

Going Beyond the Fridge Door to Explore Domestic Food Safety Risks

Ellen W. Evans and Elizabeth C. Redmond*,

ZERO2FIVE Food and Drink Research Unit, Cardiff Metropolitan University, Cardiff, CF5 2YB, Wales, United Kingdom.

Corresponding author: eredmond@cardiffmet.ac.uk

Abstract

Increased consumer demand for convenient ready-to-eat food, along with changes in consumer purchase/storage practices, have resulted in increased reliance on refrigeration to maximize food safety. UK recommendations for domestic refrigeration are $\leq 5.0^{\circ}\text{C}$. Firstly, this study identified and reviewed consumer food safety studies ($n=165$) utilising a content-analysis approach. Only 40 studies related to refrigeration, which included assessment of knowledge (58%) and self-reported practices (48%). Forty-five-percent of studies included refrigerator operating temperatures; 9–100% were operating above recommendations. However, in several studies, temperatures were determined by a single temperature data-point; which, given temperature fluctuation, may not be a true indicator of refrigerator performance.

Consequently, this study conducted a time-temperature profiling study of domestic refrigerators in consumer kitchens ($n=43$) over 6.5 days with concurrent self-report refrigerator usage and assessment of consumer cognition relating to refrigeration ($n=100$).

Findings established a significant difference ($p<0.05$) between one-off and mean operating temperatures. No refrigerator operated at $\leq 5.0^{\circ}\text{C}$ for the entire study. Mean temperatures $\geq 5.0^{\circ}\text{C}$ were recorded in 91% of refrigerators. A positive correlation ($p<0.05$) between room temperature and refrigerator temperature was determined. Reported door opening frequency correlated with temperature fluctuation ($p<0.05$). Although the majority (79%) had a positive attitude towards refrigeration being essential to maintain food safety, fewer (52%) had positive attitudes towards the importance of checking refrigerator temperatures. The majority (87%) did not know the recommended temperature and 72% did not know the operating temperature of their refrigerator; 65% reported to 'never' check temperatures. Those with positive attitudes towards refrigeration were significantly more likely ($p<0.001$) to report checking temperatures, however, no significant associations ($p>0.05$) were determined between knowledge, attitudes, self-reported practices and refrigerator operating temperatures.

Cumulatively, findings established the majority of domestic refrigerators operate at potentially unsafe temperatures influenced by consumer usage. Combining temperature profiling data with cognitive data may inform interventions to improve domestic refrigeration practices.

Introduction

Convenient, fresh foods with minimal preservatives and low thermal processing has led to increased sales of refrigerated ready-to-eat (RTE) foods worldwide¹. Such foods are commonly associated with listeriosis due to the ability of *Listeria monocytogenes* to survive and grow at refrigeration temperatures². Consequently, effective temperature control of RTE-foods by consumers in the domestic kitchen is critical for food safety as inadequate refrigeration practices are believed to increase the risk of foodborne illness³. UK recommendations for domestic refrigeration are $\leq 5.0^{\circ}\text{C}$ ⁴.

This study aims to explore consumer cognitive influences associated with food safety, domestic refrigerator use and profiled domestic refrigerator operating temperatures/reported practices.

Methodology

Review of consumer food safety studies:

- A systematic literature review was conducted to obtain consumer food safety data; primary research papers were reviewed and analysed using a content analysis approach.

Domestic time-temperature profiling:

- Time-temperature profiles of refrigerators ($n=43$) in domestic kitchens were determined using three Signatrol SL52T self-contained button dataloggers (range: -40°C – $+85^{\circ}\text{C}$; accuracy: $\pm 0.5^{\circ}\text{C}$; frequency: every minute) over 136 hours, positioned in the centre & door areas, and outside of the refrigerator.
- Households ($n=43$) documented refrigerator usage during profiling.

Cognitive analysis of consumer refrigeration behaviors:

- Consumers ($n=100$) completed quantitative self-complete questionnaires to determine knowledge, self-reported practices and attitudes towards domestic refrigeration practices.

All components of this research received ethical approval from the Cardiff Metropolitan University Healthcare and Food Ethics Panel.

Results

Review of consumer food safety studies: focus on refrigeration

- A comparison of knowledge, attitude, self-reported practice and actual behavioural data relating to domestic refrigeration is found in Table 1.
- Review analyses determined that in the UK, 35% of consumers claimed to know what temperature their refrigerator should be operating at, however only 18% were correct⁵.
- Self-report data determined that ownership of a refrigerator thermometer was low in countries including Europe and USA.
- In total, 26% of studies presented data on measured operating temperatures of domestic refrigerators; between 9% and 100%⁶ were found to be operating above recommended temperatures to ensure food safety.

Table 1. Consumer knowledge, attitudes, self-reported practices and actual behaviour associated with domestic refrigeration practices ($n=68$ reviewed studies).

Knowledge	Attitudes	Self-reported practice	Actual behavior
44-68% consumers did not know recommended refrigeration temperatures.	58-72% consumers perceived it to be very important to take perishable foods home quickly after purchase 34% felt that the most important thing that they do to keep food safe from 'germs' is refrigerate foods promptly.	Up to 24% consumers reportedly own/ have a thermometer in their refrigerator. 65-75% consumers, reportedly do not or have never checked/ measured the operating temperature of their refrigerator.	70-81% older adults' refrigerators operated at temperatures in excess of recommended guidelines. 47-71% of consumer refrigerators operated at temperatures exceeding recommended guidelines.

Adapted from Evans and Redmond (2015)⁵.

Consumer cognitive influences regarding domestic refrigeration

Attitudes

- Consumers had positive attitudes towards the perceived importance of refrigeration in relation to food safety and were aware of practices to ensure the refrigerator remains cold; however, knowledge of the recommended operating temperature was lacking (Table 2).
- Attitudes towards checking the refrigerator operating temperature were negative.

Table 2. Attitudinal responses to domestic refrigeration practices.

Attitudes towards food safety	n	Positive attitude (%)	Neutral attitude (%)	Negative attitude (%)
I am concerned about the length of time the refrigerator door is open for	100	88	5	7
Ensuring a refrigerator runs at 5°C or less is essential for maintaining the safety of foods	97	79	18	3
There is no need to check the actual temperature of my refrigerator	100	51	24	25

Knowledge and self-reported practice

- The majority (70%) of consumers in this study reported that they did not know the operating temperature of their own domestic refrigerator.
- The majority (56%) reported that they 'never' check the operating temperature of the their domestic refrigerator.

Time-temperature profiling and self-reported refrigerator use

- The age of domestic refrigerators ($n=43$) ranged from 4 months to 30 years.
- Refrigerator operating temperatures ranges can be seen below. Key findings indicate that operation temperatures ranged from -0.15°C to 17.90°C ; an average difference of 1.94°C was determined between refrigerator doors and central storage locations.
- 21% of domestic refrigerators had mean operating temperatures adhering to recommended safe operating temperatures.

Door operating temperature range: -0.15 – 17.90°C (mean = 7.84°C)

Central operating temperature range: -1.72 - 16.91°C (mean 5.88°C)

Door/central temperature difference: 0.02 – 4.51°C ; (mean 1.94°C)

Temperature fluctuations ranged from 1.51 - -6.03°C (mean 3.47°C)

- No statistical differences ($p>0.05$) were determined in (a) operating temperature according to refrigerator age or (b) refrigerator operating temperatures according to refrigerator type.

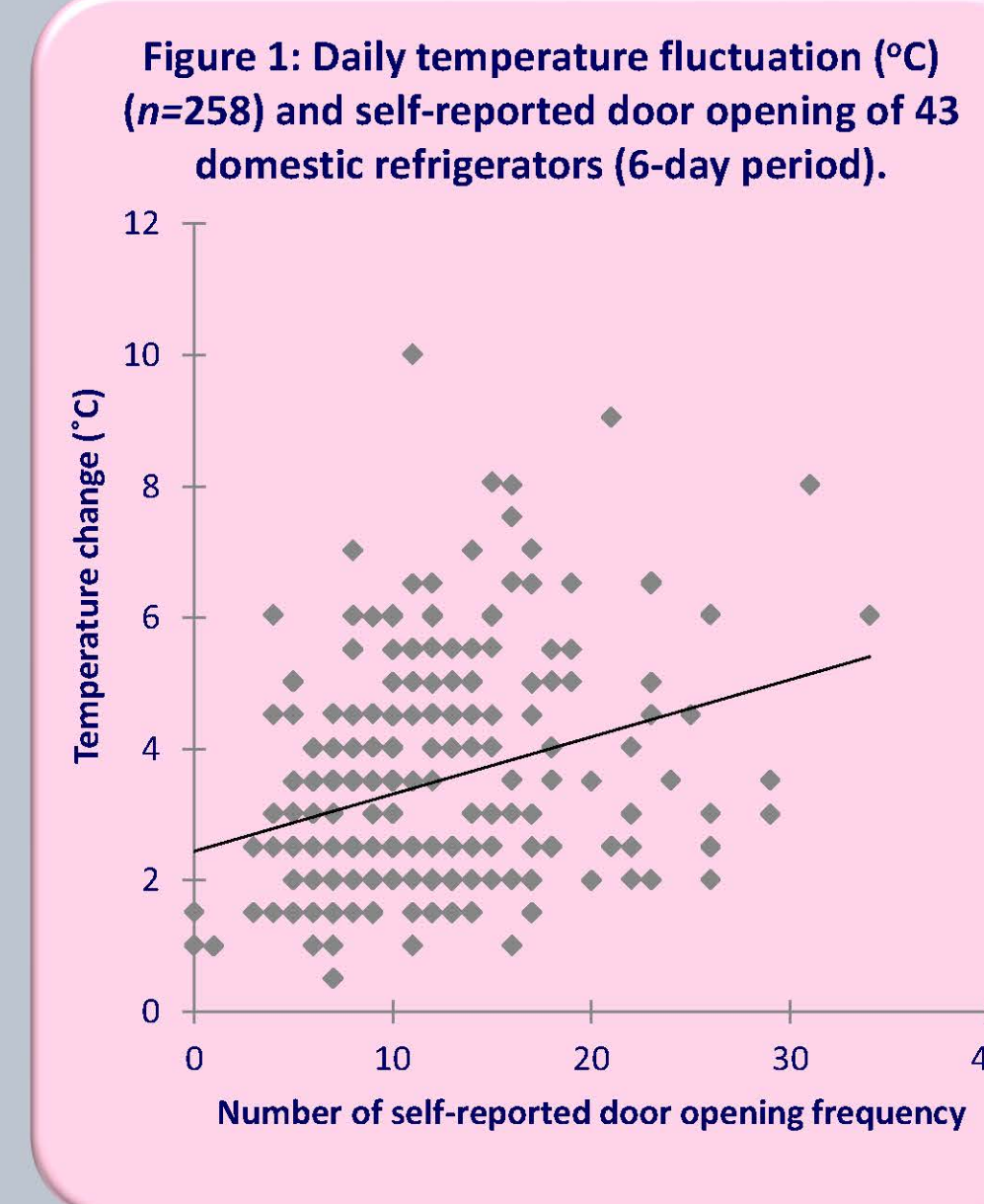
Consumers reporting to check the refrigerator temperature 'every day' and 'every week' were significantly more likely ($p<0.05$) to have mean refrigerator temperatures in-line with recommendations ($\leq 5^{\circ}\text{C}$), than those reporting 'every three months' and 'less than once a year'.

- Findings indicated that 40% central storage and 67% refrigerator door storage locations operated at unsafe ($>5^{\circ}\text{C}$) temperatures for the duration of the datalogger study (136 hours).
- No refrigerator doors or central storage locations operated at $\leq 5^{\circ}\text{C}$ for the whole duration of the study.
- 9% had a door and central temperature that was $\leq 5^{\circ}\text{C}$ for 75% of the study.
- Temperature changes correlated with self-reported use (Figure 1).

- A positive correlation between the ambient temperature of the kitchen and the temperature of the refrigerator was determined ($r=0.786$, $n=8192$, $p<0.005$).

- After putting food shopping away into refrigerators, it took up to 18 minutes to reach a maximum increase of temperature and 6-782 minutes to return to original temperatures.

- Findings illustrate that consumer refrigeration practices influence operating temperatures.



Discussion

Positive consumer attitudes towards the need for correct refrigerated temperature storage have been identified; however large proportions of consumers did not know what recommended refrigerator operating temperatures were.

- Previous consumer food safety research suggests that knowledge does not transpose to self-reported or actual behaviour^{6,7}, however, in this study a significant difference ($p<0.05$) was determined between safe/unsafe average operating temperatures of domestic refrigerators according to consumer knowledge of the recommended max operating temperature.

- 57% of consumers that knew the safe temperature had refrigerators with an average operating temperature of $<5^{\circ}\text{C}$; whilst 89% of those that did not know the maximum recommended temperature having refrigerators with an average operating temperature of $>5^{\circ}\text{C}$.

Temperatures of older adults refrigerators were found to be higher / worse (9% operated $0-5^{\circ}\text{C}$ for 75% of time) than in the kitchens of general consumers (10% operated $0-5^{\circ}\text{C}$ for 90% of the time)⁸.

Temperature changes were found to be significantly correlated with door opening frequency resulting from heat gains during door openings⁹.

Conclusions

- Although consumers were aware of the importance of refrigeration to ensure food safety, knowledge of safe refrigeration practices was lacking, attitudes towards checking temperatures were negative and the majority reported to never check the temperature.**
- Temperature profiles indicate that majority of consumers store RTE foods at unsafe temperatures which may increase risk of listeriosis.**
- Findings highlight the need for consumers to improve domestic kitchen refrigeration practices and data from this study may be used to inform development of targeted food-safety strategies.**

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