use by' dates in food purchase and storage.

Section C: "Fridge storage knowledge" - Participant knowledge of current 'best practice' guidelines on fridge temperature; placement of foods; storage of leftovers; defrosting foods; 'use by' dates.

Section D: “Food poisoning perceptions” – Participant perceptions of food safety risks associated with food preparation at home – in terms of individual and family susceptibility to food poisoning; severity of the consequences of food poisoning; effectiveness of risk reduction behaviours; barriers to the application of risk reduction behaviours; sources of food safety information; personal confidence in following safe food/fridge practice.

Section E: *Researcher observations* - Fridge type; make; model; temperature; current temperature control settings; nature and location of stored product; “use by” status of higher risk items.

Section F: *Demographics* – Participant/household gender; age; marital status; highest level of education; current occupation; occupation of highest income earner in household; number of adults and children within household and geographic location.

Ethical approvals

All necessary ethical approvals were obtained through the Research Ethics Committee of the School of Biological Sciences, QUB and written informed consent was obtained from all participants.

Completion of questionnaires and collection of fridge data

Sampling plan

All island representative participant and fridge data were collected by Social Market Research (SMR; a market research company) using quota sampling in respect to age, gender, social class and country of residence. All SMR personnel involved in the study were briefed on recruitment, administration of the questionnaire and the use of digital temperature assessment methods. Sampling (50:50 NI/RoI) was carried out in Belfast (n=34), Newcastle/Downpatrick (n=16), Dublin (n=20), Limerick (n=15) and Cork (n=15) during two periods, 25th November and 15th December 2013 and 13th to 17th January 2014.

Domestic interviews and collection of fridge data

Overall 100 appropriate participants (i.e. ≥ 18 years, responsible for at least half of the food shopping, food preparation and stocking of fridge in their household) were interviewed, and the temperatures of their fridges were determined, during home visits. The duration of each home visit was approximately 40-50 minutes.

Fridge temperature measurement

Researchers used calibrated conventional portable electronic thermometers (in line with current 'best practice') to assess fridge air temperature. The electronic thermometer was placed in the middle of the bottom shelf of each fridge at the start of the interview and allowed to stabilise for between 20 and 30 minutes. After completion of the questionnaire, the final achieved temperature was recorded. The temperatures of internal fridge surfaces and the surfaces of stored food items were also investigated using thermal imaging cameras (Appendix 1).

Additional fridge and stored food data

Researchers recorded additional data including:

- Make, model, energy rating and age of fridge
- Presence and position of a thermometer inside the fridge;
- Location of shelves and salad drawer
- Presence of any external LCD temperature display on the fridge door which displays the inner temperature,
- The placement of products on each shelf as well as the degree of shelf loading
- Adherence with 'use by' dates on high risk foods (cooked ready-to-eat meat products e.g. ham, pate, ready-to-eat-salad e.g. coleslaw, Smoked fish e.g. Salmon, Dairy products (e.g. milk, yogurt, cream)
- Adherence with storage instructions on food labels e.g. the number of days to consume a food once opened.

Data analysis

Data analysis using dedicated statistical packages

All data was entered in SPSS Version 20.0 (SPSS Inc, USA) using standard coding procedures. Means, standard deviation and range were calculated for continuous variables. Frequencies were derived for categorical variables. Kurtosis and skewness tests were carried out to assess the normality of the data. ANOVA and independent sample t-tests were performed to assess differences between groups. Scoring systems were derived to assess (a) participant reported fridge behaviour (i.e. what participants said they did) and (b) researcher observed fridge behaviour (i.e. what the researcher observed in the

fridge during the visit), with points awarded for stated/observed behaviour in line with current best practice recommendations.

Collection of external data on domestic fridges

The study confirmed that little or no data on the numbers, types and brands of fridges purchased on the IoI are available from the RoI Central Statistics Office (CSO) and the Northern Ireland Statistics Agency (NIRSA). However, some information was available from consumer research databases (Intel, Keynote and Euromonitor International) and consumer research reports, i.e. Intel (2013) and Keynote (2011) Keynote Household Appliances (White Goods).

5 Results

Demographics

Table 1 presents the demographic characteristics of the 100 participants interviewed in this study (66 females and 44 males). Participant ages ranged from 19 to 80 years (mean age 44.7). The majority (64%) of the households did not include children under the age of 16. Over half of participants (56%) were educated to 'GCSE'/Junior certificate level. Fifteen percent were educated to 'A' level/leaving certificate level, and 23% were educated to University level. Overall 49.0% of participants were social class ABC1 and 51.0% were C2DEF which is comparable to most recent census estimates of 44% ABC1 and 56% C2DEF (Census, 2011).

Table 1: Demographic characteristics of participants (n=100)

	Mean	Range
Age (Years)	44.7	19-80
Sample (%)		
Gender	Male	34
	Female	66
Social Class	ABC1	49
	C2DE	51
Geographic area	Belfast	34
	Newcastle/Downpatrick	16
	Dublin	20
	Limerick	15
	Cork	15
Marital status	Single	30
	With partner/married	52
	Widowed	11
	Divorced/Separated	7
Highest education completed	Primary/lower secondary	6
	Upper secondary vocation school	56
	Upper secondary school	15
	University	23

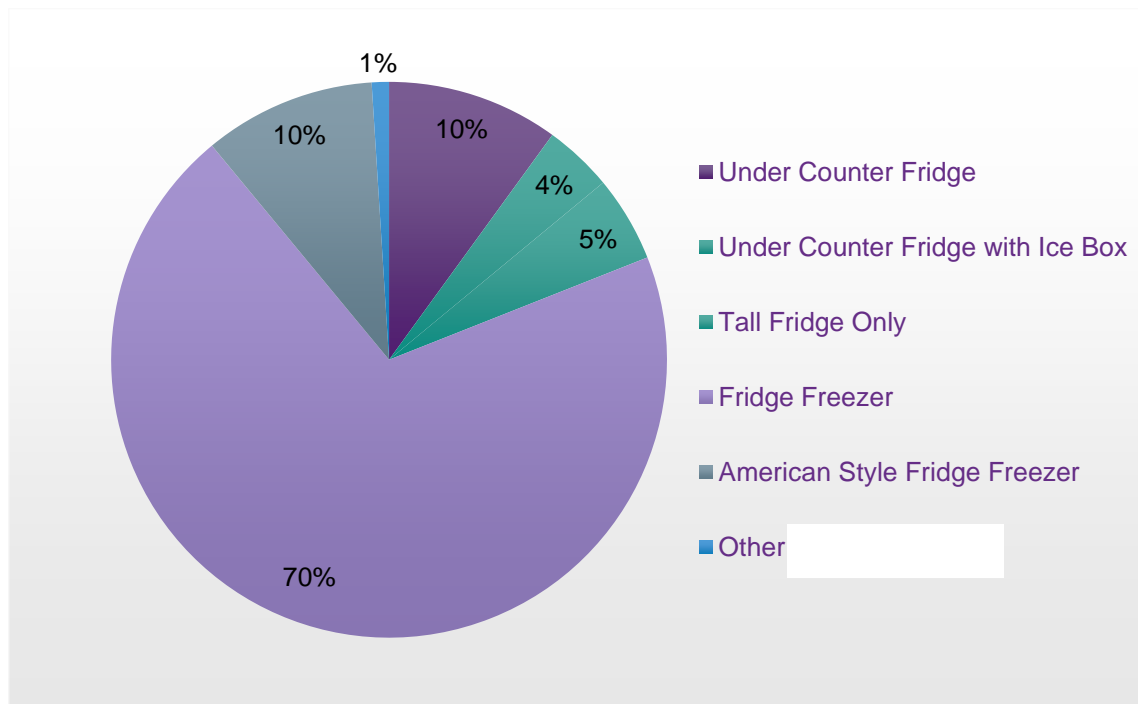
Food Responsibility

Overall, 98% of participants reported having responsibility for at least half of household food shopping and 99% of participants reported having responsibility for at least half of cooking, food preparation and fridge stocking. The majority of households (67.0%) carried out their main “food shop” on a weekly basis and 55% of participants reporting “top-up” shopping every 2-3 days. Twenty nine percent of participants reported top-up shopping on a daily basis. In relation to unpacking/storing purchased food, over two thirds (76%) of participants reported unpacking shopping within 1 hour of purchase and only 4% of participants reported taking longer than 2 hours to unpack shopping.

Fridge Design

The most common fridge type was fridge-freezer, reported by 70.0% of participants. The other reported types were American style fridge freezer (10%), under-counter fridge (10%), tall fridge (5.0%) and under-counter fridge with ice-box (4.0%) (Figure 1). Overall 90.0% fridges had a temperature control dial and 10.0% had an LCD temperature display.

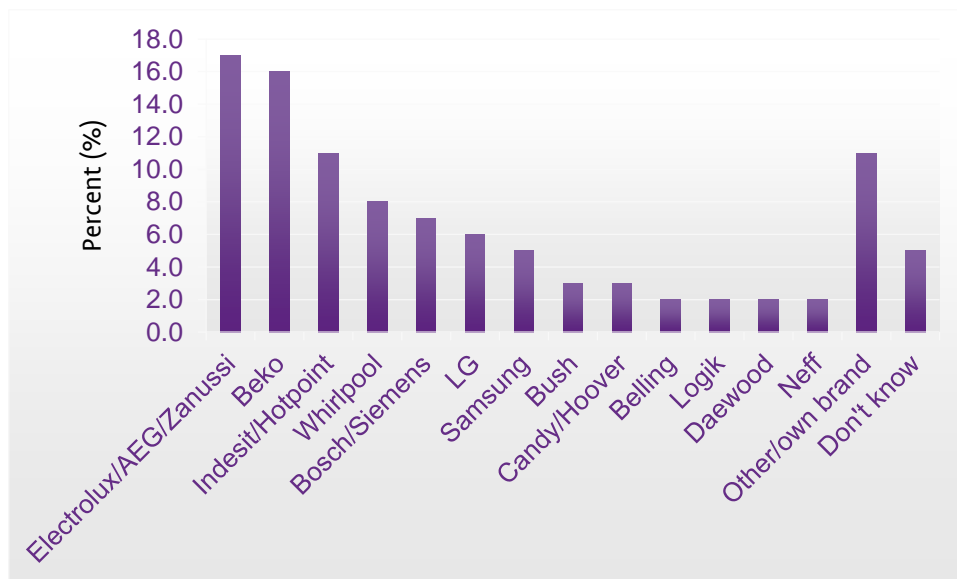
Figure 1: Proportion of households (%) with different fridge types



Twenty nine fridge brands were recorded, including Electrolux/AEG/Zanussi (17%), Beko (16%), Indesit/Hotpoint (11.0%), Whirlpool (8%) and Bosch/Siemens (7%) were the most commonly found making up over half of the sample (59.0%) of the sample (Figure 2). The mean fridge age was 6.0 years old. Slightly more than half of the surveyed fridges (52%) were < 5 years old, and 19% were \geq 10 years old.

The majority of participants (69%) did not know the energy efficiency rating of their fridge. Those who did know their fridge energy rating (39%) reported them as A+ (22%), A++ (3%) and A+++ (6%). The majority of the fridges surveyed were fitted with glass shelves and 88.0% had a salad box present. Fridge design data collected in this study are compared with UK data (Mintel, 2013) in section 5.9.

Figure 2: Range of domestic fridge brands observed in 100 households on the island of Ireland



Consumer Knowledge of Safe Fridge Storage

Temperature

Almost half of the participants (43%) correctly identified the bottom shelf as the coldest part of a fridge (Figure 3), and over a third of participants (35%) correctly identified 0-5⁰C as the recommended operating temperature for a domestic fridge (Figure 4). However, only 13% of participants correctly

identified the use of a fridge thermometer as the safest way to assess fridge temperature. Most participants (69%) reported not knowing where (in the fridge) to place a fridge thermometer.

Figure 3: Frequency of participant responses on which part of a fridge is normally the coldest (n=100)

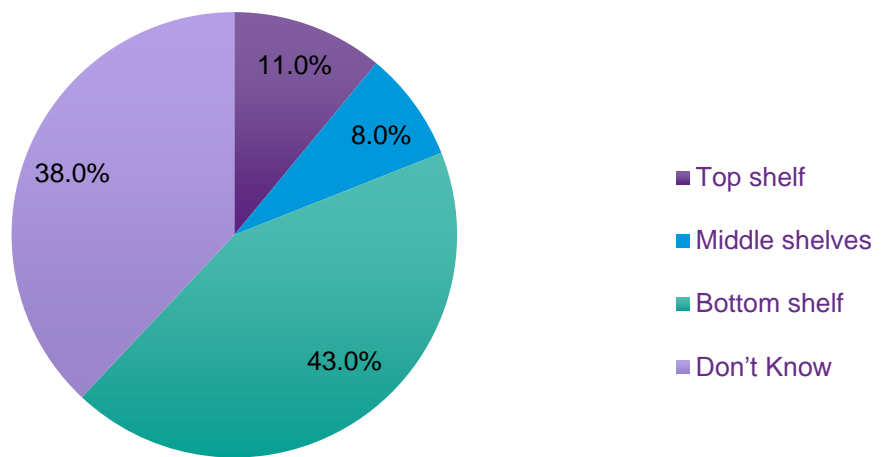
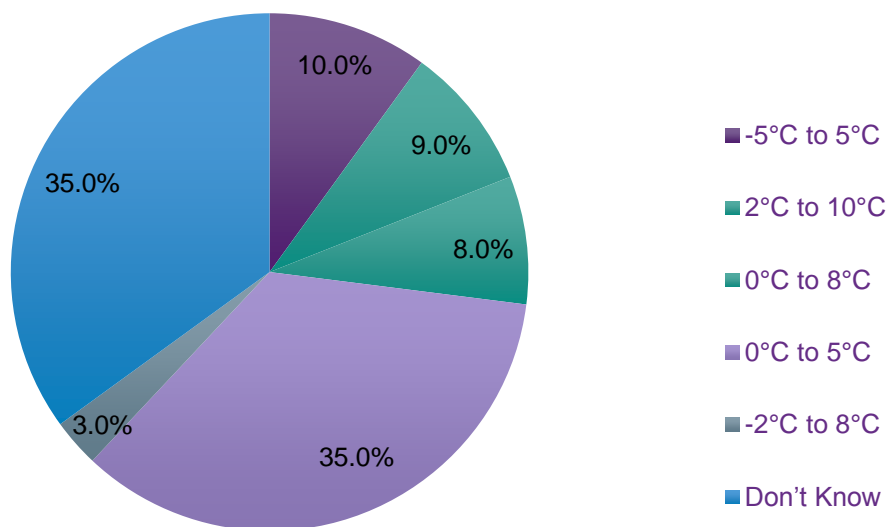


Figure 4: Frequency of participant responses on recommended operating temperature for a domestic fridge (n=100)



‘Use by’ dates

Almost a third of participants (31%) correctly identified that, after the ‘use by’ date, a food is no longer safe to eat and should always be discarded unless frozen before ‘use by’ date and subsequently used within 24 hours of defrosting. A further 39% correctly identified one aspect of current recommendations for ‘use by’ dates, with 44 participants identifying that food frozen before ‘use by’ can be consumed after ‘use by’ date and within 24 hours of being thawed.

Over half (57%) of participants identified the correct definition of a ‘best before’ date i.e. ‘After a ‘best before’ date that a food is still safe to eat but may begin to lose its flavour and texture’, whereas only 43% of participants chose “After a ‘best before’ date a food is no longer safe to eat and should be discarded”. The majority of participants (87%) correctly identified raw meat, and even higher percentage (97%) correctly identified raw poultry, as ‘high risk’ in terms of the growth of food poisoning bacteria. Other foods identified by participants as posing high risk in terms of growth of food poisoning bacteria included coleslaw (47%), smoked fish (37%), leftover rice (32%), ready meals (23%) and cooked meats (22%). More than half (54%) of participants correctly identified that a ‘high risk’ food should be thrown away if left at room temperature for more than two hours.

Storage of food after opening

Just over a quarter (28%) of participants correctly identified ‘use by’ date AND storage instructions on the food label as the two most important factors in determining if refrigerated food is safe to eat. Fifty seven other participants identified only one factor (‘use by’ date OR storage instructions on the food label).

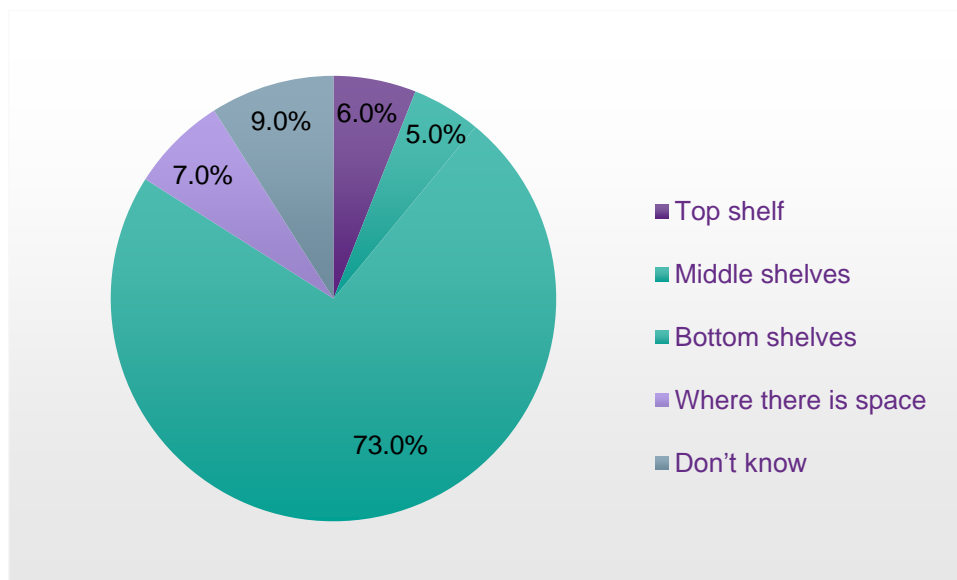
Defrosting food

Only 5% of participants correctly identified the two safest ways to defrost frozen raw meat, i.e. allowing the meat to thaw on the bottom shelf of refrigerator, and thawing in a microwave oven immediately before cooking. Of the remaining 95% of participants, over two thirds (69%) correctly identified one aspect of best practice guidelines for defrosting food. Overall 72% and 61% of participants correctly identified that raw and cooked food e.g. lasagne should be consumed within 24 hours of being completely thawed.

Placement of fresh food within the fridge and storage of leftovers

Almost three quarters of participants (73%) correctly identified the bottom shelf as the safest place to store raw meat (Figure 5). The majority of participants (81%) correctly identified that leftovers should be covered and cooled at room temperature for one to two hours before being placed in the refrigerator. However just over a third (37.1%) of participants correctly identified that it is safe to eat refrigerated leftovers within 3 days after initial cooking.

Figure 5: Frequency of participant responses on the safest place to store raw meat (n=100)



Reported fridge behaviours

Temperature control

Over half of participants (53%) reported that they had never checked the temperature of their fridge. Most of the participants, who said that they checked their fridge temperature, did so by checking that the food felt cold and only 2% of participants reported having a fridge thermometer.

‘Use by’ dates/storage instructions

Over 90% of participants reported checking ‘use by’ dates “always” or ‘most of the time’ before buying, preparing, freezing and consuming food with over three quarters of participants. More than 75% of participants reporting never consuming fresh meat and fish, cooked meats, milk, and coleslaw after the date on the label. Around 20% of participants reported that sometimes they consumed other foods including fruit, vegetables and salad, convenience foods (e.g. pasta sauce), cheese and yogurt and ready meals after the date on the label.

Storage of food after opening

The majority of participants (71-81%) reported never consuming fresh meat and fish, cooked meats, ready meals, milk, convenience foods e.g. pasta sauce, yogurt and coleslaw after the storage instructions on the label.

Placement of foods within the fridge

Almost three quarters of participants reported usually storing raw meat (70%) or raw poultry (72%) on the bottom shelf of refrigerator.

Fridge Cleanliness

Approximately two thirds (67%) of participants reported cleaning their fridge at least once a month (23 once a week, 16 once a fortnight and 28 every month). Fifteen participants reporting cleaning their fridge every three months and 17 only cleaned their fridge after a spill.

Observed fridge behaviours

Temperature

Observed fridge temperatures range from -4 to +12.5°C, after the exclusion of two sub-zero outliers, the mean fridge temperature of the remaining 98 fridges was calculated to be 4.9 °C. Fifty eight of the fridge temperatures were within the recommended range (0-5°C). Forty of the fridge temperatures were above the recommended range. In relation to fridge type, the under counter fridges with ice box had the lowest mean temperature 1.5°C, the tall fridges had a mean temperature of 4.1°C, the under counter fridges a mean temperature of 4.2°C, the combined fridge freezers a mean temperature of 5.0°C and the American style fridge-freezers a mean temperature of 5.6°C. Overall,

there were no significant differences among the mean temperatures of the fridge types examined ($P=0.171$). Two thirds (66%) of participants correctly identified that turning the thermostat towards a higher number reduced internal fridge temperature.

Placement of foods within the fridge

Ten of the examined fridges had ready-to-eat foods e.g. cooked meats and coleslaw on the top shelf (i.e. in the warmest part of the fridge). Fourteen of the fridges had raw meat on the middle shelves, 10 had raw bacon and/or sausages on the top shelf and 10 had cooked ready-to-eat foods alongside raw meat on the bottom shelf of the fridge.

Use by' dates and storage of food after opening

Eleven of the examined fridges contained sealed packs of "past use-by dated" 'high risk' foods (including milk, cooked ham, coleslaw, ready-to- eat fish and cream), and eight of the fridges contained opened packs of "past use-by dated" high risk foods (e.g. milk, cooked meat or ready-to-eat dips).

Further information

Participants identified their sources of information on current food safety recommendations and the prevention of food poisoning as: healthcare professionals (30%), health related websites (28%), *safefood* radio and TV adverts (23.0%), and the *safefood* website (11%).

Consumer perceptions of fridge safety in relation to developing food poisoning

Perceived Susceptibility

The relatively high mean score for the perceived susceptibility subscale was 4.0, indicating that participants recognised that failure to carry out the best practice recommendations for fridge safety, increased the likelihood that they or a member of their household would be at greater risk of developing food poisoning.

Perceived Severity

The relatively high mean score for the perceived severity was 4.0 indicating that participants knew that food poisoning could have severe consequences for them or a member of their household.

Perceived benefits, self-efficacy and perceived barriers

The mean scores for perceived benefits (4.1) and self-efficacy (4.1) which would suggest that, participants recognised the value of following best practice guidelines and felt confident that they had or could gain the knowledge needed to carry achieve best practice guidelines within their household.

The generally low mean scores for perceived barriers of 1.6 (1= no problem to 5 a big problem) suggests that potential barriers to safe fridge practices, i.e. lack of knowledge of 'best practice' recommendations; lack of understanding about use by dates and storage instructions; lack of time to carry out the recommendations; aspects of fridge design/layout; were not viewed as significant problems in following best practice recommendations in safe fridge practices. However, the mean score for access to a fridge thermometer (2.4) was significantly higher ($p < 0.001$) suggesting that this was viewed as a more substantial barrier.

Fridge Safety Knowledge, behaviours, perceptions and fridge temperature control

Participants whose fridge temperatures were **within** the recommended range had higher observed behaviour scores (6.6) than participants whose fridge temperatures were above the recommended range (5.4; $P < 0.001$). No other statistically significant relationships observed in relation to participant scores for perceived susceptibility; severity; benefits; barriers; cues to actions and temperature control; or among social classes or participant age. This may be due to the low statistical power associated with the small sample size (100 participants).

Collection of fridge specification data from manufacturers and statistics agencies

Fridge design

Domestic fridges are among the most frequently owned white goods. A recent market research study of 25,000 consumers reported in 2012, 93.3% of households owned a fridge and/or a freezer, and that consumers in the UK purchased more than 2.21 million domestic refrigeration appliances with a total market value of £618 million (Mintel 2013). The same study identified combined fridge-freezers as the most popular format with 65.6% households, with this design accounting for over half (57%) of appliances purchased in 2012, with standalone fridges and freezers making up 24% and 19% of the market respectively. Several factors are suggested to support the dominance of combined

fridge/freezers, including; lower price of combined fridge/freezer unit (compared to separate units), a smaller foot print, and increasing preference for “American Style” side-by-side units.

Companies and products

The Mintel report (2013) indicated Beko as the current market leader for fridge and freezers by volume, representing 421,000 units and 19% of the market share. Indesit/ Hotpoint represent 18% of the market volume having sold 399,000 units in 2012 and are the current market leaders in terms of value. Sales of Bosch/Siemens (7%), Samsung (7%), LG (6%) and Whirlpool (5%) represent 25% of market share by volume and together with Beko and Indesit/Hotpoint make up (62%) of the market share by volume.

Factors influencing the purchase of fridge freezers

The Mintel report (2013) indicated that over three quarters (79%) of respondents considered energy efficiency as the most important factor influencing the purchase of a fridge or freezer with 50% of respondents considering this factor as important and 29% considering it very important. Other important factors included; a reputable brand (75%), model (62%), and co-ordinated with other kitchen fittings (60%). There were some (respondent) age related differences, in that 90% of over 65's showed higher levels of interest in energy efficiency, as compared with 29% of under 25s, who reported that energy efficiency, and neither important nor unimportant.

Almost two thirds of respondents expected shelves on runners for easier access (66%) and automatic defrost (63%) as standard. More than half of respondents (54%) considered that odour control or anti-bacterial lining/coating should be available as standard in new fridges or freezers. More than 40% of respondents expected intelligent electronic controls (45%) and humidity control (40%) as standard.

Almost a third (30%) of respondents reported that they would pay more for a fridge with a freshness monitor/stock control system and 26% would pay more for integral chilled water/drink dispenser or ice dispenser maker. Over 20% of respondents would consider paying more for the inclusion of a barcode reader (24%), intelligent electronic controls (23%), recipe suggestions (22%), and/or compartments in fridges or freezers (21%). Respondents \leq 34 years were more likely to pay more for extra features.

Innovation in fridge manufacture

As fridges have become much more reliable in relation to their basic (low temperature) functions, fridge manufacturers are required to be highly innovative in coming up with new ways to encourage consumers to buy new appliances, including quieter and more energy efficient/lower running cost technologies, and greater convenience such as multi-compartment systems which reduce the frequency of opening the main fridge door, and reduce overall energy requirements.

Comparison of general fridge characteristics with current study observations

Most (70%) of the participants in the current study had combined fridge freezers which is comparable to the most recent market report (Mintel, 2013) which reported that 65.6% of surveyed households had a combined fridge freezer. The proportion of American style fridge freezers observed in the current study is also in line with that reported by Mintel (2013). The mean fridge age derived in the current study was 5.3 ± 0.3 years with 55.2% participants having a fridge < 5 years old. Both of these results are comparable to the results of WRAP (2010) which reported a mean fridge age of 4.3 years with 31% of participants having a fridge < 5 years old. These data suggest that between 55-66% of consumers had changed their fridge within the last five years, which is in general agreement with a previous study (Mintel, (2009) which suggested that the majority of white goods are replaced within a seven year cycle. An apparent trend towards higher mean temperatures in combined fridge freezers and American style fridge freezers than in tall and under the counter fridge only appliances, but this was not confirmed by statistical analysis.

6 Project Discussion and Key Findings

Temperature control

The overall mean fridge temperature of the fridges examined in this study was within the recommended range (0-5°C). However, the study recorded a very large variation in observed fridge temperatures (-4°C to +12.5°C), with over two fifths of fridges having an individual mean fridge temperature above, and in some cases, considerably above, the recommended range. These findings are comparable to the findings of Laguerre, Derens and Palagos (2002) who reported that 26% of domestic refrigerators had a mean operating temperature above 8°C. The findings of a study carried out by Laguerre and Flick (2004) have suggested that a rise in fridge temperature of 5°C that is sustained for 10 minutes can result in a doubling in the growth rate of some bacteria. Therefore a fridge with an operating temperature above the recommended range may impact on the safety of the refrigerated food especially ready-to-eat products such as cooked meats, smoked fish and prepared salads e.g. coleslaw. In the current study, although a trend towards increasing mean temperature in combined fridge freezers compared with fridge only appliances was observed using the conventional method, it did not reach statistical significance.

The findings of the current study also showed that only 2% participants reported having a fridge thermometer; however fridge thermometers were observed within 6% of fridges. In addition, only 12.4% of participants correctly identified using a fridge thermometer as the safest method for assessing fridge temperature and two thirds reported not knowing the recommended place to put a fridge thermometer. Also just over a third of participants correctly identified the recommended operating temperature for a domestic fridge of 0-5°C. This is a higher proportion of consumers (22%) that correctly identified the recommended operating temperature for a domestic fridge in the Kennedy et al. (2002). However it is still lower than that reported in other similar studies with the literature with carried out by (WRAP, 2010) of 329 households showing that over three quarters of participants (75%) were able to correctly identify the recommended operating temperature for a domestic fridge 0-5°C. This suggests that while there has been an increase in consumer knowledge between the study of Kennedy et al. (2002) and the current study, there is still a lack of consumer knowledge on the IOI in the recommended operating temperature for domestic fridge and the best practice guidelines on the frequency and method recommended for checking fridge temperature. It has been suggested (Ghebrehewet and Stevenson,2003) that training in this area can significantly increase consumer awareness/knowledge of recommended operating temperatures (from 31.7% to

78.4%), however it is less certain that such increases in knowledge have a similar impact on consumer behaviour (McCarthy et al., 2008).

Although consumer knowledge of recommended fridge temperatures on the lol has increased during the last twelve years i.e. from around 22% to over 33%, the presence of fridge thermometers has decreased from 23.2% to just 6% (Kennedy, 2002, the current study). This suggests that while consumer knowledge has increased, fewer households are now in a position to implement the best means of determining fridge temperatures. The current study found that “accessing a fridge thermometer” as the most significant barrier to implementation of best practice guidelines for assessing fridge temperatures. These circumstances suggest that activities to encourage greater availability of free standing fridge thermometers and/or refrigerators with built in (LED) thermometers, may enable consumers to apply their improving knowledge in improving practice.

Table 2: Comparison of findings of current study to *safefood* recommendation and findings observed by Kennedy et al. (2002)

Knowledge	<i>safefood</i> recommendation	Kennedy 2002	Current study
Recommended operating temperature for domestic fridges	0-5 ⁰ C	22%	35%
Safest methods for defrosting foods	bottom shelf of the refrigerator or defrost in microwave just before cooking	-----	4%
Reported fridge behaviour			
Storing meat correctly	store raw meat on bottom shelf	45%	76%
Defrosting foods correctly	bottom shelf of refrigerator or defrost in microwave just before cooking	36.7%	-----
Observed fridge behaviour			
Fridge thermometer present	non-mercury thermometer on bottom shelf	23.2%	6%
Mean fridge temperature	0-5 ⁰ C		4.9 ⁰ C
Mean fridge temperature within recommended range		41%	59%

Comparison of the findings of the current study with the findings of Kennedy et al. (2002) (Table 2) indicate that further work needs to increase consumer awareness of recommended fridge operating temperatures, and the importance of objective methods such as the use of a fridge thermometer, in 'best practice' assessment of fridge temperatures.

Use by dates/storage instructions on food labels

Study participants displayed considerable uncertainty and/or confusion in relation to use by/storage instructions on food labels. Just under a third of participants correctly identified the definition of a 'use by' date, and most of these participants also correctly identified that it was safe to eat a food which frozen before the 'use by' date, and used within 24 hours of being thawed. Previous studies in this area have reported that much higher percentages of consumers can correctly identify that 'use by' date as related to food safety, e.g. WRAP (2008) reported that 83% participants correctly identified 'it is not safe to eat a food after it's 'use by' date. However a more recent report WRAP (2010) showed that only 15% of respondents were able to correctly identify that a food that is a day past its use by date could be unsafe and should with thrown away. WRAP (2010) also reported that 25% of participants indicated that food which was one day past its use by date "may be unsafe but they would test it/use their own judgement".

In the current study, just under half of participants thought that, 'after its 'best before' date, a food is no longer safe to eat and should be discarded'. This is in agreement with other studies which reported that only 50% of consumers knew that a 'best before' date relates to food quality rather than food safety (WRAP, 2008). Another WRAP (2010) study reported at only a fifth (19%) of participants could correctly identify that a food that is one day beyond its "best before" date is 'past its best but not necessarily unsafe to eat.' Overall the findings of the current study confirm previous reports of continuing confusion regarding the difference between 'use by' dates (related to food safety) and 'best before' dates (related to food quality). Such confusion is significant in relation to food safety, but may also contribute to higher levels of food waste (WRAP, 2008).

Despite the undesirably high levels of consumer confusion in this area, the majority of participants reported checking 'use by' dates before buying, preparing and consuming foods and never consuming fresh meat and fish, cooked meats, ready meals, milk and coleslaw after the pack date. Nevertheless, inspection of fridge contents during the study observed that 11% of participants had "past use by date" 'high risk' foods e.g. cooked ham, coleslaw, ready-to-eat fish, milk and cream in their fridges,

and 8% of the fridges containing opened packs of 'high risk' food opened which had exceeded the storage period on the label.

Just over a quarter of participants correctly identified both of the two most important factors in assessing if a refrigerated food is safe to consume after opening, i.e. consideration of 'use by' dates and of storage instructions on food labels as. Among participants who correctly identified only one of these factors, three times as many participants correctly identified 'use by' date, as identified storage instructions. This is in contrast to the findings of previous studies which had indicated that consumers pay very little attention to storage instructions on food labels, such as "consume within X days of opening" (FSA, 2010).

In this study participants were able to identify raw meat and poultry as posing higher risks, and indicated that such foods should be disposed of more rapidly than other foods. This is in agreement with other studies which have shown that the extent to which consumers report that they follow storage instructions varies depending on food type, with consumers being most likely to follow storage instructions for fresh meat and fish and least likely to follow storage instructions for cheese and cooking sauces (WRAP, 2010).

Placement of fresh foods and storage of leftovers

Almost three quarters of participants correctly identified the bottom shelf as the safest place to store raw meat and almost half of participants correctly reported the bottom of the fridge as being the coldest region of the fridge. However, the fridge inspection observed 10% of fridges had ready-to-eat foods e.g. cooked meats and coleslaw on the top shelf (the warmest part of fridges). Other observations included raw meat stored on the middle shelves of 14% of examined fridges, uncooked bacon and/or raw sausages stored on the top shelf of 10% of examined fridges, and cooked ready-to-eat foods stored alongside raw meat on the bottom shelf of 10% of examined fridges (with potential risks of cross-contamination between these two forms/types of food). These observations suggest that although most of the study participants knew the safest place to store raw meats in refrigerators, some of them were still confused about the safest place to store cooked ready-to-eat food within their fridge.

Most, (81%) of the participants in the current study correctly identified the best practice recommendation for allowing leftovers to cool at room temperature for one to two hours before being stored in a fridge. This finding suggests that consumer knowledge has improved in comparison with

the observations of study of Kennedy et al. (2002) which reported that the majority (57.6%) of participants stored meat leftovers in the fridge, 6.0% in the oven, 5.2% at room temperature, 2.9% in the freezer and 1% in an unrefrigerated cupboard.

Consumer perceptions

In the current study, participants did not consider factors such as lack of time or knowledge as significant barriers to being able to reduce the risks of food poisoning (of themselves or their families). However, they did consider that lack of access to a fridge thermometer was a more significant barrier to good fridge safety. The study noted better consumer knowledge and better fridge behaviours among in participants whose fridges were operating within the recommended fridge temperature range (0-5°C), than among participants whose fridges were operating at temperatures above the recommended range, a finding that in agreement with previous studies (Kennedy et al., 2005; McCarthy et al., 2007) Further research, using a larger number of participants, would provide the higher statistical power necessary to investigate associations among consumer knowledge, perceptions and behaviour, across different social classes, levels of educational attainment and ages. Such investigations would allow identification of those subsets of consumers whose knowledge, perceptions and behaviours lead to unsafe fridge practices, and increase their risks of suffering foodborne illness.

7 Conclusions

The findings of the current study have highlighted seven key areas of concern in relation to consumer knowledge and practice in fridge and food safety:

1. Consumers lacked and/or did not apply knowledge of the recommended operating temperature for domestic fridge and the best practice guidelines in relation to monitoring fridge temperature.
2. A third of the consumers did not know how to adjust their fridge settings to a temperature within the recommended (safe) range (0-5°C).
3. Over two fifths of fridges had an operating temperature above the range recommended to prevent food poisoning, and only 6% of fridges had a fridge thermometer
4. Although the majority of consumers reported that they did not consuming refrigerated foods past the 'use by' date on the label, considerable amounts of past "use by" date foods were observed in their fridges.
5. Confusion remains in relation to the meanings of 'use by' (which is principally about safety) and 'best before' (which is principally about quality). Such confusion has significant implications in consumer safety, but also has wider implications in terms of the possible unnecessary generation of higher levels of food waste.
6. Consumers are uncertain about how long 'high risk' foods can safely be kept at room temperature before they becomes unsafe to eat.
7. Most consumers know to store raw meat and poultry on the bottom shelves of the fridge, but remain confused about the best place to store cooked ready-to-eat foods, and the importance of organising fridge contents to prevent cross contamination between raw and ready-to-eat foods.

The study has highlighted gaps in consumer knowledge and potential barriers which may prevent consumers from carrying out the 'best practice' recommendations. This information can be used by **safefood** to inform future campaigns and literature targeted at consumers.

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9 Appendices

Appendix 1: Pilot testing of the temperature measuring equipment: methodology and implementation

The current 'best practice' method (conventional method) recommended by *safefood* for the assessment of domestic fridge temperature is standard electronic thermometer (mercury thermometers are not recommended and rarely used nowadays) to measure the air temperature of the fridge on the bottom shelf. In this project, the application of a thermal imaging camera was proposed as an alternative method to determine domestic fridge mean temperatures. In contrast with standard thermometers, however, infrared thermal imaging measures the surface temperature of foods which in theory should be the same as the air temperature if the fridge door was been closed for a certain period. Also air temperature has been shown to change quickly once the fridge door has been opened whereas the surface temperature of food seems to stay stable for longer. Therefore, measuring the surface temperature of foods using the thermal imaging camera may be more accurate method using a fridge thermometer to measure air temperature. The information in a thermal image is also richer and more informative as it can show the distribution of air temperature in the fridge and can identify areas within the fridge where due to air circulation; the cooling effect is less effective than other areas. It can also reveal if a warm food recently added in a cold fridge, which in turn leads to increases in overall fridge temperature and may have impact on food safety.

A pilot study of the temperature measurement by thermal IR camera was carried out in a convenience sample of eight fridges of four designs (three upright fridge/freezers, three under-counter fridges, one under counter fridge with icebox and one upright larder fridge). The pilot study was carried out to: 1. Ensure that the thermal IR camera was operating as expected, 2. Determine the optimal measuring distance when using the when using thermal imaging to assess temperature in different fridge types, 3. Identify problems that may occur. The optimal distances and potential problems identified were incorporated into the standardised operating for assessment of fridge temperature using the thermal camera and software. The test method using FLIR E60 thermal camera to assess fridge temperature was compared with the reference method for assessing fridge temperature using manufacturer calibrated fridge thermometer with accuracy $\pm 0.5^{\circ}\text{C}$. The findings showed that overall the IR measurements under/overestimate the mean temperature by 4.3-16.0% compared with standard

digital fridge thermometers. Even if in theory the two methods are not based in the same principle (air vs surface temperature) the trial showed no significant differences within the controlled conditions (4 fridges, 1 camera, 1 user). The outcome of the pilot study of thermal temperature measurement was a Standard operating procedure for assessing fridge temperature and a training document for training field workers in procedure for the measurement of fridge temperature by thermal imagery.

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