DOMESTIC FOOD PRACTICES IN NEW ZEALAND 2005-2006 PROJECT REPORT

Prepared as part of a New Zealand Food Safety Authority contract for scientific services

by

Susan Gilbert
Dr Glenn Bayne
Dr Tecklok Wong
Dr Rob Lake
Rosemary Whyte

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Institute of Environmental Science & Research Limited
Christchurch Science Centre
Location address: 27 Creyke Road, Ilam, Christchurch
Postal address: P O Box 29 181, Christchurch, New Zealand
Website: www.esr.cri.nz

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Dr. Stephen On
Food Safety Programme Manager

Rob Lake
Project Leader

Peter Cressey
Peer Reviewer

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SUMMARY

A significant proportion of foodborne illness is thought to be caused by unsafe food handling practices in the home. Data on the food handling practices of New Zealanders is limited. This project was initiated to provide more, and better targeted information on domestic handling of meat and poultry in New Zealand. The information is needed to support risk assessment by the New Zealand Food Safety Authority, particularly the development of quantitative risk models to assess potential interventions.

The project was carried out over two years; July 2004 – June 2006. During the period 2004-2005, the project developed and administered two surveys; one on refrigerators, including measurements of operating temperatures, and a postal survey investigating meat and poultry handling practices, and aspects of food purchasing and transport relevant to food safety.

During the 2005-2006 period covered by this report, the project has principally investigated temperature profiles for meat and poultry during simulated transport home, and transfer rates of *Camplyobacter* under simulated domestic handling conditions.

Meat and poultry packs were stored in various packaging conditions and placed either in a car boot or car interior to simulate the period between purchase and storage of these products in the home. The temperatures of the products were monitored over several hours during three experiments each in summer and winter. Rates of temperature increase were determined to provide parameters to allow the estimation of temperature changes for modelling purposes.

Cross contamination from raw poultry to surfaces, hands, and other foods, is often cited as the key route for ingestion of *Campylobacter* originating from poultry in the home, as proper cooking readily eliminates the organism. During several preliminary experiments, this study developed a protocol with sufficent sensitivity to determine the low rates of bacterial transfer that occur during such processes. The study used naturally occurring *Campylobacter* on poultry. This approach presented sensitivity challenges, but avoided the need to artificially spike samples with bacteria. Following development of the protocol, it was used to investigate transfer rates under simulated handling of poultry breast meat portions. Transfer rates were low (<5%), but consistent.

This study has provided valuable data which can be used as generic inputs into quantitative risk models. The data on temperature increases during transport home provides graphic illustration of the importance of using insulated packaging, and storing food out of direct sunlight. The transfer rate data are similar to those from the most recent overseas publication on the topic, but incorporate the variability inherent in individual chicken portions without the need to make assumptions about uniformity of contamination. In addition, an important transfer step, from fingers to lips, is simulated. The total bacterial budget approach avoids the need to estimate such variables as proportion of surfaces in contact, and the use of different operators in the experiments goes someway to mimicking the variability that could be expected amongst the population performing the same task.

Although the transfer rates determined in these experiments are low, the use of similar values in the New Zealand *Campylobacter* in poultry risk model indicate that with frequent potential exposure events, large numbers of infections and illnesses can result.

1 INTRODUCTION

A significant proportion of foodborne illness is thought to be caused by unsafe food handling practices in the home. Data on the food handling practices of New Zealanders are limited, with the main sources being four postal and telephone surveys conducted in the 1990s (Durham *et al.*, 1991, Hodges, 1993; Kerslake, 1995; Bloomfield and Neal, 1997). Much of the information collected by these surveys related to consumer awareness of food poisoning rather than food handling practices

This project was initiated to provide more, and better targeted, information on domestic handling of meat and poultry in New Zealand. The information is needed to support risk management by the New Zealand Food Safety Authority, particularly the development of quantitative risk models to assess potential interventions. The project was begun in 2004-2005 and continued for 2005-2006.

In 2004-2005, ESR conducted a survey of domestic refrigerators (including a questionnaire assessing consumer knowledge and measurements of operating temperatures), as well as a postal survey of domestic handling practices throughout New Zealand (Gilbert *et al.*, 2005). This current report describes activity in 2005-2006, the principal components of which have been:

- Provision of information to the Foodsafe Partnership and NZFSA (see Appendix 1) for a press release (http://www.foodsafe.org.nz/news/2005-11-15-2.htm) and participation in publicity about the full refrigerator survey during November – December 2005 (results from the pilot were reported in 2004-2005);
- Review of research by Meat and Livestock Australia and development of a protocol for experiments on the temperature changes associated with meat and poultry during transport from retail purchase to home;
- Experiments on temperature changes during simulated transport conditions conducted in both January (summer) and June (winter) 2006;
- Literature reviews on defrosting of meat (see Appendix 2) and swabbing of refrigerators, and discussion with NZFSA to decide that literature data were sufficient and further experiments were not needed;
- Review of literature on bacterial transfer rate experiments (see Appendix 3), and discussions with NZFSA to determine experimental topics for determination of bacterial transfer rates;
- Design and preliminary experiments investigating transfer rates in April 2006; and,
- Experiments during May – June 2006 to investigate transfer rates of *Campylobacter* between retail poultry and various surfaces.

2 TEMPERATURES OF MEAT AND POULTRY DURING TRANSPORT FOLLOWING PURCHASE BY DOMESTIC CONSUMERS

2.1 Aim of the Study

The aim of this study was to determine the temperatures experienced by packs of meat and poultry during transportation by consumers between point of purchase and the home. The primary purpose was to provide data that would allow an assessment of potential growth by pathogenic micro-organisms present on the meat or poultry. A secondary purpose was to provide information of relevance and interest to consumers for a food safety promotion campaign late in 2006.

The 2004-2005 survey of consumer behaviour had shown that the majority of respondents (89%) used a car for transport of food home following purchase, and that was the basis of the experiments in this study. Experiments were designed with reference to a similar study in Australia (MLA, 1998). Ian Jenson at Meat and Livestock Australia (MLA) was contacted and generously provided a copy of their study methodology and results on consumer meat transportation.

2.1.1 Method

Temperature profiles of supermarket retail packs of fresh chilled meat and poultry were determined by placing data-loggers on or within the food, putting the packs inside a car interior or boot either in the plastic bags supplied or in an insulated cooler bag, and recording the temperature each minute for several daylight hours.

Packs of meat and poultry of approximately 500g were purchased from chilled displays as consumer wrapped products (expanded foam trays with over-wrap film) at a local supermarket. The meats chosen were;

- beef mince;
- beef rump steak;
- beef sausages; and,
- chicken drumsticks.

As soon as possible after purchase (approximately 5 minutes in the supermarket car park), one data logger was placed inside the meat (knife slits were made into the meat) and another on the surface between the meat and over-wrap, with the sensory part of the data-logger facing down towards the meat. Some packs were then placed in cooler bags (all bags were identical), with the remainder left in the plastic bags supplied by the supermarket. After driving back to ESR (approximately another 5 minutes) the meat/poultry packs in their packaging were transferred to the interior or boot of the experiment car.

Experiments were conducted on clear sunny days in both winter (June) and summer (January). Each experiment was run for at least 5 hours during the middle of the day, in the same car (blue saloon four-door Honda Accord 1995) parked in sunlight in the same position in the ESR carpark, with the (non-tinted) windows shut.

The ambient temperature of the interior and boot of the car, and the external temperature (data logger hanging from a tree) were also recorded. The storage condition options for the meat were:

- Plastic supermarket bag;
- Insulated cooler bag (10 litre fabric cooler-bag 35cm height x 28cm width x 9cm breadth);
- Insulated cooler bag with a frozen icepack.

There were a multiplicity of potential storage and meat type combinations, and the experiments were restricted by the number of available data loggers. The experiments conducted on each date are given in Table 1.

Table 1: Configuration of meat and the several variables tested

Meat type	Boot Cooler Bag with Icepack	Boot No packaging	Car Interior Cooler Bag With Icepack	Car Interior No packaging	Boot Cooler Bag No Icepack	CarCooler Bag No Icepack
Summer 11 January 2006						
Mince	!	!	!	!	!	!
Steak	!	!	!	!		
Chicken	!	!	!	!		
Sausages	!	!	!	!		
Summer 13 January 2006						
Mince	!	!	!	!		
Steak	!	!	!	!		
Chicken	!	!	!	!		
Sausages	!	!	!	!	!	!
Summer 17 Janaury 2006						
Mince	!	!	!	!		
Steak	!	!	!	!		
Chicken	!	!	!	!	!	!
Sausages	!	!	!	!		
Winter 6 June 2006						
Mince	!	!	!	!	!	!
Steak	!	!	!	!		
Chicken	!	!	!	!		
Sausages	!	!	!	!		
Winter 9 June 2006						
Mince	!	!	!	!		
Steak	!	!	!	!		
Chicken	!	!	!	!		
Sausages	!	!	!	!	!	!
Winter 14 June 2006						
Mince	!	!	!	!		
Steak	!	!	!	!		
Chicken	!	!	!	!	!	!

Sausages	!	!	!	!		

The temperature data from the data-loggers were downloaded the following day, into Microsoft Excel (version 2000) spreadsheets and analysed.

2.1.1.1 Data loggers

The data-loggers used for the experiments were Thermochron iButtons®. The limited number of data-loggers fell into three different categories according to their temperature range. These were –5°C to 26°C, - 20°C to +85°C and –40°C to 85°C. The shorter range of data-loggers were used in situations where 26°C was not exceeded, such as in the boot in cooler-bags containing icepacks. The data-loggers were calibrated against a reference thermometer and found to be accurate to within +/-1°C. The mean difference between the data-loggers and the reference thermometer was 0.27°C with a standard deviation of 0.20°C.

There were three instances where dataloggers failed:

- 6th June: the logger in the boot measuring the chicken drumstick surface temperature and the logger in the car measuring the surface of steak (coolerbag with icepack) failed.
- 9th June: the data logger measuring the ambient temperature of the boot failed.
- 14th June: the data logger measuring the surface temperature of the chicken drumsticks in the coolerbag with an icepack in the boot was found to have fallen out. The temperatures from this logger did not follow that pattern seen with the same experiment on other days, and so these data were not used.

2.2 Australian and New Zealand; Test Parameters Compared.

Table 2 presents the test parameters used in the MLA Australian study for comparison with those used in the ESR experiments.

Table 2: MLA and ESR test parameters compared

Location	**Melbourne, Australia (MLA)**	**Christchurch, New Zealand (ESR)**
Season	Summer, Winter	Summer, Winter
Meat products	Beef mince Sirloin steak Lamb leg Lamb chops	Beef mince Beef rump steak Beef sausages Chicken drumsticks
Weight of meat	1 kg	500g – 600g
Transport variables	CB with icepack - boot No CB - boot CB with icepack – interior No CB - interior	CB with icepack - boot No CB - boot CB with icepack – interior No CB - interior Plus For 1 meat type per experiment: CB, no icepack - boot CB, no icepack - interior
Total time duration and recording interval	2 hours; 10 minute intervals	5 hours; 1 minute intervals
Location of data-loggers	Internal meat Surface meat	Internal meat Surface meat

	Ambient car interior Ambient car boot	Ambient car interior Ambient car boot External temperature in shade
Retail outlet	Butcher and supermarket	Supermarket
Trial replication	8 replicates	6 replicates
Car type	Gold coloured Ford Falcon	Blue coloured Honda Accord

CB: Cooler-bag, 10 litre.

2.3 Results

In the analysis that follows, the intention has been to generate information that can be used as generic inputs into risk assessment models. Consequently, within the summer or winter results, the data have been aggregated wherever possible to provide predictive equations that can serve for as wide a variety of foods and scenarios as possible.

2.3.1 Ambient, car interior and car boot temperatures

The average temperatures shown in Table 3 indicate the heating effect of sunlight on internal car temperatures. The effect is greater for the car interior than the boot.

Table 3: Mean weather, car interior and car boot temperatures

		Mean temperature (°C)		
	Time	**External**	**Car interior**	**Car boot**
Summer				
11th January	11:39 – 16:39	24.6	40.1	31.9
13th January	11:42 – 16:42	24.1	40.5	34.6
17th January	11:40 – 16:42	21.4	45.7	32.7
Mean		23.4	42.1	33.1
Winter				
6th June	11:55 – 16:55	13.1	21.2	16.8
9th June*	10:22 – 16:52	12.5	18.0	N/A
14th June*	10.08 – 16:38	8.7	19.9	11.9
Mean		11.4	19.7	14.3

N/A = not available due to data logger failure.
*Note: trial lasted 6.5 hours

The temperature profiles for these measurements are shown in Figures 1-4. The boot temperatures are relatively stable, while the car interior temperatures peak around midday. There is no explanation for the early peak in temperature in the car interior on the 17th January. The only difference being that the weather was predominately hazy sunshine on the previous two experimental days and 3 degrees warmer. Weather conditions on the 17th were clear sunshine throughout the test period.

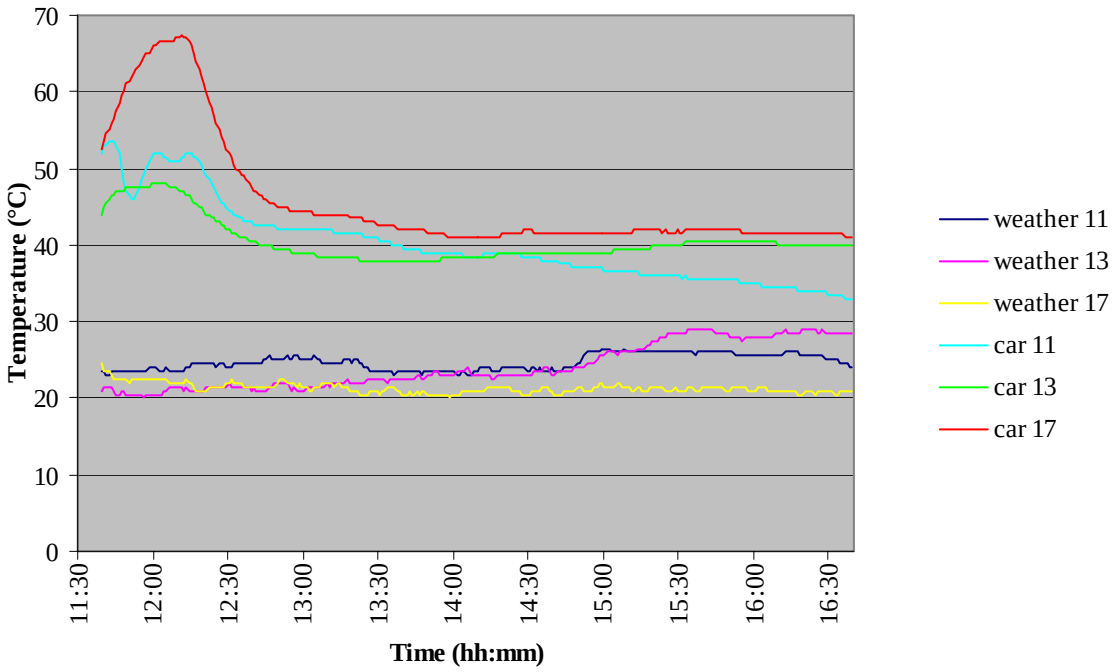


Figure 1: The external air temperature and the car interior temperature on the 11th, 13th and 17th January

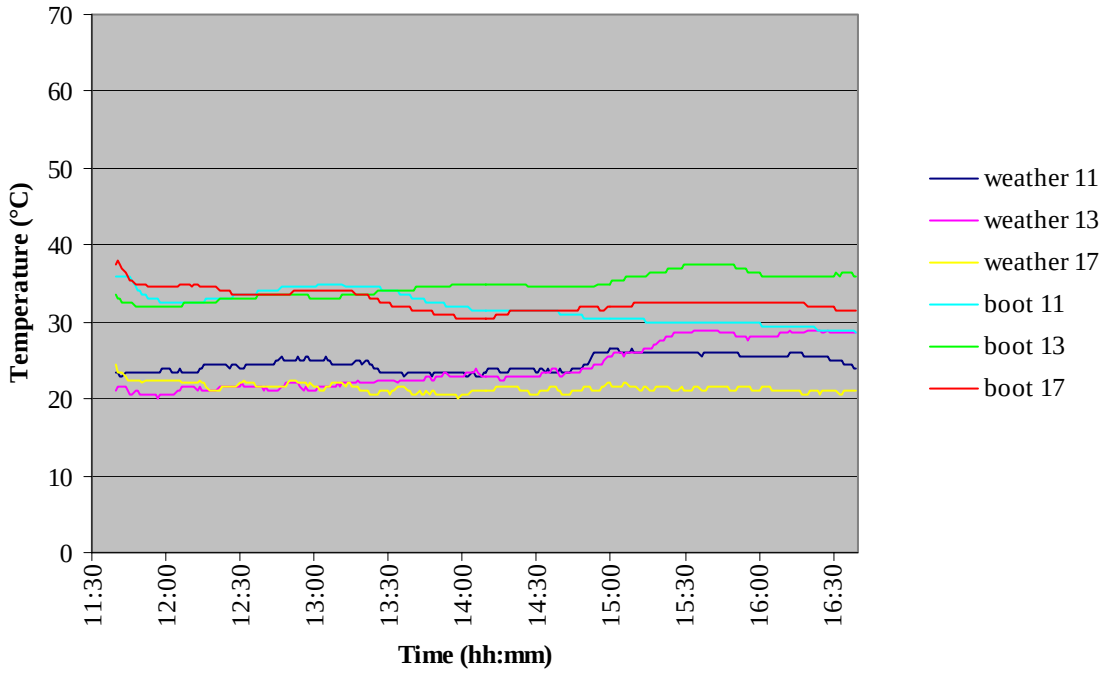


Figure 2: The external air temperature and the car boot temperature on the 11th, 13th and 17th January

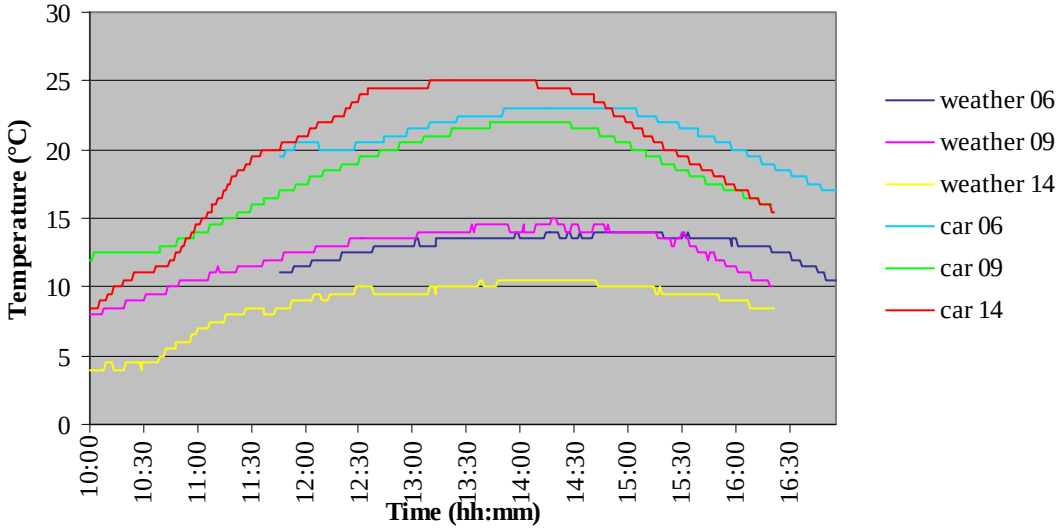


Figure 3: The external air temperature and the car interior temperature on the 6th, 9th and 14th June, 2006

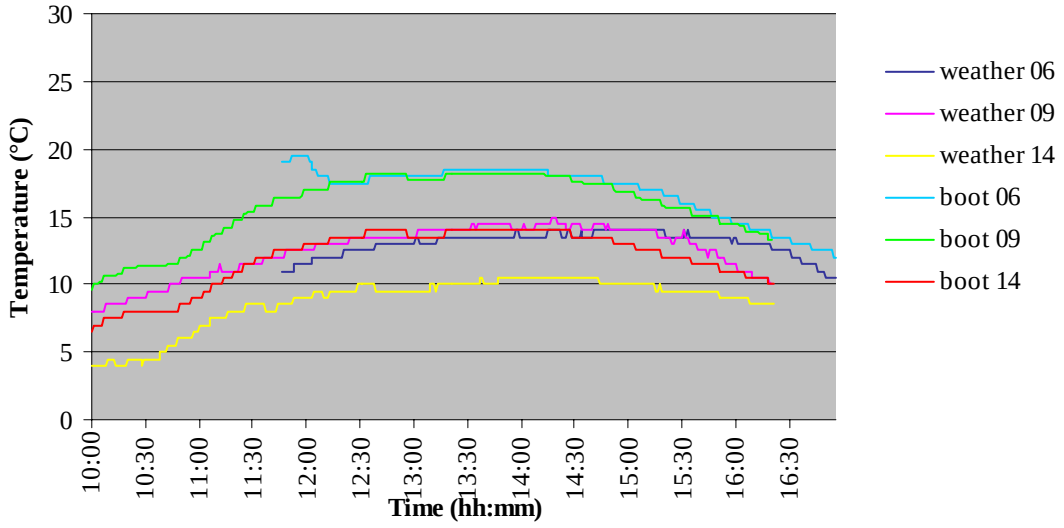


Figure 4: The external air temperature and the car boot temperature on the 6th, 9th and 14th June, 2006

2.3.2 Initial meat temperatures

The starting temperature for the meats was defined as being the minimum temperature recorded by the data logger, following the initial cool down period after being placed in or on the meat. The time to this point was 2-3 minutes, and we assume that this is too short a time for the icepacks to have had an effect. The results are potentially useful for modelling, as they provide an indication of typical initial temperatures to assign to such products, and are shown in Table 4. Means and ranges for these temperatures are shown in Table 5.

Table 4: Temperature of meats at start of experiment

Date		Minced beef(°C)		Steak (°C)		Chicken (°C)		Sausages (°C)	
		Internal	Surface	Internal	Surface	Internal	Surface	Internal	Surface
11 January	Boot - no bag	7	9	8	6.5	8	10	4.5	8.5
	Boot - cooler bag and icepack	8	8.5	4.5	6.5	7	10.5	4.5	8.5
	Boot – bag only	8	9	-	-	-	-	-	-
11 January	Interior - no bag	8.0	8.5	6.0	6.5	6.0	10.5	5.5	6.5
	Interior - cooler bag and icepack	6.5	8.5	6.0	9	5.5	9	6.9	6.9
	Interior – bag only	8	9.0	-	-	-	-	-	-
13 January	Boot - no bag	9.0	13.5	9.5	11.5	8.5	10.0	6.0	6.0
	Boot - cooler bag and icepack	7.4	10.5	8.0	9.0	8.9	10.3	5.5	8.5
	Boot – bag only	-	-	-	-	-	-	5.0	7.5
13 January	Interior - no bag	7.5	11.5	10.0	10.0	9.5	9.5	6.0	10.5
	Interior - cooler bag and icepack	8	11.0	7.0	6.5	9.5	11.0	5.5	7.0
	Interior – bag only	-	-	-	-	-	-	5.5	9.0
17 January	Boot - no bag	8.0	11	4.0	8.5	9.5	13	11	14.0
	Boot - cooler bag and icepack	6.9	9.5	3.6	6	9.5	11.8	8.8	12.5
	Boot – bag only	-	-	-	-	9.5	12.0	-	-
17 January	Interior - no bag	7.5	11	3.5	6.5	10.0	12.5	10	12.5
	Interior - cooler bag and icepack	8	9.5	4.5	6.5	9.0	12.0	8	12.5
	Interior – bag only	-	-	-	-	8.0	8.5	-	-
6 June	Boot - no bag	4	6	3.5	5	11	ND	9.5	9.5

	Boot - cooler bag and icepack	6.5	7	5.6	8.3	10.4	12.5	7.1	9.5
	Boot – bag only	8	8.5	-	-	-	-	-	-
6 June	Interior - no bag	7	9.0	4.5	6.5	12.0	12.5	7.5	8.5
	Interior - cooler bag and icepack	3.5	6.5	4.0	ND	10.6	11.5	8.1	9.5
	Interior – bag only	7.5	9.0	-	-	-	-	-	-
9 June	Boot - no bag	3.5	4.5	4.8	4.5	6.5	8.5	4.0	5.5
	Boot - cooler bag and icepack	4.5	5.5	4.1	6.5	6.0	7.5	4.0	5.0
	Boot – bag only	-	-	-	-	-	-	4.5	5.0
9 June	Interior - no bag	4	6	4.9	6.8	6.0	8.0	5.5	6.5
	Interior - cooler bag and icepack	4	4.5	4.9	5.5	7.0	8.0	5.5	6.5
	Interior – bag only	-	-	-	-	-	-	5.5	5.5
14 June	Boot - no bag	8.0	8.0	3.5	3.5	7.5	8.0	4.5	7.0
	Boot - cooler bag and icepack	7.4	7.9	4.0	3.5	6.9	ND	5.0	5.5
	Boot – bag only	-	-	-	-	7.5	7.5	-	-
14 June	Interior - no bag	7.5	8.0	4.5	5.5	8.0	7.5	7.5	8.0
	Interior - cooler bag and icepack	8.0	9.0	4.0	4.8	6.0	7.0	7.3	7.3
	Interior – bag only	-	-	-	-	7.0	7.0	-	-

ND: No data due to faulty data logger

Table 5: Initial surface and internal temperatures of meat/poultry

Mean and range from individual packs	Minced beef (°C)	Steak (°C)	Chicken (°C)	Sausages (°C)
January 11	8.2	6.6	8.3	6.5
January 13	9.8	8.9	9.7	6.8
January 17	8.9	5.4	10.4	11.2
Summer	9.0	7.0	9.5	8.1
June 6	6.9	5.3	11.5	8.7
June 9	4.6	5.3	7.2	5.3
June 14	8.0	4.2	7.3	6.5
Winter	6.5	4.9	8.7	6.8
Overall mean	7.7	6.9	9.0	7.3
Overall range	3.5-13.5	3.5-11.5	5.5-13	4-14

2.3.3 Rate of temperature increase

The curves for temperature increases of the meat/poultry samples are shown in full in Appendix 4. For the purposes of this discussion, each set of three replicate experiments in each season are treated as a single data set and the mean temperature increase curve generated Figure 5shows an example of these calculations.

For the initial winter experiment (6 June), begun at the same time as the summer experiment (approximately 11.30 am), only a modest temperature increase was observed. In order to increase the amount of data, the experiments for the 9 and 14 June were commenced approximately 2 hours earlier. This causes the slight break in some averaged curves; for example the bag and icepack (red) average curve in winter in Figure 5.

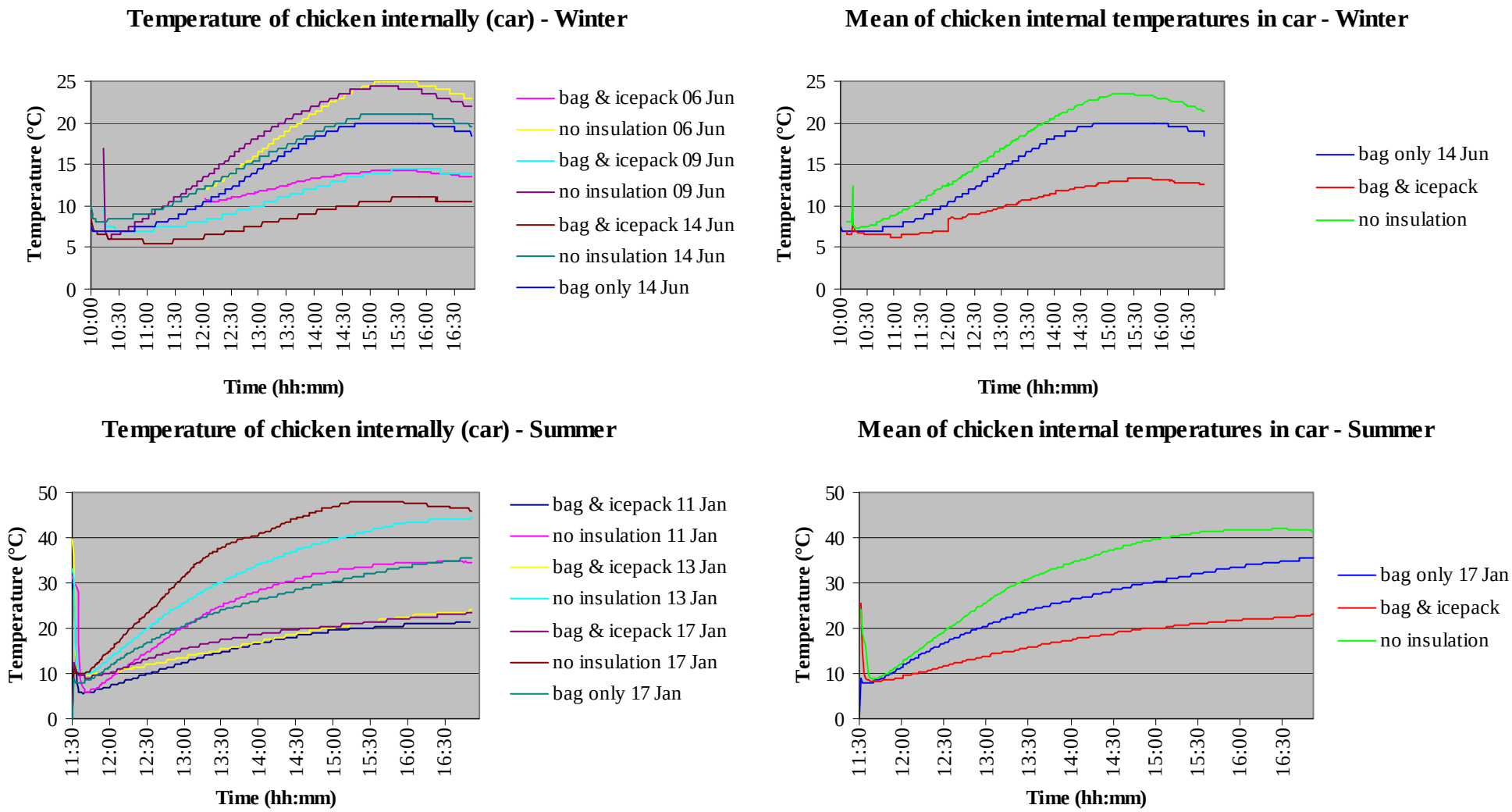


Figure 5: Examples of averaging of experimental data from 3 replicate temperature increase experiments.

2.3.4 Curve fitting

In order to consolidate these data, it was decided that two fitting options would be pursued for these average curves:

- Polynomial (degree 1), of the form $y = a_0 x + c$ where y = temperature (°C), a_0 = fitted polynomial coefficient, x = time (minutes), c = y intercept. This is fitted to the steeper initial linear portion of the curve, as a worst case scenario being around midday, for up to 90 minutes. These linear equations would then be applicable to the majority of transport scenarios (more than 80% of respondents using a car for transport took an hour or less to travel home).

- Polynomial (degree 2), of the form $y = b_1 x^2 + b_0 x + c$ where y = temperature (°C), b_1, b_0 = fitted polynomial coefficients, x = time (minutes), c = y intercept. The quadratic is fitted to entire rising part of the curve, for situations where a longer time period is applicable.

In this curve fitting process, a slope and constant term are generated. The constant term represents the intercept, or starting temperature. In a modelling situation, the modeller has the option of using this mean initial temperature value, or selecting a value from the information given in Table 5, and then applying the slope term to describe the rate of temperature increase.

The length of time over which the winter experiments were conducted varied. The first, 6th June 2006 was of similar length to all of the summer experiments (approximately 12 noon to 17:00, 5 hours). The next two winter experiments on 9th and 14th of June respectively were conducted over a 7-hour period (10:00 – 17:00). Therefore the temperatures at a given time in experiments on the 9th and 14th June will not be directly comparable to the experiment on the 6th June. In order to analyse the temperatures from these three winter experiments, the different time frames must be borne in mind.
Curve fits for each of the scenarios were generated as follows:

- Parameter values for temperature increase curves determined for each meat type, each data logger location (internal or surface), and each packaging type, with the data averaged across the three experiments in each season;
- The same results but with the data averaged across data logger location (i.e. combining surface and interior measurements).

The parameters from these curve fits are provided in tables in Appendix 5.

To provide more generic information, equation parameters have also been generated for surface and internal temperatures combined, and the data then averaged across all meat types. These parameters are given in Table 6.

All slope values are in °C per minute. As might be expected, heating rates for the pieces of steak are higher than for the other meat types. This is likely to be due to the thinness of this meat type.

On most experiment days, there were sufficient data loggers to monitor a single meat type in a cooler bag without an icepack. The same parameters have been derived for these experiments, but as they comprise a much more limited dataset, the results have been reported separately. The parameters are also given in Appendix 5.

Table 6: Parameters for calculating temperature increases of meat/poultry for location, packaging type and season.

Experiment Conditions	Season	Linear x (°C/minute)	Linear c	Quadratic x^2	Quadratic x	Quadratic c
Boot/Cooler Bag/Icepack/Meat	Summer	0.0664	7.9149	-0.0001	0.0848	8.1108
	Winter	0.0107	5.7645	0.0000	0.0213	5.1028
Boot/No packaging/Meat	Summer	0.1105	8.8788	-0.0002	0.1203	9.0098
	Winter	0.0303	5.1794	-0.0001	0.0484	4.2773
Car/Cooler Bag/Icepack/Meat	Summer	0.0661	8.2886	-0.0001	0.0838	7.8719
	Winter	0.0332	5.3252	-0.0001	0.0567	4.0264
Car/No packaging/Meat	Summer	0.2444	9.3617	-0.0005	0.2649	9.7949
	Winter	0.0792	5.5226	-0.0002	0.1282	3.0854

The temperature increase data have been provided for both individual experiments and aggregated (averaged) form. This provides the modeller with options depending on the particular scenario being addressed.

The validity of the aggregations was examined by observing the residuals of the fitted polynomials versus the data with most cases exhibited no obvious pattern. Exceptions were the first few minutes of heating, however not all meats started at the exact same temperature. Therefore the initial temperatures, and hence initial heating rates, could account for these fittings discrepancies. We have chosen to provide a graphical illustration of the spread of data, shown in Figure 6. This shows a plot of the temperature increase rates for data from the interior of the meat versus the surface, which will be independent of starting temperature.

A first order polynomial using a least squares regression model is fitted to the data, giving a line of slope 1.06 (green line) with 95% confidence intervals for the data set (dashed red lines). That the slope of this correlation is close to 1 gives confidence that surface and internal temperature increase rate data can be combined. This is sensible, as the meat samples had only a short distance between internal and surface loggers due to the shape of the meat (steak, chicken, sausage), or else packaging in flat trays (mince). In winter, temperature increase rates for the meat types are lower and more closely grouped, while in summer the rates are more variable across meat types.

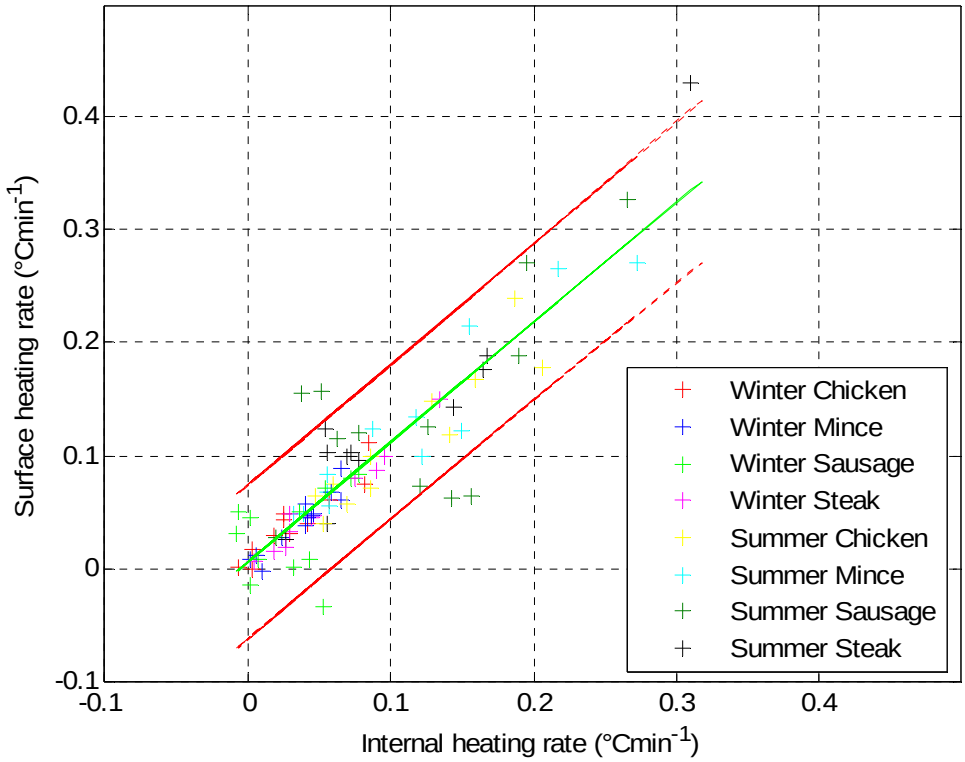


Figure 6: Comparison of temperature rate increases from measurements at the surface and interior of meat/poultry samples

2.4 Results from the Australian Experiments

The study by Meat and Livestock Australia found no significant difference between the core and surface temperatures of the same piece of meat. There was also no significant difference between the meat types. However, no details of the statistical analyses used for these comparisons are given. Temperature increase rates found for 1 kg pieces of meat in Australia are given in Table 7, alongside New Zealand rates for 500g pieces of meat or poultry for up to 90 minutes, derived from data shown in Table 6. The New Zealand heating rates are generally higher; this may be due to a variety of reasons, but the size of the meat portion probably plays an important role. Experiments in both countries were performed in direct sunlight weather conditions.

Table 7: Rate of temperature increase for the surface and interior of transported meat in Australia and New Zealand

	Car boot Australia (°C / 10 min)	Car interior Australia (°C / 10 min)	Car boot New Zealand (°C / 10 min)	Car interior New Zealand (°C / 10 min)
Summer				
With bag and icepack	0.3	0.3	0.7	0.7
Without insulating bag	0.7	1.0	1.1	2.4
Winter				
With bag and icepack	0.2	0.2	0.1	0.3
Without insulating bag	0.3	0.3	0.3	0.8

3 BACTERIAL TRANSFER RATE EXPERIMENTS

3.1 Aim of the Study

The objective of this part of the project was to provide transfer rate data for bacteria from foods to surfaces (including hands) which will be relevant to the exposure assessment as a component of a quantitative risk assessment. The primary organism of interest was *Campylobacter*, in keeping with the focus of the NZFSA science strategy.

These data were intended to encompass the variability expected amongst such a stochastic process (for example the proportion of each surface that actually makes contact will vary). Thus the experiments were designed to include replicates, as well as the experiments being performed by different operators. The experiments determined total numbers of bacteria giving a bacterial "budget" that provided a percentage transfer based on the total numbers of bacteria available for transfer, without the need to estimate other variables.

3.2 Published Data on Transfer Rates

Prior to commencing experimental work a review was conducted of bacterial transfer rate data already published (for full review see Appendix 3). Extracting data of relevance to *Campylobacter* gave four key references, and three of these deal with stainless steel surfaces only. The results are summarised in Table 8.

Table 8: Literature data for transfer rates for *Campylobacter*

Reference	Transfer step	Transfer Rate Mean (%)	Transfer Rate Standard Deviation
Luber *et al.*, 2006	Chicken legs to hands	2.9	5.5
	Chicken legs to plate	0.3	0.3
	Plate to fried sausage	27.5	23.7
	Breast fillets to hands	3.8	5.9
	Breast fillets to wooden board and knife	1.1	0.7
	Board and knife to cucumber	10.3	9.6
	Hands to bread	2.9	3.8
Kusumaningrum *et al.*, 2003	Transfer rate from sponges to stainless steel: high contamination (log_{10}cfu 9.4/10 ml)	9	43
	Transfer rate from sponges to stainless steel: moderate contamination (log_{10}cfu 8.5/10 ml)	28	13
	Transfer rate from stainless steel to cucumber with pressure (log_{10}cfu 4.2/ cm^2)	185	75
	Transfer rate from stainless steel to cucumber: with no pressure (log_{10}cfu 4.2/ cm^2)	177	72
	Transfer rate from stainless steel to roast chicken fillet: with pressure (log_{10}cfu 4.1/ cm^2)	101	42
	Transfer rate from stainless steel to roast chicken fillet: with no pressure (log_{10}cfu 4.1/ cm^2)	66	26
	Transfer rate from stainless steel to roast chicken fillet: with pressure after 15 minutes delay after contamination of surface (log_{10}cfu 3.7/ cm^2)	24	16
	Transfer rate from stainless steel to roast chicken fillet: with no pressure after 15 minutes delay after contamination of surface (log_{10}cfu 3.7/ cm^2)	70	83
Kusumaningrum *et al.*, 2004	carcasses to stainless steel	1.25	4.03
	stainless steel to cucumber	34.3	34.1
Moore *et al.*, 2003	stainless steel to wet romaine lettuce Note: high inoculum levels: 10^6 cfu/28 mm^2)	29	2.4 (standard error)
	stainless steel to dry romaine lettuce Note: high inoculum levels: 10^6 cfu/28 mm^2)	16.9	2.4 (standard error)

3.3 Experimental Design

Potential transfer pathways for bacteria that were of interest were:

- *Campylobacter from poultry to hands during initial food preparation*
- *Campylobacter from poultry to surfaces (wooden chopping boards) during food preparation*
- *Campylobacter* from poultry to surfaces (plastic chopping boards) during food preparation
- *Campylobacter from hands to other foods*
- *Campylobacter from surfaces to other foods*
- *Campylobacter* from hands to mouth

The most recent publication on *Campylobacter* transfer rates (Luber *et al*., 2006) had addressed a number of the steps identified above (in italics), that were not directly examined in earlier studies. After discussions with the NZFSA, it was decided to develop a protocol for transfer rate experiments that would be applicable to a variety of scenarios, and would use native *Campylobacter* contamination, thus avoiding the problems that may result from spiking. In order to develop such a protocol a number of preliminary experiments were performed. The protocol was then applied to determine transfer rates for several steps involved in preparation of poultry for cooking, some of which replicated the transfers studied by Luber *et al*., (2006).

3.3.1 Preliminary experiments

The preliminary experiments were intended to investigate the numbers of *Campylobacter* present on poultry pieces, and whether these bacteria were present in sufficient numbers to allow transfer rates to be determined. The studies also investigated methods of concentrating low numbers of bacteria to improve detection. In addition to experiments to determine counts of bacteria, presence/absence testing on broths and identification of *Campylobacter* colonies by PCR were conducted. This meant that, in the results that follow, results where no colonies were grown, but the presence/absence testing was positive, are reported as 'less than" results. Similarly where colonies were seen and counted, the identity of a representative number was confirmed by PCR.

3.3.1.1 Experiment 1

Single chicken breast portions packed on meat trays were purchased from four supermarkets and transported to the laboratory in a chilly bin containing frozen pads. Each chicken breast was transferred from its original tray or bag into a stomacher bag. The skin was separated from the breast and transferred to a separate stomacher bag. The weights of the skinless breast meat and the piece of skin were measured and maximum recovery diluent (MRD) was added to each subsample in a 1/3 ratio and homogenised in a stomacher for 2 min.

A dilution series from 10^{-1} to 10^{-2} for the breast meat and 10^{-1} to 10^{-3} for the skin was prepared. One ml each of the 10^{-1} dilution of the breast and skin homogenates was plated onto three mCCDA plates, in duplicate. The remaining dilutions were plated using 0.1 ml amounts spread over an mCCDA plate, in duplicate. All plates were incubated at 37°C for 4

h (to resuscitate process injured *Campylobacter*) followed by incubation at 42°C for up to 48 h in a microaerobic environment. *Campylobacter* colonies from the mCCDA plates were counted and five representative colonies were picked and preliminary identified by gram staining and oxidase test. Representative colonies (up to five) were combined and identified by PCR.

The results are expressed in Table 9.

Table 9: ***Campylobacter*** **on the skin and meat parts of chicken breast portions**

Cut	Weight of skin (g)	Count from skin (cfu/g)	*Campylobacter* on skin	Weight of breast meat (g)	Count from breast meat (cfu/g)	*Campylobacter* on breast meat (cfu)	Estimated count of *Campylobacter* on portion
Breast 1	41.04	10	410.4	341.46	<10	<341	410-751
Breast 2	21.03	<10	<210.3	196.43	<10	<196	0-406
Breast 3	26.41	<10	<264.1	178.05	<10	<178	0-442
Breast 4	40.16	20	803.2	404.28	<10	<404	803-1207

The numbers of *Campylobacter* spp. on these four pieces of breast meat were low, with all breast meat and half of the skin samples being <10 cfu/g. A very low *Campylobacter* count was obtained from two pieces of chicken skin, but the rest were below the level of detection of the spread method. The method was not sensitive enough in this situation. In situations of low counts, the high dilution factor makes the plating method insensitive for detection of low numbers of *Campylobacter* in the samples.

The low counts could also be associated with batches of chicken breasts having low levels of *Campylobacter* at time of purchase. The observations from this first experiment suggested that in the next experiment, Exeter broth instead of MRD should be used and that the portions should be rinsed rather than macerated in the stomacher to increase sensitivity. This also provides the opportunity to concentrate very low levels of cells by centrifugation. Enumeration can be set up by first plating 1 ml directly from the rinse broth followed by fixed volume inocula from a short dilution series. The portion of rinse left over after enumeration can then be incubated as an enrichment culture for presence/absence testing.

3.3.1.2 Experiment 2

In this experiment, four breasts (with skin) were again purchased from different retail outlets. Each breast portion was treated separately in this experiment. The samples were treated similarly in Experiment 1 except that this time, Exeter broth was used to rinse the samples. The skin was processed with twice the weight in Exeter broth and homogenised in a stomacher for 2 min. The skinless breast meat was rinsed in a standardised volume of 100 ml of Exeter broth and given a 15 min agitated shake in a vertical shaker. The spread plating format was the same as in Experiment 1 with the exception that 1 ml was drawn directly from the rinse broth for spreading over 3 mCCDA plates followed by 0.1 ml onto a plate from dilution 10^{-1} and 10^{-2}, in duplicate.

The results of Experiment 2 are tabulated in Table 10.

Table 10: Recovery of *Campylobacter* from retail chicken breast portions

Chicken portion	Total *Campylobacter* count on skin (cfu/sample)	Total *Campylobacter* count on breast meat (cfu/sample)	Total *Campylobacter* count on breast with skin
Breast 1	7535	8300	15835
Breast 2	39	400	439
Breast 3	1408	1000	2408
Breast 4 (skinless)	N/A	1500	1500

Experiment 2 protocols resulted in countable colonies on all the spread plates. Using Exeter broth to rinse has apparently increased sensitivity, with numbers of *Campylobacter* being approximately 10 fold higher than in Experiment 1. The other possibility is that this product was more heavily contaminated however the protocol should be able to enumerate *Campylobacter* from light to heavily contaminated samples. Fixing a volume of Exeter broth used for rinsing the meat gave a standardised procedure for recovery of *Campylobacter* and to provide a basis for an enumeration method. Using Exeter broth to rinse the meat and process the skin has provided an opportunity to test for presence/absence of Campylobacter

on the samples if enumeration fails to show any colonies on the mCCDA plates. The combination of Exeter broth and mCCDA plating is also the recommended approach in the report by Donnison (2003).

The methods described in this experiment resulted in a total *Campylobacter* count being recovered from all portions, and this offers a good basis for further transfer experiments. One breast sample was a skinless breast portion and a count of 1500 cfu/sample was recovered from it (Table 10). On two of the samples, the *Campylobacter* counts on the skin were similar in level to the meat portion. On the fourth sample, the count on the breast meat was higher than the count from the skin.

The goal of these two initial experiments was to work out a method for counting *Campylobacter* efficiently from the whole sample so that follow-on experiments could be designed to measure transfer rates from meat to hand and fomites such as cutting boards and knives. The next experiment was designed to test the hypothesis that different chicken portions could be mixed in order to provide a uniform level of *Campylobacter* contamination.

3.3.1.3 Experiment 3

In this experiment, chicken breast portions (with skin) were purchased from various retail outlets and mixed together in a large sterile bag in the laboratory and then kept overnight to allow time for mixing, re-distribution and re-adhesion of bacteria onto samples, assuming that such activity takes place when portions contaminated with *Campylobacter* are mixed together.

Six chicken breasts were purchased from different retail outlets, all were mixed together in a large sterile bag in the laboratory and left to stand at 4°C overnight. The portions were then divided into two protocols with three breasts per protocol:

Protocol A - Skin was removed from each breast by hand. The breast meat sub-sample was shaken using the vertical agitating shaker for 15 min and the skin was homogenised in the stomacher for 2 min. The volume of Exeter broth used was as in Experiment 2.

Protocol B - Skin was removed from each breast by hand. The breast meat was gently rinsed for 2 min and the skin homogenised in the stomacher for 2 min.

Following enumeration, the rest of the samples in Exeter broth were incubated as P/A enrichment cultures in the same conditions as the plates.

The results from this experiment are presented in Tables 11 and 12.

Table 11: Recovery of *Campylobacter* from retail chicken breast portions using Protocol A

Chicken portion	Total *Campylobacter* count on skin (cfu/sample)	Total *Campylobacter* count on breast meat (cfu/sample)	Total *Campylobacter* count on breast with skin
Breast 1	1200	3400	4600

Breast 2	41	500	541
Breast 3	256	200	456

Table 12: Recovery of *Campylobacter* from retail chicken breast portions using Protocol B

Chicken portion	Total *Campylobacter* count on skin (cfu/sample)	Total *Campylobacter* count on breast meat (cfu/sample)	Total *Campylobacter* count on breast with skin
Breast 4	<69 (mean 35)	300	335
Breast 5	144	2300	2444
Breast 6	335	600	935

The counts on each chicken breast sample were different. Counts on the skin were lower on most samples compared to breast meat. There did not appear to be much difference in counts between the two protocols.

The skin sub-sample of Breast 4 only had *Campylobacter* detected from the enrichment culture. No count was present per ml of homogenate. Since the volume of Exeter broth used for processing the skin was 70 ml and 1 ml was used for spreading, an indication count of <69 cfu/sample was assigned to this sub-sample. However there should at least be >1 cfu/sample in this enrichment. As this scenario is not uncommon in enumerative bacteriology, the procedure outlined by Luber *et al.* (2006) was adopted, where in such a situation, samples with a positive enrichment only were set to a mean number of cfu by adding 1 to 69 and calculating the mean, in this case 35.

The results showed that *Campylobacter* count on each piece of chicken breast remained different (by a factor of 10) even though the samples were mixed together in a bag overnight at 4°C. Based on the results of this experiment, and the results in Experiment 2, the method of using Exeter broth to rinse the chicken meat for 15 min in an agitator shaker was sensitive enough to deal with a sample with a low *Campylobacter* count as well as giving good recovery of *Campylobacter* from the chicken breast portions for transfer experiments to proceed.

The preliminary experiments using chicken breast meat showed that:

- Both breast meat and skin can be contaminated with *Campylobacter*, sometimes at similar (experiments 2 & 3) and sometime at different numbers;
- Shaking the chicken breast in a vertical agitating shaker for 15 min did not noticeably increase numbers of *Campylobacter* recovered (experiments 3) when compared to rinsing for 2 min;
- The numbers of *Campylobacter* were not "evened" out by preliminary mixing of chicken pieces together in a bag (experiment 3).

3.3.2 Bacterial transfer experiments

The aim of the experiments is to generate transfer rate data for an entire process in meat preparation. This is achieved by calculating a total bacterial "budget" at the various locations to which bacteria have been transferred as well as those remaining on the chicken.

Knowing that large variations in counts are likely to occur with wild *Campylobacter* on retail poultry, more than one piece of chicken was used in each transfer experiment to increase the likely numbers of bacteria available for transfer and reduce the likelihood of non-informative "less than" results. Handling of more than one piece of chicken meat when preparing a meal is also likely in "real life". The inherent variability in different events (replicates) and handling preferences (more than one operator) when performing a defined routine food handling operation was also considered in these experiments. Three different operators performing three replicate experiments using three pieces of chicken were used in these two series of experiments.

Two series of experiments were performed:

Series A:

In this series, three volunteers (laboratory staff) performed routine handling of three chicken breast portions (with skin), each repeating the routine three times. Each person first washed his/her hands with soap and warm water for 20 secs and then dried with paper towels for 20 secs before the experiment. The person then transferred, by hand three pieces of chicken breast (with skin) purchased from 3 retail outlets (3 lots, one portion from each lot), to a white plastic cutting board which had been pre-wiped with 70% alcohol before each experiment. The skin from each piece of breast meat was removed with one hand while the other held onto the meat. Both sub-samples were transferred to separate bags for *Campylobacter* enumeration. The juice left on the cutting board was recovered and enumerated for *Campylobacter*, as were both hands. A helper assisted with the opening of bags, pouring of media, sponging etc.

The handling and *Campylobacter* recovery protocol are illustrated in Flow Diagram 1 in Figure 7. It must be pointed out that in anticipation of low *Campylobacter* numbers being present in the hand washings and cutting board rinses, two further additional steps were introduced into the method:

- A centrifugation step to concentrate 10 ml of rinse into 1 ml was introduced. This step was introduced to increase sensitivity of the method by 10 fold.
- A second (repeat) rinse step of the cutting board, the hands and the knife, to recover residual cells left behind by the first rinse since the number of cells in total on these surfaces were expected to be low.

Series B:
The procedures here were the same as in series A, except that a knife was introduced to dice the breast meats after the skins were removed, and that the fingers from the hand used for holding the meat during dicing were allowed to contact the surface of an mCCDA plate to mimic touching of lips by person preparing chicken. The *Campylobacter* recovery protocol for the knife was the same as for the hand washings and cutting board. The experiments were also repeated three times by each laboratory volunteer. The procedure is illustrated in Flow Diagram 2 in Figure 8.

Figure 7: Flow Diagram 1

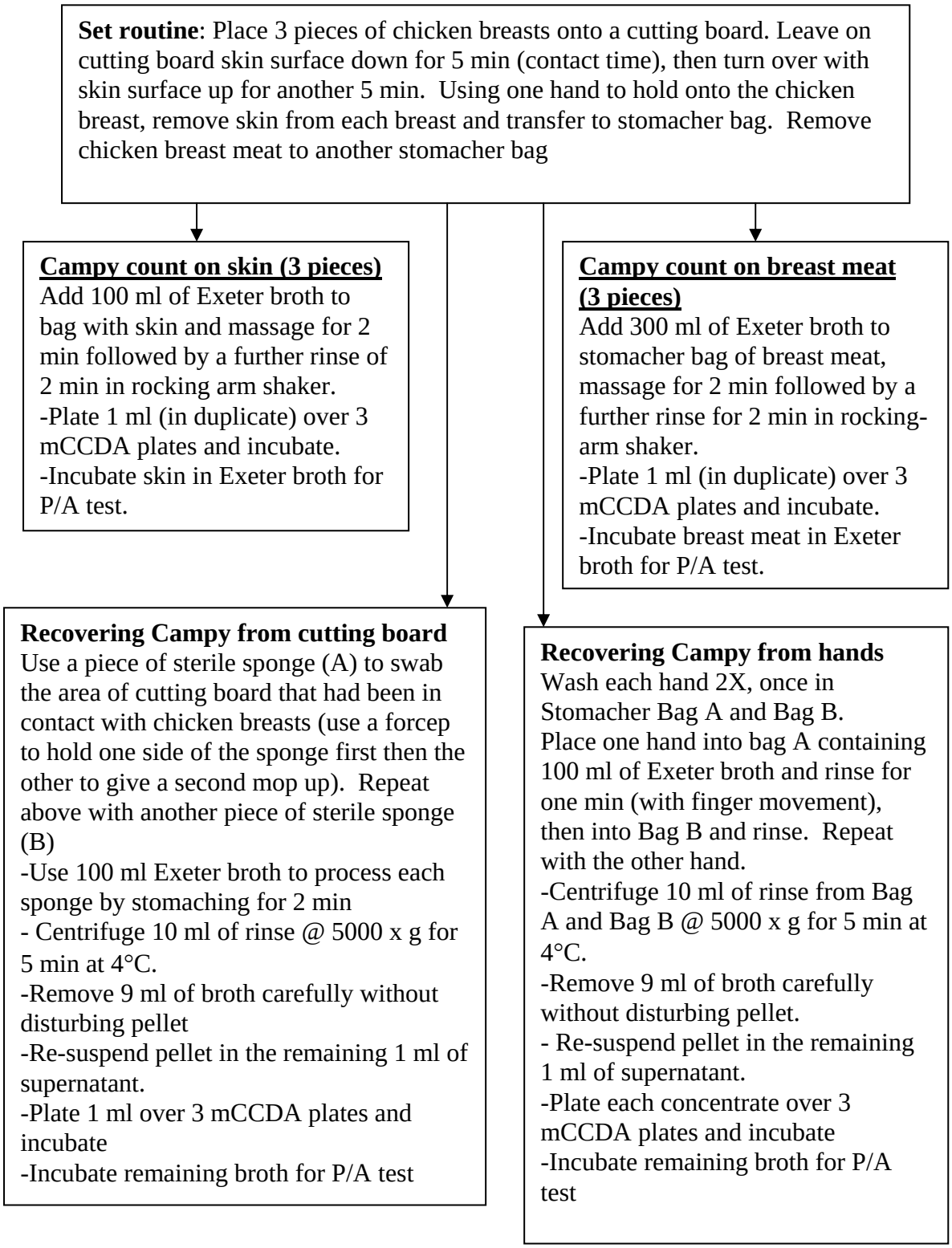


Figure 8: Flow Diagram 2

Place 3 pieces of chicken breasts onto a cutting board. Leave on cutting board skin surface down for 5 min (contact time), then turn over with skin surface up for another 5 min.

Using one hand to hold onto the chicken breast, remove skin from each breast and transfer to stomacher bag. Use a knife to dice the 3 pieces of breast meat to cubes. Transfer the chicken cubes to a stomacher bag.

Recovering Campy from cutting board (Repeat the sponging of board 2X using the procedure below)
Use a piece of sterile sponge to swab the area of cutting board that had been in contact with chicken breasts (use one side of the sponge first then the other to give a second mop up)
-Use 100 ml Exeter broth to process sponge by stomaching for 2 min
- Centrifuge 10 ml of rinse @ 5000 x g for 5 min at RT.
-Remove 9 ml of broth carefully without disturbing pellet
-Re-suspend pellet in the remaining 1 ml of supernatant.
-Plate 1 ml over 3 mCCDA plates and incubate
-Incubate remaining broth for P/A test

Count Campylobacter on knife (Repeat the knife washing 2X using the procedure below)
Add 100 ml of Exeter broth to bag with knife and massage for 2 min (carefully) followed by a further rinse of 2 min with gentle shaking.
- Centrifuge 10 ml of rinse @ 5000 x g for 5 min at RT.
-Remove 9 ml of broth carefully without disturbing pellet
-Re-suspend pellet in the remaining 1 ml of supernatant.
-Plate 1 ml over 3 mCCDA plates and incubate
-Incubate remaining broth for P/A test

Recover Campy from "Lips" and from hands (Repeat hand washing 2X using the procedure below)
-Touch fingers from hand used to hold meat during dicing (not the hand knife) on surface of a mCCDA plate and incubate to recover Campylobacter colonies (to mimic touching of lips by person preparing chicken).
-Place one hand into stomacher bag containing 100 ml of Exeter broth and rinse for one min (with finger movement), then the other hand for another min.
-Centrifuge 10 ml of rinse @ 5000 x g for 5 min at RT.
-Remove 9 ml of broth carefully without disturbing pellet.
- Re-suspend pellet in the remaining 1 ml of supernatant.
-Plate over 3 mCCDA plates and incubate
-Incubate remaining broth for P/A test

Campy count on skin (3 pieces)
Add 100 ml of Exeter broth to bag with skin and massage for 2 min followed by a further rinse of 2 min in rocking arm shaker.
-Plate 1 ml (in duplicate) over 3 mCCDA plates and incubate.
-Incubate skin in Exeter broth for P/A test.

Count Campylobacter from the chicken cubes. Add 300 ml of Exeter broth to stomacher bag and massage for 2 min followed by a further rinse of 2 min in rocking-arm shaker.
-Plate 1 ml (in duplicate) over 3 mCCDA plates and incubate.
-Incubate breast meat in Exeter broth for P/A test.

Results from experiments in Series A and B are given in Tables 13 and 14 respectively.

The summed (breast, skin, board, hands) *Campylobacter* spp. total counts originating from the three chicken breast portions (with skin) ranged from 420 to 18,345 cfu/experiment in Series A and 490 to 14825 cfu/experiment in Series B. The mean total count of *Campylobacter* spp. on the three portions of chicken breasts (with skin) obtained from Series A experimentation was 5913 cfu/portion. From Series B experiments, the mean count was 3554 cfu/portion.

The second stage recovery of *Campylobacter* from rinses and washings of the board and hands showed that this extra effort was worthwhile and resulted in a slight improvement in the recovery counts. Analysing the remaining rinses or washings by PCR from enrichment culture ensured that *Campylobacter* could be detected in the second stage recovery even though no counts might be enumerated.

Transfer rates from meat to hand, meat to cutting board, meat to knife and meat to "lip" were obtained from the two series of experiments (Tables 13 and 14). In the experimental series where three chicken breast portions were transferred to a cutting board, skins removed and then placed in a bag for recovery of *Campylobacter* from meat, the mean transfer rate from meat to cutting board was 1.15% (Standard deviation, SD 0.86%, range 0.08% –2.95%), and on the hands was 2.29% (SD 1.73%).

In Series B where three chicken breast portions were transferred to a cutting board, skins were removed, diced into cubes with a knife, fingers touched a culture plate mimicking the touching of "lips", the mean transfer rate from meat to cutting board was 1.46% (SD 1.95%), from meat to knife was 0.29% (SD 0.28%), from meat to hands was 1.17% (SD 0.84%) and from meat to "lip" was 0.05% (SD 0.11%).

The *Campylobacter* counts obtained from all the experiments were combined into Table 15 to provide a set of useful data on levels to be expected from retail chicken breast portions (with skin). From this table, a retail chicken breast portion (with skin) sold in Christchurch outlets could harbour a mean count of approximately 1500 – 3000 cfu of *Campylobacter* spp. on the surfaces of the meat and skin. The numbers of *Campylobacter* on such portions of meat are highly variable, as indicated by the large standard deviation values. All portions of poultry purchased were positive for *Campylobacter*, which is consistent with the high prevalence found in the survey of chicken mince (Wong *et al.*, 2006, submitted).

Campylobacter counts obtained from the two-stage recovery method used for rinsing fomites and hands coupled with an increased sensitivity using centrifugation and P/A culture, have provided a very useful method for these transfer studies. The information generated will be very useful for quantitative risk models to assess potential interventions. Where comparable, the transfer rate percentages are consistent with the results obtained from experiments by Luber *et al.*, (2006). Future experiments could involve *Campylobacter* measurements from skinless breast meat portions.

Table 13: ***Campylobacter*** **transfer from 3 chicken breast portions to cutting board and hands when removing skin from chicken breast portions during preparation.**

Chicken breast transfer experiments (3 pieces per experiment)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Mean value**	**Std Deviation.**
Campylobacter counts on meat (cfu)	1650	7050	2550	1500	8700	150	4500	750	600		
Campylobacter counts on skins (cfu)	1150	11200	600	850	6600	250	3050	500	500		
Total *Campylobacter* count on Breasts with skin (cfu)	**2800**	**18250**	**3150**	**2350**	**15300**	**400**	**7550**	**1250**	**1100**		
Recovery from board (first wipe with sponge) (cfu)	**30**	**10**	**20**	**10**	**40**	**5***	**90**	**30**	**10**		
Recovery from board (second wipe with sponge) (cfu)	**10**	**5***	**5***	**5***	**5***	**5***	**20**	**5***	**0**		
Recovery from hand (first wash) (cfu)	**20**	**70**	**30**	**50**	**230**	**5***	**160**	**80**	**30**		
Recovery from hand (second wash) (cfu)	**0**	**10**	**10**	**20**	**10**	**5***	**20**	**5***	**5***		
Total recovery of *Campylobacter* from 3 chicken breasts with skin, board and hands (cfu)	**2860**	**18345**	**3215**	**2435**	**15585**	**420**	**7840**	**1370**	**1145**	**5912.8**	**6652.6**
% Transfer to board	**1.4**	**0.08**	**0.8**	**0.62**	**0.29**	**2.38**	**1.40**	**2.55**	**0.87**	**1.15**	**0.86**
% Transfer to hands	**0.7**	**0.4**	**1.2**	**2.87**	**1.54**	**2.38**	**2.30**	**6.20**	**3.06**	**2.29**	**1.73**

*A mean count of 5 [(1+9)/2] is assigned to a result where P/A testing of 90 ml of rinse detected positive *Campylobacter* presence (>1 CFU) but a plate count of 10 ml detected <10 CFU (1+9/2)

Table 14: *Campylobacter* transfer from 3 chicken breast portions to cutting board, hands, knife, and "lip" during the dicing of skinless chicken breast portions

Chicken breast transfer experiments (3 pieces per experiment)	1	2	3	4	5	6	7	8	9	Mean value	Std Deviation
Campylobacter count on meat (cfu)	600	600	150*	6000	600	300	3000	150	4800		
Campylobacter count on skin (cfu)	300	200	600	500	400	600	2600	300	9900		
Total *Campylobacter* count on breasts with skin (cfu)	**900**	**800**	**750**	**6500**	**1000**	**900**	**5600**	**450**	**14700**		
Recovery from board (1st wipe) (cfu)	**5#**	**20**	**5**	**20**	**5**	**5**	**10**	**20**	**90**		
Recovery from board (2nd wipe) (cfu)	**0##**	**5**	**5**	**5**	**5**	**0**	**0**	**10**	**0**		
Recovery from knife (1st wash) (cfu)	**0**	**5**	**5**	**5**	**0**	**5**	**5**	**0**	**0**		
Recovery from knife (2nd wash) (cfu)	**0**	**0**	**0**	**5**	**5**	**0**	**5**	**0**	**0**		
Recovery from hand (1st wash) (cfu)	**10**	**10**	**5**	**5**	**5**	**5**	**5**	**10**	**30**		
Recovery from hand (2nd wash) (cfu)	**10**	**5**	**5**	**5**	**5**	**5**	**5**	**0**	**5**		
Mimic presence on "lip" (mCCDA plate) (cfu)	**3**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**		
Total recovery of Campy from 3 chicken breasts with skin, board, knife and hands (cfu)	**928**	**846**	**775**	**6545**	**1025**	**920**	**5631**	**490**	**14825**	**3553.9**	**4808.5**
% Transfer to board	**0.54**	**2.96**	**1.29**	**0.38**	**0.98**	**0.54**	**0.18**	**6.12**	**0.61**	**1.46**	**1.95**
% Transfer to knife	**0**	**0.59**	**0.65**	**0.15**	**0.49**	**0.54**	**0.18**	**0**	**0**	**0.29**	**0.28**
% Transfer to hands	**2.16**	**1.77**	**1.94**	**0.15**	**0.98**	**1.09**	**0.18**	**2.04**	**0.24**	**1.17**	**0.84**
% Transfer to "Lip"	**0.32**	**0.12**	**0**	**0**	**0**	**0**	**0.02**	**0**	**0**	**0.05**	**0.11**

#<**10** (Assign count of **5** since P/A of 90 ml was positive)
0 (P/A of 90 ml was negative, no growth from 10 ml)
* **150** (P/A of 299 ml was positive, no growth from 1 ml, assigned (299+1)/2=150)

Table 15: Consolidated *Campylobacter* counts from retail chicken breast portions (with skin) used in the transfer rate experiments

Count per portion (preliminary experiments) (cfu)	Count from 3 portions (transfer rate experiments) (cfu)	Average count per portion (transfer rate experiments) (cfu)
15835	2860	953
439	18345	6115
2408	3215	1072
4600	2435	812
541	15585	5195
456	420	140
335	7840	2613
2444	1370	457
935	1145	382
Mean = 3110.3	928	309
S.D. = 4978.6	846	282
	775	258
	6545	2182
	1025	342
	920	307
	5631	1877
	490	163
	14825	4941
		Mean = 1578
		S.D. = 1920

4 CONCLUSIONS

This study has provided valuable data which can be used as generic inputs into quantitative risk models. The data on temperature increases during transport home provides graphic illustration of the importance of using insulated packaging, and storing food out of direct sunlight. The transfer rate data are similar to those from the most recent overseas publication on the topic, but incorporate the variability inherent in individual chicken portions without the need to make assumptions about uniformity of contamination. In addition, an important transfer step, from fingers to lips, is simulated. The total bacterial budget approach avoids the need to estimate such variables as proportion of surfaces in contact, and the use of different operators in the experiments goes someway to mimicking the variability that could be expected amongst the population performing the same task.

Although the transfer rates determined in these experiments are low, the use of similar values in the New Zealand *Campylobacter* in poultry risk model indicate that with frequent potential exposure events, large numbers of infections and illnesses can result.

5 REFERENCES

Acuff, GR, Vanderzant C, Hanna MO, Ehlers JG, Gardner FA. (1986). Effects of handling and preparation of turkey products on the survival of *Campylobacter jejuni*. Journal of Food Protection: 49; 627-631

Barker J, Naeeni M, Bloomfield SF. (2003) The effects of cleaning and disinfection in reducing *Salmonella* contamination in a laboratory model kitchen. Journal of Applied Microbiology; 95:1351-1360.

Bloomfield A, Neal G. (1997) Consumer food safety knowledge in Auckland. Auckland Healthcare Public Health Protection.

Bradford MA, Humphrey TJ, Lappin-Scott HM. (1997) The cross-contamination and survival of *Salmonella enteritidis* PT4 on sterile and non-sterile foodstuffs. Letters in Applied Microbiology: 24; 261-264.

Brown P, Kidd D, Riordan T, Barrell RA. (1988) An outbreak of food-borne *Campylobacter jejuni* infection and the possible role of cross-contamination. Journal of Infection: 17; 171-176.

Chen Y, Jackson KM, Chea FP, Schaffner DW. (2001) Quantification and variability analysis of bacterial cross-contamination rates in common food service tasks. Journal of Food Protection: 64; 72-80.

Coates D, Hutchinson DN, Bolton FJ. (1987) Survival of thermophilic campylobacters on fingertips and their elimination by washing and disinfection. Epidemiology and Infection: 99; 265-274.

Cogan TA, Bloomfield SF, Humphrey TJ. (1999) The effectiveness of hygiene procedures for prevention of cross-contamination from chicken carcases in the domestic kitchen. Letters in Applied Microbiology: 29; 354-358.

Cools I, Uyttendaele M, Cerpentier J, D'Haese E, Nelis HJ, Debevere J. (2005) Persistence of Campylobacter jejuni on surfaces in a processing environment and on cutting boards. Letters in Applied Microbiology: 40; 418-423.

De Boer E, Hahné M. (1990) Cross-contamination with *Campylobacter jejuni* and *Salmonella* spp. from raw chicken products during food preparation. Journal of Food Protection: 53; 1067-1068.

De Wit JC, Broekhuizen G, Kampemacher EH. (1979). Cross-contamination during the preparation of frozen chickens in the kitchen. Journal of Hygiene: 83; 27-32.

De Cesare A, Sheldon BW, Smith KS, Jaykus L-A. (2003) Survival and persistence of *Campylobacter* and *Salmonella* species under various organic loads on food contact surfaces. Journal of Food Protection: 66; 1587-1594.

Donnison, A. (2003) Isolation of thermotolerant *Campylobacter* – Review and Methods for New Zealand laboratories. Client Report prepared for the Ministry of Health, Wellington, New Zealand.

Durham G, Baldwin H, Thompson D. (1991) Food Safe – Baseline Survey. Wellington Area Health Board, unpublished report.

Evans J. (1992) Consumer handling of chilled foods: perceptions and practice. International Journal of Refrigeration; 15: 290-298.

Gilbert SE, Lake R, Whyte R, Bayne G, (2005). Domestic food practices; New Zealand refrigerator survey &meat handling survey. Final Report. Client No. FW0542, ESR, Christchurch.

Gorman R, Bloomfield S, Adley CC. (2002) A study of cross-contamination of food-borne pathogens in the domestic kitchen in the Republic of Ireland. International Journal of Food Microbiology: 76; 143-150.

Haysom I, Sharp K (2004) Cross-contamination from raw chicken during meal preparation. British Food Journal: 106: 38-50.

Hodges I. (1993) Raw to cooked, community awareness of safe food handling practices. Department of Health. Internal Report. Wellington.

Humphrey TJ, Martin KW, Whitehead A. (1994) Contamination of hands and work surfaces with *Salmonella enteritidis* PT4 during the preparation of egg dishes. Epidemiology and Infection: 113; 403-409.

Humphrey T, Mason M, Martin K. (1995) The isolation of *Campylobacter jejuni* from contaminated surfaces and its survival in diluents. International Journal of Food Microbiology: 26; 295-303.

Humphrey TJ, Martin KW, Slader J, Durham K. (2001). *Campylobacter* spp. in the kitchen: spread and persistence. Journal of Applied Microbiology: 90; 115S-120S.

Kerslake VB, (1995) Community Awareness of Safe Food Handling Practices and Food Poisoning: Knowledge and Experience. Thesis. Victoria University, Wellington.

Kusumaningrum HD, Riboldi G, Hazeleger WC, Beumer RR (2003) Survival of foodborne pathogens on stainless steel surfaces and cross-contamination to foods. International Journal of Food Microbiology: 85; 227-236.

Kusumaningrum HD, Van Asselt ED, Beumer RR, Zwietering MH. (2004) A quantitative analysis of cross-contamination of *Salmonella* and *Campylobacter* spp. via domestic kitchen surfaces. Journal of Food Protection: 67; 1892-1903.

Luber P, Brynestad S, Topsch D, Scherer K, Bartelt E. (2006) Quantification of *Campylobacter* Species Cross-Contamination during Handling of Contaminated Fresh Chicken Parts in Kitchens. Applied and Environmental Microbiology: 72; 66-70.

Mattick K, Durham K, Hendrix M, Slader J, Griffith C, Sen M, Humphrey T. (2003) The microbiological quality of washing up water and the environment in domestic and commercial kitchens. Journal of Applied Microbiology: 94; 842-848.

Mattick K, Durham K, Domingue G, Jørgensen F, Sen M, Schaffner DW, Humphrey T. (2003) The survival of foodborne pathogens during domestic washing up and subsequent transfer onto washing-up sponges, kitchen surfaces and food. International Journal of Food Microbiology: 85; 213-226.

Miller AJ, Brown T, Call JE. (1996) Comparison of wooden and polyethylene cutting boards: potential for the attachment and removal of bacteria from ground beef. Journal of Food Protection: 59; 854-858.

MLA (1998) Hazards and Exposure in the Meat Distribution, Foodservice and Home Sectors. Sub-Project Domestic Sector, Project MSHE.007, May 1998, Australia.

Montville R, Chen Y, Schaffner DW. (2001) Glove barriers to bacterial cross-contamination between hands to food. Journal of Food Protection: 64; 845-849.

Montville R, Schaffner DW. (2003) Inoculum size influences bacterial cross contamination between surfaces. Applied and Environmental Microbiology: 69: 7188-7193

Moore CM, Sheldon BW, Jaykus L-A. (2003) Transfer of *Salmonella* and *Campylobacter* from Stainless Steel to Romaine Lettuce. Journal of Food Protection: 66; 2231-2236.

Redmond EC, Griffith CJ, Slader J, Humphrey TJ. (2004) Quantitative microbiological risks associated with food-handling behaviours implemented during domestic food preparation. Poster, University of Wales Institute, Cardiff. Poster: IAFP Conference, New Orleans.

Rusin P, Maxwell S, Gerba C. (2002) Comparative surface-to-hand and fingertip-to-mouth transfer efficiency of gram-positive bacteria, gram-negative bacteria and phage. Journal of Applied Microbiology: 93; 585-592.

Scott E, Bloomfield SF. (1990) The survival and transfer of microbial contamination via cloths, hands and utensils. Journal of Applied Bacteriology: 68; 271-278.

Schaffner DW. (2003) Challenges in cross contamination modeling in home and food service settings. Food Australia: 55; 583-586

Schaffner DW, Sithole S, Montville R. (2004) Use of microbial modeling and Monte Carlo simulation to determine microbial performance criteria on plastic cutting boards in use in foodservice kitchens. Food Protection Trends: 24; 14-19.

Wachtel MR, McEvoy JL, Luo Y, Williams-Campbell AM, Solomon MB. (2003) Cross-contamination of lettuce (*Lactuca sativa* L.) with *Escherichia coli* O157:H7 via contaminated ground beef. Journal of Food Protection: 66: 1176-1183.

Wong TL, Hollis L, Cornelius A, Nicol C, Cook R, Hudson JA. (2006) Prevalence, Numbers and Subtypes of *Campylobacter jejuni* and *C. coli* in Uncooked Retail Meat Samples. Submitted to Journal of Food Protection.

Zhao P, Zhao T, Doyle MP, Rubino JR, Meng J. (1998) Development of a Model for evaluation of microbial cross-contamination in the kitchen. Journal of Food Protection: 61; 960-963.

APPENDIX 1: SUMMARY OF INFORMATION ON REFRIGERATOR SURVEY PREPARED FOR FOODSAFE PARTNERSHIP AND NZFSA SEPTEMBER 2005

ESR Domestic Refrigerator survey: Christchurch, Auckland and Rural areas 2004-2005
Information for Foodsafe Partnership:

Why do we want to know about refrigerator temperatures?

Refrigeration is one of the most important means of keeping foods safe. Refrigeration slows bacterial growth, allowing perishable foods to be eaten over a number of days. Most pathogenic bacteria (those that cause food poisoning) are not able to grow in foods at refrigeration temperatures. The exception is *Listeria monocytogenes*, which can grow slowly at 1 to 5°C, but growth can be minimised by making sure our fridges do not operate above this range. Obviously if a fridge is operating above the ideal temperature, then the safety of food is at risk. The types of bacteria that cause foods to deteriorate and go slimy or smelly in the refrigerator are called spoilage bacteria and do not usually make people sick.

Refrigerators should be set to maintain a temperature of around 5°C or cooler. If you don't already have one, buy a fridge thermometer, available at most hardware stores. Checking your thermometer will tell you whether you need to alter your settings.

It is also recommended that hot foods are cooled slightly before placing them in the refrigerator to avoid raising the temperature of other stored foods. Raw meats, poultry and seafood should be placed in a container and stored on the lowest shelf of the refrigerator to avoid juices dripping and contaminating other foods.

One important step in keeping your food safe in the refrigerator is to keep the inside of your refrigerator clean. Wipe up spills immediately, wash surfaces with soapy water and dry. It is a good idea to have a general sort and wipe out every week or two.

The NZFSA asked the Institute of Environmental Science and Research (ESR) to find out how New Zealand fridges are doing in comparison to the ideal temperature range. This will help assess the size of the problem, and what to do about it.

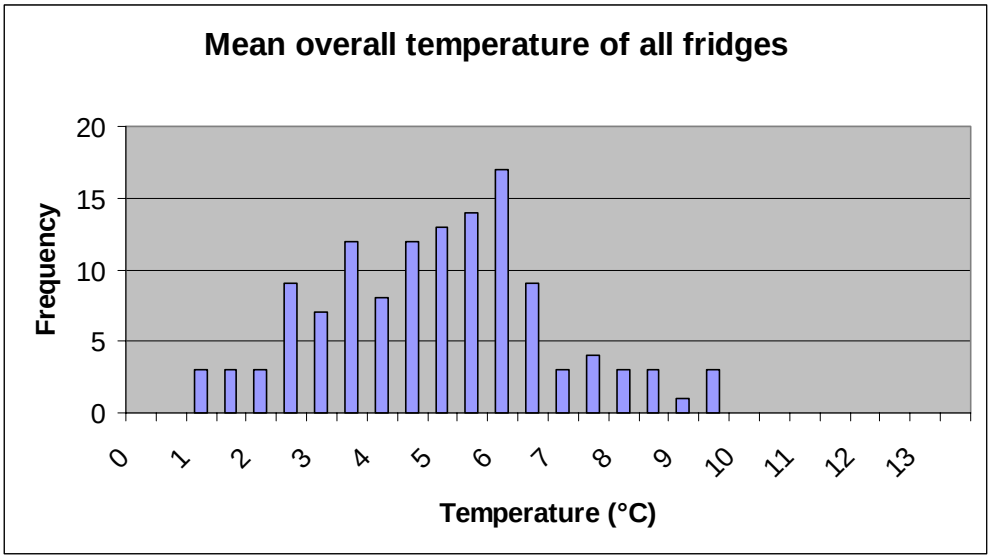
ESR conducted a survey of 127 domestic fridges in urban and rural New Zealand from September 2004 to June 2005. Data loggers were used to record the internal air temperature on top and bottom shelves every 10 minutes, over a 3 day period (1 weekday and a weekend). The average time that a data logger spent in a fridge was 86 hours. The average temperature was then calculated for each fridge. The data loggers are accurate to within +/- 1°C. The recommended temperature range in a refrigerator is 1 to 5°C. Therefore a margin of error of 1°C means that those refrigerators operating above 6°C are above the recommended temperature range.

Some findings from this survey are listed below:

Figure one shows that 84/127: 66% of the refrigerators had average air temperatures below 6°C. This means that 43/127: 34% had average air temperatures above 6°C,

The mean average temperature of all 127 fridges in the survey was 5.2°C,

Figure one



There were 4 fridges that recorded average air temperatures over 9°C. They were all in the 6 to 15 year old age bracket. The fridge with the warmest average air temperature recorded 9.9°C.

The highest temperature recorded was on a top shelf at 18°C. The lowest recorded temperature (in a different fridge) was –4.9°C on a bottom shelf,

91 out of 127 fridges (72%) recorded higher temperatures on the top shelf than on the bottom shelf,

A questionnaire regarding refrigeration of food was also administered, key points found were;

Out of the 125 people who answered the question, 105 (84%) correctly identified that refrigerated food should be kept between 1°C and 5°C,

A third (42/127) of fridges in the survey were 0 – 5 years old,

Out of 122 people who answered the question, 119 (98%) did not have a fridge thermometer,

The three fridge thermometers (one inbuilt and 2 shelf thermometers) that were found in the survey, were accurate (within 1°C of their data logger average),

Half of the respondents (47.5%) reported door seals in excellent condition. Although there were 6.5% who reported poor seals,

Just over half of the respondents 64/122 (52%) stated they never changed their thermostat settings,

A common finding was that the dial/setting mechanism which determines how much electricity is used by the appliance is often mistaken for a fridge thermometer. For example, a setting of 3 was thought to be a reading of 3°C.

Seventy nine of the survey participants provided a photograph of the internal layout of their fridge. 10% of these fridges were considered to be overloaded (average air temperature of these fridges 6.1°C) and 4% of fridges had the potential for cross contamination to occur.

ESR
Christchurch
September 2005

APPENDIX 2 SUMMARY OF DEFROSTING INFORMATION, FROM LITERATURE REVIEW AND RISK COMMUNICATION WEBSITES

Organisation	Refrigerator	Room temperature	Microwave oven	Kitchen sink/cold water
UK Food Standards Authority	In a fridge (4°C) allow about 10 to 12 hours per kg, but warns that not all refrigerators will be this temperature.	In a cool room, (below 17.5ºC) allow approximately 3 to 4 hours per kg, longer if the room is particularly cold. At room temperature (20ºC), allow approximately 2 hours per kg		
Canada (Food Safety Network Factsheet)	In plastic wrap, 10 hours per kilo Canadian Food Inspection Agency, 2002)	Meat to be either left in wrap or removed. The overwrap with newspaper (8 sheets) (Lee, 1993). Parameters given are no longer than 12 hours for 4.7kg turkey and no longer than 18 hours for 11.9kg (Lee, 1993).		
USDA	Turkey: 24 hours per 5lbs. Ground meat/chicken breasts 24 hours per pound.		Discusses microwave defrosting but has no guidelines.	A leak-proof bag is used and the water is changed every 30 minutes. Small 1lb packages will take about an hour or less. 3-4 lbs takes 2-3 hours. When defrosting a whole turkey allow about 30 mins per lb
Hospitality Institute of Technology and Management, Sept. 2004 Edition; "Food safety hazards and controls for the home food preparer" O.P Snyder	Recommends fridge thawing on the bottom shelf or lower rack. Spoilage begins at 23°F, thawing begins at 28°F.		Microwave defrosting – needs to be cooked immediately because of surface temperature rises.	Food thawed on the kitchen counter or in the sink is OK but must not rise above 50°F before being returned to fridge/or being cooked.

Scientific literature:

Anderson BA., Sun S, Erdogdu, F. Singh RP. (2004) Thawing and freezing of selected meat products in household refrigerators. International Journal of Refrigeration: 27: 63-72

Refrigerator models with "quick thaw' capabilities were assessed against other models and found to be significantly faster in thawing food. Overall heat transfer coefficients ranged from 5 to 7 Wm^{-2} K^{-1} during thawing.

Ingham SC, Wadhera RK, Fanslau MA, Buege DR. (2005) Growth of *Salmonella* serovars, *Escherichia coli* O157:H7, and *Staphylococcus aureus* during thawing of whole chicken and retail ground beef portions at 22 and 30°C. Journal of Food Protection: 68; 1457-1461.

Pathogen growth was predicted from USDA Pathogen Modeling Program. Inoculation study data corroborated the predictions;

- No growth occurred on whole chickens or 1,359g portions of ground beef thawed at 30°C for 9 hours
- Pathogen nos. increased (0.2-0.5 log) on surface of 453g portions ground beef thawed at 22 or 30°C for 9 hours.

The authors concluded that thawing $\geq$ 1,670g whole chicken at $\leq$ 30°C for $\leq$ 9 hours and thawing >453g ground beef portions at $\leq$ 22°C for $\leq$ 9 hours are not particularly hazardous practices. Thawing smaller portions at higher temperatures or for longer cannot be recommended.

Kolbe ER. (2003) Thawing bibliography, Oregon State University, Portland, Oregon, USA. http://seafood.ucdavis.edu/pubs/thawing.rtf
A bibliography of 84 abstracts

James SSJ, Bailey C. (1984) The theory and practice of food thawing. Thermal processing and quality of foods. Editor P Zeuthen *et al.*, London, Elsevier (P.566-578).

Jiménez SM, Pirovani ME, Salsi MS, Tiburzi MC, Snyder OP. (2000) The effect of different thawing methods on the growth of bacteria in chicken. Dairy, Food and Environmental Sanitation: 20; 678-683.

Frozen raw chickens were thawed by three different methods, spoilage bacteria and *Salmonella hadar* populations were studied during thawing. Thawing chicken at ambient temperatures (21-22°C) within 14 hours or less (internal temperature 4.4°C,3.5cm into breast meat) was a safe procedure. Thawing chicken in flowing water was a safe rapid method. Thawing chicken in a refrigerator (3.5-7.2°C) was also a safe method. However, the longer time period required to thaw chicken under refrigeration temperatures permitting the growth of pseudomonas spoilage bacteria. Most regulatory agencies in the USA follow FDA recommendations which do not allow food to be thawed at ambient temperature.

Taher BJ. Farid MM. (2001) Cyclic microwave thawing of frozen meat: experimental and theoretical investigation. University of Auckland, NZ. Chemical Engineering and Processing;40:379-389
Experimental and theoretical investigation of microwave thawing of frozen minced beef in order to develop a theoretical model to predict temperature distribution in frozen meat

samples of different thicknesses. Thawing process starts from the surface and progresses slowly down to bottom due to strong absorption of microwaves at positions close to the surface. Results show that it is possible to thaw meat under controlled conditions such that surface temperature never exceeds 10°C. Thawing time less than one-fifth of that required in conventional thawing.

Websites

UK Food Standards Authority
http://www.eatwell.gov.uk/healthydiet/seasonsandcelebrations/winter/saferchristmaseating/#cat246164
Recommends that packaging is removed and meat is placed in a cool, dry place, ideally in a refrigerator. A garden shed or garage can be used. A turkey defrosting calculator allows consumers to input their weight of turkey and calculates defrost times. This is based on three defrosting methods (i) a refrigerator set at 4ºC (39ºF) (ii) a cool room below 17.5°C (60°F) or (iii) room temperature at about 20°C (68°F).

USDA http://www.fsis.usda.gov/Fact_Sheets/Big_Thaw/index.asp

Canada (Food Safety Network Factsheet)
http://www.eatwelleatsafe.ca/factsheets/Turkey%20Handling.pdf

Hospitality Institute of Technology and Management, www.hi-tm.com.
O. P. Snyder comments that food may be safely cooked from the frozen state without loss of quality, however cooking time is usually doubled.

APPENDIX 3: SUMMARY OF LITERATURE ON TRANSFER RATES FOR BACTERIA

Acuff *et al.*, 1986: *Campylobacter*, no quantitative data on transfers, presence/absence only.

Barker *et al.*, 2003: *Salmonella* PT4, counts on poultry 1-30 cfu/cm^2. Various transfers to boards, cloths, utensils, etc. were determined, but results were reported as greater than values only. Difficult to establish percentage transfers.

Bradford *et al.*, 1997: *Salmonella* PT4, rapid transfer from egg droplets to melon or beef observed but not quantified.

Brown *et al.*, 1988: *Campylobacter*, demonstrated transfers (poultry to hand, hand to another food), outbreak investigation but presence/absence only

Chen *et al.*, 2001: *Enterobacter aerogenes*,:

Chicken	Hand	E aerogenes	Mean 8.7% (± 1 SD = 1.8-41.7%)
Cutting board*	Lettuce	E aerogenes	Mean 7.9% (± 1 SD = 2.0-30.9%)
Chicken carcass	Cutting board*	E aerogenes	Mean 17.2%, Range 3-32%
Spigot to clean hand		E aerogenes	Mean 2.3% (± 1 SD = 0.3-18.2%)
Hand to lettuce		E aerogenes	Mean 0.8% (± 1 SD = 0.06-8.9%)
Handwashing (reduction)		E aerogenes	Mean 0.6% (± 1 SD = 0.02-16.6%)
Hand to spigot		E aerogenes	Mean 0.2% (± 1 SD = 0.01-1.9%)

Coates *et al.*, 1987: *Campylobacter*, survival on hands, up to 20 minutes (longest period tested) for *Campylobacter* suspended in blood or chicken juice. Not quantified.

Cogan *et al.*, 1990: *Salmonella* and *Campylobacter*, presence/absence only,

Cools *et al.*, 2005: *Campylobacter*, presence absence only for surface, survival on wood and plastic chopping boards quantified, 3-4 log decrease after 30 minutes

De Boer *et al.*, 1990: *Campylobacter* and *Salmonella*: percentages of transfers reported between poultry and surfaces, and then to other foods but not all carcasses were contaminated so data is flawed.

De Wit *et al.*, 1979: *E. coli* K12 indicator: high frequency of transfer between frozen broilers and various surfaces/utensils, not quantitated.

De Cesare *et al.*, 2003: *Campylobacter* and *Salmonella*, survival times on various inoculated surfaces, close to 100% survival for 60 minutes or more

Gorman *et al.*, 2002: *Campylobacter*, *Salmonella*, *E. coli*, *S. aureus*, frequent transfer from poultry to hands and surfaces, but not quantified, presence/absence only.

Haysom *et al.*, 2004: *Salmonella*, TVC, transfers during simulated meal preparation, Salmonella transfers from inoculated poultry to kitchen surfaces etc frequent (most frequent for dishcloths, and lettuce – from hands, board or knife) but not quantitated.

Humphrey *et al.*, 1994: *Salmonella* PT4, presence/absence only, spread of Salmonella during mixing of eggs demonstrated, long survival times on surfaces.

Humphrey *et al.*, 1995: *Campylobacter*, survival on surfaces, rapid drop off once dried.

Humphrey *et al.*, 2001: review paper

Kusumaningrum *et al.*, 2003: *Salmonella enteritidis, Staphylococcus aureus, Campylobacter jejuni*: Survival on stainless steel: marked decline for *Salmonella* and *Campylobacter* (about 3 logs) in first 15 minutes, but after that numbers stabilised and were still present after 4 hours. The author noted that although 100% was a maximum transfer rate. In some cases, food recipients demonstrated higher numbers than contributors. Less than 100% transfer rates were found on surface recipients. Therefore growth must have occurred in those cases where food was the recipient. The following tables are from the Kusumaningrum *et al.*, 2003 research;

Transfer rate from sponges[a] to stainless steel:

Organism	***n*, Contamination (log CFU/10ml)**	**Count numbers**		**Transfer rate**
		Sponges (log CFU/ sponge)	Surfaces[b] (log CFU/ 4000cm^2)	Sponges to surfaces (%)
S. aureus	3, high 8.8 ± 0.2	9.0 ± 0.2	8.6 ± 0.2	38 ± 12
	6, moderate 6.7 ± 0.1	6.8 ± 0.1	6.4 ± 0.2	41 ± 17
S. enteritidis	3, high, 9.3 ± 0.1	9.4 ± 0.2	8.8 ± 0.2	29 ± 23
	6, moderate, 7.3 ± 0.1	7.3 ± 0.0	6.6 ± 0.2	21 ± 8
C jejuni	3, high, 9.4 ± 0.1	9.4 ± 0.1	9.0 ± 0.0	43 ± 10
	6, moderate, 8.5 ± 0.1	8.4 ± 0.1	7.8 ± 0.1	28 ± 13

± : standard deviation

[a:] sponges artificially contaminated with 10 ml of appropriate pathogen suspension

[b:] sampled using a single contact plate

Transfer rate from stainless steel[a] to cucumber (*n*=6) with or without pressure of 500g /slice

Organism	**Moment of sampling**	**Count numbers Surface[b] (log CFU/ cm^2) Cucumbers**			**Transfer rate: Surface to cucumber**	
			Pressure (log CFU/ cm^2)	No pressure (logCFU/ cm^2)	Pressure (%)	No pressure (%)
S. aureus	Direct after cont. 15 min after cont.	2.8 ± 0.2 2.9 ± 0.1	2.9 ± 0.1 2.8 ± 0.3	2.8 ± 0.1 2.7 ± 0.2	117 ± 48 100 ± 59	95 ± 30 74 ± 41
S. enteritidis	Direct after cont. 15 min after cont.	3.0 ± 0.2 3.1 ± 0.3	3.0 ± 0.2 3.0 ± 0.3	2.8 ± 0.2 2.8 ± 0.3	105 ± 26 90 ± 27	65 ± 21 50 ± 18
C jejuni	Direct after cont. 15 min after cont.	4.2 ± 0.2 3.8 ± 0.5	4.4 ± 0.1 3.7 ± 0.8	4.4 ± 0.1 3.9 ± 0.5	185 ±75 134 ± 89	177 ± 72 153 ± 99

± : standard deviation

[a:] surfaces artificially contaminated with sponges (moderate level: *S. aureus* 6.8 ± 0.1, *S. enteritidis* 7.3 ± 0.0 and *C. jejuni* 8.4 ± 0.1.

[b:] sampled using a single contact plate

Transfer rate from stainless steel [a] to roast chicken fillet (n=3) with or without pressure of 500g/slice

Organism	**Moment of sampling**	**Count numbers Surface[b] (log CFU/ cm^2) Roasted chicken fillet**			**Transfer rate: Surface to roasted chicken fillet**	
			Pressure (log CFU/ cm^2)	No pressure (logCFU/ cm^2)	Pressure (%)	No pressure (%)
S. aureus	Direct after cont. 15 min after cont.	2.9 ± 0.2 2.9 ± 0.2	2.8 ± 0.1 2.8 ± 0.0	2.7 ± 0.1 2.7 ± 0.0	76 74 100 ± 17	62 ± 28 56 ± 20
S. enteritidis	Direct after cont. 15 min after cont.	3.1 ± 0.3 3.0 ± 0.0	3.1 ± 0.2 2.8 ± 0.4	2.8 ± 0.1 2.9 ± 0.0	94 ± 42 55 ± 21	49 ± 21 32 ± 9
C jejuni	Direct after cont. 15 min after cont.	4.1 ± 0.2 3.7 ± 0.4	4.2 ± 0.2 3.4 ± 0.2	4.1 ± 0.1 3.5 ± 0.4	101 ± 42 24 ± 16	66 ± 26 70 ± 83

± : standard deviation

[a:] surfaces artificially contaminated with sponges (moderate level: *S. aureus* 6.8 ± 0.1, *S. enteritidis* 7.3 ± 0.0 and *C. jejuni* 8.4 ± 0.1.

[b:] sampled using a single contact plate

(Note: quite high transfer rates but broad variability)

Kusumaningrum *et al.,* 2004: Development of a model for transfers of *Salmonella* and *Campylobacter* – adds information on transfer from carcasses to stainless steel, and more data on stainless steel to cucumber:

Log%	*Salmonella*	*Campylobacter*
Transfer rate to surface	RiskNormal(0.171, 0.162)	RiskNormal(0.098, 0.606)
Transfer rate to food	RiskNormal(1.458, 0.298)	RiskNormal(1.535, 0.320)

Converted to %	*Salmonella*	*Campylobacter*
Transfer rate to surface	RiskNormal(1.48, 1.45)	RiskNormal(1.25, 4.03)
Transfer rate to food	RiskNormal(28.7, 1.98)	RiskNormal(34.27,2.08)

Luber *et al.,* 2006: *Campylobacter*.

Chicken legs to hands: mean 2.9%, SD 5.5%
Chicken legs to plate: mean 0.3%, SD 0.3%
Plate to fried sausage: mean 27.5%, SD 23.7%

Breast fillets to hands: mean 3.8% SD 5.9%
Breast fillets to wooden board and knife: mean 1.1%, SD 0.7%
Board and knife to cucumber: mean 10.3%, SD 9.6%

Hands to bread: Mean 2.9%, SD 3.8%

Mattick *et al*., 2003 (a and b): *Campylobacter*, *Salmonella*, *E coli* O157: demonstrated survival of bacteria on under various conditions, including simulated washing up with transfer (not quantitated) to sterile dishes via washup water of *Salmonella* and *E coli* O157 (*Campylobacter* did not survive washup water).

Miller *et al*., 1996: *E coli* O157: wood and plastic cutting boards, effect of washing, not transfer.

Montville *et al*., 2001: *Enterobacter aerogenes:*

Log% transfer rate

Chicken to bare hand: Normal(0.71, 0.42)
Chicken to hand through gloves: gamma(5.91, 0.40, -5.00)
Bare hand to lettuce: logistic (1.16, 0.30)
Hand to lettuce through gloves (low inoculum): normal (0.35, 0.88)
Hand to lettuce through gloves (high inoculum): normal (-2.52, 0.61)

Indicates that gloves are permeable but do reduce transfer.

Montville and Schaffner, 2003: *Enterobacter aerogenes*:

Showed that transfer rate was proportional to initial inoculum – higher numbers of source bacteria had lower transfer rates.

Log10 transfer (%):

	Mean	Max	Min
Chicken to cutting board	1.05	0.48	1.49
Cutting board to lettuce	0.79	-0.47	1.73
Chicken to bare hand	0.59	-0.44	2.00
Bare hand to lettuce	0.21	-2.54	2.00
Spigot to bare hand	0.16	-1.70	2.00
Bare hand to spigot	-1.08	-2.95	1.09
Gloved hand to lettuce	-1.26	-3.98	1.53
Chicken to gloved hand	-2.94	-4.40	-0.62

Moore *et al*., 2003: *Salmonella*, *Campylobacter*: from stainless steel to romaine lettuce

Salmonella
Dry lettuce Mean % transfer 30.6 SE 2.4 Range 2.3 – 66
Wet lettuce Mean % transfer 27.0 SE 2.4 Range 22.5-31.4

Campylobacter
Dry lettuce Mean % transfer 29.0 SE 2.4 Range 16.3-38.4
Wet lettuce Mean % transfer 16.9 SE 2.4 Range 7.2-26.6

(Note: high inoculum levels: 106 cfu/28 mm^2)

Redmond *et al.*, poster: *Campylobacter*, *Salmonella*: transfers during simulated kitchen activities frequent but not quantitated.

Rusin *et al*., 2002: *Micrococcus luteus*, *Serratia rubidea*, and phage PRD-1. Although unusual organisms – did look at transfer from fomites to hands, and from hands to lips (mean transfer of 41%, 34% and 34% of organisms respectively from fingertips to lips).

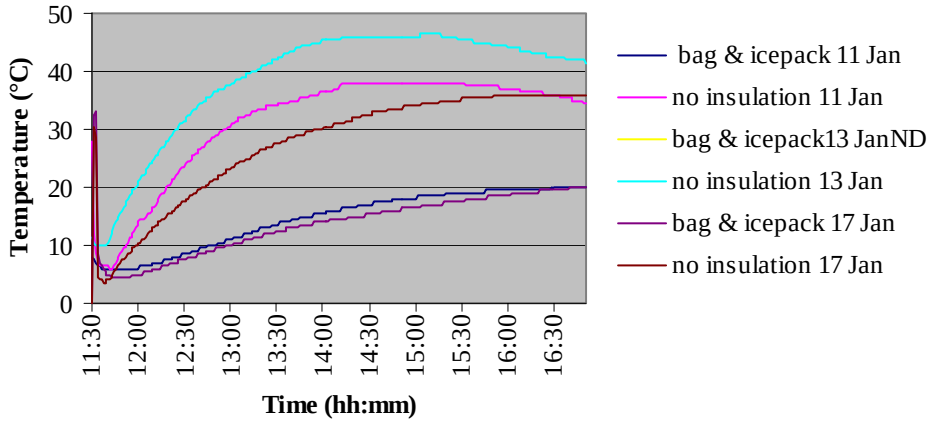
Scott *et al*., 1990: *E. coli*, *Salmonella*, *S aureus*: survival and transfer experiments. From laminate surface to fingertips about 20-30% of organisms transferred immediately, or up to 1 hour later.

Wachtel *et al*., 2003: *E. coli* O157: transfer from mince to boards, from boards to successive lettuce pieces. Difficult to estimate transfer rates, but did show that successive leaves were contaminated.

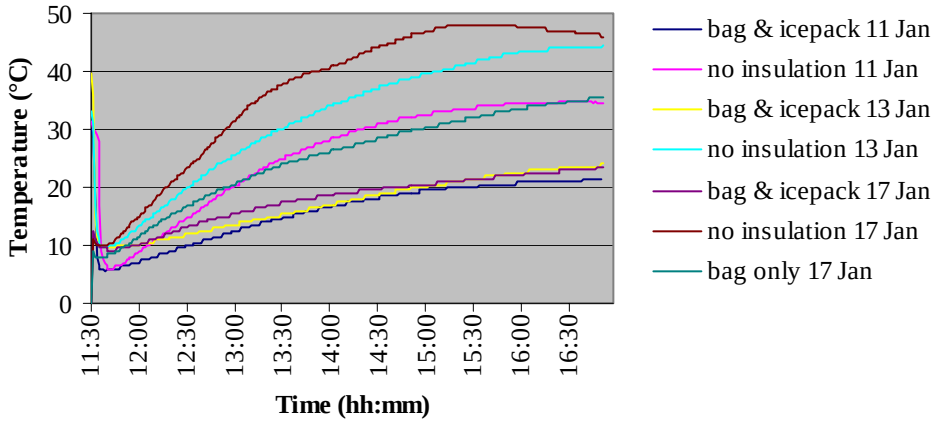
Zhao *et al*., 1998: *Enterobacter aerogenes*. Variety of survival studies, including transfers from cutting boards to vegetables cut on the boards: For 5.0 $\log_{10}$ cfu/cm^2 contamination, approximately 3.0 $\log_{10}$ cfu/g were recovered form the vegetables.

APPENDIX 4: GRAPHS SUMMARISING TEMPERATURE GAINS OF MEAT

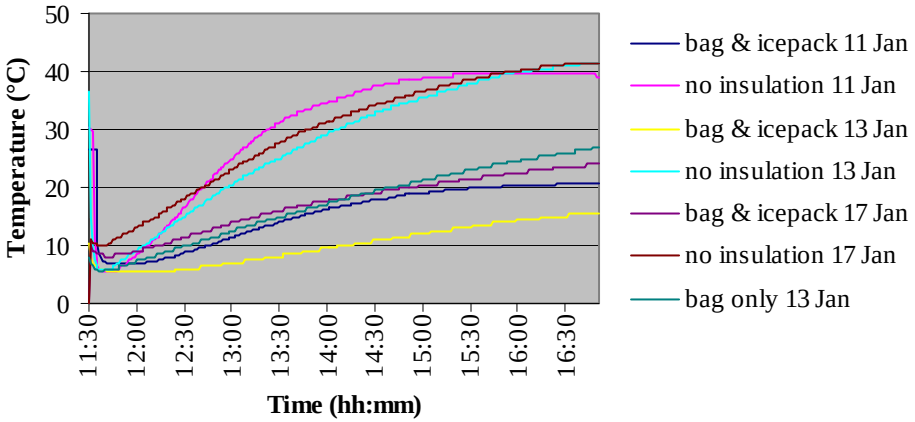
Temperature of steak internally (car) - Summer



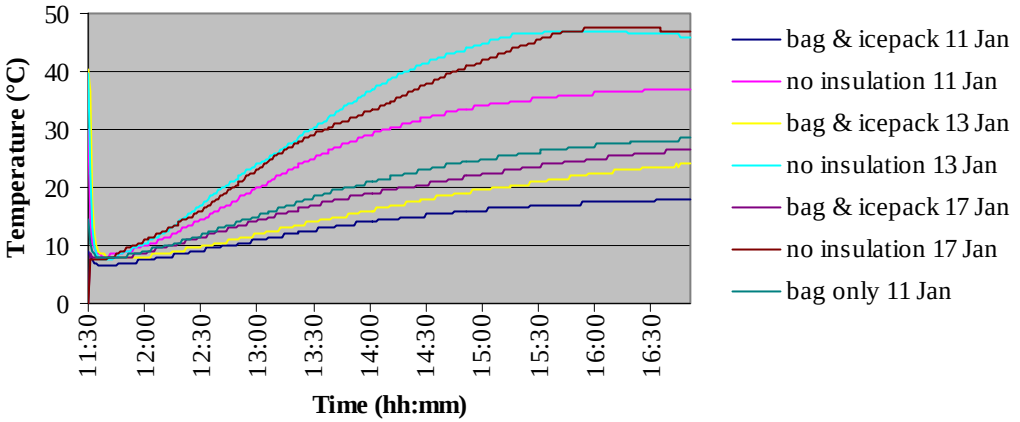
Temperature of chicken internally (car) - Summer



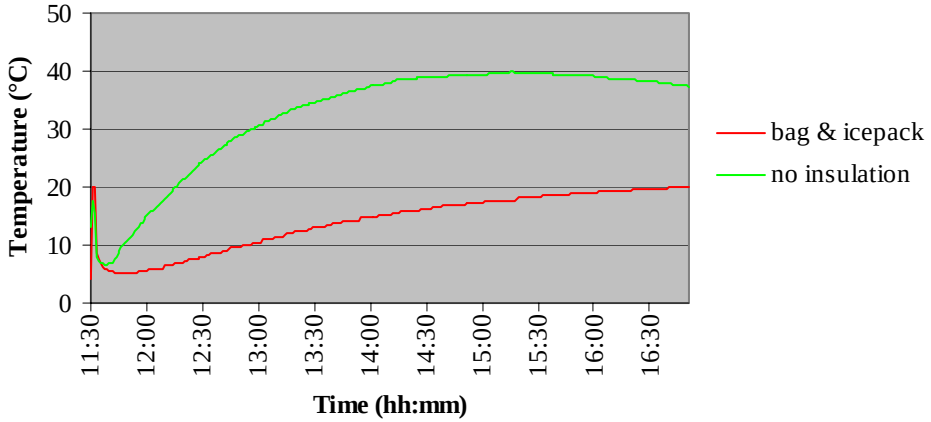
Temperature of sausages internally (car) - Summer



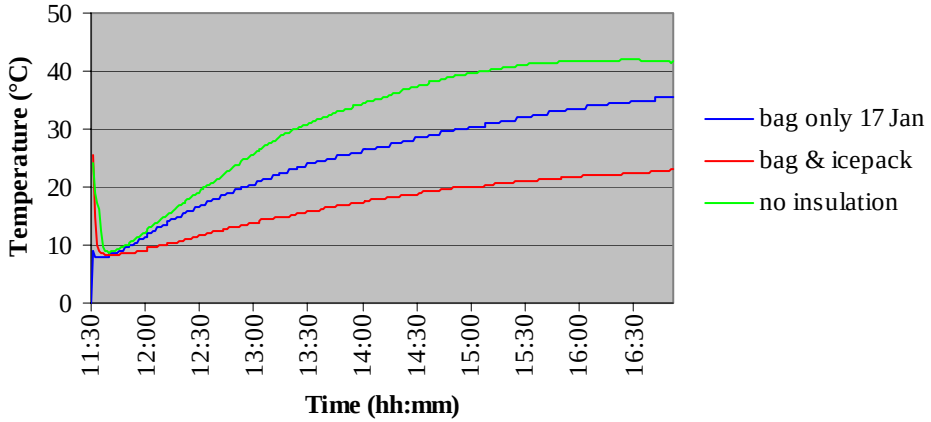
Temperature of mince internally (car) - Summer



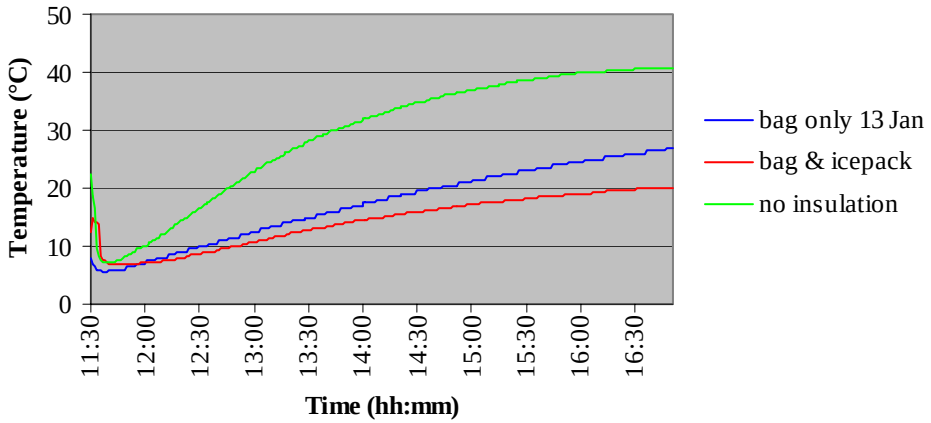
Mean of steak internal temperatures in car - Summer



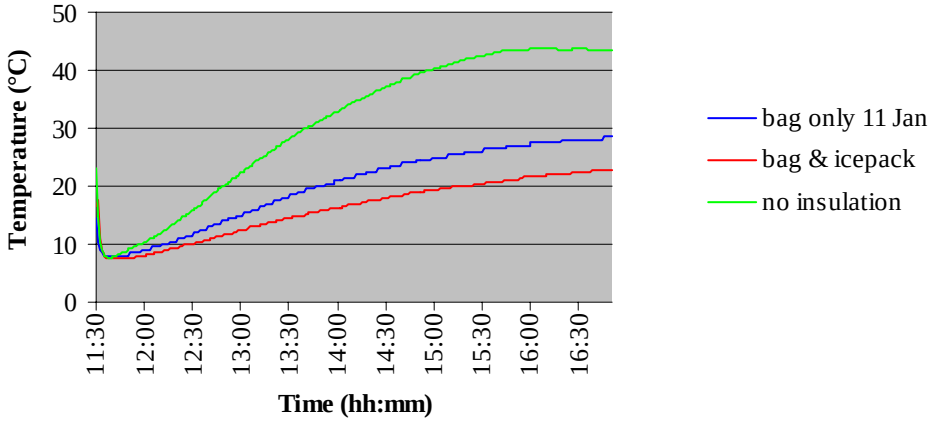
Mean of chicken internal temperatures in car - Summer



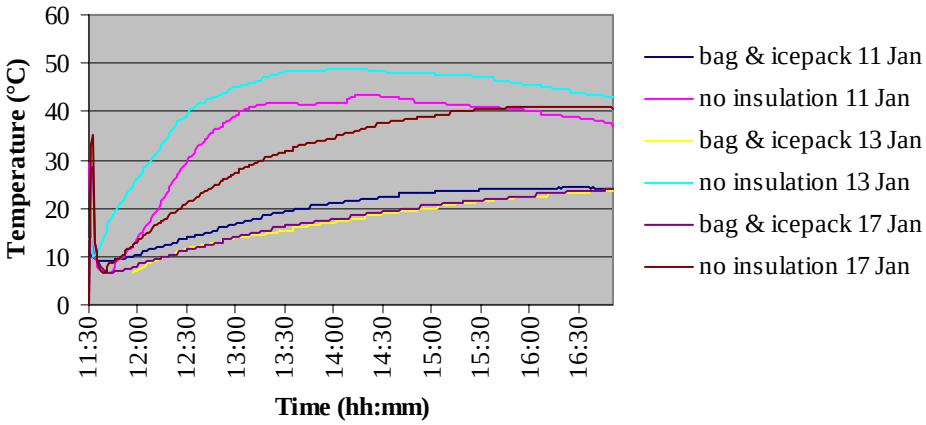
Mean of sausage internal temperatures in car - Summer



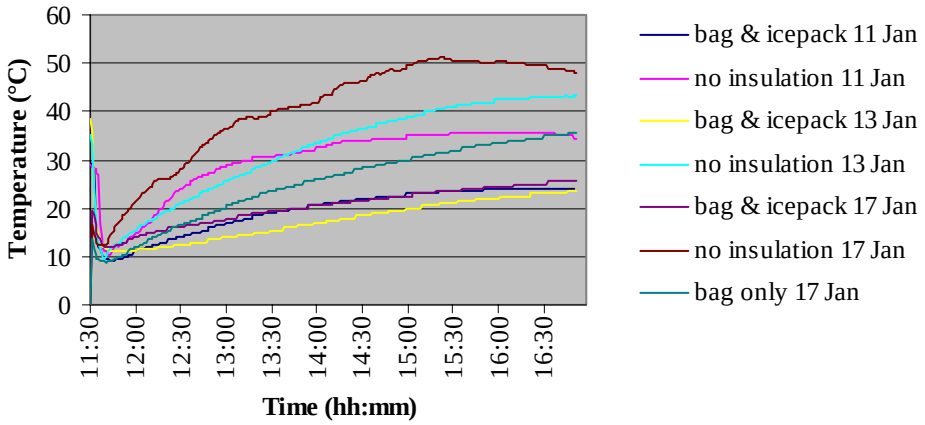
Mean of mince internal temperatures in car - Summer



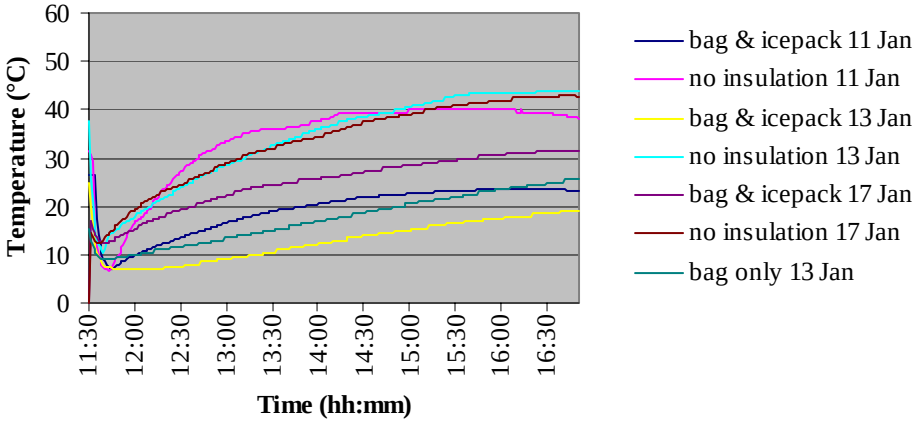
Temperature of steak surfaces (car) - Summer



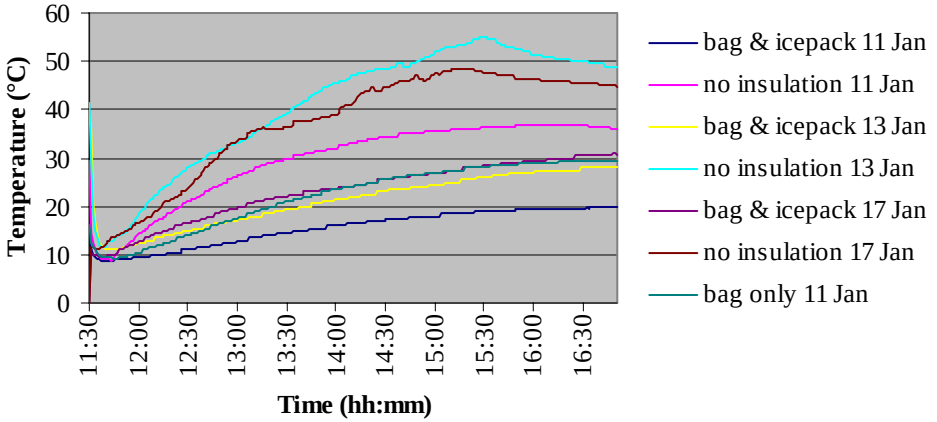
Temperature of chicken surfaces (car) - Summer

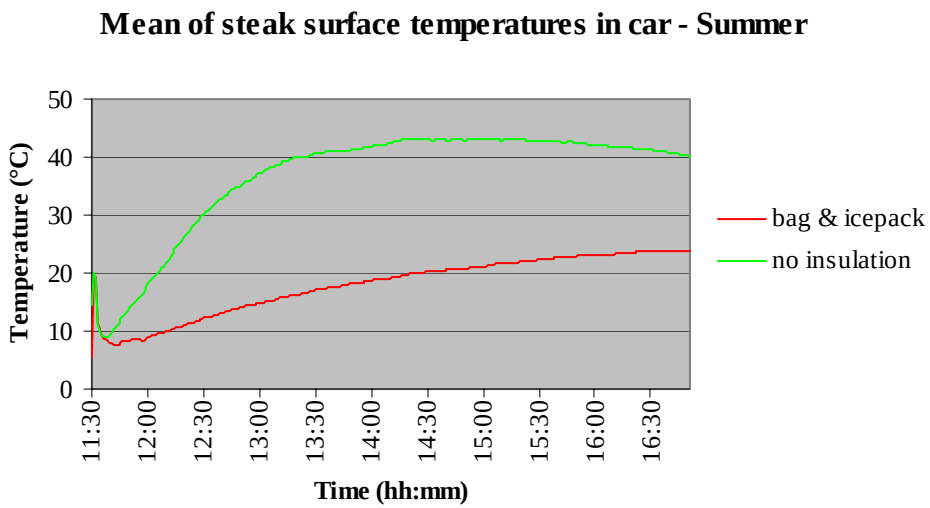


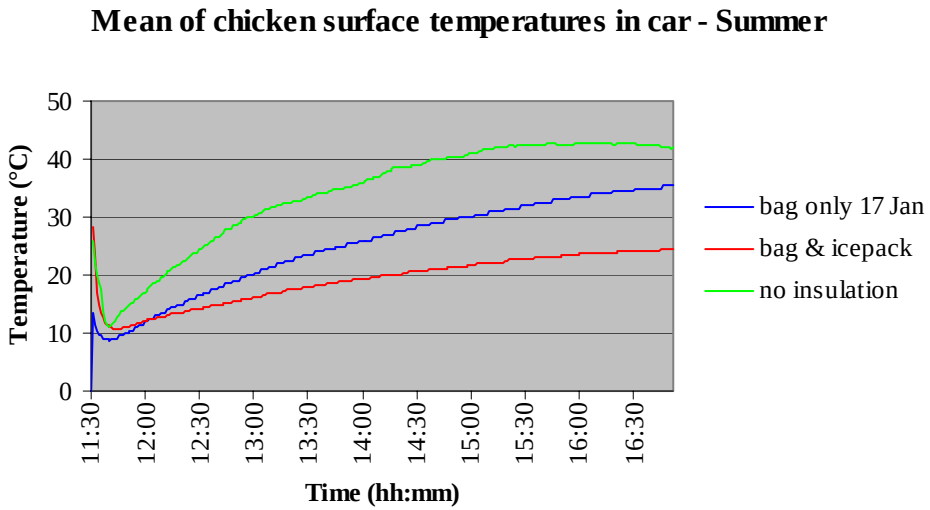
Temperature of sausage surfaces (car) - Summer

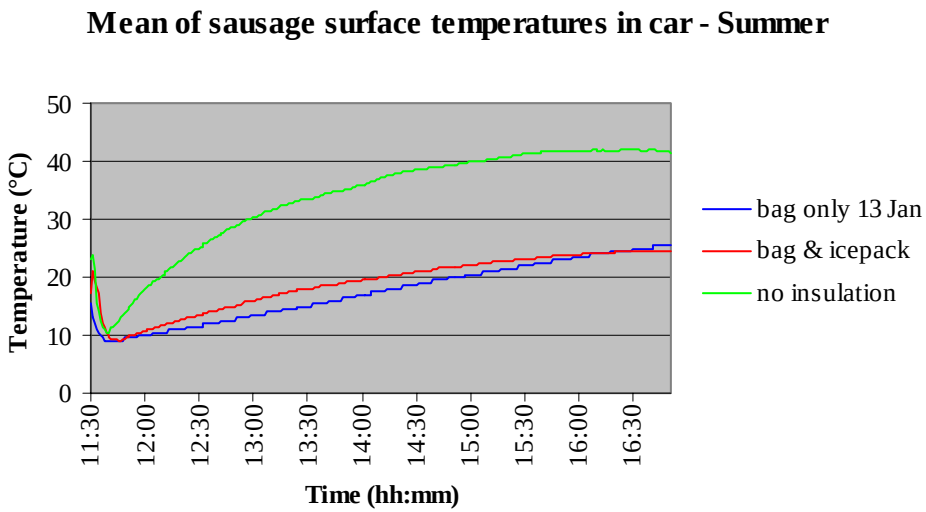


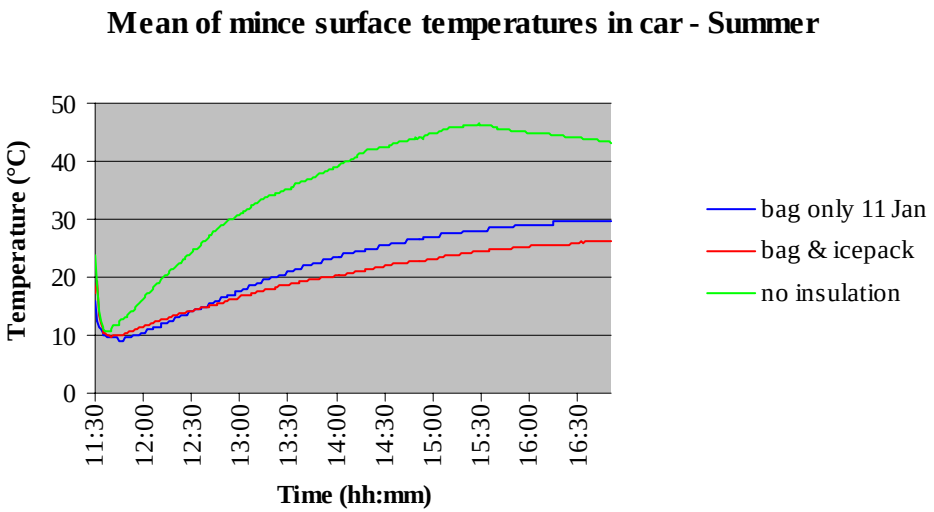
Temperature of mince surfaces (car) - Summer



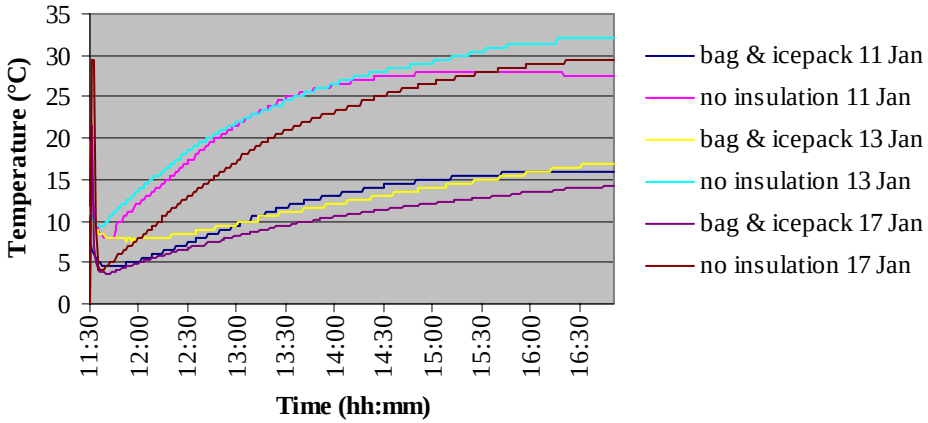

Mean of steak surface temperatures in car - Summer
Temperature (°C)
0
10
20
30
40
50
11:30
12:00
12:30
13:00
13:30
14:00
14:30
15:00
15:30
16:00
16:30
Time (hh:mm)
bag & icepack
no insulation


Mean of chicken surface temperatures in car - Summer
Temperature (°C)
0
10
20
30
40
50
11:30
12:00
12:30
13:00
13:30
14:00
14:30
15:00
15:30
16:00
16:30
Time (hh:mm)
bag only 17 Jan
bag & icepack
no insulation

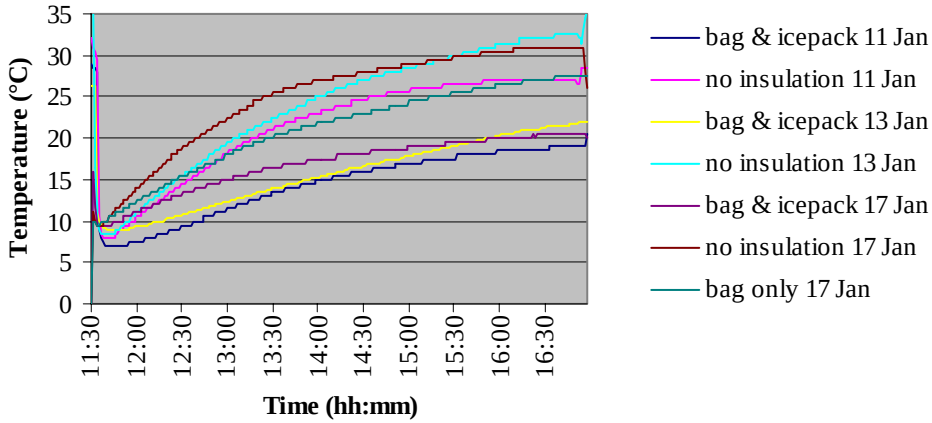

Mean of sausage surface temperatures in car - Summer
Temperature (°C)
0
10
20
30
40
50
11:30
12:00
12:30
13:00
13:30
14:00
14:30
15:00
15:30
16:00
16:30
Time (hh:mm)
bag only 13 Jan
bag & icepack
no insulation


Mean of mince surface temperatures in car - Summer
Temperature (°C)
0
10
20
30
40
50
11:30
12:00
12:30
13:00
13:30
14:00
14:30
15:00
15:30
16:00
16:30
Time (hh:mm)
bag only 11 Jan
bag & icepack
no insulation

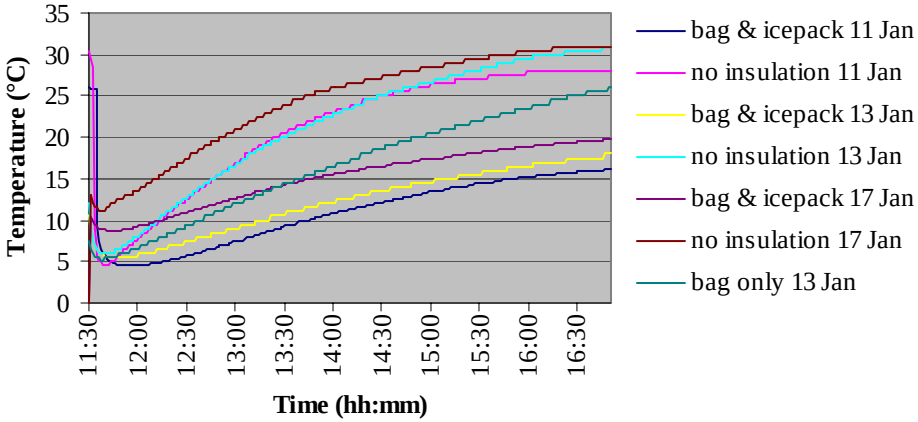
Temperature of steak internally (boot) - Summer



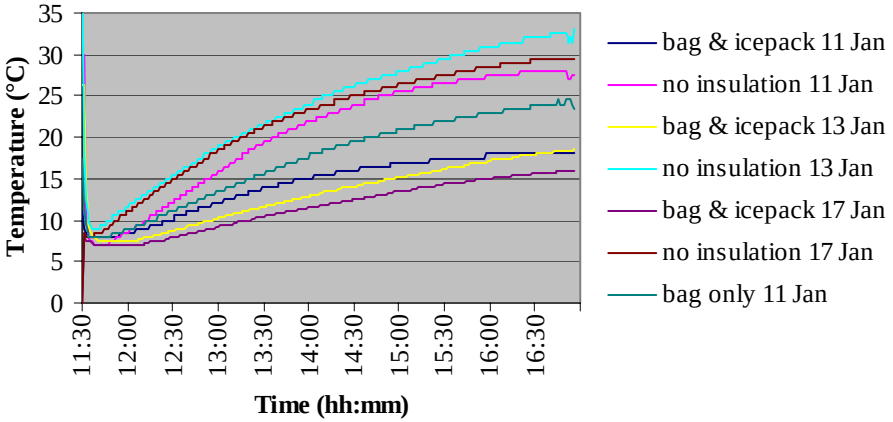
Temperature of chicken internally (boot) - Summer



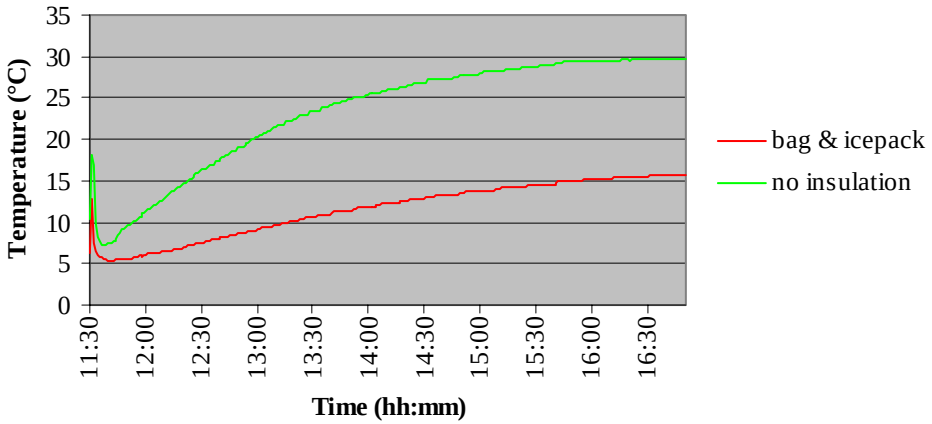
Temperature of sausage internally (boot) - Summer



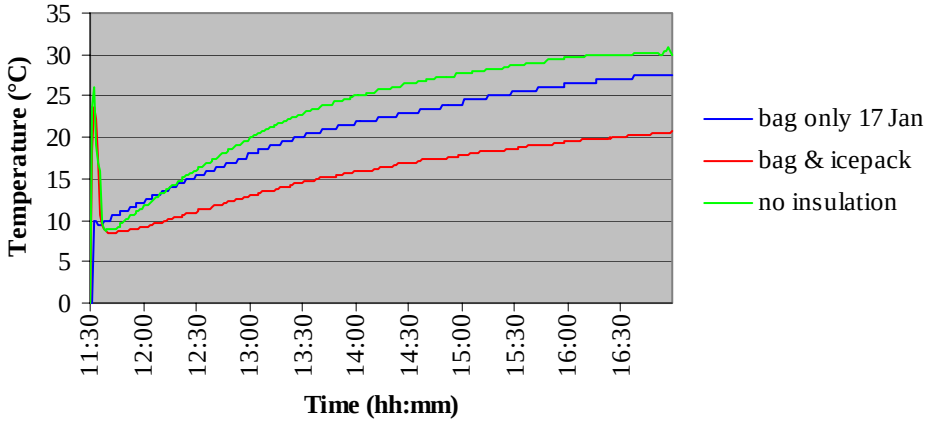
Temperature of mince internally (boot) - Summer



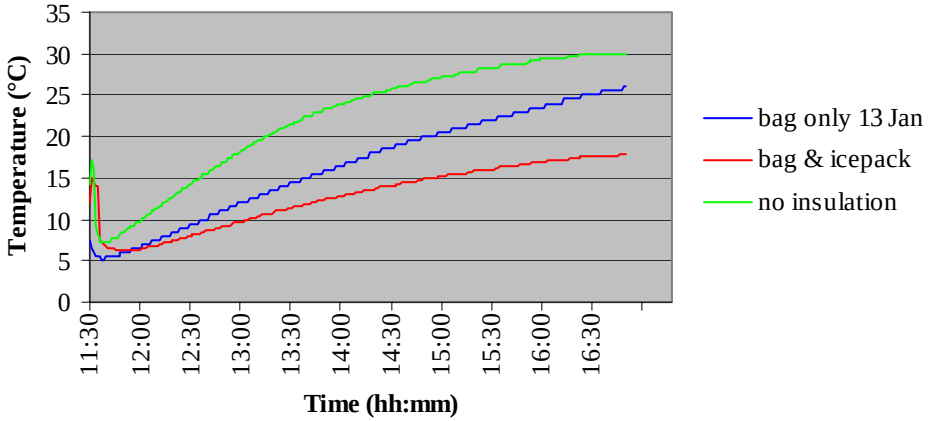
Mean of steak internal temperatures in boot - Summer



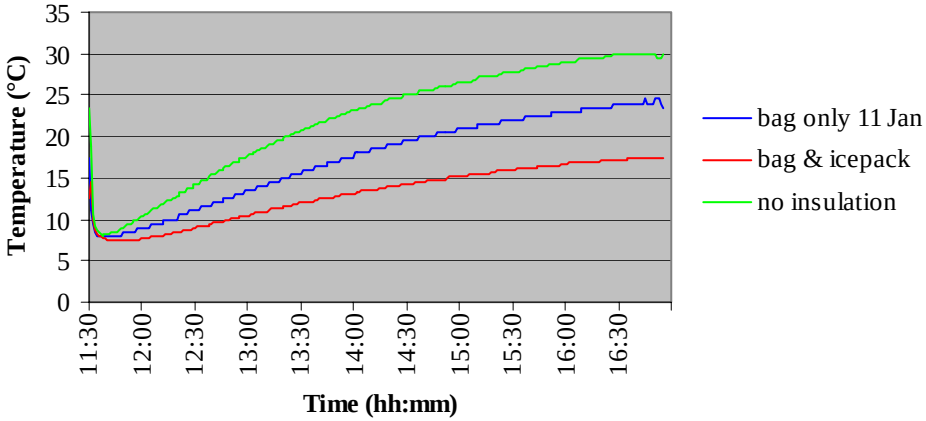
Mean of chicken internal temperatures in boot - Summer



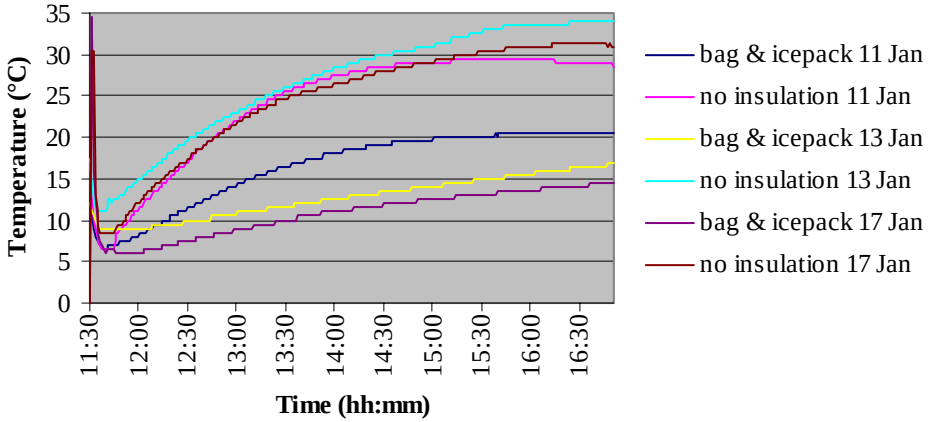
Mean of sausage internal temperatures in boot - Summer



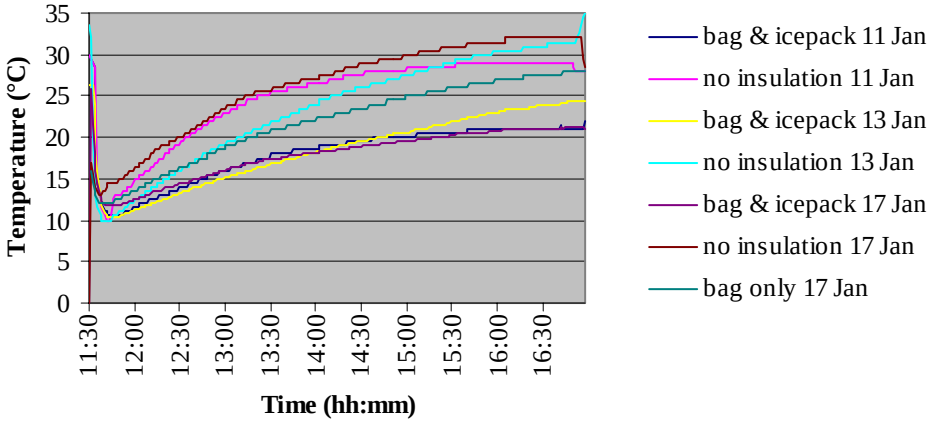
Mean of mince internal temperatures in boot - Summer



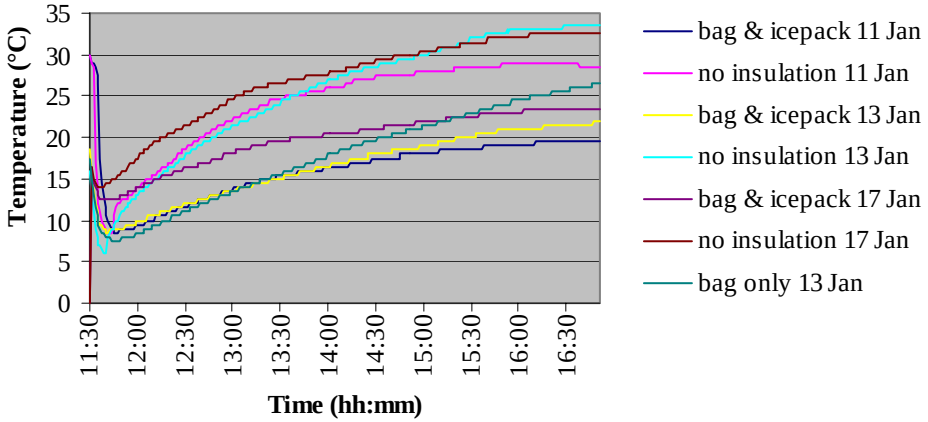
Temperature of steak surfaces (boot) - Summer



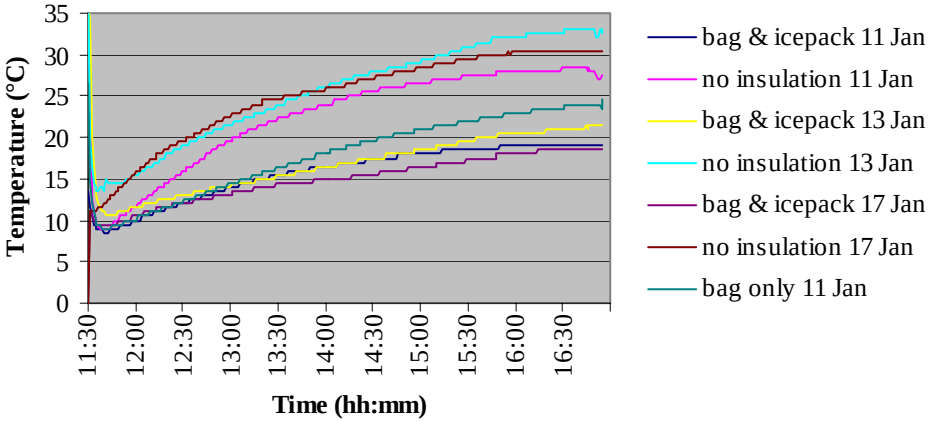
Temperature of chicken surfaces (boot) - Summer



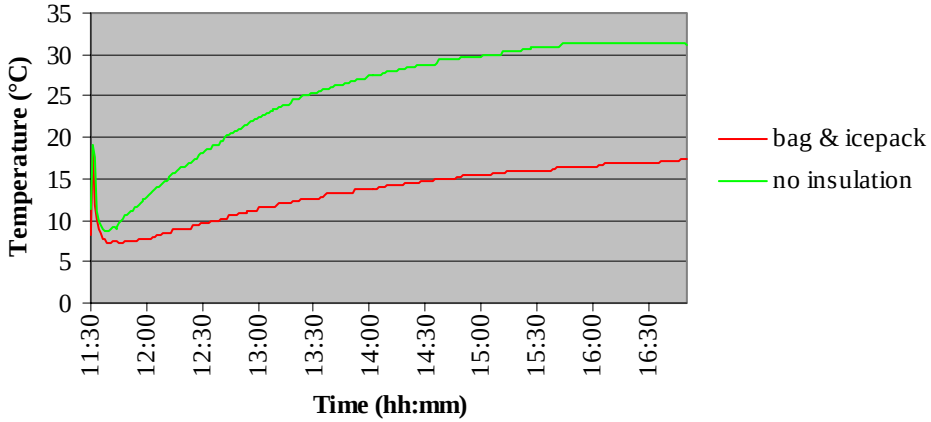
Temperature of sausage surfaces (boot) - Summer



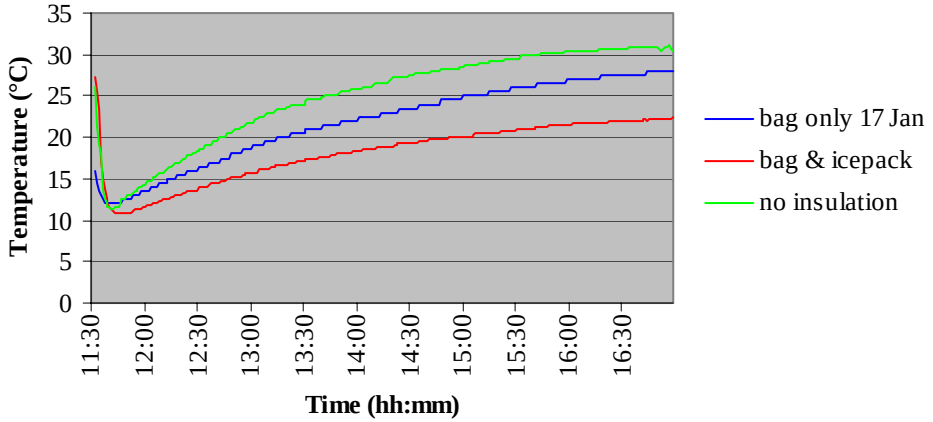
Temperature of mince surface (boot) - Summer



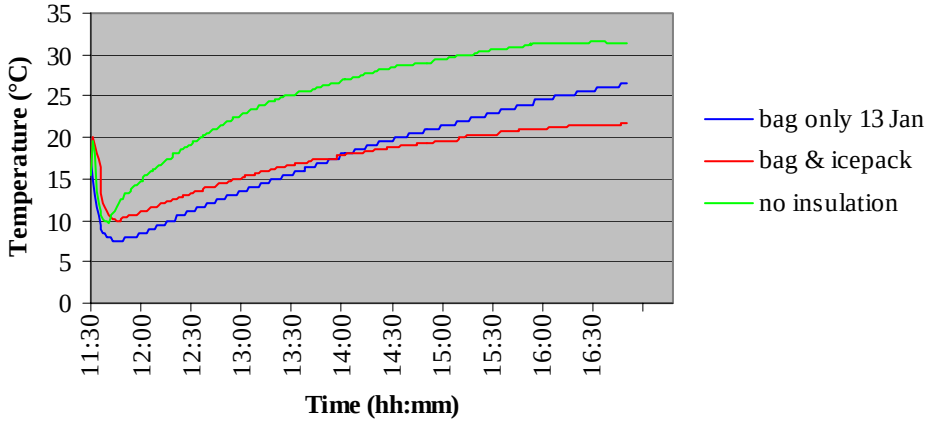
Mean of steak surface temperatures in boot - Summer



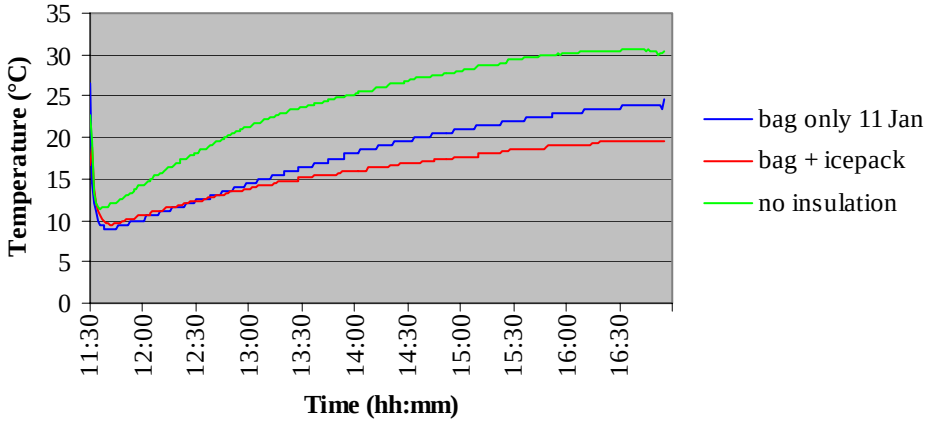
Mean of chicken surface temperatures in boot - Summer



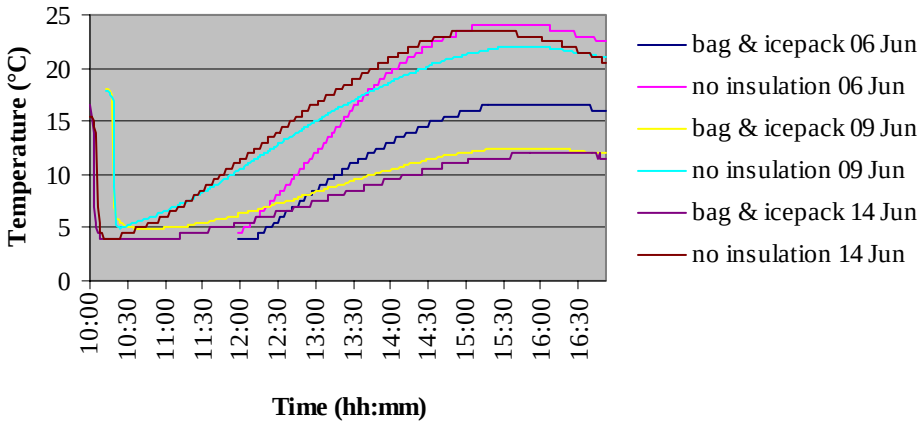
Mean of sausage surface temperatures in boot - Summer



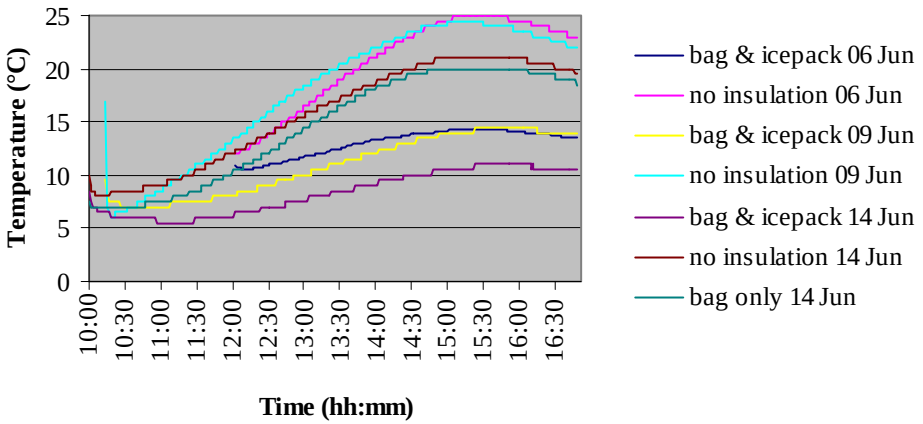
Mean of mince surface temperatures in boot - Summer



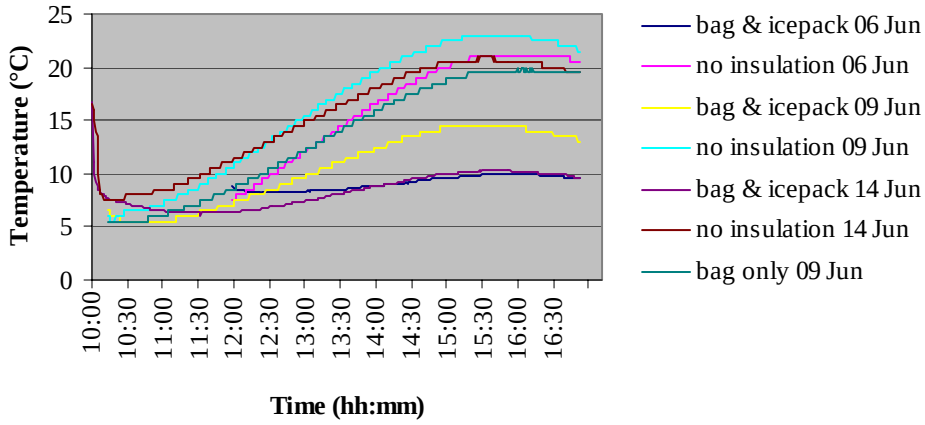
Temperature of steak internally (car) - Winter



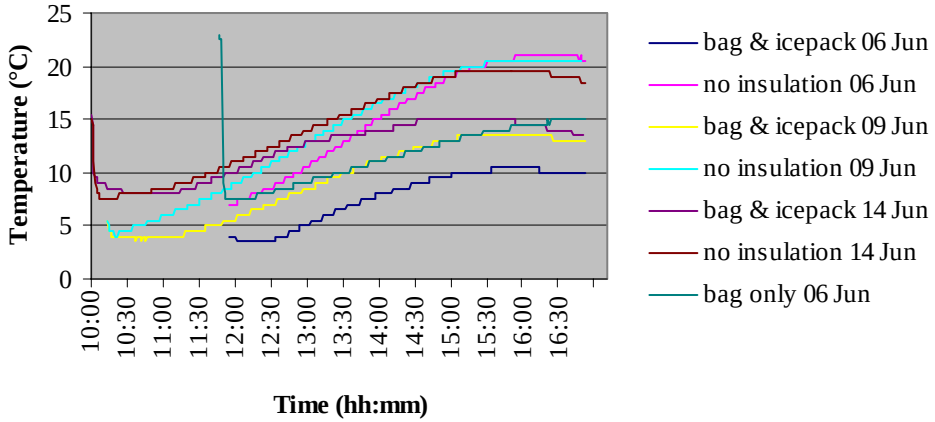
Temperature of chicken internally (car) - Winter



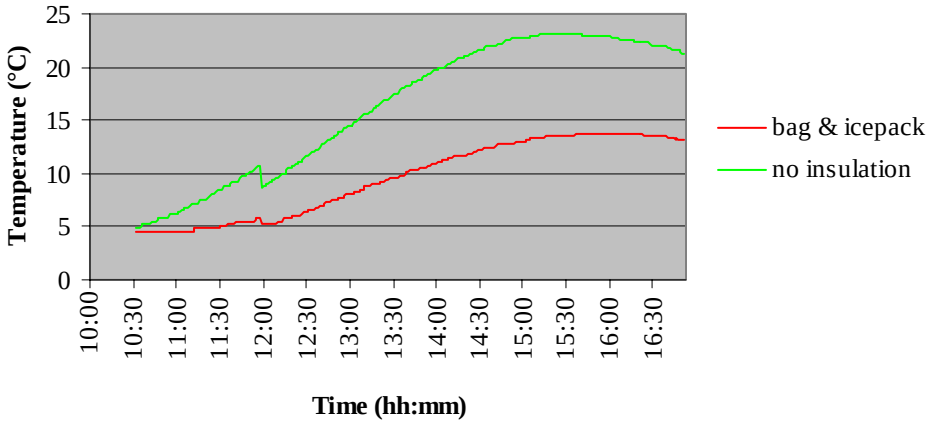
Temperature of sausage internally (car) - Winter



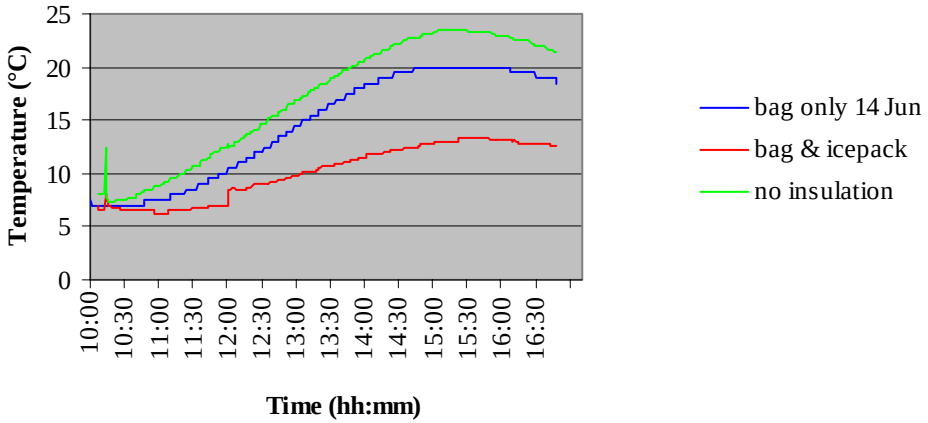
Temperature of mince internally (car) - Winter



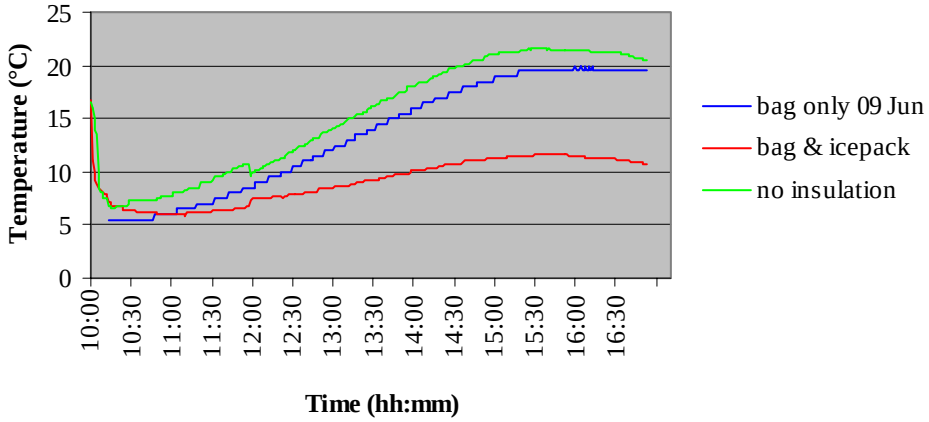
Mean of steak internal temperatures in car - Winter



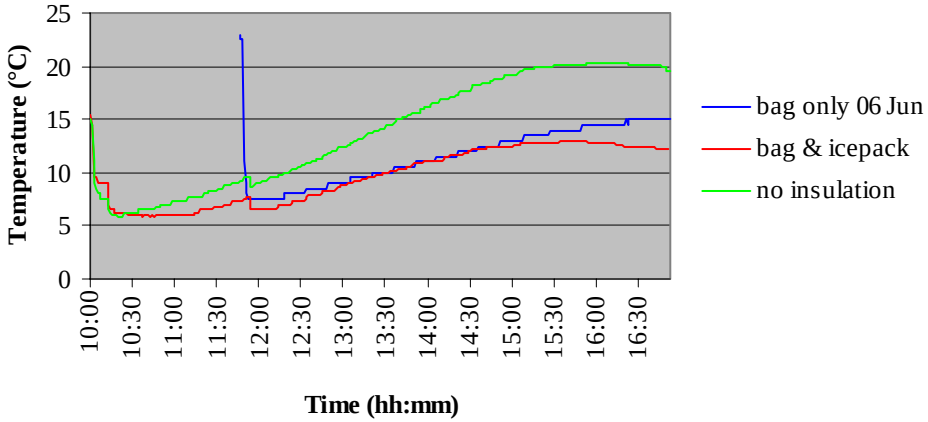
Mean of chicken internal temperatures in car - Winter



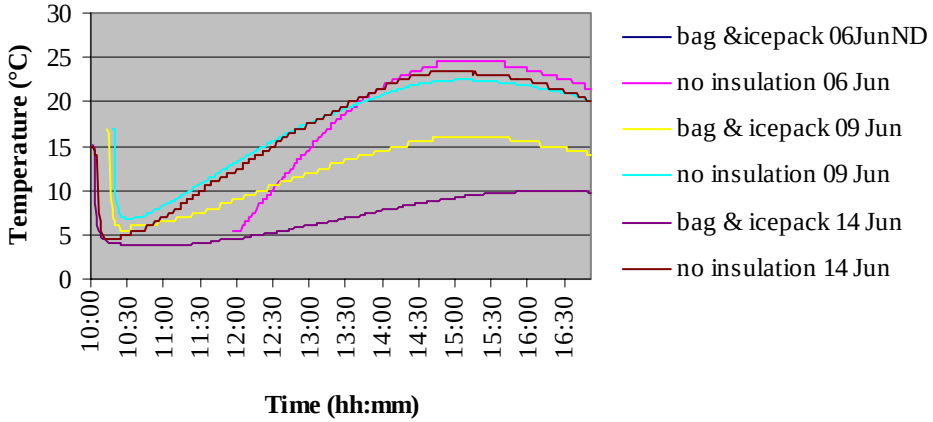
Mean of sausage internal temperatures in car - Winter



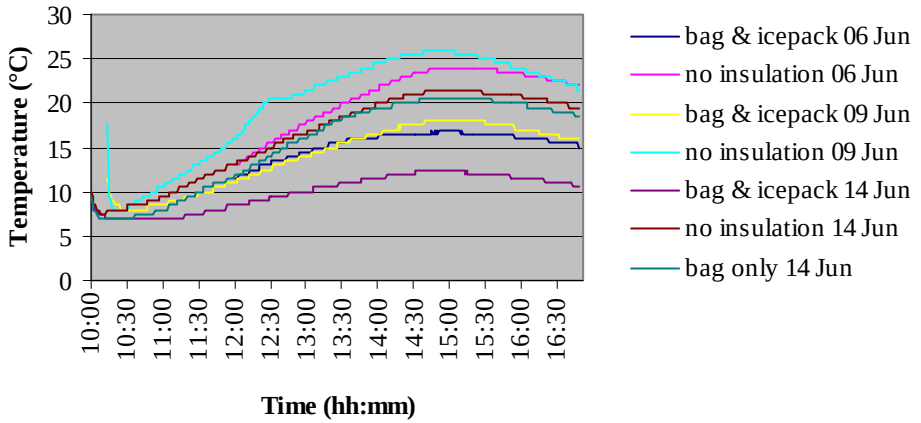
Mean of mince internal temperatures in car - Winter



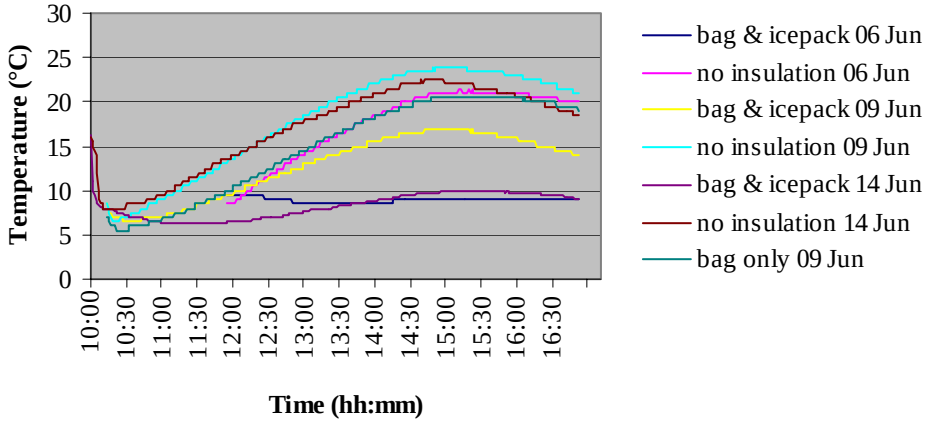
Temperature of steak surfaces (car) - Winter



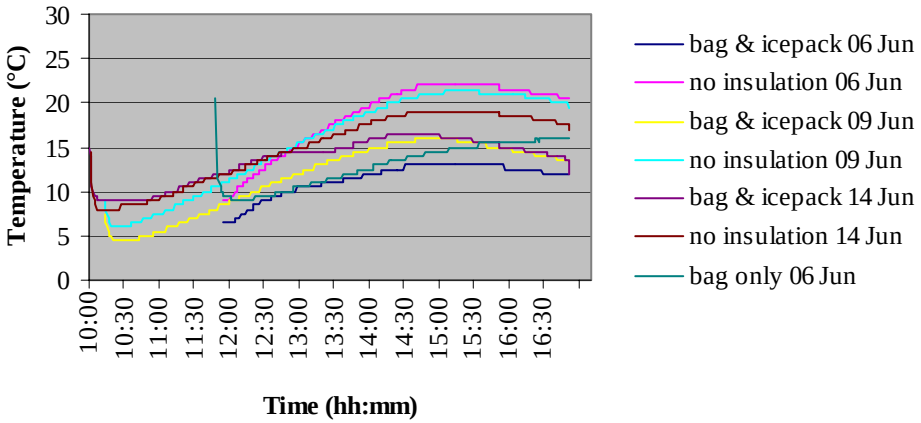
Temperature of chicken surface (car) - Winter



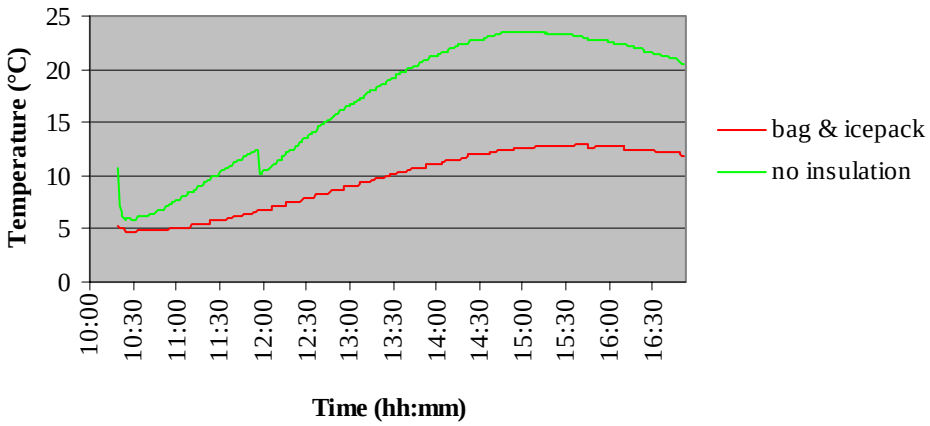
Temperature of sausage surfaces (car) - Winter



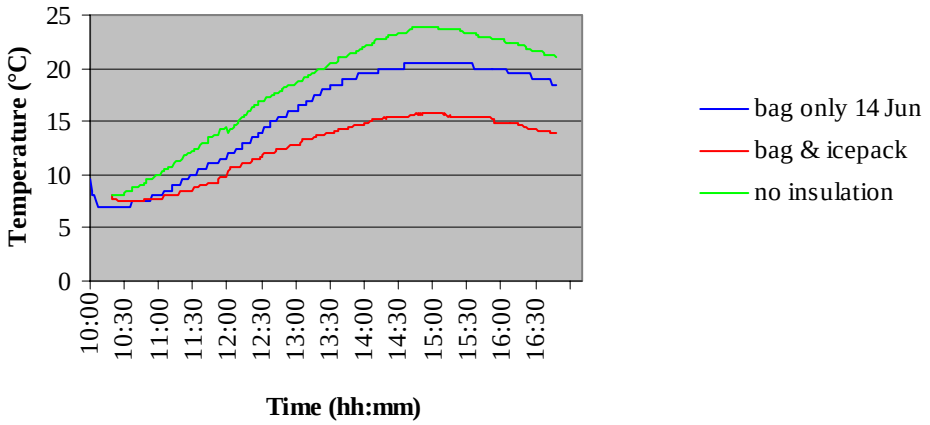
Temperature of mince surfaces (car) - Winter



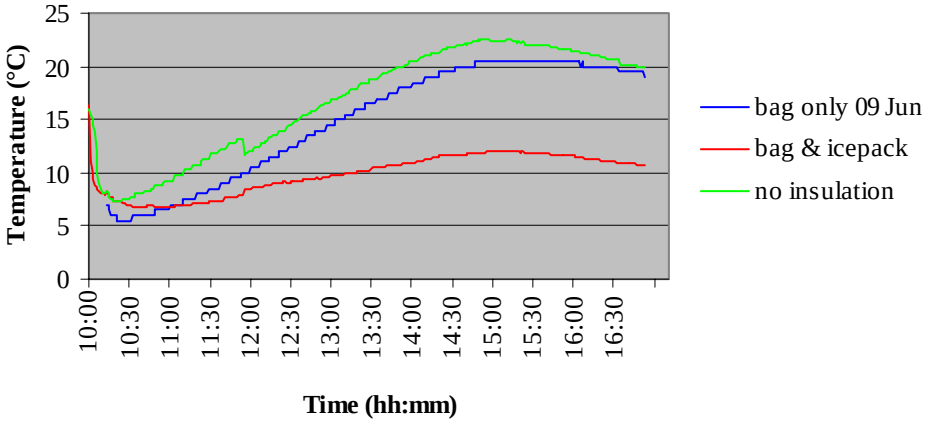
Mean of steak surface temperatures in car - Winter



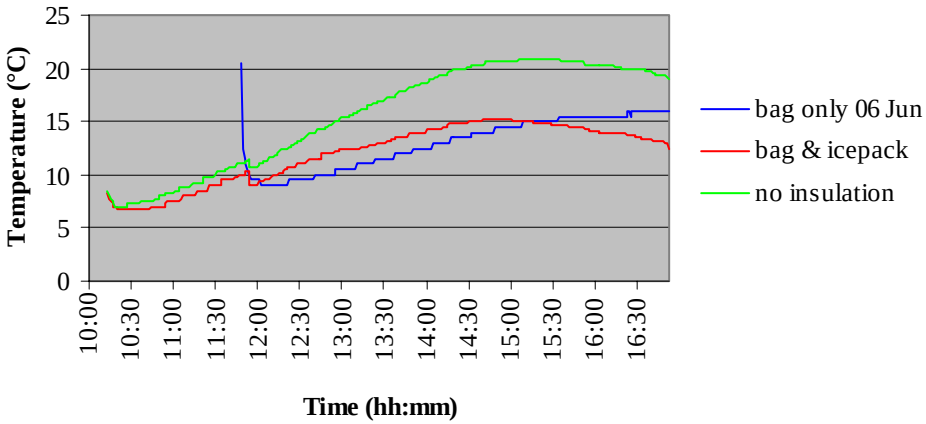
Mean of chicken surface temperatures in car - Winter



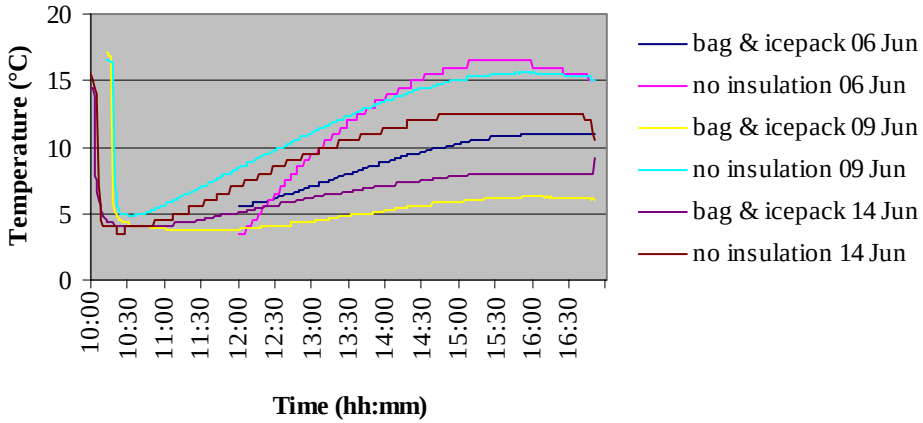
Mean of sausage surface temperatures in car - Winter



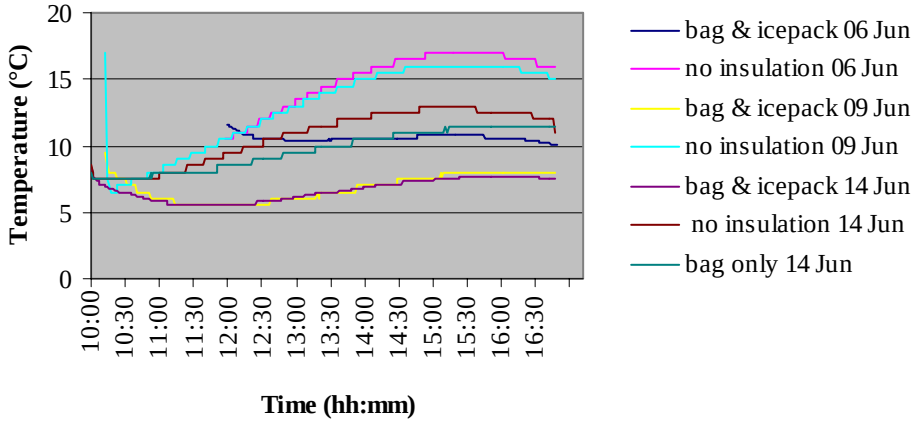
Mean of mince surface temperatures in car - Winter



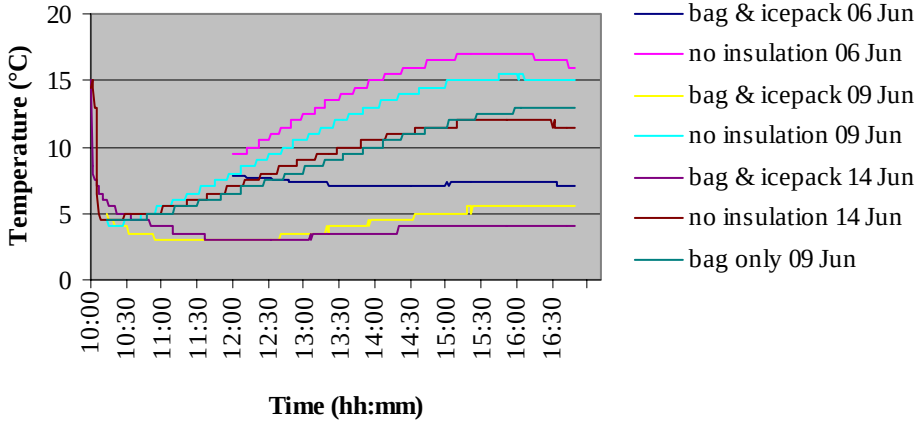
Temperature of steak internally (boot) - Winter



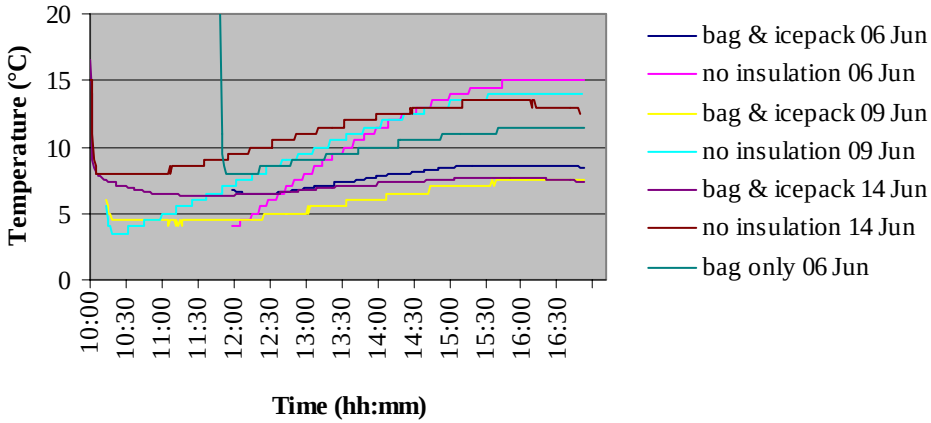
Temperature of chicken internally (boot) - Winter



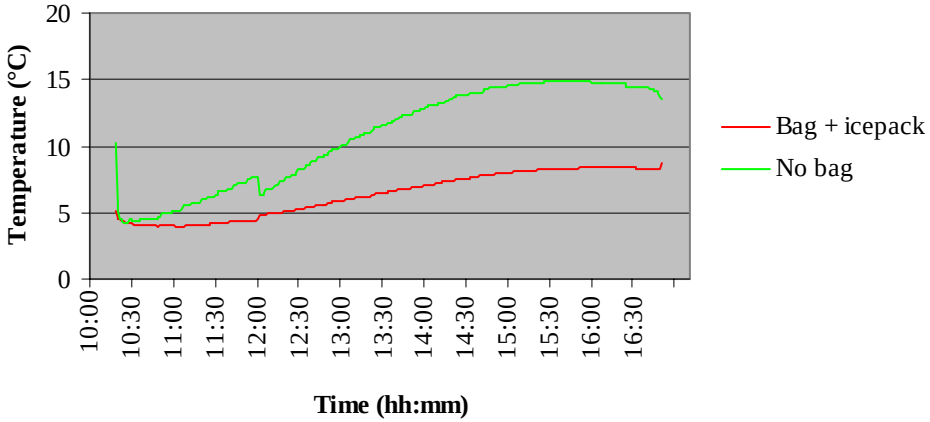
Temperature of sausage internally (boot) - Winter



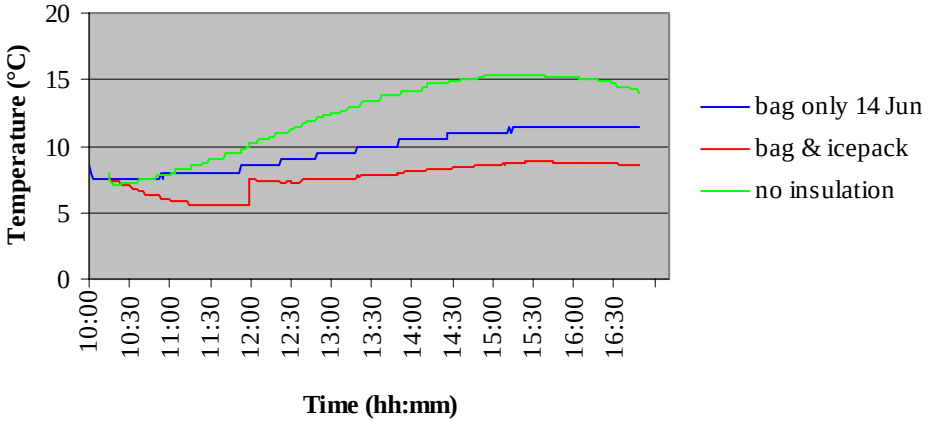
Temperature of mince internally (boot) - Winter



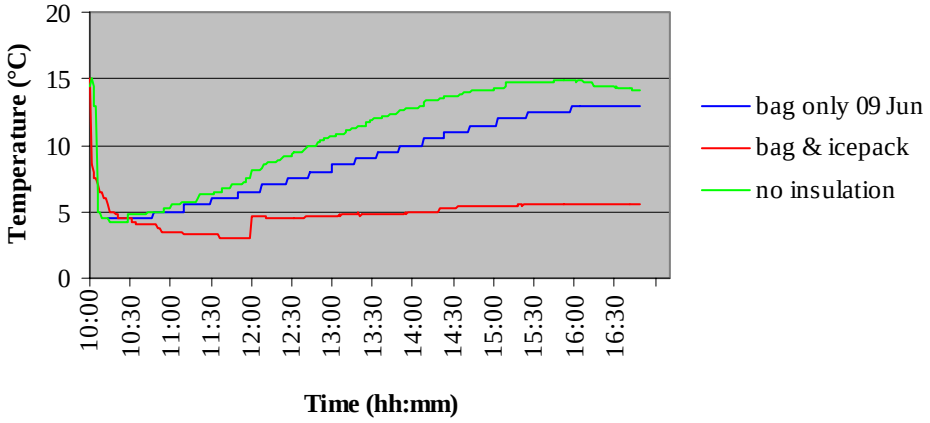
Mean of steak internal temperatures in boot - Winter



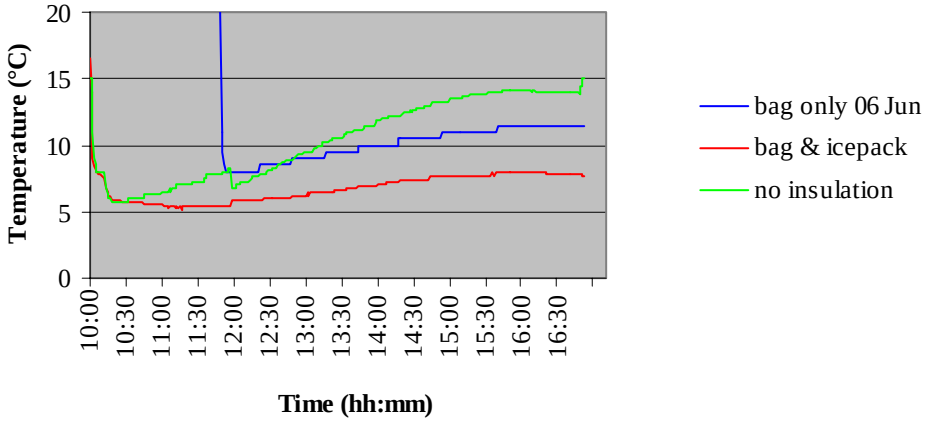
Mean of chicken internal temperatures in boot - Winter



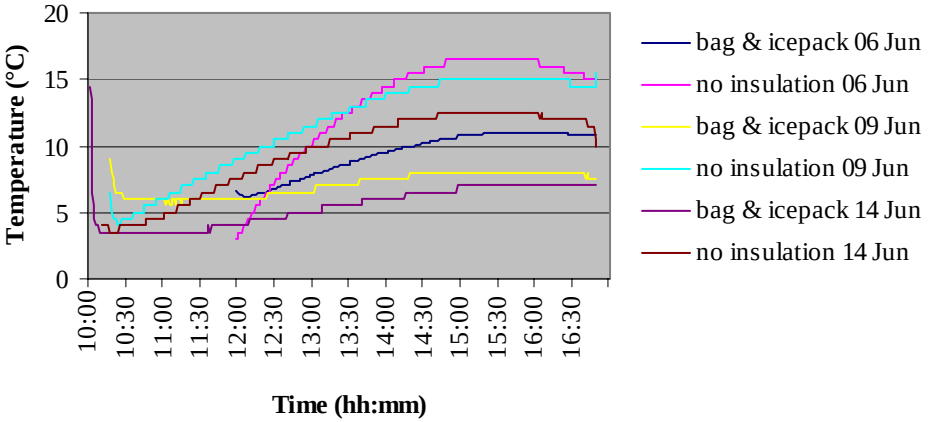
Mean of sausage internal temperatures in boot - Winter



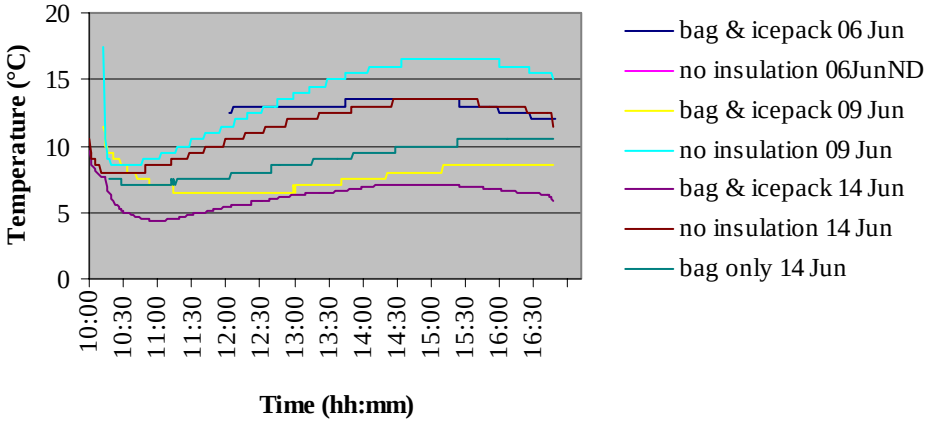
Mean of mince internal temperatures in boot - Winter



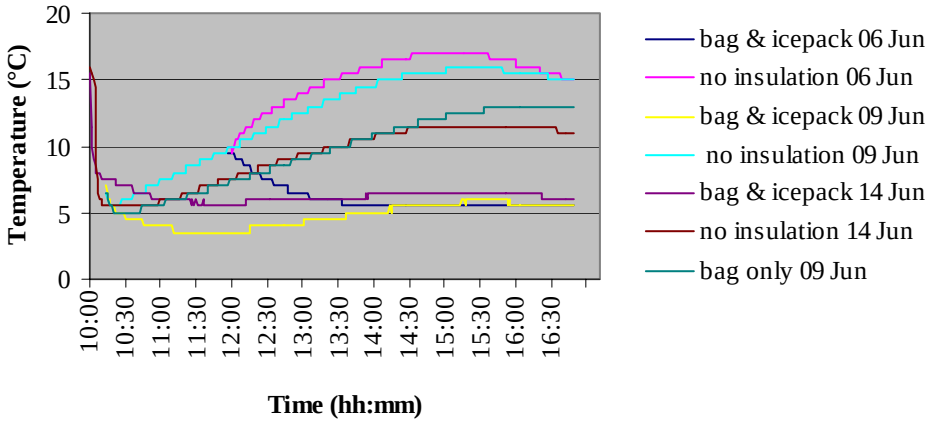
Temperature of steak surfaces (boot) - Winter



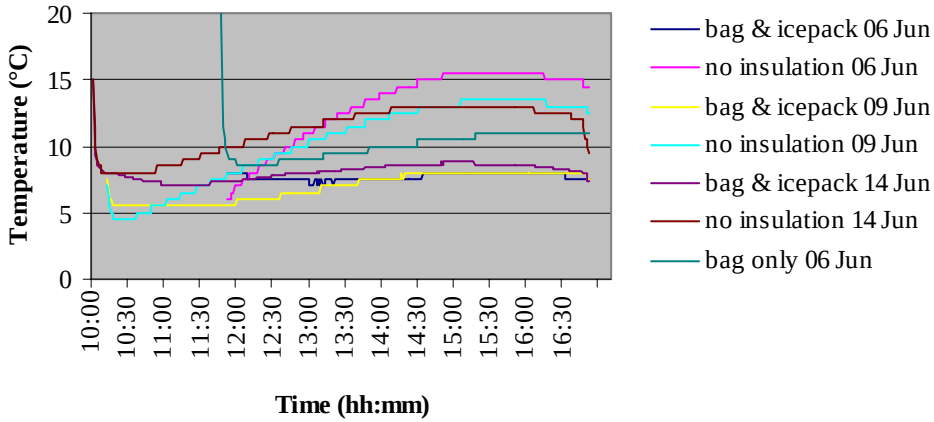
Temperature of chicken surfaces (boot) - Winter



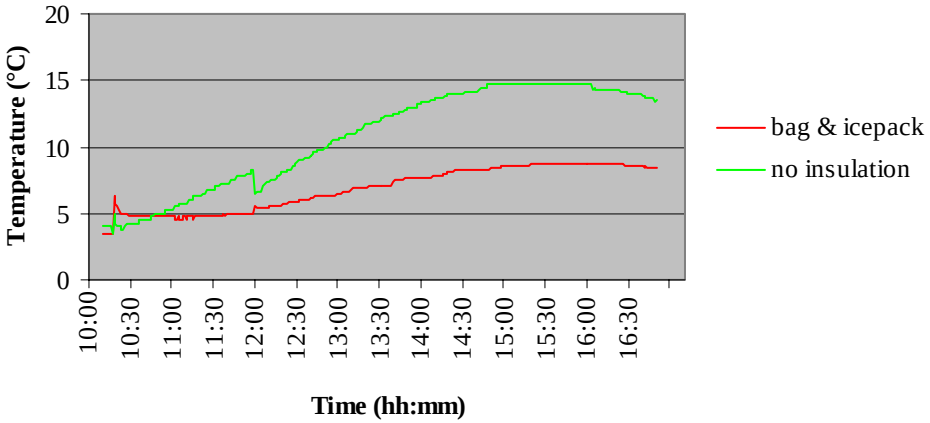
Temperature of sausage surfaces (boot) - Winter



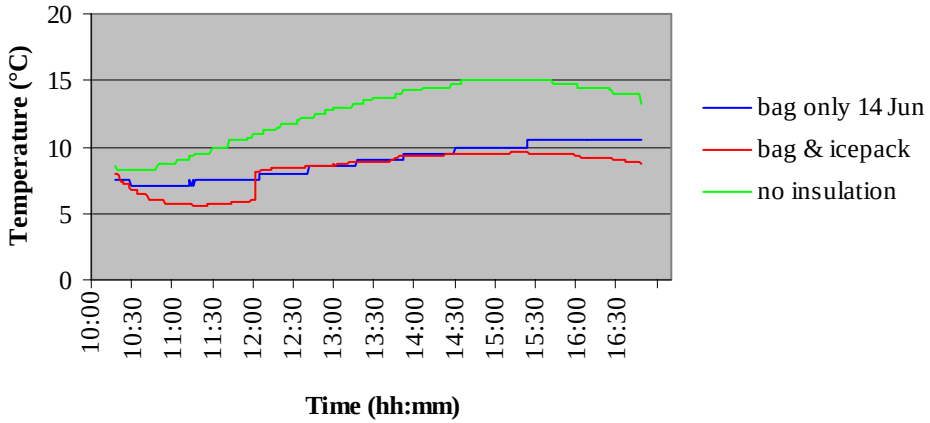
Temperature of mince surfaces (boot) - Winter



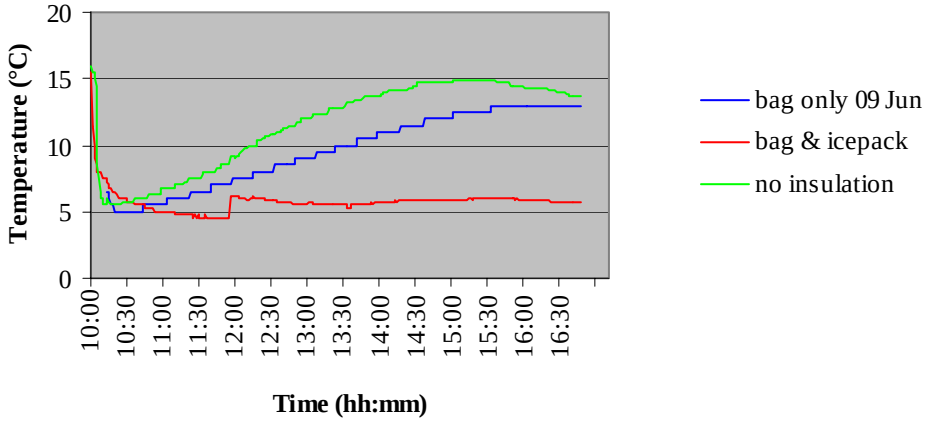
Mean of steak surface temperatures in boot - Winter



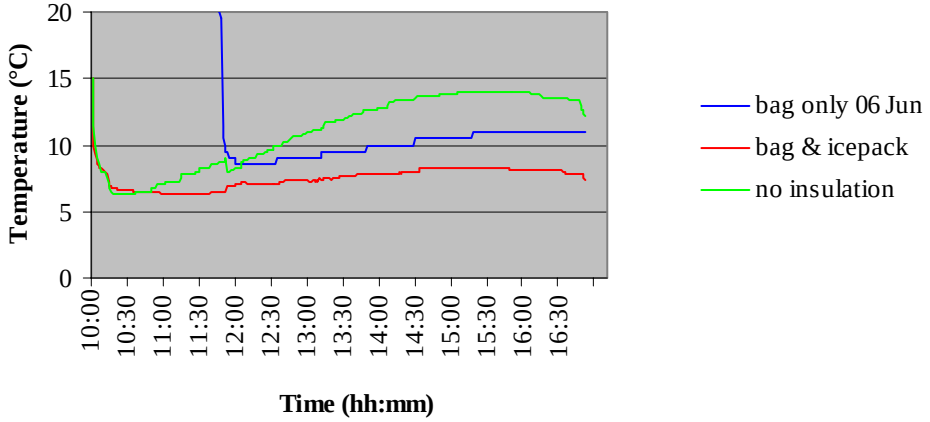
Mean of chicken surface temperatures in boot - Winter



Mean of sausage surface temperatures in boot - Winter



Mean of mince surface temperatures in boot - Winter



APPENDIX 5: PARAMETERS FOR CURVE FITTING TO EXPERIMENTAL DATA FROM MEAT/POULTRY EXPERIMENTS

Parameters for calculating heating of meat/poultry for individual meat types, packaging, season, and position on meat.

Experiment Conditions	Season	Linear x (°C/minute)	Linear c	Quadratic x^2	Quadratic x	Quadratic c
Boot/Cooler Bag/Icepack/Interior/Chicken	Summer	0.0590	8.0712	-0.0001	0.0683	7.9373
	Winter	-0.0005	7.2685	0.0000	0.0066	6.6820
Boot/No packaging/Interior/Chicken	Summer	0.1403	8.7272	-0.0003	0.1516	8.9782
	Winter	0.0385	7.4840	-0.0001	0.0626	6.3197
Boot/Cooler Bag/Icepack/Surface/Chicken	Summer	0.0650	10.4505	-0.0001	0.0710	10.4928
	Winter	0.0060	7.7146	0.0000	0.0169	7.0481
Boot/No packaging/Surface/Chicken	Summer	0.0650	10.4505	-0.0001	0.0710	10.4928
	Winter	0.0060	7.7146	0.0000	0.0169	7.0481
Boot/Cooler Bag/Icepack/Interior/Mince	Summer	0.0425	6.8662	-0.0001	0.0554	6.5167
	Winter	0.0063	5.3747	0.0000	0.0135	4.8750
Boot/No packaging/Interior/Mince	Summer	0.1217	7.7945	-0.0002	0.1395	7.6347
	Winter	0.0431	4.1334	-0.0001	0.0622	3.2025
Boot/Cooler Bag/Icepack/Surface/Mince	Summer	0.0541	9.4746	-0.0001	0.0565	9.5626
	Winter	0.0057	6.3867	0.0000	0.0146	5.8086
Boot/No packaging/Surface/Mince	Summer	0.1199	11.7519	-0.0002	0.1241	12.0895
	Winter	0.0419	5.7561	-0.0001	0.0638	4.7849
Boot/Cooler Bag/Icepack/Interior/Sausage	Summer	0.1395	6.9086	-0.0003	0.1586	6.8452
	Winter	0.0426	5.1336	-0.0001	0.0661	3.9526
Boot/No packaging/Interior/Sausage	Summer	0.0476	5.6715	-0.0001	0.0622	5.2620
	Winter	-0.0043	4.9079	0.0000	-0.0004	4.4877
Boot/Cooler Bag/Icepack/Surface/Sausage	Summer	0.0668	9.7369	-0.0001	0.0721	9.8061
	Winter	-0.0086	6.1972	0.0000	-0.0052	5.7628
Boot/No packaging/Surface/Sausage	Summer	0.0668	9.7369	-0.0003	0.1435	12.0677
	Winter	-0.0086	6.1972	0.0000	-0.0052	5.7628
Boot/Cooler Bag/Icepack/Interior/Steak	Summer	0.0504	4.9973	-0.0001	0.0613	4.7763
	Winter	0.0171	3.7155	0.0000	0.0277	3.0885

Boot/No packaging/Interior/Steak	Summer	0.1566	7.7705	-0.0003	0.1683	8.1313
	Winter	0.0619	2.4026	-0.0002	0.0928	1.0327
Boot/Cooler Bag/Icepack/Surface/Steak	Summer	0.0542	6.8139	-0.0001	0.0638	6.6873
	Winter	0.0175	4.3248	0.0000	0.0302	3.6049
Boot/No packaging/Surface/Steak	Summer	0.1665	9.1273	-0.0003	0.1739	9.6836
	Winter	0.0636	2.8393	-0.0002	0.0943	1.5801
Car/Cooler Bag/Icepack/Interior/Chicken	Summer	0.0751	7.7130	-0.0001	0.0874	7.5211
	Winter	0.0226	6.6792	0.0000	0.0393	5.6698
Car/No packaging/Interior/Chicken	Summer	0.2217	7.7591	-0.0005	0.2604	7.4178
	Winter	0.0747	7.0854	-0.0002	0.1262	4.4135
Car/Cooler Bag/Icepack/Surface/Chicken	Summer	0.0697	10.5663	-0.0001	0.0781	10.4836
	Winter	0.0401	7.6789	-0.0001	0.0679	6.3206
Car/No packaging/Surface/Chicken	Summer	0.2293	12.1395	-0.0005	0.2342	12.9218
	Winter	0.0824	8.2442	-0.0002	0.1303	6.0814
Car/Cooler Bag/Icepack/Interior/Mince	Summer	0.0666	6.7998	-0.0001	0.0835	6.3718
	Winter	0.0423	3.1326	-0.0001	0.0690	1.7298
Car/No packaging/Interior/Mince	Summer	0.1894	6.4588	-0.0004	0.2593	4.6327
	Winter	0.0567	4.9578	-0.0001	0.0921	2.8760
Car/Cooler Bag/Icepack/Surface/Mince	Summer	0.0870	9.6021	-0.0001	0.0958	9.5710
	Winter	0.0493	5.8656	-0.0002	0.0798	4.4587
Car/No packaging/Surface/Mince	Summer	0.2505	10.9948	-0.0006	0.2914	10.6366
	Winter	0.0682	6.5840	-0.0002	0.1110	4.4680
Car/Cooler Bag/Icepack/Interior/Sausage	Summer	0.0535	6.1180	-0.0001	0.0744	5.5109
	Winter	0.0151	6.0728	0.0000	0.0317	4.9291
Car/No packaging/Interior/Sausage	Summer	0.2070	5.9333	-0.0004	0.2455	5.4923
	Winter	0.0676	5.2068	-0.0002	0.1095	2.9094
Car/Cooler Bag/Icepack/Surface/Sausage	Summer	0.0876	8.8904	-0.0001	0.0962	8.9106
	Winter	0.0146	7.1359	-0.0001	0.0360	5.7437
Car/No packaging/Surface/Sausage	Summer	0.2306	12.4084	-0.0004	0.2250	13.6268
	Winter	0.0783	6.6274	-0.0002	0.1308	4.0435
Car/Cooler Bag/Icepack/Interior/Steak	Summer	0.0684	4.9589	-0.0001	0.0896	4.4252
	Winter	0.0484	2.1775	-0.0001	0.0748	0.7980

Car/No packaging/Interior/Steak	Summer	0.2857	8.4305	-0.0007	0.2918	9.8053
	Winter	0.0996	2.0074	-0.0003	0.1587	-0.8819
Car/Cooler Bag/Icepack/Surface/Steak	Summer	0.0205	11.6599	-0.0001	0.0653	10.1814
	Winter	0.0334	3.8592	-0.0001	0.0554	2.5613
Car/No packaging/Surface/Steak	Summer	0.3414	10.7695	-0.0008	0.3120	13.8261
	Winter	0.1062	3.4674	-0.0003	0.1671	0.7730

Parameters for calculating heating of meat/poultry according to meat type, packaging, location, and season

Experiment Conditions	Season	Linear x (°C/minute)	Linear c	Quadratic x^2	Quadratic x	Quadratic c
Boot/Cooler Bag/Icepack/Chicken	Summer	0.0620	9.2609	-0.0001	0.0697	9.2151
	Winter	0.0027	7.4916	0.0000	0.0117	6.8650
Boot/No packaging/Chicken	Summer	0.1026	9.5889	-0.0002	0.1113	9.7355
	Winter	0.0222	7.5993	-0.0001	0.0397	6.6839
Boot/Cooler Bag/Icepack/Mince	Summer	0.0483	8.1704	-0.0001	0.0559	8.0397
	Winter	0.0060	5.8807	0.0000	0.0140	5.3418
Boot/No packaging/Mince	Summer	0.1208	9.7732	-0.0002	0.1318	9.8621
	Winter	0.0425	4.9447	-0.0001	0.0630	3.9937
Boot/Cooler Bag/Icepack/Sausage	Summer	0.0572	7.7042	-0.0001	0.0672	7.5341
	Winter	-0.0064	5.5526	0.0000	-0.0028	5.1252
Boot/No packaging/Sausage	Summer	0.1031	8.3227	-0.0003	0.1511	9.4564
	Winter	0.0170	5.6654	0.0000	0.0304	4.8577
Boot/Cooler Bag/Icepack/Steak	Summer	0.0523	5.9056	-0.0001	0.0625	5.7318
	Winter	0.0173	4.0201	0.0000	0.0290	3.3467
Boot/No packaging/Steak	Summer	0.1615	8.4489	-0.0003	0.1711	8.9074
	Winter	0.0628	2.6209	-0.0002	0.0935	1.3064
Car/Cooler Bag/Icepack/Chicken	Summer	0.0724	9.1397	-0.0001	0.0827	9.0023
	Winter	0.0314	7.1790	-0.0001	0.0536	5.9952
Car/No packaging/Chicken	Summer	0.2255	9.9493	-0.0005	0.2473	10.1698
	Winter	0.0785	7.6648	-0.0002	0.1283	5.2474
Car/Cooler Bag/Icepack/Mince	Summer	0.0768	8.2010	-0.0001	0.0897	7.9714
	Winter	0.0458	4.4991	-0.0001	0.0744	3.0942
Car/No packaging/Mince	Summer	0.2199	8.7268	-0.0005	0.2754	7.6346
	Winter	0.0625	5.7709	-0.0002	0.1015	3.6720
Car/Cooler Bag/Icepack/Sausage	Summer	0.0706	7.5042	-0.0001	0.0853	7.2107
	Winter	0.0148	6.6043	0.0000	0.0338	5.3364
Car/No packaging/Sausage	Summer	0.2188	9.1709	-0.0004	0.2352	9.5595
	Winter	0.0730	5.9171	-0.0002	0.1202	3.4764
Car/Cooler Bag/Icepack/Steak	Summer	0.0444	8.3094	-0.0001	0.0774	7.3033
	Winter	0.0409	3.0183	-0.0001	0.0651	1.6796

Car/No packaging/Steak	Summer	0.3135	9.6000	-0.0007	0.3019	11.8157
	Winter	0.1029	2.7374	-0.0003	0.1629	-0.0544

Parameters for experiments with meat stored in cooler bags without an icepack.

Experiment Conditions	Season	Linear x (°C/minute)	Linear c	Quadratic x^2	Quadratic x	Quadratic c
Boot/Cooler Bag/No Icepack/Interior/Mince	Summer	0.07153	7.43995	-0.00011	0.09138	6.92290
	Winter	0.01874	7.15026	-0.00004	0.02632	6.78109
Boot/Cooler Bag/No Icepack/Surface/Mince	Summer	0.06889	8.72647	-0.00010	0.08222	8.43606
	Winter	0.01375	7.76709	-0.00003	0.02101	7.37369
Car/Cooler Bag/No Icepack/Interior/Mince	Summer	0.09728	6.96804	-0.00018	0.12910	6.14694
	Winter	0.03138	6.04718	-0.00004	0.04451	5.27080
Car/Cooler Bag/No Icepack/Surface/Mince	Summer	0.11382	8.25468	-0.00024	0.14427	7.62476
	Winter	0.03180	7.37739	-0.00007	0.05179	6.22707
Boot/Cooler Bag/No Icepack/Interior/Sausage	Summer	0.08452	4.95968	-0.00009	0.09626	4.70496
	Winter	0.02724	4.21262	-0.00002	0.03404	3.77274
Boot/Cooler Bag/No Icepack/Surface/Sausage	Summer	0.07899	6.94469	-0.00008	0.08964	6.72134
	Winter	0.02877	4.85745	-0.00003	0.03861	4.28850
Car/Cooler Bag/No Icepack/Interior/Sausage	Summer	0.08578	5.43571	-0.00009	0.09738	5.18232
	Winter	0.05153	4.30854	-0.00009	0.08269	2.35086
Car/Cooler Bag/No Icepack/Surface/Sausage	Summer	0.05603	8.77278	-0.00002	0.06245	8.54209
	Winter	0.06809	4.49337	-0.00017	0.11362	2.00495
Boot/Cooler Bag/No Icepack/Interior/Chicken	Summer	0.09677	10.21386	-0.00016	0.10203	10.40454
	Winter	0.01320	7.19796	-0.00002	0.02025	6.73990
Boot/Cooler Bag/No Icepack/Surface/Chicken	Summer	0.08723	11.71423	-0.00014	0.09291	11.82664
	Winter	0.01011	6.76671	-0.00001	0.01491	6.42627
Car/Cooler Bag/No Icepack/Interior/Chicken	Summer	0.15676	8.22871	-0.00024	0.15806	8.76476
	Winter	0.05629	5.03465	-0.00015	0.10501	2.12447
Car/Cooler Bag/No Icepack/Surface/Chicken	Summer	0.14394	8.78964	-0.00022	0.15047	9.06119
	Winter	0.06695	5.62014	-0.00020	0.11937	2.83583