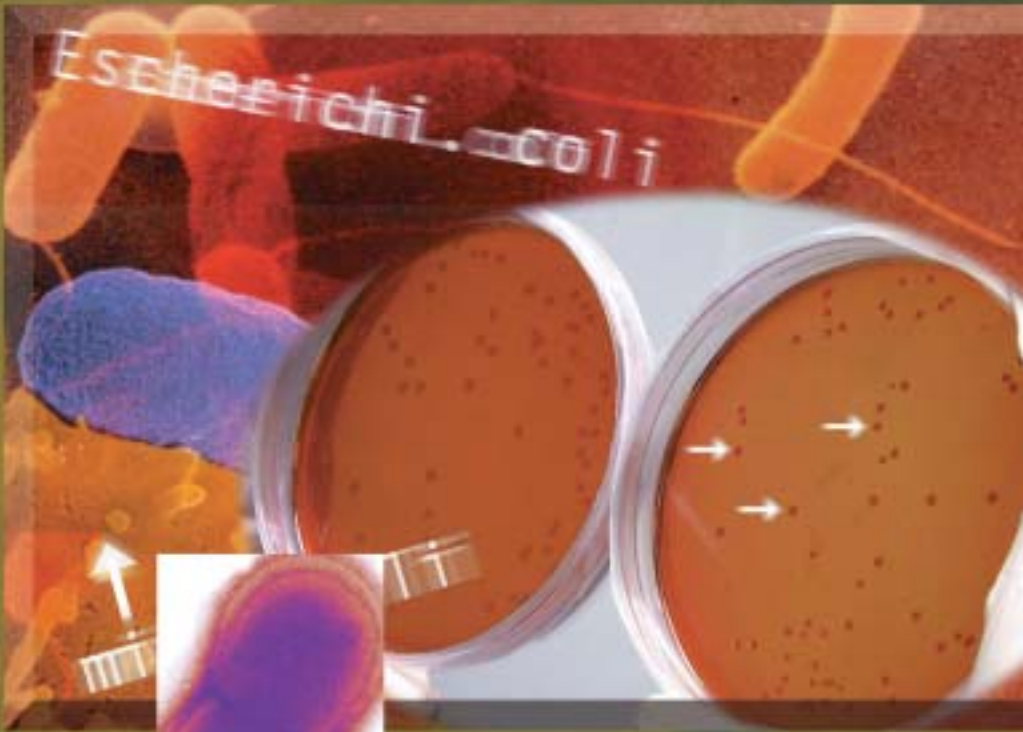


Hygiene and Safety of Irish Beef Carcasses





HYGIENE AND SAFETY OF IRISH BEEF CARCASSES

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ISBN 1 84170 314 1
October 2002



AGRICULTURE AND FOOD DEVELOPMENT AUTHORITY





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SUMMARY

Investigations were carried out in a number of beef abattoirs in Ireland. Information was obtained on the hygienic status of the carcasses being produced and also on their safety, using the presence of *Salmonella* as an indicator. The data showed that, in general, the hygiene of the carcasses being produced was of a satisfactory quality and that faecal contamination was low, as indicated by the coliform and *E. coli* counts. The safety of the carcasses as indicated by the presence of *Salmonella* was considered to be a cause for concern. The level of contamination by this pathogen of 7.6% was considered to be high and requires investigation. The majority of the *Salmonella* present on carcasses was *S. typhimurium* DT104, which is resistant to a range of antibodies.

The work was part of an EU project and some results are presented from other partners.

INTRODUCTION

During the slaughter and dressing of beef animals, the carcass may be contaminated with faeces or gut contents. In consequence, slaughter hygiene has included efforts to prevent visible dirt reaching the carcass surface by avoiding contact with the hide and other surfaces likely to transfer microbes to it.

Meat spoilage can have serious financial implications for industry and affects not only the carcasses originally contaminated, but any product subsequently produced such as vacuum packaged primals or retail gas packs.

Although spoilage may be serious in economic terms, it is not nearly as damaging as lapses in the control of food safety. Huge economic losses are a consequence of the contamination of beef with pathogens such as *E. coli* O157:H7. Another pathogen of great significance is *Salmonella*. While this organism is more usually associated with pig carcasses and poultry, it can also be found on beef (Cloak *et al.*, 1999; Bolton *et al.*, 2002). One of the largest outbreaks of *Salmonella* food poisoning, with nearly 9000 recorded cases and 90 deaths, was caused by contaminated beef carcasses (Lundbeck *et al.*, 1953).



OBJECTIVES OF THE PROJECT

To determine the hygienic status of beef in Irish abattoirs and examine the effectiveness of chilling in the abattoirs visited in controlling microbial growth.

To determine the prevalence of *Salmonella* on beef carcasses as an indicator of safety. This pathogen has previously been detected at high levels on beef (McEvoy *et al.*, 2002).

BACTERIAL CONTAMINATION OF BEEF CARCASSES

The nine abattoirs selected are in the export trade and slaughtered more than 30,000 cattle/year. Abattoirs number 1, 2, 3, 4 and 5 were visited three times over a one-year period, numbers 6, 7, 8 and 9 were visited twice. A third visit to these plants was abandoned because of a foot and mouth disease outbreak. On each abattoir visit, 30 carcasses were selected at random throughout the day. Both sides of beef from the same animal were swabbed with a sterile sponge over the entire lateral surface according to the method of Lasta *et al.* (1992). One side was swabbed after the carcass entered the chill but before chilling commenced, and the other side was swabbed 24 h later before removal from the chill.

The sponges were returned to the laboratory in refrigerated containers and stomached in buffered peptone water. The samples were examined for the presence of (a) the total viable counts, (b) coliforms and (c) generic *E. coli* to determine the hygienic status of the carcasses before and after chilling. The hygiene data were subjected to analysis of variance and are presented for plants 1, 2, 3, 4, and 5 since the data were complete for these abattoirs only, *i.e.* three visits over a one-year period.

Based on the total viable counts, differences in carcass hygiene were observed between abattoirs before chilling ($P < .05$) [Table 1]. After chilling, reductions in carcass contamination occurred in all the abattoirs, although these were significant only in abattoirs 1 and 2 ($P < .05$). One of the effects of these reductions was that the difference between abattoirs previously observed was no longer evident and carcass hygiene was now similar in all abattoirs.



Table 1: Bacterial counts on beef carcasses before and after chilling in five Irish abattoirs. Data are log₁₀ bacterial numbers per cm²

Abattoir	1	2	3	4	5	SED	DF
Total viable counts							
Before chilling	3.38	3.09	2.37	2.42	2.59	0.43	18
After chilling	2.17	2.12	1.99	1.83	1.76		
Coliforms							
Before chilling	-	-0.34*	-0.37	-1.14	-0.71	0.40	14
After chilling	-	-1.33	-1.62	-1.74	-1.62		
<i>E. coli</i>							
Before chilling	-0.92	-0.71	-1.32	-1.96	-1.66	0.30	18
After chilling	-2.11	-1.57	-2.17	-2.21	-1.97		

SED = standard error of differences between means

DF = degrees of freedom

* Negative values represent less than 1 bacterial cell / cm²

With the exception of abattoirs 1 and 2, there were significant differences between abattoirs for the coliforms before chilling ($P < 0.05$) and this was particularly noteworthy for the *E. coli* counts ($P < 0.001$). Reductions in counts, as a result of carcass chilling, were evident for both the coliform and *E. coli* counts in all the abattoirs tested. These differences were highly significant and occurred both between and within abattoirs ($P < .001$).

It appears that, in some abattoirs, chilling was effective in reducing beef carcass contamination after slaughter. This was evident with the coliform and *E. coli* counts which are indicators of faecal contamination. The data suggest that chilling could be an effective control for pathogens where refrigeration of carcasses is properly undertaken. As will be discussed later this may be an erroneous assumption.



Recently the EU has set microbiological performance standards for the successful implementation of HACCP in beef slaughter operations. The following are the criteria that have been set based on excision (Anon, 2001) and swab (Anon, 2002) sampling (Table 2).

Table 2: Microbiological criteria for use in a HACCP system for beef carcasses based on excision or swab sampling

	Range of counts		
	Acceptable	Marginal	Unacceptable
Total viable counts (log ₁₀ cfu/g)	A below 3.5 B below 2.8	3.5 – 5.0 2.8 - 4.3	Above 5.0 Above 4.3
<i>Enterobacteriaceae</i> (log ₁₀ cfu/g)	A below 1.5 B below 0.8	1.5 – 2.5 0.5 – 1.5	Above 2.5 Above 1.8

A = excision values

B = swab values

Source: Off. J. Eur. Comm., L165, 48-56

At the present time, the meat industry prefers to use a swab technique rather than excision to determine the hygienic status of beef carcasses. It is generally accepted that swab samples detect only about 20% of the bacteria counted by excision sampling. The second set of criteria shown in Table 2 are for swabs and correspond generally to the method used to obtain data in the present and other studies (McEvoy *et al.*, 2002a). Using these criteria for swabs, two of the five abattoirs in Table 1 had total viable counts in the marginal category. This means that these abattoirs require actions to review their process controls within their HACCP system with a view to improvement of carcass hygiene. It is interesting to note that the coliform counts in the present study were well within the acceptable limit for *Enterobacteriaceae* (0.8 log₁₀cfu/g) indicating a satisfactory control of faecal contamination. This result is not reflected in the data on carcass contamination with *Salmonella* to be discussed later.



BEEF CARCASS CONTAMINATION WITH *SALMONELLA*

The microbiological safety of beef carcasses was determined by examining the swabs taken at each plant visit for the presence of *Salmonella*. Isolates that had been confirmed by biochemical and serological procedures as being *Salmonella* were identified to species level in the Veterinary Research Laboratories in Abbotstown, Dublin. Isolates that were confirmed as *Salmonella Typhimurium* were phage typed in the Public Health Laboratory, Colindale. The data presented are from 690 carcasses taken in nine abattoirs over a one year period. Abattoirs 1, 2, 3, 4 and 5 were each visited three times, while abattoirs 6, 7, 8 and 9 were visited twice. The data are presented on a 'presence or absence' basis for each carcass examined.

Figure 1 shows the percentage of carcasses that were *Salmonella* positive. Overall, 6.5% of carcasses were contaminated before chilling and this number increased to 7.7% after chilling. Of the *Salmonella* positive carcasses, the majority were contaminated with *S. Typhimurium* DT 104, followed by smaller numbers with *S. Dublin* and *S. Agona*.

The influence of the time of year on the incidence of *Salmonella* on beef carcasses is shown in Figure 2. Carcass contamination occurred in every month except January, May and September. Samples were not taken in December. Peaks occurred in the spring and again in late autumn. The negative influence of chilling was again evident and further demonstrated the inadequacy of the chilling process in controlling the presence of the pathogen on the surface of carcasses. This is also indicated by the data in Table 3 for carcasses before and after chilling in each of the abattoirs visited. There were large variations between abattoirs in respect of the number of carcasses contaminated before and after chilling, but in particular it suggested that chilling was generally an ineffective means of controlling contamination. It was also noted that carcass contamination was detected after chilling in all of the nine abattoirs visited, compared to seven before chilling.



Table 3: Numbers of beef carcasses positive for *Salmonella* in each of the nine abattoirs visited. In each abattoir, 90 carcasses were examined.

	<i>S. Typhimurium</i> DT 104		<i>S. Dublin</i>		<i>S. Agona</i>	
	Before Abattoirs	After Chilling	Before chilling	After chilling	Before chilling	After chilling
1	0	1	0	0	0	0
2	6	12	0	0	0	0
3	1	15	0	0	0	0
4	1	2	0	0	0	0
5	0	0	0	0	1	2
6	23	2	8	1	0	0
7	13	4	0	0	0	0
8	0	12	0	0	0	0
9	1	5	0	0	1	2

The presence of *Salmonella* on 6.5% of beef carcasses before chilling and 7.7% after chilling was considered very high. In general, the percentage of beef carcasses contaminated with *Salmonella* in other countries varied between 0.3 and 8.5% with a mean of about 2% (Hogue *et al.*, 1993; Vanderlinde *et al.*, 1998; Sofos *et al.*, 1999; Schlosser *et al.*, 2000; Phillips *et al.*, 2001; Bacon *et al.*, 2002). The present result however was not unexpected, since in a previous investigation carried out in 1998-1999 in an Irish beef abattoir, the incidence of *Salmonella* on carcasses before chilling was 7.6% (McEvoy *et al.*, 2002).

The data in Table 3 show that the pathogen was present on carcasses in all the abattoirs tested, with some showing a high percentage of carcasses contaminated both before and after chilling. From the results in Table 1, which showed a significant reduction in bacterial numbers after chilling for

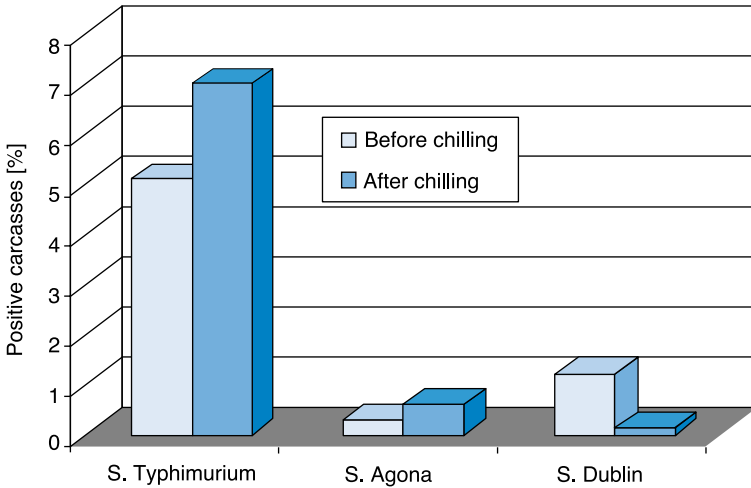


Figure 1: Percentage of beef carcasses positive for *S. Typhimurium*, *S. Agona* and *S. Dublin* in Irish abattoirs before and after chilling

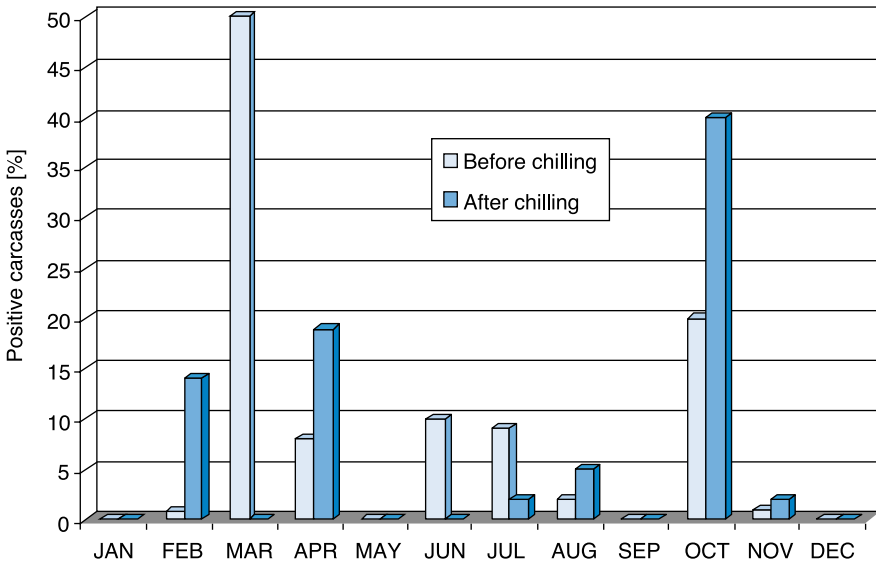


Figure 2: Percentage of *Salmonella* positive carcasses detected over a one year period in nine abattoirs



the coliforms and *E. coli* counts, this result would not be expected. In six of the nine abattoirs visited, *Salmonella* counts were higher after chilling than before, which is at variance with the result for coliforms and *E. coli* (Table 1).

A possible explanation for the survival of *Salmonella* on beef carcasses after chilling may be related to cell injury. When cells on carcasses are exposed to chilling some will be killed but a significant proportion will be injured. This situation occurs with any process, such as chilling or heating, that can produce sub-lethal stresses in cells. During chilling, two sub-lethal stresses operate; drying of the meat surface and cold stress as a result of low temperature. Surface drying may lower the water activity (a_w) of the cells by removing water from the cell through osmosis. Under these conditions of low temperature and a_w , cells are still viable but stressed. Experiments with *E. coli*, *Salmonella* and other gram negative organisms have shown that there is a synergistic effect between a_w , low temperature and pH (Presser *et al.*, 1998). At the pH of fresh meat entering the chill, above 6.0, until the ultimate pH is reached (5.4-5.5), *E. coli* at an a_w of 0.95 and a temperature of 5°C will survive for at least 48 h without a significant decrease in viability (Clavero and Beuchat, 1996). A similar relationship between a_w and low temperature has also been observed for the survival of *Salmonella typhimurium* (Li and Torres, 1993). The cells are injured but are capable of recovery when incubated in suitable media. If selective media are used for their isolation they will contain substances that prevent the growth of injured cells but allow the growth of uninjured cells. Because of this, *Salmonella* are routinely enriched in specific nutrient media that facilitate the growth of injured cells, prior to their selective isolation.

These stress factors also raise issues in relation to the coliform and *E. coli* counts already presented (Table 1). It is likely that the reductions in cell counts were not as large as estimated, since selective media were used for their isolation and injured cells may not have been counted. The injury of coliforms on pig carcass surfaces has been shown in the past (Yu *et al.*, 1999). In summary, chilling is unlikely to have a major influence on the death of cells on carcass surfaces but does cause injury that cells can subsequently recover from.

While the successful recovery of injured cells could account for carcasses remaining *Salmonella* positive after chilling, this would not explain the



increased number of positive carcasses observed after chilling in some abattoirs. However, if the pathogen count was very low during the initial swabbing before chilling they might escape detection. In some of the abattoirs visited it was observed that the chills were not operational during loading and this situation was maintained for several hours before the refrigeration was turned on. During this period the carcasses were hot, and any *Salmonella* cells present could grow. These carcasses could then be *Salmonella*-positive on examination after chilling. If this explanation is valid, the increased number of carcasses positive for *Salmonella*, although observed after chilling, would have occurred before the refrigeration was turned on. While these explanations present possible ways in which *Salmonella* survived or actually multiplied on beef carcasses in the chills, the precise mechanism is not known. Other scenarios, such as cross contamination during the refrigeration process or from contact with personnel, cannot be ruled out. The data emphasise the need to thoroughly investigate the events that are occurring, since they have the potential to cause major problems for beef processors.

One of the most important observations was that the majority of *Salmonella* isolates were *S. Typhimurium* DT104. This is a notifiable organism and was the most frequently isolated *Salmonella* from humans in Ireland in 2000 (Foley *et al.*, 2001). It is also of considerable importance because of its antibiotic resistance profile, which shows that it is resistant to 5 – 7 different antibiotics. In earlier work between 1998 and 1999 we observed that while this particular pathogen was present on beef carcasses, it accounted for only 14% of the *Salmonella* isolates present, the majority being *S. Dublin* (72%) (McEvoy *et al.*, 2002). The present study suggests that *S. Dublin* had been replaced on beef carcasses by *S. typhimurium* DT104 as the predominant serovar within a three-year period. Once again this is a serious situation that needs to be investigated further to determine if this change persists over time. The cyclic nature of *Salmonella* serovars in cattle in Ireland has been reported (Crilly *et al.*, 2001).

Control of beef carcass hygiene is mandated by the EU but has yet to be implemented in the majority of beef plants. While HACCP is concerned with hygiene, it is ultimately a system to assure the safety of meat being produced. In the USA, HACCP systems have been in operation in beef abattoirs since



1996. Recently, data released by the US Department of Agriculture show that the prevalence of *Salmonella* in raw meat decreased with the introduction of HACCP (Lipsky, 2002). The introduction of HACCP to Irish beef abattoirs should help reduce the pathogen count on carcasses but information on the underlying causes of contamination is urgently required.

RESULTS FROM OTHER EU COUNTRIES

The research partners in the project were: The University of Bristol, UK; Association Pour le Development de l'institut de la Viande (ADIV), France; Silsoe Research Institute, UK; Health and Safety Laboratory, Sheffield, UK and Institute for Agricultural and Environmental Engineering, Cemagref, France.

Their objectives were:

1. To establish a database of the diversity of slaughter practices within the EU through the use of a questionnaire.
2. To investigate the occurrence and extent of the dispersal of CNS material and enteric bacteria on carcasses and abattoir structures during normal slaughter.
3. To produce dynamic models for slaughter of beef to identify the areas that pose the greatest risk of contamination with CNS tissue.
4. To produce guidelines on best practices to minimise CNS contamination during beef slaughter.

A considerable amount of work in the project could not be completed because of the BSE crisis in the EU during the period of this project and also the foot and mouth epidemic. Many abattoirs in EU countries, except those of the partner countries, refused entry to the researchers.

A pattern of contamination was established on the spread of CNS tissue on beef carcasses during cutting of animals into sides. The carcasses were most heavily contaminated from the spinal column on the inside medial surfaces adjacent to the vertebral column. Carcass contamination levels varied between abattoirs in the same country and between countries. Of fifty one abattoirs tested, only one showed no contamination with CNS tissue on any of the carcasses tested.



An aim of the project was to obtain data from all countries within the EU on the hygiene and safety status of carcasses being produced in beef abattoirs. Only abattoirs in the partner countries and in Austria, Finland and Belgium were prepared to cooperate in the project out of a total of thirteen countries that could have participated. The mean values for total viable counts, coliforms and *E. coli* counts on beef carcasses in abattoirs in six EU countries are shown in Table 4.

Although the data in Table 4 have yet to be statistically analysed and compared to that for Irish abattoirs in Table 1, some general comments can be made. The data suggest that the total viable, coliform and *E. coli* counts are higher in some EU countries than those found under Irish conditions. This indicates that better standards of hygiene may be in operation in Irish abattoirs resulting in cleaner carcasses. In terms of *Salmonella*, however, only three isolates were obtained, one in Belgium and two in Finland. This emphasises the concerns already expressed regarding the carcasses examined in Ireland, where almost 8% were positive for *Salmonella* (Figure 1).

Table 4: Bacterial counts on beef carcasses before and after chilling in abattoirs in six EU countries. Data are log₁₀ bacterial numbers per cm². Negative values represent less than one bacterial cell per cm²

Country	Ireland	Belgium	Austria	Finland	UK	France
Total viable counts						
Before chilling	2.77	*	3.49	2.52	1.71	*
After chilling	1.97	3.53	3.52	2.37	3.14	2.78
Coliforms						
Before chilling	-0.51	*	-0.91	0.39	-1.31	*
After chilling	-1.26	-0.53	-0.67	0.15	-1.74	-0.03
<i>E. coli</i>						
Before chilling	-1.31	*	-1.89	0.32	-2.03	*
After chilling	-2.01	-0.44	-0.47	-0.33	-1.82	-0.23

* Data not available



CONCLUSIONS

- The hygienic status of beef carcasses in some Irish abattoirs does not reach the required EU microbiological standard.
- Chilling did not reduce the *Salmonella* count on beef carcasses.
- About 7% of carcasses examined were positive for *Salmonella* and *Salmonella Typhimurium* DT104 was the most common serovar found.
- The phage type DT104 is particularly undesirable since the organism is resistant to several common antibiotics.
- The spread of *Salmonella* on beef carcasses needs to be addressed as a matter of urgency.

RECOMMENDATIONS TO INDUSTRY

The general standard of hygiene in Irish beef abattoirs is good and compares favourably with that in other European countries or in the United States. The introduction of HACCP into the beef industry should further improve standards and will have the added advantage of giving an on-going measure of carcass hygiene throughout the industry. While HACCP is designed to improve carcass hygiene, its primary purpose is to eliminate or reduce the presence of pathogenic bacteria on the surface of the carcass. It is generally recognised that pathogen elimination is not possible but reductions can be achieved as indicated by recent results from the introduction of HACCP in beef abattoirs in the USA. According to reports, since the introduction of HACCP in 1996 the incidence of *Salmonella* in raw beef and poultry has been reduced (Anon, 2002). For beef, the pathogens of major concern are *E. coli* O157:H7 and *Salmonella*. Studies carried out at The National Food Centre have established that *E. coli* O157:H7 is present on about 3% of beef carcasses (McEvoy, 2002b). This is comparable to that in other countries and, while this level of contamination is undesirable, the introduction of HACCP should assist in effecting a reduction in its incidence on carcasses. While HACCP will also have a similar effect in reducing the presence of *Salmonella* on beef



carcasses, this pathogen will require additional work in an attempt to determine why for example it is increasing after chilling, what influence, if any, the personnel in the meat plants have on its spread and why the incidence in Ireland is so much higher than in some other countries.

Recently, work at the The National Food Centre has indicated that *Salmonella* may be aerosolised in meat plants, in which case it could be spread extensively by this means. This has never been shown before but may be part of the overall picture in relation to the spread of the organism in the chills. This of course would need to be investigated.

To assist processors in combating the presence of pathogens on beef carcasses, the The National Food Centre has published a procedure for the introduction of effective HACCP systems (Bolton et al., 2000). Some of the research publications related to this are listed below in the Reference section.

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