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Microbiological risk factors associated with the domestic handling of meat: sequential transfer of bacterial contamination

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Microbiological risk factors associated with the domestic handling of meat: sequential transfer of bacterial contamination

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SUMMARY

In England and Wales there has been an increase in the reported incidence of food poisoning in recent years. Notification of cases has risen from 70,130 in 1993 (CDR 1996) to 86,500 in 2000 (PHLS, 21/10/02). It has been suggested that 15% of cases originate in the home (Djuretic, 1996).

There have been relatively few studies into the domestic handling of raw meat, although it has been shown that hazardous food handling behaviours are prevalent in the home. Worsfold and Griffith (1997) studied the food safety behaviour of 100 people in their own homes and showed that basic food handling practices indicated great potential for cross contamination, of which the participants seemed to be unaware. Further work on the identification of food safety risks in the home, quantification of these practices and verification of microbiological contamination in the domestic environment are essential to support the adoption of successful methods of reducing food poisoning incidence in the home. The aim of this study was to assess the nature, extent and persistence of cross contamination from different cuts of meat and different preparation methods.

The aim of this research was to establish if there was a potential for sequential transfer of microbial contamination.from repeatedly placing meat on clean surfaces (different areas of the same clean surface on several occasions). In addition, the work established if washing and soaking of meat reduced contamination levels on the meat surface and established the distance that droplets travelled when meat was washed.

Various meat types were used in this trial. This was to establish if the potential for sequential transfer of microbial contamination was greatest when a particular meat type or cut was used.

The following types of meat were used:

1. Chicken thighs (skin on)
2. Beef joint (small topside/top rump with added basting fat)
3. Beefburgers (quarter pounders with seasoning)
4. Chicken: boneless and skinless breast fillets
5. Lamb: half leg joint (bone present)
6. Pork joint: boneless leg joint
7. Sausages: thick pork sausages with skin

Separate meat pieces were used for each surface type and condition.

Two surfaces commonly found in the domestic kitchen environment were used:

1. Laminate surface (laminate, on top of plywood)
2. Stainless steel (food grade)

Each of the meat types were placed onto each of the twenty-five (laminate) or five (steel) numbered squares and left on each square for one minute. For the laminate trial, squares 1-5, 10, 15, 20 and 25 and three blank squares were analysed for Total Viable Count at time 0, 4, 24 and 48 hours. For the steel trial, squares 1-5 plus one blank square were assessed at each time interval.

In order to ascertain whether the risk of surface contamination was affected by the level of moisture, the trials were repeated using wet and dry meat placed onto wet and dry surfaces (four combinations) for chicken thighs (skin on) and beef joints. For the other meat types, only the meat was wetted.

Analysis of variance (ANOVA) was performed on the data using the general linear model function in Minitab.

The results indicated that there was a statistically significant difference between meat types, wet and dry meat, number of transfers, surface and time. It was shown that the meat types varied in transfer of contaminants: wet meat tended to transfer higher levels of contamination than *dry* meat; after repeated transfer the contamination level lowered; more micro-organisms were recovered from steel compared with laminate; and the TVC levels dropped over the 48 h test period.

Transfer of bacteria from the surface of various types of raw meat onto two typical kitchen surfaces was demonstrated in this study. The TVC levels that were transferred ranged from 10^2 cfu/25 cm^2 to 10^5 cfu/25 cm^2. This, of course, has cross contamination implications when raw meat is placed on surfaces in the domestic kitchen. It could be possible for bacteria to be transferred from contaminated surfaces to ready-to-eat foods.

The study also demonstrated that there is a difference in contamination level when meats are placed upon surfaces, depending upon surface type. Higher levels of bacteria were recovered from stainless steel compared with laminate. Sinks, taps and draining boards are likely to be made of stainless steel and sinks/draining boards are places in which meat preparation could be carried out.

It was also observed that bacteria persisted on surfaces throughout the 48 h test period. This could have important implications with respect to cross contamination if surfaces are not thoroughly cleaned after use or indeed dishclothsltea towels are used to wipe contaminated surfaces. A previous study (Newsholme *et* al., 2002) demonstrated the ability of dishclothsltea towels to provide an environment in which bacteria are able to grow and multiply to high levels.

This study also demonstrated that there was a decrease in contanlination throughout sequential transfer; however, even after placing meat down twenty five times, contamination of a laminate surface still occurred at fairly high levels (generally 10^2 - 10^3 cfu/25 cm^2); therefore, if consumers continually place raw meat on surfaces, they are increasing the risk of cross contamination.

Therefore, in overall conclusion, repeatedly placing raw meat or contaminated hands onto clean surfaces could contaminate these surfaces. The contamination level will become less the more transfers are done, but even at lower levels risk of providing foci for cross contamination exist. Also, wet meat generally contaminates surfaces at a higher level than dry meat.

As part of this study the level of hand contamination was evaluated. Hands, both meat handling and non-meat handling, were sequentially placed onto the surface of 20 pre-poured PCA and VRBGA plates. A similar observation to the meat studies was seen with respect to hand contamination. Bacteria were present after placing hands on twenty consecutive agar plates. Therefore, if consumers repeatedly touched surfaces after handling raw meat, the touched surfaces could become contaminated. It was shown that meat handling hands were more highly contaminated than non-meat handling hands.

This study also demonstrated the ability of wet meat to transfer higher levels of bacteria to surfaces compared with dry meat. This also has important implications because in a previous quantitative study (Newsholme, 2002) it has been shown that 80% of consumers questioned washed meat, thus making the meat wetter.

Studies carried out to assess the washing and soaking of meat using various techniques did decrease microbial contamination on the surface of the meat, but this was not consistent and was more apparent when contact plates were used.

When washing chicken, a droplet splash study indicated that droplets could travel up to 50 cm in front of the sink and 60/70 cm to the sides.

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APPENDIX

1 INTRODUCTION

1.1 Background

In England and Wales there has been an increase in the reported incidence of food poisoning in recent years. Notification of cases has risen from 70,130 in 1993 (CDR, 1996) to 86,500 in 2000 (PHLS, 21/10/02). It has been suggested that 15% of cases originate in the home (Djuretic, 1996).

Raw red meat and poultry can be vehicles for the carriage of pathogenic bacteria, which cause food poisoning. Raw meat, including poultry, may act as a source of ***Salmonella*** and ***Campylobacter,*** which are causes of food poisoning. Other food poisoning bacteria, including some strains of ***Escherichia coli,*** may also be present in raw meat. It has been suggested that many people do not consider the domestic environment a place with a high risk of food poisoning and feel that the responsibility of lowering risks of food poisoning lies with the food manufacturers or restaurants (Worsfold and Griffith, 1997). Thus, the implications of incorrect handling of raw meat may not be apparent to the consumer and so risks may be increased.

There have been relatively few studies into the domestic handling of raw meat, although it has been shown that hazardous food handling behaviours are prevalent in the home. Worsfold and Griffith (1997) studied food safety behaviour of 100 people in their own homes and showed that basic food handling practices indicated great potential for cross contamination, of which the participants seemed to be unaware. A previous study by the same authors identified the principal causes of cross contamination in domestic food preparation as faulty food handling techniques, poor personal hygiene and a lack of facilities for the segregation of raw and cooked foods (Worsfold and Griffith, 1996). Further work on the identification of food safety risks in the home, quantification of these practices and verification of microbiological contamination in the domestic environment are essential to support the adoption of successful methods of reducing food poisoning incidence in the home.

1.2 Aim

To establish if there is a potential for sequential transfer of microbial contamination from repeatedly placing meat on clean surfaces (different areas of the same clean surface on several occasions). Also, to establish if washing and soaking of meat reduced bacterial contamination on the meat surface and establish the distance which droplets travelled when chicken was washed.

1.3 Scope

This report constitutes the fourth phase of the FSA funded project: Microbiological risk factors associated with the domestic handling of meats. The first qualitative phase identified consunier practices; in the second phase these practices have been quantified, and in the third

phase, consumer practices were observed and microbial contamination within the kitchen monitored.

2. METHODS

2.1 Meat types

Various meat types were used in this trial. This was to establish if the potential for sequential transfer of microbial contamination was greatest when a particular meat type or cut was used.

The following types of meat were used:

1. Chicken thighs (skin on)
2. Beef joint (small topside/top rump with added basting fat)
3. Beefburgers (quarter pounders with seasoning)
4. Chicken: boneless and skinless breast fillets
5. Lamb: half leg joint (bone present)
6. Pork joint: boneless leg joint
7. Sausages: thick pork sausages with skin

2.2 Surface type

Separate meat pieces were used for each surface type and condition.

Two surfaces commonly found in the domestic kitchen environment were used:

1. Laminate surface (laminate, on top of plywood)
2. Stainless steel (food grade)

The surfaces were thoroughly cleaned prior to use. A hypochlorite based disinfectant (2,500 ppm) was used to clean the surface. Following this, sterile Universal Quenching Agent (UQA: Maximum Recovery Diluent [Oxoid CM73371 containing Sodium Thiosulphate 3 g, Lecithin 3 g, Tween 80 3 g per litre) was used to quench any remaining disinfectant residues. The surfaces were then sprayed with 70% (v/v) alcohol, and left to dry prior to use. Prior to the start of the trial, two blank laminate and one blank steel square were swabbed and the Total Viable Count (TVC) measured in order to assess the presence of any initial contamination.

The laminate surface was divided into 30 (25 squares to be used in the trial, with 5 extra controls), 10 x 10 cm numbered squares, with a sufficient gap between each square to ensure that neighbouring squares would not become contaminated when the meat was placed down. Each large square was divided into four smaller, 5 x 5 cm squares.

The steel surface was divided up in the same way, but only six large squares (5 test + 1 control) were used.

Each of the meat types were placed onto each of the twenty five (laminate) or five (steel) numbered squares and left on each square for one minute. It was ensured that the meat covered the whole 10 x 10 cm square. With respect to the sausages, a whole pack was placed on the square, and for the chicken thighs, large samples were chosen which were flattened. For the laminate trial, squares 1-5, 10, 15, 20 and 25 and three blank squares were analysed for Total Viable Count at time 0, 4, 24 and 48 hours. For the steel trial, squares 1-5 plus one blank square, were assessed at each time interval. On each sampling occasion a separate smaller square within the 10 x 10 cm square was swabbed as below:

0 h	4 h
24 h	48 h

2.3 **Surface condition**

In order to ascertain whether the risk of surface contamination was greatest when the meat and/or surface was wet or dry, all combinations shown below were used with the chicken thighs (skin on) and beef joints. For the other meat types, only the meat was wetted.

The combinations used are summarised Table 1.

2.3.1 Wetting procedure

The meat was wetted by placing under a running tap for 10 seconds and then meat was held over a sink for 5 seconds to drain.

The wet surface (laminate/steel) was produced by placing a small quantity (0.1 ml) of sterile distilled water in the centre of each square. The water was spread over each square using a sterile plastic spreader to ensure that the surface was evenly wetted.

Table 1: Summary of transfer trial parameters

Trial No.	Meat	Meat cut	Meat surface	Surface
1	Chicken	Breast fillet skin on	Dry	Dry
2			Wet	Dry
3			Dry	Wet
4			Wet	Wet
5	Beef	Joint	Dry	Dry
6			Wet	Dry
7			Dry	Wet
8			Wet	Wet
9	Beef	Burger	Dry	Dry
10			Wet	Dry
11	Chicken	Breast fillet skin off	Dry	Dry
12			Wet	Dry
13	Lamb	Joint	Dry	Dry
14			Wet	Dry
15	Pork	Joint	Dry	Dry
16			Wet	Dry
17	Pork	Sausages	Dry	Dry
18			Wet	Dry

2.4 Assessment of initial contamination

In order to establish that the contamination level was similar in each of the four small squares (to be swabbed at times 0, 4, 24 and 48 hours) within the large 10 cm by 10 cm square, meat pieces were placed on each large square and all four squares were separately swabbed at time 0 h.

This was carried out with triplicate meat pieces and four meat types as described previously. The meat types were:

Beef joint
Pork joint
Lamb joint
Chicken fillets, skin off

Each meat piece was placed on the large square and left for one minute.

This was carried out using *dry* meat on a *dry* laminate surface.

2.5 Microbiological analysis

2.5.1 Swabs

The swabbing procedure was as follows: Sterilin cotton tipped swabs were dampened in UQA and the whole square (5 x 5 cm) was swabbed; the swab was returned to the UQA and shaken immediately after sampling and vortexed for 15 seconds prior to enumeration for Total Viable Count (TVC). The TVC was enumerated using 1 ml pour plates with Plate Count Agar (PCA, LabM Lab 149) incubated at 30°C for 48 h. All resultant colonies were counted.

2.5.2 Meat pieces

The TVC level was also enumerated on each meat piece (separate pieces used for each surface type/condition). This was carried out using an excision technique. A small area of the meat surface (2 x 2.5 cm) (1 g) was removed using a scalpel. This meat sample was a thin section and was placed in a known volume (10 ml) of Maximum Recovery Diluent (MRD, Oxoid CM 7337) and vortexed. A serial dilution series was then performed using MRD and 1 ml pour plates using PCA set up.

The plates were allowed to set, inverted and incubated at 30°C for 48 h, after which time all resultant colonies were counted.

2.5.3 Exposure plates

In order to monitor airborne contamination, exposure plates were set up. PCA and Violet Red Bile Glucose Agar (VRBGA, Oxoid CM485) plates were poured and allowed to set.

Plates were placed open in four locations around the laboratory. The PCA and VRBGA plates were then removed and incubated at 30°C for 48 h after each trial had been completed, e.g. 0 h, then after 4, 24 and 48 hours. The VRBGA plates were incubated at 37°C for 24 h. One set of exposure plates were set up on any one sampling day.

2.5.4 Hand contamination

A study of hand contamination was carried out. Hands, both meat handling and non-meat handling from the same person, were sequentially placed onto the surface of 20 pre-poured PCA and VRBGA plates. These plates were then incubated at 30°C for 24 h and 37°C for 24 h respectively, after which time all colonies were counted. Where possible, counts for each individual finger were noted.

One set of hand plates were set up for each of the meat/surface conditions.

2.6 **Statistical Methods**

Analysis of variance (ANOVA) was performed on the data using the general linear model function in Minitab.

Statistical significance was determined by P values, a P value of 0.01 indicating a 99.9% (***) difference, 0.1 a 99% (**) difference and 0.5 a 95% (*) difference.

The conditions given in Table 1 were tested using a laminate surface and also stainless steel.

2.7 **Washing Trials**

In order to assess the effect of washing and soaking of meat on initial bacterial contamination and hence transfer of bacteria to surfaces, trials were carried out using various washing and soaking techniques.

2.7.1 Washing methods

Two meat types were used in this trial: whole chicken and beef joint.

The washing techniques used were cold water (18°C) and hot water (45°C) and washing for 10 and 30 seconds.

In order to ensure a standard washing technique, water was passed through a funnel (exit hole of 1 cm diameter) using a similar speed on each occasion. The volume of water (ml) used on each occasion was measured.

This was repeated in triplicate.

2.7.2 Microbiological techniques

The excision technique was used in order to monitor TVC and Enterobacteriaceae level before and after washing. The method employed was as described in 2.5.2.

Contact plates (PCA and VRBGA) were also taken from the meat surface before and after washing in order to monitor TVC and Enterobacteriaceae levels. Two areas were tested on each sampling occasion. These plates were incubated at 30°C (PCA) and 37°C (VRBGA) for 24 h.

2.8 **Soaking trials**

This trial was undertaken in order to assess the effect of soaking meat in various solutions on bacterial contamination of meat pieces.

2.8.1 Soaking methods

Two meat types were used in this trial: whole chicken and beef joint.

The soaking techniques were: cold water, 10% (v/v) malt vinegar, and 5 and 10% (w/v) salt solutions. Two soak times were used: 5 and 30 minutes.

The soaking trials were repeated in triplicate.

2.8.2 Microbiological techniques

The excision technique and contact plate methods were as used in the washing trials and described in 2.7.2.

2.9 **Droplet splash**

The aim of this trial was to assess the distance in which droplets travelled when a whole chicken was washed.

Paper was used to cover the area around the sink, walls, floor and draining board area.

A whole chicken was then covered with red food dye. The chicken was then placed under a tap at a medium speed (35 ml/sec) for 10 seconds. The distance that the dye droplets had travelled around the sink area was measured. This was repeated three times.

3. RESULTS

The individual data sets for each trial are placed in an Appendix at the end of the report and summarised below.

3.1 Assessment of initial contamination in each square

The contamination in each of the four sub-squares was similar with respect to TVC and Enterobacteriaceae level (Appendix 7.1). There was, as would be expected, a difference between each meat type and replicate meat pieces.

In order to ensure that the differences in TVC and Enterobacteriaceae levels between each of the squares, one way ANOVA was carried out (Table 2).

Table 2: Statistical results for initial contamination study

	P value	
	TVC	**Enterobacteriaceae**
Meat type	0.423 N/S	0.351 N/S
Pork	0.703 N/S	0.733 N/S
Lamb	0.703 N/S	0.733 N/S
Chicken	0.894 N/S	0.745 N/S
Beef	0.607 N/S	0.607 N/S

There was no statistically significant difference between TVC and Enterobacteriaceae levels with respect to each of the sub-squares within the 10 x 10 sampling area.

3.2 Exposure/blank square results

No Enterobacteriaceae were obtained from the exposure plates for any of the trials. The TVC level increased on exposure plates over the 48 h test period. Although the TVC level varied between trials, this was not great.

The TVC levels for the swabs taken prior to the start of each of the trials were low, thus indicting that the surfaces were clean. The levels within the blank squares generally remained low, in comparison to the meat and meat contaminated squares, indicating that little airborne contaminated occurred.

The TVC levels of the different pieces of the same meat type used for the various meat/surface condition trials differed, but this difference was not usually greater than one log order.

3.3 Chicken thighs, skin on

The results of this trial are given in Appendix 7.2. The data show that the TVC levels appeared to be greater on the steel surface than on the laminate for all surface/meat conditions. The level of TVC also decreased from square 1 to 25 for the laminate, with the greatest decrease occurring for the dry chicken/dry surface. The level also decreased slightly for the steel from squares 1 - 5, with the greatest decrease also for the *dry* chickeddry surface.

The levels also decreased throughout the 48 h test period for both the laminate and steel although levels generally exceeded 10^2 cfu/25 cm^2. This was greatest for the dry and wet meat on the *dry* surface for the steel and laminate. The results also indicated that the levels were slightly higher when the chicken or surface was wet. The main effects plots (Figures 1 and 2) illustrate the differences in log TVC for each of the various factors.

No real difference in microbial transfer was observed when the meat was wet or dry and placed on a dry surface (Figure 1). There was a 1.2 log increase in TVC level for steel compared to laminate. There was a decrease in TVC level over the squares and a 0.6 log decrease over the 48 h test period.

With respect to the wet surface trial, there was a 0.8g log decrease in TVC level when wet meat was used rather than *dry* meat, and a 1 log decrease over the 48 h test period and over the squares (Figure 2). There was also a slight increase in TVC level when steel was used.

Figure 1: Chicken, skin on/dry surface

Trial 1 Main Effects Plot - LS Means for TVClog

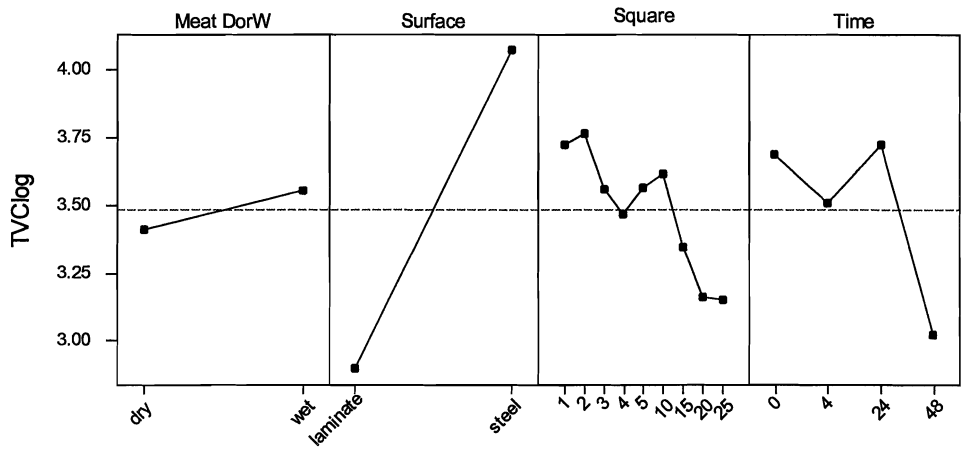
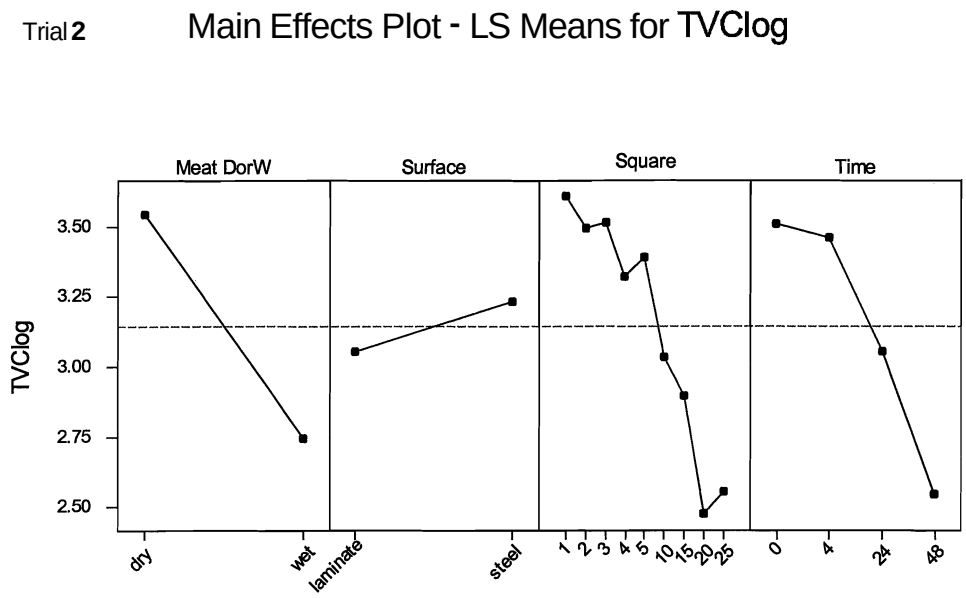


Figure 2: Chicken, skin on/wet surface



ANOVA was carried out on the data. The P values obtained were as follows:

Table 3: Statistical results for chicken skin on study

	P value	
	Dry Surface	**Wet Surface**
Meat dry or wet	0.109 N/S	0.000 ***
Surface	0.000 ***	0.114 N/S
Square	0.043 *	0.000 ***
Time	0.000 ***	0.000 ***
Surface x Time	0.151 N/S	0.228 N/S

Key: N/S = Not Significant
* = 95% significant difference
*** = 99.9% significant difference

The P value results indicated (Table 3) that the differences between steel and laminate, square number and time were statistically significant when the surfaces were dry. When the contact surfaces were wet the difference between dry and wet meat, square number and time were statistically significant.

3.4 **Beefjoint**

The results of this trial are given in Appendix 7.3. The data shows that the TVC levels were higher for most meat/surface conditions when the beef was placed upon the steel surface. The TVC levels also decreased throughout the *25* squares for the laminate and throughout squares 1 - *5* for the steel. The greatest decrease was observed when wet beef was placed upon wet laminate or *dry* beef was placed upon wet steel. The levels also decreased over the 48 h test period for both the steel and laminate.

The main effects plots (Figures **3** and 4) illustrate differences between log TVC for each factor. With respect to the dry surface trial, there was a large difference (approximately 1 log) between wet and *dry* meat, with wet meat exhibiting highest TVC levels. There was also a *0.5* log increase in TVC observed for steel compared to laminate. There was a decrease of approximately 1 log in TVC over the 48 h test period. It was also observed that there was a decrease in log TVC over the squares.

With respect to the wet surface trial there was a *0.2* log increase in TVC when the meat was wet. Higher TVC levels (0.8 log) were also observed when laminate was used. There was also a decrease in TVC level (1.3 log) over the squares.

Figure 3: Beef joint, dry surface

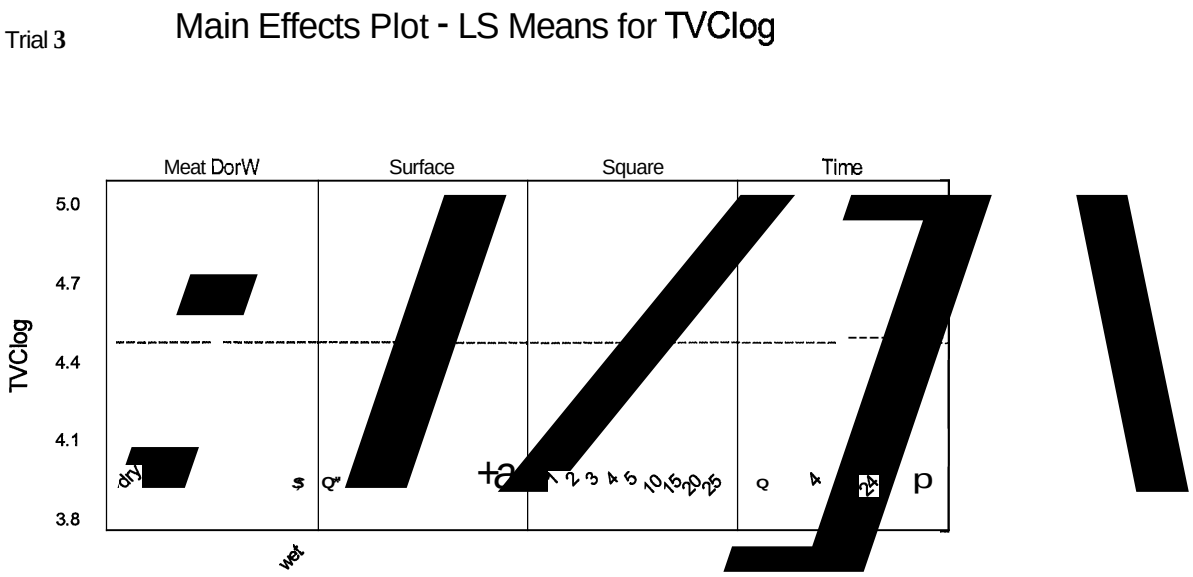
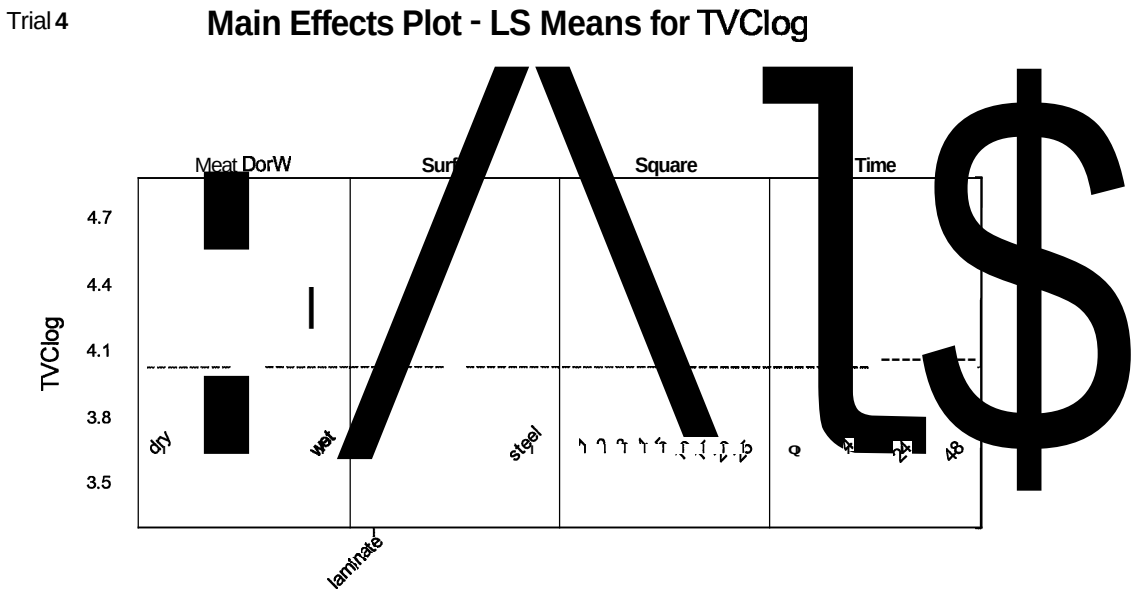


Figure 4: Beef joint, wet surface



ANOVA was carried out on the data and the P value results indicated (Table 4) that surface type, square number, and time differences in log TVC were all statistically significant for both the dry surface and wet surface trials.

Table 4: Statistical analysis results of the beef joint study

	P value	
	Dry Surface	**Wet Surface**
Meat dry or wet	0.000 ***	0.046 *
Surface	0.000 ***	0.000 ***
Square	0.000 ***	0.000 ***
Time	0.000 ***	0.000 ***
Surface x Time	0.001 ***	0.311 N/S

Key: N/S = Not Significant
* = 95% significant difference
*** = 99.9% significant difference

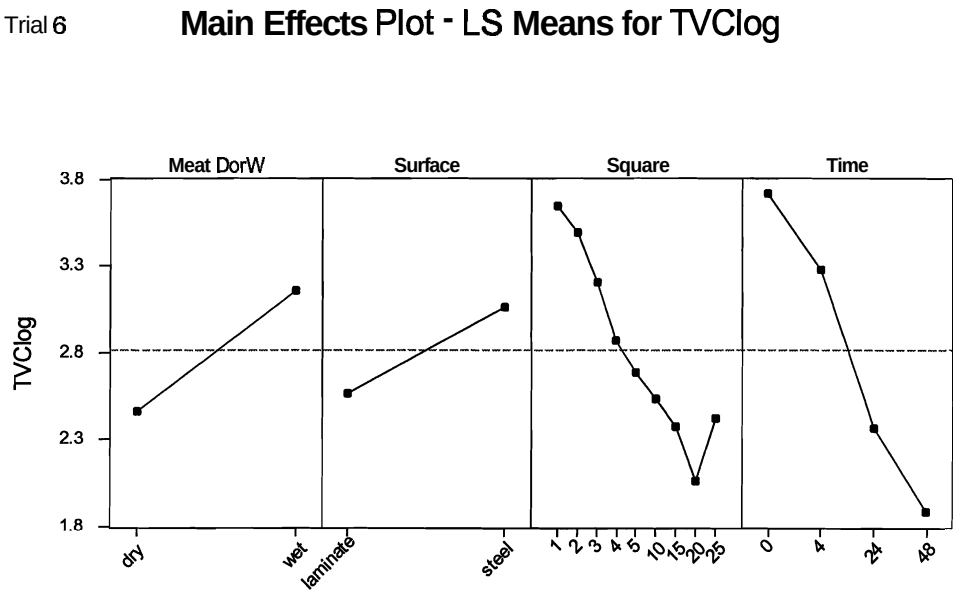
3.5 **Chicken breast fillet, skin off**

The results of this trial are given in Appendix 7.4. The TVC levels were greater on the steel than the laminate for the dry chicken but the levels on the surfaces were similar for the wet chicken. The levels decreased from squares 1 - 25 for the laminate and squares 1 - 5 for the steel when dry or wet chicken were used.

The TVC level decreased throughout the 48 h test period, for both dry and wet chicken, and laminate and steel.

The main effects plots (Figure 5) illustrate differences in log TVC for each of the factors. There was a 0.7 log increase in TVC level when the meat was wet and a 0.5 log increase for steel compared to laminate. The TVC level decreased by about 1.2 logs over the squares and 1.8 logs over the 48 h time period.

Figure 5: Chicken skin off - dry surface



ANOVA was carried out on the data the P values obtained were as follows:

Table 5: Statistical analysis results for the chicken skin off study

	P value
Meat dry or wet	0.000 ***
Surface	0.000 ***
Square	0.000 ***
Time	0.000 ***
Surface x Time	0.001 ***

Key: N/S = Not Significant
*** = 99.9% significant difference

The P values indicated (Table 5) that the differences between dry/wet meat, surface type, time and square number were all statistically significant.

3.6 **Lambjoint**

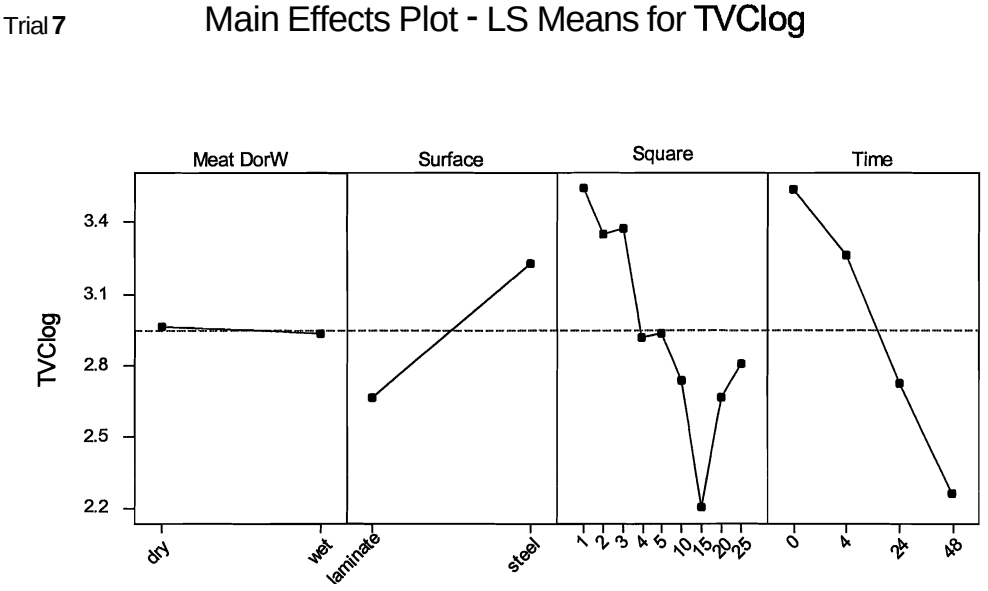
The results of this trial are indicated in Appendix 7.5. The TVC levels were greatest on the steel when the lamb was dry. The TVC level was highest on the laminate when the lamb was wet, although this difference was not statistically significant.

The TVC level also decreased throughout the 25 squares for the laminate. This decrease was greater when the lamb was wet. The TVC level also decreased through squares 1 - 5 for the wet lamb on the steel. The levels decreased over the 48 h test period; however, this decrease was greatest when the lamb was wet.

The hand plate results indicated that the Enterobacteriaceae level was highest when the lamb was wet but the TVC level was highest when the lamb was dry.

The main effects plots (Figure 6) illustrate difference in log TVC for each of the factors. There was no real difference between log TVC when the meat was wet or dry; there was a 0.5 log increase in TVC for steel compared with laminate. There was also a 0.7 log decrease over the squares and a 1.3 log decrease over the 48 h test period.

Figure 6: Lamb Joint - dry surface



ANOVA was carried out and the P values are described below:

Table 6: Statistical analysis results for the lamb joint study

	P value
Meat dry or wet	0.902 N/S
Surface	0.000 ***
Square	0.000 ***
Time	0.000 ***
Surface x Time	0.000 ***

Key: N/S = Not Significant
*** = 99.9% significant difference

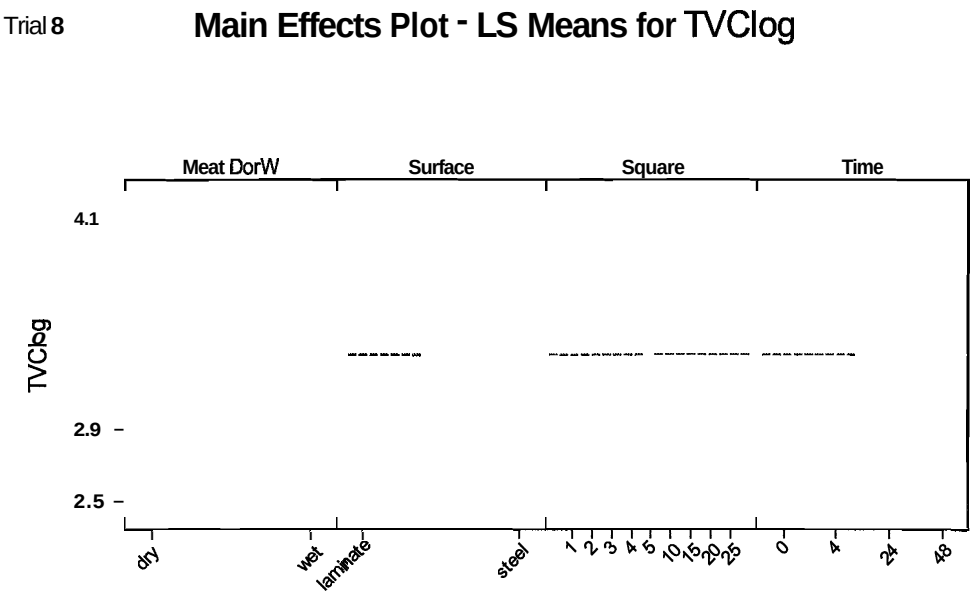
The P values indicate (Table *6)* that the differences between meat being wet/dry were not statistically different, but that the difference in log TVC between surface type, time and square number were statistically significant.

3.7 **Pork joint**

The results for the pork joint trial are given in Appendix 7.6. The TVC level was greatest when the pork was wet. **A** decrease in TVC level occurred over the *25* squares for the laminate and over the *5* squares for the steel, but this was not significant. The TVC level also decreased over the 48 h test period, but was not significant. The pattern of decrease was similar for wet and dry pork.

The main effects plots (Figure 7) illustrate differences in log TVC for each of the factors. There was a 1.8 log increase in TVC level when the meat was wet and a *0.2* log increase when steel was used. There was a decrease of about 1.3 logs over the *25* squares; however, statistical analysis illustrated no significant difference over the first *5* squares. There was a 0.3 log reduction over the 48 h test period.

Figure 7: Pork joint



ANOVA was carried out and the P values are given below.

Table 7: Statistical analysis results for the pork joint trial

	P value
Meat dry or wet	0.000 ***
Surface	0.613 N/S
Square	0.756 N/S
Time	0.925 N/S
Surface x Time	0.956 N/S

Key: N/S = Not Significant
*** = 99.9% significant difference

The P values indicate (Table 7) that the difference between wet and dry meat was statistically significant, but that the differences between square numbers, time and surface type were not statistically significant.

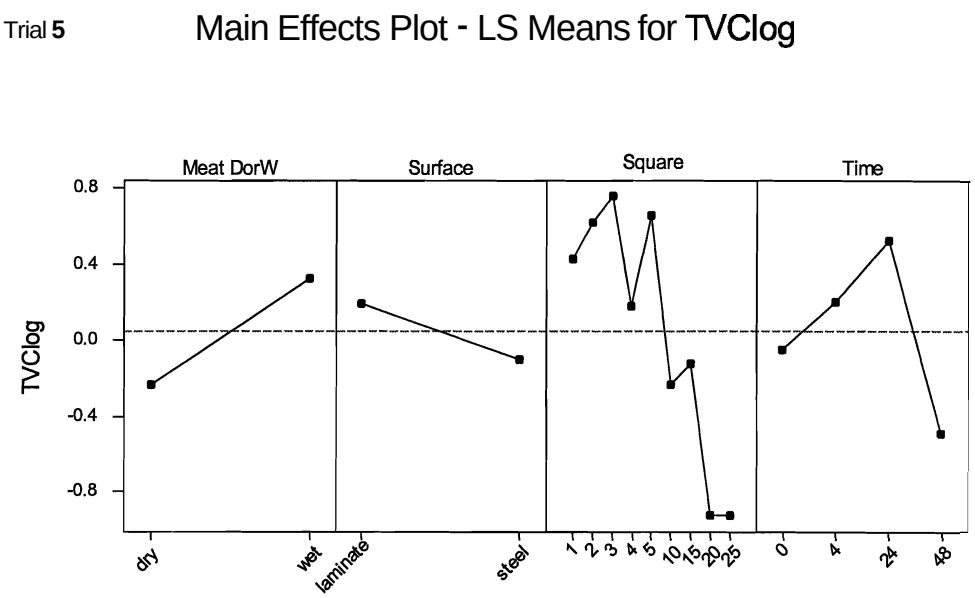
3.8 **Sausages**

The results for the sausage trial are given in Appendix 7.7. The TVC levels were highest for the wet sausages for both the laminate and steel. For the dry sausages, the levels were highest for the laminate. For the wet sausages the levels did not decrease significantly throughout the sequential transfer, or over the 48 h test period.

The data illustrated that there was a 1.7 log increase when the sausages were wetted, but that there was no real difference between surface type. There was a 0.7 log decrease over the 25 squares. There was also a slight decrease, 0.3 log, over the 48 h time period.

Statistical analysis was not carried out due to a large proportion of the data being lower than the limit of detection. However, the main effects plots (Figure 8) illustrate differences in log TVC for each of the factors.

Figure 8: Sausages



3.9 Beefburgers

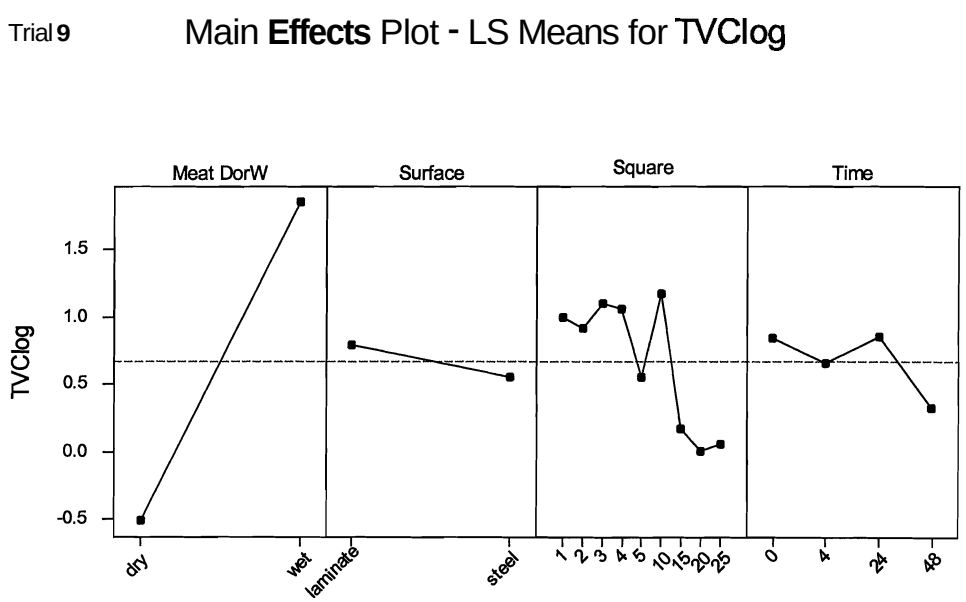
The results are given in Appendix 7.7. The levels were low for both the wet and *dry* burgers, but were slightly higher when the burgers were wet. However, there was no consistent pattern.

There was no real difference in log TVC if the meat was *dry* or wet; there was a slight difference (0.3 log increase) for the laminate compared to steel. There was also a slight decrease over the 48 h time period and across the squares.

The main effects plots (Figure 9) illustrate differences in log TVC for each of the factors.

Statistical analysis was not carried out due to a large proportion of the data being lower than the limit of detection.

Figure 9: Beefburger



3.10 Statistical analysis of all meat types combined

ANOVA was carried out on all the meat types as one combined data set and the meat type/condition was coded according to the table below:

Table 8: Trial coding

Trial	Meat	Cut	Surface
1	Chicken	Breast fillet skin on	Dry
2	Chicken	Breast fillet skin on	Wet
3	Beef	Joint	Dry
4	Beef	Joint	Wet
5	Beef	Burger	Dry
6	Chicken	Breast fillet skin off	Dry
7	Lamb	Joint	Dry
8	Pork	Joint	Dry
9	Pork	Sausages	Dry

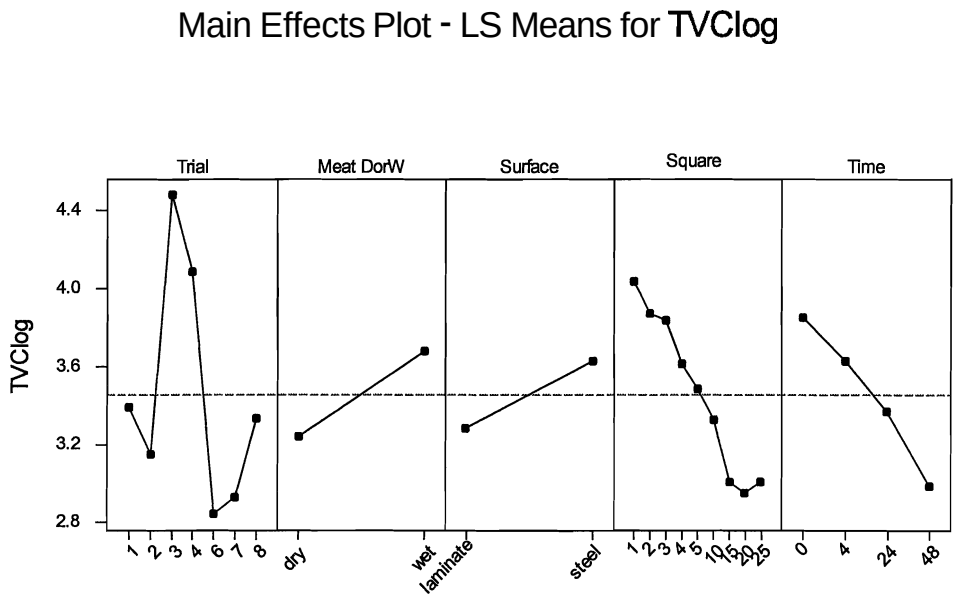
Table 9: ANOVA results of all data combined

Factors and interactions		Significance
Trial type (i.e. meat type/surface condition)	(Tr)	***
Meat wet or dry	(M)	***
Surface laminate or steel	(Su)	***
Square	(Sq)	***
Time from swabbing	(Ti)	***
Tr x M		***
Tr x Su		***
Tr x Sq		***
Tr x Ti		***
M x Su		NS
M x Sq		NS
M x Ti		NS
Su x Sq		Not fitted
Su x Ti		NS
Sq x Ti		NS

As can be seen in Table 9, trial type, whether the meat was wet or dry, surface type, square number (i.e. 1-25 or 1-5) and time were all highly significant. With regards to interactions, only interactions containing trial type were significant. The Su x Sq interaction was not fitted because only squares 1-5 were used for the steel surface.

Appendix 7.8 illustrates the fitted mean log counts for all significant main effects. It can be seen that there is a difference between the mean counts for each of the trials and the mean counts for all trials combined It can be seen that wet meat, stainless steel, time 0 h and the first square have the highest TVC levels. There was a difference in the log TVC for all of the main effects and interactions (Table 24). The main effect plots (Figure 10) show the type of surface and whether the meat was wet or dry. The effect of square number was a reduction in count by about 1 log, and there was at least 1 log reduction over the 48 h time period.

Figure 10: All trials combined



3.11 Hand contamination

The TVC and Enterobacteriaceae counts from hands that had touched meat were higher than that of clean hands. In this data, there were a number of cases where the count was zero or the counts were too high to count. Therefore, ANOVA methods could not be used. However, it was evident in every trial that there was a clear difference in TVC count between the 'clean hand' and the hand (Table 10) which had handled the meat. To illustrate the effect, a survivor function was used to represent the degree of contamination in the 20 replicate measurements. The survivor functions show the proportion of trials in which the measured count was below or above given limits. The level of both TVC and Enterobacteriaceae dropped throughout the sequential transfer on agar plates.

The counts from hands that had touched chicken (skin-on) (Appendix 7.2) indicated that the level of both Enterobacteriaceae and TVC dropped throughout the sequential transfer on agar plates.

The counts from hands that had touched beef (Appendix 7.3) indicated that once again the levels decreased throughout the sequential transfer; however, there was no apparent pattern with meat/surface condition.

The chicken skin off data (meat hand) (Appendix 7.4) indicated that the Enterobacteriaceae level was highest when the chicken was wet and there was a decrease in level over the sequential transfer.

The counts from hands that had touched lamb (Appendix 7.5) indicated that the Enterobacteriaceae level was highest when the lamb was wet but that the TVC was highest when the lamb was dry.

The pork data (meat) (Appendix 7.6) indicated that the Enterobacteriaceae and TVC levels were greatest when the pork was wet. A decrease was observed over the sequential transfer.

The meat hand plate results for the sausage trial (Appendix 7.7) indicated that there were no Enterobacteriaceae present on the hands and the TVC level was greatest when the sausages were wet. Again, the levels decreased over the sequential transfer.

With respect to the burger meat hand plate results (Appendix 7.7), no Enterobacteriaceae were present when either dry or wet burgers were used. The TVC levels were highest when the burgers were wet.

Table 10: Proportions of counts below and above limits and median micro-organism counts (cfu/hand) TVC

Trial Number	Clean hand: Proportion of counts below 20	Meat hand: Proportion of counts below 20	Clean hand: Proportion of counts over 100	Meat hand: Proportion of counts over 100	Clean hand: Median Count	Meat hand: Median count
Chicken skin on Dry surface	88	4	0	72	5	Too large
Chicken skin on Wet surface	100	23	0	47	Too small	90
Beef Dry surface	80	0	5	86	Too small	Too large
Beef Wet surface	84	3	6	***65***	*5*	150
Chicken skin off Dry surface	82	82	*5*	0	Too small	2
Lamb Dry surface	84	0	0	100	Too small	Too large
Pork Dry surface	97	*5*	0	82	Too small	Too large
Sausages Dry surface	96	0	0	83	Too small	Too large
Beefburger Dry surface	90	12	3	55	Too small	105
Mean	89	14	2	66	Too small	Too large

Key: Too small indicates data contains large proportion of 0 counts.
Too large indicates data contains large proportion of counts with values to great to count.

3.12 **Washing trial**

The results of the washing trial are given in Appendix 7.8.

As can be seen, there was no particular pattern of decrease in TVC or Enterobacteriaceae level when chicken was washed. In some of the replicates there appeared to be very little difference between TVC and Enterobacteriaceae level before and after washing when the excision technique was used; however, the levels were generally lower after washing. There appeared to be more of a consistent pattern observed when the contact plate method was used, which showed a greater reduction in Enterobacteriaceae levels.

There also appeared to be no noticeable difference between washing techniques.

With respect to the beef joint, the results were not consistent for either excision or contact plate methods and so washing appeared to have little microbiological benefit.

3.13 **Soaking types**

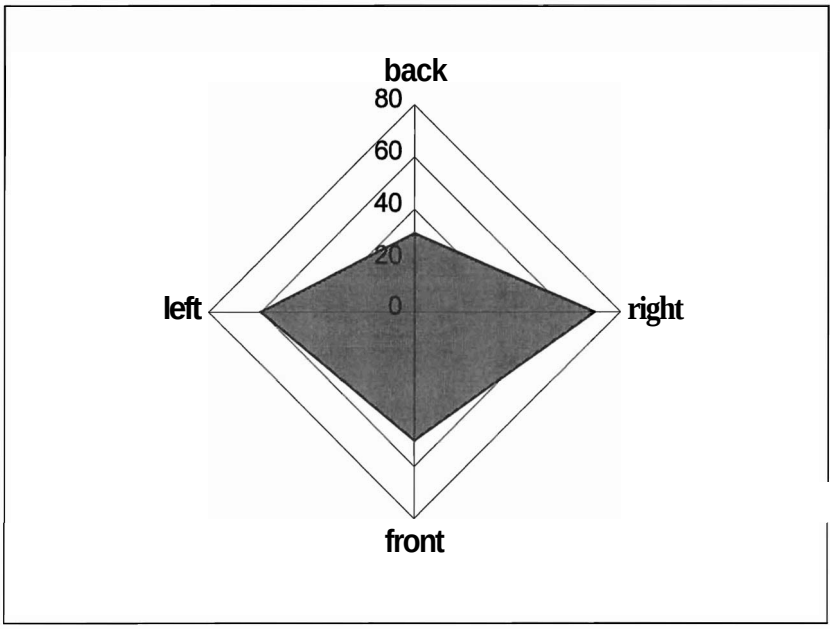
The results are given in Appendix 7.8. The results indicate that there was no pattern to the reduction in TVC and Enterobacteriaceae level, as determined by the excision method, when the meat was soaked in any of the various solutions. With the contact plate method, there appeared to be a ½ - 0 log order reduction with water, a 1-2 log order reduction with vinegar, a 0.8 - 2 log order reduction with salt (5%) and a >2 log order reduction with salt (10%) in Enterobacteriaceae. With respect to the TVC contact plate results, only the vinegar appeared to have a slight effect. This difference in results with the two techniques may be due to a carry over of vinegar/salt onto the contact plates which inhibited growth of the micro-organisms, rather than a reduction in numbers on the meat.

3.14 **Droplet splash**

The results of the droplet splash study indicate (Figure 13) that splashes travelled up to 70 cm to the right of the sink and 60 cm to the left. It was also found that splashes were observed up to 50 cm in front of the sink and up to 30 cm behind the sink. This distance was limited due to the presence of a wall but splashes were noted up to 30 cm on this wall.

Splash zone associated with washing chicken

Figure 13



4. CONCLUSIONS

The results of the statistical analysis of individual meat types are summarised in Table 11 Several conclusions can be drawn fiom this data.

For most meat types:

- The levels of bacteria able to persist throughout the trial was dependent to some degree on the level of bacteria initially present on the meat type. The greater the level of initial contamination of the meat, the greater was the persistence.

- There was a significant reduction in the levels of bacteria present during the 48 h trial, although it is important to note that relatively high numbers (up to 2.8×10^5 per 25 cm^2) persisted throughout this period. In many cases, the largest decrease occurred within the first 4 h, with a steady decline in numbers thereafter. Scott and Bloomfield (1990) also found that Gram negative bacteria could persist for up to 4 hours and in some cases up to 24 hours on solid laminate surfaces. In our studies survival persisted beyond this to 48 h. Thus, if surface contamination is left and not treated, numbers will decline but contamination remains present, highlighting the importance of cleaning and disinfection.

- There was a significant reduction in the levels of bacteria present following sequential transfer of meat to clean surfaces, although it is important to note that relatively high numbers (up to 8.2×10^4 per 25 cm^2) were still present after the meat had been placed on a surface 25 times. There was also a high level of bacteria present on hands after handling meat, which persisted for over 20 sequential transfers.

- Repeatedly placing meat or hands which have prepared meat products on to kitchen surfaces, act as a route of contamination.

- In most cases where there was a difference between dry or wet meat, there was a significantly higher level of bacteria present when the meat surface was wet. In studies carried out by Taylor *et al* (2000) to assess the transfer of bacterial contamination fiom hands and footwear, it was observed that higher levels of bacterial contamination were transferred when either the hand/footwear or contact surface was wet. It appears that this is similar when meat or the contact surface was wetted.

- In most cases where there was a difference between surface type, there was a significantly higher level of bacteria obtained from stainless steel. Many of the surfaces within the domestic kitchen, e.g. sinks, draining boards, taps, are made from this material.

- Washing and soaking of meat, using various techniques, did not consistently reduce microbial contamination.

- It was found that, when washing poultry, droplets could travel as far as 70 cm away from the site of washing. Such splashing would transfer any bacterial pathogens present on meat.

- Since neither washing nor soaking appeared to reduce levels of microbial contamination on meat surfaces, they are not recommended for this purpose within the domestic environment. Should such practices need to be done to remove blood from the meat, then soaking and draining is preferable to washing, as there is less potential for splashing contaminated water around the domestic kitchen environment.

Table 11: Indicating significance of various factors when ANOVA was carried out for sequential transfer work

Meat type/surface condition	Dry or wet meat	Surface Laminate/Steel	Square No.	Time
Chicken skin on *dry* surface	N/S	***	*	***
Chicken skin on wet surface	*** (D)[a]	N/S	***	***
Beef dry surface	*** (W)	*** (S)	***	***
Beef wet surface	* (W)	*** (L)	***	***
Chicken skin off dry surface	*** (W)	*** (S)	***	***
Lamb dry surface	N/S	*** (S)	***	***
Pork *dry* surface	*** (W)	N/S	N/S	N/S
Sausage	*** (W)	N/S	*	N/S
Burger	N/S	N/S	N/S	N/S

N/S = not significant
*** = **99.9%** significant
** = **99%** significant
* = **95%** significant
( )[a] = D or W in brackets indicates whether dry or wet surface had the highest count.
( )[b] = L or S in brackets indicates whether laminate or steel had the highest count.

5. IMPLICATIONS

Transfer of bacteria from the surface of various types of raw meat onto two typical kitchen surfaces was demonstrated in this study. The TVC levels that were transferred ranged from 10^2 cfu/25 cm^2 to 10^5 cfu/25 cm^2. This, of course, has cross contamination implications when raw meat is placed on surfaces in the domestic kitchen. It could be possible for bacteria to be transferred from contaminated surfaces to ready-to-eat foods.

The study also demonstrated that there is a difference in contamination level when meats are placed upon surfaces, depending upon surface type. Stainless steel became more contaminated than laminate. Sinks, taps and draining boards are likely to be made of stainless steel a i d sinks/draining boards are places in which meat preparation could be carried out.

It was also observed that bacteria persisted throughout the 48 h test period. This could have important implications with respect to cross contamination if surfaces are not thoroughly cleaned after use or indeed dishclothsltea towels are used to wipe contaminated surfaces. A previous study (Newsholme *et* al., 2002) demonstrated the ability of dishclothsltea towels to provide an environment in which bacteria are able to grow and multiply to high levels.

This study also demonstrated that there was a decrease in contamination throughout sequential transfer. However, even after placing meat down twenty five times, contamination of a laminate surface still occurred at fairly high levels. Therefore, if consumers continually place raw meat on surfaces they are increasing the risk of cross contamination.

A similar observation was seen with respect to hand contamination. Hands that had touched raw meat were much more contaminated than those which had not. Despite placing hands on twenty consecutive agar plates, more bacteria were obtained from hands that had handled raw meat than those that had not. Therefore, whilst the surfaces touched by consumers in the first instance will be contaminated with higher levels of micro-organisms, subsequently touched surfaces will also become contaminated.

This study also demonstrated the ability of wet meat to transfer higher levels of bacteria to surfaces compared with *dry* meat. This also has important implications because in a previous quantitative study (Newsholme, 2002) it was shown that 80% of consumers questioned washed meat. The washing and soaking of meat did not consistently decrease the TVC and Enterobacteriaceae level present on the surface of whole chicken or beef. Therefore, consumers that wash meat are not significantly reducing microbial contamination by washing/soaking meat and could increase the likelihood of contaminating surfaces that meat/hands are placed on.

A droplet splash method indicated that droplets of water can travel quite long distances, either to the side and behind, when meat is washed. This could have cross contamination implications if the droplets contain microbial contaminants.

6. REFERENCES

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7. APPENDIX

7.1 Initial contamination levels on meat surfaces

7.2 Microbiological data for chicken thighs

7.3 Microbiological data for beef joints

7.4 Microbiological data for chicken breast

7.5 Microbiological data for lamb joints

7.6 Microbiological data for pork joint

7.7 Microbiological data for sausages and burgers

7.8 Statistical analysis of the combined data set for all seven trials

7.9 Microbiological results from washing and soaking trials.

7.1 Initial contamination levels on meat surfaces

Table 12: Initial contamination levels in four sub-squares

Meat type	Replicate no.	Square	Entero-bacteriaceae (cfu/25 cm^2)	TVC (cfu/25 cm^2)
Chicken	1	a	8.2E+03	2.7E+05
Chicken	1	b	1.7E+04	4.7E+05
Chicken	1	c	9.9E+03	3.2E+05
Chicken	1	d	6.4E+03	2.7E+05
Excision (cfu/5 cm^2)			7.0E+05	1.7E+07
Chicken	2	a	90	8.4E+03
Chicken	2	b	620	3.6E+04
Chicken	2	c	90	2.5E+04
Chicken	2	d	150	2.7E+04
Excision (cfu/5 cm^2)			2.0E+05	6.5E+07
Chicken	3	a	<10	5.8E+03
Chicken	3	b	810	5.0E+03
Chicken	3	c	<10	6.0E+04
Chicken	3	d	<10	6.9E+03
Excision (cfu/5 cm^2)			2.1E+05	1.65E+07
Pork	1	a	90	2.0E+04
Pork	1	b	60	1.1E+04
Pork	1	c	410	2.1E+04
Pork	1	d	280	6.9E+04
Excision (cfu/5 cm^2)			1.25E+03	7.5E+04

Table 12: Initial contamination levels in four sub-squares (continued)

Meat type	Replicate no.	Square	Entero-bacteriaceae (cfu/25 cm^2)	TVC (cfu/25 cm^2)
Pork	2	a	1.7E+03	1.7E+05
Pork	2	b	710	1.1E+05
Pork	2	c	1.7E+04	4.4E+05
Pork	2	d	1.2E+03	9.2E+04
Excision (cfu/5 cm^2)			2.25E+03	3.1E+05
Pork	3	a	1.3E+04	2.9E+05
Pork	3	b	140	6.3E+03
Pork	3	c	1.8E+03	2.1E+05
Pork	3	d	270	9.1E+03
Excision (cfu/5 cm^2)			1.85E+03	8.5E+04
Lamb	1	a	40	4.4E+05
Lamb	1	b	10	3.2E+05
Lamb	1	c	10	1.4E+05
Lamb	1	d	<10	1.4E+04
Excision (cfu/5 cm^2)			900	1.85E+07
Lamb	2	a	10	4.0E+05
Lamb	2	b	60	6.9E+05
Lamb	2	c	<10	3.9E+04
Lamb	2	d	210	9.0E+05
Excision (cfu/5 cm^2)			1.85E+04	1.1E+08

Table 12: Initial contamination levels in four sub-squares (continued)

Meat type	Replicate no.	Square	Entero-bacteriaceae (cfu/25 cm^2)	TVC (cfu/25 cm^2)
Lamb	3	a	<10	9.0E+04
Lamb	3	b	<10	6.5E+04
Lamb	3	c	<10	1.1E+05
Lamb	3	d	<10	1.5E+05
Excision (cfu/5 cm^2)			1.4E+03	1.75E+07
Beef	1	a	1.4E+03	1.2E+06
Beef	1	b	1.3E+03	1.4E+06
Beef	1	c	670	3.9E+05
Beef	1	d	1.1E+03	8.7E+05
Excision (cfu/5 cm^2)			350	8.0E+04
Beef	2	a	2.3E+03	1.2E+06
Beef	2	b	1.5E+03	6.9E+05
Beef	2	c	1.4E+03	4.3E+05
Beef	2	d	370	1.3E+05
Excision (cfu/5 cm^2)			250	4.0E+05
Beef	3	a	780	3.5E+05
Beef	3	b	10	3.2E+04
Beef	3	c	360	3.1E+05
Beef	3	d	60	4.1E+04
Excision (cfu/5 cm^2)			50	1.1E+05

7.2 Microbiological data for chicken thighs

Table 13: Chicken thigh results - Dry/Wet meat on dry surfaces

Dry chicken dry surface - Laminate				
Chicken cfu/5 cm^2	3.6E+06	cfu/25 cm^2	1.8E+07	
Square No. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	<10			
Prior	<10			
1	1.5E+04	2.5E+03	5.2E+03	2.7E+03
2	7.6E+03	1.3E+03	2.9E+03	3.2E+02
3	3.1E+03	9.3E+02	1.5E+03	4.3E+02
4	1.5E+03	7.2E+02	1.5E+03	2.6E+02
5	2.3E+03	9.9E+02	1.1E+03	2.7E+02
10	1.1E+03	9.0E+02	1.1E+03	2.6E+02
15	1.6E+03	5.8E+02	1.9E+03	20
20	1.0E+03	4.0E+02	5.9E+02	70
25	3.8E+02	3.5E+02	3.1E+02	1.0E+02
Blank 1	<10	<10	<10	40
Blank 2	<10	<10	<10	20
Blank 3	10	<10	20	<10

Wet chicken dry surface - Laminate				
Chicken cfu/5 cm^2	5.6E+06	cfu/25 cm^2	2.8E+07	
Square No.	0 h	4 h	ZdΛ	48 h
Prior	<10			
Prior	<10			
1	1.1E+03	1.0E+03	1.8E+03	1.0E+02
2	5.3E+02	7.3E+02	9.2E+02	70
3	8.5E+02	6.9E+02	6.3E+02	4.1E+02
4	1.5E+03	1.7E+03	5.1E+02	2.2E+02
5	1.6E+03	4.00E+04	1.5E+03	2.9E+02
10	1.8E+03	3.0E+03	2.1E+03	5.5E+02
15	1.6E+03	8.3E+02	7.7E+02	3.1E+02
20	1.0E+03	1.0E+03	3.8E+02	60
25	6.4E+02	6.1E+02	1.1E+03	*
Blank 1	<10	<10	<10	60
Blank 2	<10	<10	<10	<10
Blank 3	20	<10	<10	10

Dry chicken dry surface - Steel				
Chicken cfu/5 cm^2	3.3E+06	cfu/25 cm^2	1.7E+07	
Square No. cfu/25 cm	0 h	4 h	24 h	48 h
Prior	<10			
1	5.4E+04	1.2E+04	1.3E+04	5.8E+03
2	8.9E+04	4.3E+04	1.3E+04	3.8E+03
3	4.4E+04	1.4E+04	1.3E+05	4.4E+03
4	1.5E+04	1.2E+04	6.4E+03	1.5E+03
5	6.1E+03	4.7E+03	3.4E+03	2.5E+02
Blank	<10	10	<10	<10

Wet chicken dry surface - Steel				
Chicken cfu/5 cm^2	2.1E+07	cfu/25 cm^2	1.1E+08	
Square No. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	<10			
1	3.8E+04	3.8E+03	2.7E+04	2.2E+04
2	1.5E+04	2.1E+04	4.0E+06	3.4E+04
3	1.6E+04	7.9E+03	8.1E+04	1.0E+04
4	6.3E+03	3.3E+04	2.6E+04	2.8E+04
5	1.8E+04	1.1E+04	2.1E+05	5.6E+04
Blank	<10	10	<10	1.8E+02

Exposure plates	PCA			
Position	0 h	4 h	24 h	48 h
1	6	5	17	31
2	1	4	10	25
3	1	7	6	21
4	4	2	8	9

Exposure plates	VRBGA			
Position	0 h	4 h	ZdΛ	48 h
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

Table 14: Chicken thigh results - Dry/Wet meat on wet surfaces

Dry chicken wet surface				
Chicken cfu/5 cm^2	4.0E+07	cfu/25 cm^2 2.0E+08		
Square No. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	<10			
Prior	<10			
1	1.9E+04		1.5E+04	2.1E+04
2	2.3E+04	3.4E+04	3.4E+03	1.3E+04
3	3.6E+04	1.4E+04	6.9E+03	3.0E+02
4	1.2E+04	4.6E+03	1.1E+03	1.2E+03
5	1.1E+04	8.9E+03	2.1E+03	1.2E+03
10	2.1E+04	9.4E+03	5.3E+03	1.7E+02
15	1.1E+04	3.8E+03	7.6E+02	3.9E+02
20	3.6E+04	2.7E+03	2.4E+03	2.8E+02
25	7.7E+04	7.9E+02	9.4E+02	80
Blank 1	<10	<19	<10	<10
Blank 2	10	20	<10	<10
Blank 3	<10	<10	1.5E+02	10

Wet chicken wet surface				
Chicken cfu/5 cm^2	1.3E+07	cfu/25 cm^2 6.5E+07		
Square No. cfu/25 cm^2	0	4 h	24 h	48 h
Prior	<10			
Prior	<10			
1	1.1E+02	1.9E+03	40	1.20E+02
2	1.2E+03	3.0E+03	1.4E+03	90
3	8.8E+02	4.8E+03	6.1E+02	3.9E+02
4	2.3E+03	3.9E+03	1.5E+02	2.7E+02
5	3.4E+03	6.3E+03	3.3E+02	1.1E+03
10	8.8E+02	1.6E+03	50	30
15	3.1E+02	6.7E+02	1.4E+02	80
20	1.0E+02	1.3E+02	1.4E+02	<10
25	2.1E+02	3.5E+02	50	30
Blank 1	10	<10	<10	<10
Blank 2	10	10	<10	<10
Blank 3	<10	<10	<10	<10

Dry chicken wet surface				
Chicken cfu/5 cm^2	2.3E+07	cfu/25 cm^2 1.2E+08		
Square No. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	<10			
1	2.4E+04	1.4E+04	1.1E+04	6.2E+03
2	9.9E+03	8.3E+03	2.4E+03	3.9E+02
3	6.8E+03	6.6E+03	2.5E+03	1.6E+03
4	2.0E+04	5.4E+03	3.0E+03	7.3E+02
5	8.7E+03	1.0E+04	4.1E+03	2.6E+02
Blank	<10	<10	<10	<10

Wet chicken wet surface				
Chicken cfu/5 cm^2	2.4E+06	cfu/25 cm^2 1.2E+07		
Square No. cfu/25 cm^2	0h	4 h	24 h	48 h
Prior	<10			
1	1.8E+04	9.0E+03	8.0E+03	1.3E+03
2	3.5E+03	3.3E+03	4.9E+03	1.2E+03
3	2.5E+03	2.5E+03	6.1E+03	2.5E+03
4	3.6E+03	2.7E+03	1.7E+03	1.3E+03
5	2.2E+03	3.5E+03	4.3E+03	3.0E+02
Blank	10	<10	1.3E+02	<10

Exposure plates	PCA			
Position	0 h	4 h	24 h	48 h
1	1	5	3	31
2	0	4	1	25
3	0	7	2	21
4	0	2	3	9

Exposure plates	VRBGA			
Position	0 h	4 h	24 h	48 h
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

Table 15: Summary of chicken thigh total meat hand contamination plate results (cfu/hand)

	Enterobacteriaceae				TVC			
	DCDS	WCDS	DCWS	WCWS	DCDS	WCDS	DCWS	WCWS
1.	182	255	447	269	>750	>750	>1,100	>1,033
2.	139	223	328	160	>750	>750	>1,100	>870
3.	63	142	284	101	>750	>750	>1,100	870
4.	30	131	215	48	>750	>750	>950	860
5.	28	70	99	64	>750	>750	>850	>856
6.	22	32	172	93	>750	>750	>900	662
7.	20	38	190	37	>750	>750	>990	437
8.	15	52	116	31	>750	>750	>740	424
9.	14	41	63	17	>750	565	726	337
10.	19	38	48	15	>750	>440	481	303
11.	11	25	26	13	>750	>450	635	199
12.	15	26	23	9	>750	>370	520	189
13.	10	20	18	12	>750	>440	683	206
14.	24	23	17	17	>750	>369	552	154
15.	2	15	12	2	>750	269	453	117
16.	6	5	23	1	402	245	543	93
17.	12	9	14	2	>750	249	331	35
18.	7	7	4	0	468	273	277	39
19.	9	4	7	1	>750	281	46	45
20.	4	6	2	1	556	254	48	58

DCDS = Dry chicken, *dry* surface
WCDS = Wet chicken, *dry* surface
DCWS = Dry chicken, wet surface
WCWS = Wet chicken, wet surface

Table 16: Summary of chicken thigh total TVC non-meat hand contamination plate results (cfu/hand)

	DCDS	WCDS	DCWS	WCWS
1.	40	11	5	1
2.	19	4	1	2
3.	18	4	0	0
4.	15	6	0	1
5.	18	1	2	2
6.	30	3	1	0
7.	23	2	4	0
8.	19	1	4	1
9.	2	**3**	2	0
10.	17	2	1	0
11.	2	0	0	0
12.	9	0	0	1
13.	3	3	0	6
14.	5	22	0	1
15.	6	36	2	1
16.	6	52	0	0
17.	3	44	0	0
18.	5	20	0	0
19.	3	13	0	0
20.	0	6	9	0

DCDS = Dry chicken, dry surface
WCDS = Wet chicken, *dry* surface
DCWS = Dry chicken, wet surface
WCWS = Wet chicken, wet surface

7.3 Microbiological data for beef joints

Table 17: Beef joint results - dry/wet beef and dry surface

Dry beef dry surface - Laminate				
Beef cfu/5 cm^2	4.5E+04	cfu/25 cm^2 1.3E+05		
Square No. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior 1	<10			
Prior 2	<10			
1	1.6E+05	3.5E+04	3.3E+03	4.2E+04
2	1.2E+05	4.2E+04	3.9E+03	7.0E+03
3	7.8E+04	1.7E+04	1.3E+03	8.1E+03
4	7.6E+04	3.3E+04	1.7E+03	2.4E+03
5	2.6E+04	1.5E+04	1.4E+03	6.8E+03
10	1.8E+04	7.3E+03	3.2E+03	6.7E+02
15	2.2E+04	3.2E+03	1.2E+03	1.1E+02
20	3.0E+03	1.1E+03	1.2E+03	1.1E+02
25	9.9E+03	7.4E+03	2.6E+03	3.3E+02
Blank 1	20	50	<10	<10
Blank 2	<10	<10	<10	<10
Blank 3	<10	40	<10	20
Dry beef dry surface - steel				
Beef cfu/5 cm^2	3.6E+04	cfu/25 cm^2 1.8E+05		
	0 h	4 h	24 h	48 h
Prior cfu/25 cm^2	<10			
1	2.5E+05	9.0E+03	3.3E+04	5.4E+03
2	3.5E+05	1.4E+04	2.9E+04	2.1E+03
3	8.2E+04	2.2E+04	3.9E+04	8.3E+04
4	1.5E+05	6.7E+03	5.6E+04	1.8E+04
5	1.7E+04	1.8E+04	2.2E+03	3.8E+03
Blank	10	<10	20	10
Exposure plates	**VRBGA**			
Position	0 h	4 h	24 h	48 h
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

Wet beef dry surface - Laminate				
Beef cfu/5 cm^2	6.2E+04	cfu/25 cm^2 3.1E+05		
Square No.	0 h	4 h	24 h	48 h
Prior 1	20			
Prior 2	10			
1	1.0E+06	7.0E+05	1.8E+04	2.0E+04
2	1.0E+06	6.0E+05	1.6E+04	6.1E+03
3	5.6E+05	3.9E+05	3.2E+04	6.9E+03
4	1.4E+05	2.9E+05	1.5E+05	4.8E+03
5	2.5E+05	5.4E+05	2.4E+04	7.0E+03
10	8.3E+04	7.1E+04	7.2E+04	5.5E+04
15	5.1E+04	1.5E+05	1.3E+03	2.6E+03
20	1.6E+04	2.6E+05	2.3E+03	8.2E+03
25	8.2E+04	1.4E+05	8.0E+03	7.3E+02
Blank 1	<10	60	<10	60
Blank 2	10	<10	<10	30
Blank 3	<10	<10	<10	10
Wet beef dry surface - steel				
Beef cfu/5 cm^2	2.0E+05	cfu/25 cm^2 1.0E+06		
	0 h	4 h	24 h	48 h
Prior cfu/25 cm^2	<10			
1	1.0E+06	1.3E+06	1.0E+06	1.1E+05
2	1.0E+06	2.0E+06	3.6E+05	5.4E+05
3	1.0E+06	4.4E+05	3.2E+05	8.0E+05
4	8.2E+05	1.6E+06	2.3E+05	1.5E+05
5	1.2E+06	3.6E+05	1.8E+05	2.8E+05
Blank	80	50	<10	20
Exposure plates	**PCA**			
Position	0 h	4 h	24 h	48 h
1	3	0	13	22
2	0	1	7	12
3	3	1	17	17
4	0	1	12	7

Table 18: Beef joint results - dry/wet beef and wet surface

Dry beef wet surface - Laminate				
Beef cfu/5 cm^2	2.4E+06	cfu/25 cm^2 1.2E+07		
Square No. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior 1	0.0E+00			
Prior 2	30			
1	7.5E+04	7.1E+04	2.0E+05	5.4E+04
2	6.5E+04	2.8E+04	3.3E+05	1.6E+04
3	6.4E+04	4.5E+04	2.2E+05	2.8E+05
4	7.0E+03	1.8E+04	2.4E+05	2.8E+05
5	9.0E+03	1.9E+03	2.0E+05	2.5E+04
10	5.7E+03	3.8E+03	2.7E+04	6.3E+03
15	7.0E+03	3.2E+03	1.3E+04	2.5E+03
20	1.5E+03	3.3E+03	4.0E+03	4.7E+04
25	1.7E+04	9.3E+02	2.9E+04	6.3E+03
Blank 1	<10	10	<10	70
Blank 2	<10	20	<10	<10
Blank 3	20	10	<10	<10
Dry beef wet surface - steel				
Beef cfu/5 cm^2	9.3E+05	cfu/25 cm^2 40.7E+06		
Steel cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	<10			
1	1.9E+05	9.4E+03	5.6E+03	1.6E+04
2	2.7E+03	4.4E+03	5.5E+04	9.9E+04
3	2.1E+03	6.4E+03	6.7E+04	3.6E+04
4	4.1E+03	1.4E+03	5.6E+03	3.1E+04
5	1.1E+03	3.3E+03	5.2E+03	6.8E+03
Blank	<10	<10	20	30
Exposure plates	**VRBGA**			
Position	0 h	4 h	24 h	48 h
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

Wet beef wet surface - Laminate				
Beef cfu/5 cm^2	1.9E+05	cfu/25 cm^2 9.5E+05		
Square No cfu/25 cm^2.	0 h	4 h	24 h	48 h
Prior 1	1.0E+01			
Prior 2	10			
1	8.9E+05	1.7E+05	3.1E+05	4.1E+04
2	6.7E+04	7.9E+04	1.7E+05	8.8E+04
3	1.1E+05	3.2E+05	2.1E+04	1.1E+05
4	1.1E+05	4.2E+04	5.4E+04	3.4E+04
5	1.3E+05	7.4E+04	1.6E+04	2.0E+04
10	1.2E+04	1.1E+04	1.8E+04	5.7E+03
15	5.5E+03	6.6E+03	3.6E+03	9.2E+03
20	1.3E+04	1.5E+04	1.3E+04	2.0E+03
25	9.0E+03	3.2E+03	3.7E+04	4.4E+03
Blank 1	<10	<10	<10	10
Blank 2	<10	10	<10	<10
Blank 3	<10	10	<10	<10
Wet beef wet surface - steel				
Beef cfu/5 cm^2	2.5E+05	Cfu/25 cm^2 1.25E+06		
Steel cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	300			
1	2.4E+05	3.0E+03	1.6E+05	7.2E+04
2	2.7E+03	2.0E+03	8.9E+04	1.1E+04
3	6.2E+04	8.7E+03	2.7E+04	9.5E+03
4	1.5E+04	9.6E+03	5.2E+04	4.6E+03
5	8.1E+03	8.6E+03	6.2E+03	1.5E+04
Blank	<10	20	<10	10
Exposure plates	**PCA**			
Position	0 h	4 h	24 h	48 h
1	0	3	4	
2	1	0	5	
3	1	3	2	
4	1	0	5	

Table 19: Summary of beef joint total meat hand contamination plate results (cfu/hand)

	Enterobacteriaceae				TVC			
	DBDS	**WBDS**	**DBWS**	**WBWS**	**DBDS**	**WBDS**	**DBWS**	**WBWS**
1.	>200	50	0	48	>1,500	>1,500	>1,500	>1,500
2.	>200	102	1	120	>1,500	>1,500	>1,500	>1,500
3.	>200	64	1	65	>1,500	>1,500	>1,500	>900
4.	25	95	0	84	>1,500	>1,500	>1,500	>900
5.	25	93	1	23	>1,500	>1,500	>1,500	>900
6.	99	113	0	34	>1,000	>1,250	>1,250	>650
7.	88	146	0	5	>1,000	>1,420	>1,250	>600
8.	96	91	0	8	>1,000	>700	>850	>550
9.	88	79	0	5	>1,000	824	>600	600
10.	101	36	3	1	>1,000	570	>439	496
11.	80	18	0	5	>1,000	672	>486	568
12.	103	34	2	0	>1,000	>692	>500	470
13.	76	31	0	1	>750	460	>472	462
14.	97	34	0	1	>750	442	>594	360
15.	51	38	0	0	>750	630	*	342
16.	75	47	0	1	>750	447	>464	448
17.	63	39	0	1	>750	464	>386	310
18.	67	30	0	3	732	530	>396	265
19.	66	33	1	5	808	314	>430	318
20.	66	18	0	1	739	298	>490	396

DBDS = Dry beef, dry surface
WBDS = Wet beef, dry surface
DBWS = Dry beef, wet surface
WBWS = Wet beef, wet surface
* = Not tested

Table 20: Summary of beef joint non-meat hand total TVC contamination plate results (cfu/hand)

	DBDS	WBDS	DBWS	WBWS
1.	172	49	298	49
2.	170	45	375	36
3.	114	50	345	33
4.	136	Plates contaminated	249	43
5.	112		186	35
6.	88		144	17
7.	140		111	15
8.	114		114	11
9.	105		107	8
10.	78		173	8
11.	68		133	3
12.	94		128	0
13.	56		99	2
14.	97		105	3
15.	93		50	0
16.	68		36	0
17.	98		56	1
18.	77		64	1
19.	104		94	1
20.	107		98	1

DBDS = Dry beef, dry surface
WBDS = Wet beef, dry surface
DBWS = Dry beef, wet surface
WBWS = Wet beef, wet surface

7.4 Microbiological data for chicken breast

Table 21: Chicken breast fillet (skin off) results - dry/wet meat on dry surfaces

Dry chicken (skin off) dry surface - Laminate				
Chicken skin off cfu/5 cm^2	5.3E+06	cfu/25 cm^2	2.65E+07	
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior 1	<10			
Prior 2	<10			
1	3.8E+03	1.6E+04	2.6E+02	20
2	2.2E+03	5.5E+03	1.3E+02	60
3	1.4E+03	9.3E+03	4.1E+02	1.1E+02
4	3.0E+02	1.6E+03	3.9E+02	1.6E+03
5	2.8E+02	8.3E+02	20	20
10	1.8E+02	3.3E+03	60	30
15	6.8E+02	1.2E+04	10	10
20	3.4E+02	1.8E+02	<10	10
25	1.3E+02	7.9E+02	10	10
Blank 1	<10	<10	10	<10
Blank 2	20	<10	<10	<10
Blank 3	<10	<10	<10	<10

Dry chicken dry surface - steel				
Chicken cfu/5 cm^2	3.4E+06	cfu/25 cm^2	1.7E+07	
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	<10			
1	1.8E+05	7.1E+02	1.8E+03	70
2	5.5E+05	3.0E+03	6.9E+02	1.3E+03
3	4.5E+04	6.3E+02	2.2E+02	1.0E+02
4	1.8E+04	5.9E+02	40	20
5	8.2E+03	5.8E+02	1.2E+02	20
Blank	<10	<10	10	<10

Exposure plates	VRBGA			
Position	0 h	4 h	24 h	48 h
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

Wet chicken (skin off) dry surface - Laminate				
Chicken skin off cfu/5 cm^2	2.4E+07	cfu/25 cm^2	1.2E+08	
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior 1	<10			
Prior 2	<10			
1	1.0E+06	1.8E+04	2.7E+03	2.3E+03
2	3.1E+04	2.1E+03	9.6E+02	8.6E+02
3	2.0E+04	4.2E+03	1.0E+03	50
4	2.7E+03	7.6E+03	2.5E+02	<10
5	2.1E+03	3.8E+03	1.1E+03	40
10	1.0E+03	2.1E+03	30	30
15	2.2E+02	6.3E+02	90	10
20	3.1E+03	1.1E+03	50	30
25	6.3E+03	2.6E+03	1.3E+02	10
Blank 1	<10	<10	<10	<10
Blank 2	<10	<10	10	<10
Blank 3	<10	<10	<10	<10

Wet chicken dry surface - steel				
Chicken cfu/5 cm^2	1.2E+07	cfu/25 cm^2	6.0E+07	
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	10			
1	1.5E+04	1.3E+04	4.2E+04	6.0E+03
2	3.1E+04	3.4E+04	1.0E+04	1.1E+03
3	1.8E+04	1.1E+04	2.4E+03	2.7E+03
4	1.8E+04	2.1E+04	4.6E+03	4.1E+03
5	2.8E+04	1.7E+03	1.7E+03	3.8E+02
Blank	<10	<10	<10	<10

Exposure plates	PCA			
Position	0 h	4 h	24 h	48 h
1	3	2	0	24
2	0	4	0	23
3	0	1	0	20
4	0	1	0	17

Table 22: Summary of chicken (skin off) total meat hand contamination plate results (cfu/hand)

	Enterobacteriaceae		TVC	
	DCDS	**WCDS**	**DCDS**	**WCDS**
1.	>200	>200	>1,500	>1,500
2.	128	101	>1,500	>1,500
3.	204	78	>1,500	>1,500
4.	>200	>200	>1,500	>1,500
5.	>200	64	>1,500	>1,500
6.	>200	148	>1,500	>1,500
7.	>200	221	>1,500	>1,500
8.	>200	144	>1,500	>1,500
9.	>200	>200	>1,500	>1,500
10.	>200	49	>1,500	>1,500
11.	50	60	>1,500	>1,500
12.	>200	72	>1,500	>1,500
13.	>200	80	>1,500	>1,500
14.	>200	77	>1,500	>1,500
15.	>200	27	>1,500	>1,500
16.	44	73	>1,500	>1,500
17.	>200	70	>1,500	>1,500
18.	>200	33	>1,500	>1,500
19.	200	9	>1,500	>1,500
20.	>200	20	>1,500	>1,500

DCDS = Dry chicken, *dry* surface
WCDS = Wet chicken, *dry* surface

Table 23: Summary of chicken (skin off) total non-meat hand contamination TVC plate results (cfu/hand)

	DCDS	WCDS
1.	181	115
2.	101	87
3.	58	68
4.	59	72
5.	68	81
6.	34	81
7.	48	52
8.	37	38
9.	42	32
10.	36	22
11.	33	28
12.	31	22
13.	46	37
14.	39	20
15.	77	30
16.	37	19
17.	35	15
18.	32	18
19.	28	6
20.	20	

DCDS = Dry chicken, dry surface
WCDS = Wet chicken, dry surface

7.5 Microbiological data for lamb joints

Table 24: Lamb joint results for dry/wet meat on dry surfaces

Dry lamb dry surface - Laminate				
Lamb cfu/5 cm^2	4.2E+05	cfu/25 cm^2 2.4E+06		
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior 1	<10			
Prior 2	10			
1	5.1E+03	1.9E+03	4.7E+02	5.2E+02
2	2.9E+03	4.2E+03	90	2.7E+02
3	6.9E+03	1.7E+03	90	40
4	6.0E+02	2.0E+03	1.3E+02	30
5	2.2E+03	9.1E+02	5.1E+02	30
10	7.0E+02	1.4E+03	1.0E+02	1.1E+02
15	8.9E+02	1.9E+02	1.0E+02	20
20	3.0E+03	3.7E+02	80	20
25	6.2E+02	4.7E+02	3.4E+02	1.7E+02
Blank 1	<10	<10	<10	10
Blank 2	<10	40	<10	<10
Blank 3	<10	<10	<10	<10

Dry lamb dry surface - steel				
Lamb cfu/5 cm^2	2.9E+06	cfu/25 cm^2 1.45E+07		
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	<10			
1	1.9E+04	6.9E+03	5.5E+03	8.0E+03
2	1.1E+04	5.8E+03	7.9E+03	2.9E+02
3	1.2E+04	6.9E+03	6.4E+03	3.0E+03
4	1.8E+04	9.2E+03	3.5E+03	1.4E+03
5	5.3E+03	4.9E+03	6.1E+03	2.8E+02
Blank	<10	<10	20	<10

Exposure plates	VRBGA			
Position	0 h	4 h	24 h	48 h
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

Wet lamb dry surface - Laminate				
Lamb cfu/5 cm^2	9.5E+05	cfu/25 cm^2 4.75E+06		
Square no. cfu/25 cm^2	0 h	4h	24 h	48 h
Prior 1	10			
Prior 2	<10			
1	1.3E+05	3.2E+03	6.0E+03	4.5E+02
2	2.4E+05	3.6E+02	2.8E+02	2.4E+02
3	1.3E+05	1.1E+04	2.2E+03	1.8E+02
4	3.4E+03	2.1E+03	40	30
5	3.1E+03	1.8E+03	1.6E+02	40
10	2.7E+02	2.7E+03	40	1.3E+02
15	4.3E+02	1.2E+03	<10	1.3E+02
20	5.7E+03	1.4E+03	80	10
25	2.0E+03	1.3E+03	90	40
Blank 1	<10	<10	<10	10
Blank 2	30	<10	<10	60
Blank 3	<10	<10	<10	70

Wet lamb dry surface - steel				
Lamb cfu/5 cm^2	4.5E+06	cfu/25 cm^2 2.25E+07		
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	10			
1	3.3E+03	1.6E+03	1.2E+04	4.3E+02
2	4.8E+04	5.1E+03	1.6E+04	3.9E+02
3	1.6E+03	1.9E+04	2.3E+03	3.3E+02
4	2.0E+03	1.2E+03	1.8E+03	3.4E+02
5	8.1E+02	1.8E+03	4.3E+02	9.7E+02
Blank	10	<10	<10	<10

Exposure plates	PCA			
Position	0 h	4 h	24 h	48 h
1	2	2	10	11
2	2	2	6	5
3	0	0	7	5
4	0	1	4	8

Table 25: Summary of lamb joint total meat hand contamination plate results (cfu/hand)

	Enterobacteriaceae		TVC	
	DLDS	WLDS	DLDS	WLDS
1.	>200	>393	>1,500	>1,500
2.	91	>455	>1,500	>1,500
3.	96	>472	>1,500	>1,250
4.	83	95	>1,500	>1,250
5.	77	91	>1,500	>1,000
6.	48	53	>1,500	614
7.	43	49	>1,500	504
8.	33	45	>1,250	702
9.	31	26	>1,250	497
10.	40	19	>1,250	514
11.	35	16	>1,250	430
12.	26	11	>1,250	300
13.	13	5	>1,000	245
14.	21	5	>1,000	353
15.	15	0	>1,000	341
16.	17	6	>1,000	317
17.	6	6	>750	237
18.	4	3	>750	168
19.	5	11	>750	145
20.	5	5	>750	160

DLDS = Dry lamb, dry surface
WLDS = Wet lamb, dry surface

Table 26: Summary of lamb joint total non-meat hand TVC contamination plate results (cfu/hand)

	DLDS	WLDS
1.	16	6
2.	20	1
3.	5	1
4.	5	1
5.	4	1
6.	2	5
7.	7	1
8.	1	2
9.	1	1
10.	0	1
11.	0	1
12.	0	1
13.	0	3
14.	1	1
15.	2	2
16.	2	0
17.	5	1
18.	3	0
19.	0	0
20.	1	0

DLDS = Dry lamb, dry surface
WLDS = Wet lamb, dry surface

7.6 **Microbiological data for pork joint**

Table 27: Pork joint results - dry/wet pork on dry surfaces

Dry pork dry surface - Laminate				
Pork cfu/5 cm^2	3.7E+06	cfu/25 cm^2	1.85E+07	
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior 1	<10			
Prior 2	<10			
1	4.8E+05	1.0E+06	2.6E+05	1.0E+05
2	3.7E+05	4.0E+05	2.7E+05	8.4E+04
3	3.4E+05	3.0E+05	7.2E+04	5.8E+04
4	1.5E+05	5.0E+05	3.5E+04	6.4E+04
5	2.8E+05	3.0E+05	2.9E+04	4.9E+04
10	9.2E+04	1.4E+05	2.6E+04	3.4E+04
15	2.7E+04	9.0E+04	8.3E+03	1.1E+04
20	4.8E+04	2.0E+04	5.1E+03	1.6E+03
25	1.8E+04	1.2E+04	2.7E+03	6.3E+03
Blank 1	<10	10	<10	<10
Blank 2	<10	<10	<10	<10
Blank 3	<10	20	9.0E+02	10

Dry pork dry surface - steel				
Pork cfu/5 cm^2	3.2E+05	cfu/25 cm^2	1.6E+06	
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	80			
1	8.4E+03	5.7E+04	1.9E+04	7.4E+02
2	2.1E+03	3.6E+04	1.4E+03	4.2E+02
3	7.8E+02	7.8E+02	1.2E+04	4.0E+03
4	1.0E+02	3.6E+02	7.3E+02	4.6E+03
5	8.6E+02	1.4E+03	1.9E+03	60
Blank	2.2E+02	10	<10	10

Exposure plates	VRBGA			
Position	0 h	4 h	24 h	48 h
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

Wet pork dry surface - Laminate				
Pork cfu/5 cm^2	1.4E+06	cfu/25 cm^2	7.0E+06	
Square no cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior 1	<10			
Prior 2	20			
1	1.3E+06	1.8E+05	4.4E+04	8.0E+04
2	8.4E+04	4.6E+04	2.7E+04	1.9E+04
3	8.4E+03	7.0E+04	3.1E+04	5.2E+04
4	4.2E+03	4.0E+04	9.5E+04	1.1E+04
5	1.2E+04	2.6E+04	4.8E+03	1.1E+04
10	7.0E+04	2.3E+04	2.3E+04	5.8E+03
15	9.4E+03	5.8E+03	6.6E+03	1.8E+03
20	1.0E+06	4.5E+04	7.1E+03	1.6E+04
25	1.4E+04	2.2E+04	3.5E+03	1.1E+03
Blank 1	1.0E+03	3.0E+03	<10	10
Blank 2	5.0E+02	3.8E+02	10	<10
Blank 3	<10	<10	1.3E+02	<10

Wet pork dry surface - steel				
Pork cfu/5 cm^2	1.9E+05	cfu/25 cm^2	9.5E+05	
Square no cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	<10			
1	2.9E+05	1.7E+03	1.6E+04	3.6E+04
2	9.0E+05	9.2E+03	2.5E+04	1.0E+04
3	3.2E+04	1.9E+04	8.6E+03	3.0E+05
4	2.3E+04	4.9E+03	7.1E+03	6.7E+03
5	1.7E+04	6.9E+03	7.5E+03	2.1E+03
Blank	<10	<10	20	<10

Exposure plates	PCA			
Position	0 h	4 h	24 h	48 h
1	0	6	9	16
2	0	2	7	11
3	0	0	4	13
4	0	1	5	4

Table 28: Summary of pork joint total meat hand contamination plate results (cfu/hand)

	Enterobacteriaceae		TVC	
	DPDS	**WPDS**	**DPDS**	**WPDS**
1.	>200	>200	>1,500	>1,500
2.	>200	>200	>1,500	>1,500
3.	>200	>200	>1,500	>1,500
4.	>200	>200	>1,500	>1,500
5.	>200	38	>1,500	>1,500
6.	>200	48	>1,500	>1,500
7.	>200	26	>1,500	>1,500
8.	>200	25	>1,500	>1,500
9.	>200	15	>1,500	>1,500
10.	>200	8	>1,500	>1,500
11.	>200	16	>1,500	>1,184
12.	>200	3	>1,500	>1,026
13.	>200	9	>1,500	>1,024
14.	69	6	>1,500	>1,056
15.	62	7	>1,500	>866
16.	54	7	>1,500	>792
17.	39	6	>1,500	896
18.	36	9	>1,500	628
19.	34	2	>1,500	566
20.	33	2	>1,500	537

DPDS = Dry **pork,** dry surface
WPDS = Wet **pork,** dry surface

Table 29: Summary of pork joint total non-meat hand TVC contamination plate results (cfu/hand)

	DPDS	WPDS
1.	53	87
2.	51	46
3.	39	24
4.	40	14
5.	63	12
6.	46	8
7.	17	8
8.	44	12
9.	47	8
10.	56	8
11.	37	0
12.	3	8
13.	0	28
14.	12	10
15.	11	5
16.	17	6
17.	42	14
18.	29	7
19.	26	0
20.	5	0

DPDS = Dry **pork,** dry surface
WPDS = Wet **pork,** dry surface

7.7 Microbiological data for sausages and burgers

Table 30: Sausage results for dry/wet meat on dry surfaces

Dry sausages dry surface - Laminate				
Sausages cfu/5 cm^2	3.2E+04	cfu/25 cm^2	1.6E+05	
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior 1	<10			
Prior 2	<10			
1	<10	20	<10	<10
2	<10	<10	<10	20
3	10	<10	30	<10
4	<10	<10	20	20
5	<10	<10	<10	<10
10	1.8E+03	<10	20	<10
15	1.1E+02	<10	<10	<10
20	50	<10	<10	<10
25	20	<10	10	<10
Blank 1	<10	<10	<10	<10
Blank 2	10	<10	<10	<10
Blank 3	<10	<10	<10	<10

Dry sausages dry surface - steel				
Sausages cfu/5 cm^2	1.1E+05	cfu/25 cm^2	5.5E+05	
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	10			
1	<10	10	<10	<10
2	<10	<10	<10	<10
3	<10	<10	<10	<10
4	<10	<10	<10	<10
5	<10	<10	10	<10
Blank				<10

Exposure plates	VRBGA			
Position	0 h	4 h	24 h	48 h
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

Wet sausages dry surface - Laminate				
Sausages cfu/5 cm^2	8.3E+04	cfu/25 cm^2	4.15E+05	
Laminate cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior 1	<10			
Prior 2	<10			
1	2.4E+02	2.1E+02	1.0E+03	50
2	1.5E+02	4.1E+02	4.4E+03	4.4E+02
3	4.6E+02	1.6E+02	5.2E+02	4.9E+02
4	60	3.0E+02	3.9E+02	1.0E+02
5	20	2.5E+02	6.1E+02	60
10	40	1.5E+02	90	1.1E+02
15	10	1.8E+02	10	<10
20	10	10	<10	20
25	1.3E+02	<10	10	<10
Blank 1	<10	<10	<10	<10
Blank 2	<10	<10	<10	<10
Blank 3	<10	<10	<10	<10

Wet sausages dry surface - steel				
Sausages cfu/5 cm^2	2.4E+04	cfu/25 cm^2	1.2E+05	
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	<10			
1	1.1E+02	1.8E+02	1.4E+03	6.0E+02
2	1.0E+02	2.9E+02	1.4E+02	4.0E+02
3	4.8E+02	6.9E+02	3.1E+02	6.7E+02
4	1.3E+03	6.8E+02	1.0E+03	3.1E+02
5	4.2E+02	8.1E+02	1.0E+02	<10
Blank	<10	<10	<10	<10

Exposure plates	PCA			
Position	0 h	4 h	24 h	48 h
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

Table 31: Results for beefburgers - dry/wet meat on dry surfaces

Dry burgers dry surface - Laminate				
Burgers cfu/5 cm^2	6.2E+03	cfu/25 cm^2	3.1E+04	
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior 1	<10			
Prior 2	<10			
1	<10	<10	<10	40
2	<10	<10	10	<10
3	<10	10	10	<10
4	40	<10	40	40
5	<10	10	<10	<10
10	<10	10	<10	<10
15	<10	10	<10	<10
20	<10	<10	<10	<10
25	<10	<10	<10	<10
Blank 1	<10	10	<10	<10
Blank 2	<10	<10	<10	<10
Blank 3	<10	<10	20	10

Dry burgers dry surface - steel				
Burgers cfu/5 cm^2	4.5E+03	cfu/25 cm^2	2.25E+04	
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	<10			
1	<10	<10	<10	5.7E+04
2	<10	<10	60	<10
3	<10	10	<10	<10
4	<10	<10	<10	<10
5	<10	10	30	>1e6
Blank	<10	<10	<10	<10

Exposure plates	VRBGA			
Area	0 h	4 h	24 h	48 h
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0

Wet burgers dry surface - Laminate				
Burgers cfu/5 cm^2	3.4E+03	cfu/25 cm^2	1.7E+04	
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior 1	<10			
Prior 2	<10			
1	70	260	<10	<10
2	40	30	10	1.1E+02
3	30	60	30	50
4	30	80	40	20
5	<10	40	<10	10
10	30	20	<10	<10
15	<10	20	<10	80
20	10	<10	<10	<10
25	<10	<10	<10	10
Blank 1	<10	10	<10	<10
Blank 2	<10	<10	<10	<10
Blank 3	<10	<10	<10	<10

Wet burgers dry surface - steel				
Burgers cfu/5 cm^2	4.3E+03	cfu/25 cm^2	2.15E+04	
Square no. cfu/25 cm^2	0 h	4 h	24 h	48 h
Prior	<10			
1	2.5E+02	<10	20	<10
2	10	<10	40	30
3	20	30	10	10
4	10	<10	90	10
5	<10	10	<10	20
Blank	<10	10	<10	<10

Exposure plates	PCA			
Area	0 h	4 h	24 h	48 h
1	0	0	40	15
2	0	0	55	19
3	0	10	26	21
4	0	10	28	20

Table 32: Summary of sausage and burger total meat hand TVC contamination plate results (cfu/hand)

	Sausages		Burgers	
	DSDS	**WSDS**	**DBDS**	**WBDS**
1.	856	>779	1	47
2.	763	>758	2	67
3.	>739	>734	3	54
4.	>721	>598	5	52
5.	>679	>554	5	62
6.	>680	>444	2	73
7.	>675	>386	0	62
8.	>655	>344	0	111
9.	>668	>312	4	51
10.	>555	>327	0	35
11.	>661	299	0	37
12.	>652	315	0	45
13.	>606	374	0	36
14.	>541	313	1	40
15.	>480	294	2	34
16.	>409	263	3	52
17.	>425	>219	0	86
18.	426	>202	2	57
19.	423	>295	1	71
20.	327	81	7	63

DSDS = Dry sausage, dry surface
WSDS = Wet sausage, dry surface
DBDS = Dry burger, dry surface
WBDS = Wet burger, dry surface

Table 33: Summary of beefburger and sausage total non-meat hand TVC contamination plate results (cfu/hand)

	DMDS	WMDS	DMDS	WMDS
1.	13	20	178	13
2.	8	19	184	13
3.	6	21	121	11
4.	7	25	139	15
5.	3	20	130	13
6.	4	61	107	23
7.	1	62	112	9
8.	2	70	98	8
9.	1	65	89	0
10.	0	43	78	12
11.	3	76	74	11
12.	0	40	97	3
13.	1	152	75	0
14.	0	150	97	0
15.	0	66	72	0
16.	2	126	70	0
17.	0	0	82	0
18.	1	126	103	0
19.	0	124	80	0
20.	1	118	92	0

DMDS = Dry burger/sausage, dry surface
WMDS = Wet burger/sausage, dry surface

7.8 Statistical analysis of the combined data set for all seven trials

Table 34: Mean log counts for significant factors and interactions in 7 trials, as fitted by the model (sausages and burgers not included - data limited)

Trial	Mean	SE Mean
1	3.485	0.11254
2	3.143	0.11255
3	4.477	0.11254
4.	4.030	0.11254
6.	2.812	0.11254
7.	2.946	0.11254
8.	3.334	0.10373

Meat D or W	Mean	SE Mean
Dry	3.243	0.05461
Wet	3.679	0.05552

Surface	Mean	SE Mean
Laminate	3.289	0.04400
Steel	3.633	0.07178

Square	Mean	SE Mean
1	4.033	0.09429
2	3.876	0.09381
3	3.839	0.09381
4	3.612	0.09381
5	3.491	0.09381
10	3.325	0.13786
15	3.006	0.13786
20	2.944	0.13786
25	3.023	0.13786

Trial	Surface	Mean	SE Mean
1	Laminate	2.897	0.11863
1	Steel	4.074	0.19128
2	Laminate	3.053	0.11955
2	Steel	3.234	0.19164
3	Laminate	4.219	0.1186
3	Steel	4.735	0.19128
4	Laminate	4.400	0.11863
4	Steel	3.660	0.19128
6	Laminate	2.563	0.11863
6	Steel	3.062	0.19128
7	Laminate	2.666	0.11863
7	Steel	3.227	0.19128
8	Laminate	3.227	0.10104
8	Steel	3.441	0.18120

Trial		Mean	SE Mean
0		3.863	0.07426
4		3.691	0.07437
24		3.331	0.07426
48		2.959	09.07426

Trial	Meat D or W	Mean	SE Mean
1	Dry	3.413	0.14735
1	Wet	3.557	0.14735
2	Dry	3.545	0.14776
2	Wet	2.741	0.14757
3	Dry	3.940	0.14735
3	Wet	5.014	0.14735
4	Dry	3.942	0.14735
4	Wet	4.118	0.14735
6	Dry	2.464	0.14735
6	Wet	3.160	0.14735
7	Dry	2.961	0.14735
7	Wet	2.931	0.14735
8	Dry	2.435	0.12541
8	Wet	4.233	0.14385

7.9 Microbiological results from washing and soaking trials

Table 35: Chicken washing results

Trial	Temp. ("C)	Time (secs)	Meat	Excision (cfu/5 cm^2)				Contact (cfu/plate)			
				Enterobac-teriaceae before	Enterobac-teriaceae after	TVC before	TVC after	Entero before	Entero after	TVC before	TVC after
1	Cold	10	Chicken	150	<10	1.6E+05	4.2E+03	400	70	>2.5E+03	251
1	Cold	10	Chicken					180	3	223	106
1	Cold	30	Chicken	130	<10	5.4E+04	3.2E+03	900	244	>2.5E+03	185
1	Cold	30	Chicken					400	18	291	188
1	Hot	10	Chicken	5.5E+03	1.2E+03	6.3E+04	1.3E+04	840	347	172	>2.5E+03
1	Hot	10	Chicken					550	30	240	196
1	Hot	30	Chicken	310	60	6.8E+04	4.1E+03	460	350	>2.5E+03	204
1	Hot	30	Chicken					300	4	268	60
2	Cold	10	Chicken	50	<10	6.5E+03	3.6E+03	72	4	328	141
2	Cold	10	Chicken					68	1	736	32
2	Cold	30	Chicken	100	30	1.1E+04	1.5E+03	146	36	>1.E+03	204
2	Cold	30	Chicken					151	12	>1.E+03	108

Table 35: Chicken washing results (continued)

Trial	Temp. ("C)	Time (secs)	Meat	Excision (cfu/5 cm^2)				Contact (cfu/plate)			
				Enterobac-teriaceae before	Enterobac-teriaceae after	TVC before	TVC after	Entero before	Entero after	TVC before	TVC after
2	Hot	10	Chicken	130	100	8.8E+03	6.6E+03	112	19	>1.E+03	227
2	Hot	10	Chicken					108	5	>1.E+03	201
2	Hot	30	Chicken	250	80	9.7E+03	1.3E+03	178	12	>1.E+03	436
2	Hot	30	Chicken					101	10	444	25
3	Cold	10	Chicken	140	<10	1.0E+04	3.8E+03	72	76	>1.E+03	320
3	Cold	10	Chicken					137	85	456	216
3	Cold	30	Chicken	260	<10	5.0E+03	2.2E+03	48	6	>1.1E+03	56
3	Cold	30	Chicken					68	1	468	42
3	Hot	10	Chicken	110	40	6.4E+03	8.5E+03	177	50	560	140
3	Hot	10	Chicken					113	12	500	224
3	Hot	30	Chicken	40	<10	4.5E+03	820	83	50	>1.E+03	42
3	Hot	30	Chicken					75	12	>1.0E+03	15

Table 36: Beef washing results

Trial	Temp. ("C)	Time (secs)	Meat	Excision (cfu/5 cm^2)				Contact (cfulplate)			
				Enterobac-teriaceae before	Enterobac-teriaceae after	TVC before	TVC after	Entero before	Entero after	TVC before	TVC after
1	Cold	10	Beef	<10	60	4.6E+04	5.6E+04	2	8	178	132
1	Cold	10	Beef					4	49	184	>1.0E+03
1	Cold	30	Beef	<10	<10	2.9E+03	4.0E+04	0	4	228	>1.0E+03
1	Cold	30	Beef					23	6	71	131
1	Hot	10	Beef	<10	60	3.1E+04	1.3E+05	4	3	118	95
1	Hot	10	Beef					0	0	188	214
1	Hot	30	Beef	4.6E+02	1.2E+03	4.9E+05	7.4E+05	7	110	175	>1.0E+03
1	Hot	30	Beef					15	158	>1.0E+03	>1.0E+03
2	Cold	10	Beef	170	10	2.5E+04	1.3E+05	1	1	*	*
2	Cold	10	Beef					1	3	7.8E+02	3.0E+03
2	Cold	30	Beef	50	<10	4.3E+04	1.7E+04	3	2	1.6E+03	3.0E+0.3
2	Cold	30	Beef					2	15	4.3E+03	7.5E+03

* = Not tested

Table 36: Beef washing results (continued)

Trial	Temp. ("C)	Time (secs)	Meat	Excision (cfu/5 cm^2)				Contact (cfu/plate)			
				Enterobac-teriaceae before	Enterobac-teriaceae after	TVC before	TVC after	Entero before	Entero after	TVC before	TVC after
2	Hot	10	Beef	60	<10	1.2E+04	1.9E+0.4	1	3	314	384
2	Hot	10	Beef					4	2	1.5E+03	1.9E+03
2	Hot	30	Beef	1.6E+03	270	9.0E+06	1.4E+06	2	300	2.6E+03	>1.0E+04
2	Hot	30	Beef					3	200	2.2E+03	>1.0E+04
3	Cold	10	Beef	160	170	3.3E+07	4.3E+0.5	2	32	3.4E+03	5.7E+03
3	Cold	10	Beef					4	34	3.7E+03	4.6E+03
3	Cold	30	Beef	30	<10	3.3E+03	3.6E+03	1	8	746	552
3	Cold	30	Beef					0	3	1.1E+03	1.1E+03
3	Hot	10	Beef	10	10	3.0E+03	3.0E+03	1	16	1.3E+03	2.7E+03
3	Hot	10	Beef					0	1	1.1E+03	1.4E+0.3
3	Hot	30	Beef	10	<10	5.0E+06	1.1E+06	12	10	7.2E+03	8.4E+03
3	Hot	30	Beef					4	6	3.4E+03	8.0E+03

Table 37: Soaking trial results

Soak Type	Concen-tration %	Time (mins)	Meat Type	Contact (cfu/plate)				Excision (cfu/5 cm^2)			
				Enterobac-teriaceae before	Enterobac-teriaceae after	TVC before	TVC after	Enterobac-teriaceae before	Enterobac-teriaceae after	TVC before	TVC after
Water	**NA**	5	Chicken	43	54	1.53E+03	1.4E+03	<10	70	2.8E+04	2.4E+04
Water	**NA**	5	Chicken	61	9	2.1E+03	900				
Water	**NA**	30	Chicken	88	25	2.5E+03	1.25E+03	90	240	1.3E+05	9.2E+04
Water	**NA**	30	Chicken	42	10	>3.0E+03	>3.0E+03				
Vinegar	10%	5	Chicken	248	17	>3.0E+03	410	130	60	5.9E+03	4.8E+03
Vinegar	10%	5	Chicken	278	14	1.5E+03	82				
Vinegar	10%	30	Chicken	93	1	>3.0E+03	496	60	50	1.7E+05	1.4E+04
Vinegar	10%	30	Chicken	180	0	1.08E+03	437				
Salt	5%	5	Chicken	372	39	2.23E+03	575	6200	140	2.7E+05	1.2E+04
Salt	5%	5	Chicken	151	0	2.3E+03	221				
Salt	5%	30	Chicken	123	27	>3.0E+03	1.95E+03	100	560	5.9E+04	1.0E+05
Salt	5%	30	Chicken	123	1	2.5E+03	650				
Salt	10%	5	Chicken	>3.0E+03	11	>3.0E+03	1.9E+03	20	20	2.4E+04	2.6E+03
Salt	10%	5	Chicken	154	0	2.5E+03	1.55E+03				
Salt	10%	30	Chicken	>3.0E+03	43	300	496	<10	30	1.2E+03	4.2E+03
Salt	10%	30	Chicken	152	2	1.08E+03	437				

Table 37: Soaking trial results (continued)

Soak Type	Concen-tration %	Time (mins)	Meat Type	Contact (cfulplate)				Excision (cfu/5 cm^2)			
				Enterobac-teriaceae before	Enterobac-teriaceae after	TVC before	TVC after	Enterobac-teriaceae before	Enterobac-teriaceae after	TVC before	TVC after
Water	**NA**	5	Beef	2	18	350	920	50	20	1.7E+04	3.9E+03
Water	**NA**	5	Beef	9	18	640	400				
Water	**NA**	30	Beef	5	1	464	580	<10	20	1.1E+04	1.6E+05
Water	**NA**	30	Beef	1	23	1.17E+03	1.5E+03				
Vinegar	10%	5	Beef	58	15	480	254	<10	300	4.7E+04	1.1E+05
Vinegar	10%	5	Beef	10	0	656	764				
Vinegar	10%	30	Beef	9	0	720	1.4E+03	<10	20	1.3E+05	8.0E+03
Vinegar	10%	30	Beef	3	2	1.38E+03	1.45E+30				
Salt	5%	5	Beef	8	18	>2.5E+03	2.5E+03	<10	<10	5.0E+03	1.3E+03
Salt	5%	5	Beef	1	15	1.1E+03	2.5E+03				
Salt	5%	30	Beef	6	0	1.63E+03	1.78E+03	<10	<10	4.3E+03	6.3E+03
Salt	5%	30	Beef	1	0	1.28E+03	1.5E+03				
Salt	10%	5	Beef	58	83	860	875	<10	<10	2.9E+03	5.0E+04
Salt	10%	5	Beef	10	66	1.25E+03	1.35E+03				
Salt	10%	30	Beef	9	1	2.18E+03	1.78E+03	<10	<10	2.4E+04	5.6E+03
Salt	10%	30	Beef	3	0	1.1E+03	576				