APPLICATION OF HACCP PRINCIPLES IN THE MEAT INDUSTRY: A UNITED KINGDOM PERSPECTIVE

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Abstract

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Because of the rising incidence of microbial foodborne disease in the UK, particular attention is being given to the application of HACCP principles in all sectors of the food industry, including meat production.

The basic requirements of HACCP systems for the red meat and poultry industries are well known, but not yet uniformly applied in UK abattoirs. To monitor progress in hygiene control, the Hygiene Assessment System (HAS) has been developed for abattoirs and meat cutting plants and the basis for the system is described. In a study of beef abattoirs, there was a significant negative correlation between mean HAS scores for each premises and mean total viable counts from carcasses sampled prior to chilling.

In poultry plants, cross-contamination of carcasses via processing equipment is a continuing problem. Measures to reduce such contamination have been studied with the aid of a readily identifiable marker organism, which can be introduced and followed at any stage in the process. When similar control measures were used in an attempt to reduce contamination of carcasses with naturally occurring campylobacters, a small but significant reduction in count was observed. Further possible benefits of using more hygienic processing equipment and a terminal decontamination treatment for carcasses are discussed.

The use of HACCP systems in the producion of ready-to-eat meat and poultry products is considered essential for optimum pathogen control. It is not yet possible, however, to exclude *Listeria monocytogenes*, which occurs in various niches in the processing environment. Thus, low levels of *Listeria* are to be expected in a proportion of ready-to-eat products and are not regarded in the UK as hazardous to consumers.

Foodborne illness, food safety, public health

Over the last decade, foodborne illness has continued to rise in the UK and "new" causative agents have emerged, particularly thermophilic campylobacters, *Salmonella enteritidis* PT4 and *Listeria monocytogenes*. Between 1985 and 1994, the number of notified cases in England and Wales for all agents rose from approximately 12,000 to 49,000 per annum. By the late 1980s, the problem had received considerable publicity and consumer concern was widespread. The British Government responded to the situation by establishing an advisory body, the Committee on the Microbiological Safety of Food. The remit of the Committee included a thorough investigation of the relationship between foodborne disease and existing practices in food production, processing and handling and the development of effective control measures. An important outcome of the exercise was the realisation that a more systematic approach was needed for the identification and control of microbial hazards in the food industry, as provided by the Hazard Analysis Critical Control Point (HACCP) system (Report 1990, 1991). It was recognised that the HACCP approach directs attention to the key factors in controlling food safety, defines both safety parameters and the action to be taken when safe limits are exceeded and provides documentary evidence of regular process monitoring.

How has this modern view of food-safety control affected the UK Meat Industry? Firstly, it has highlighted the inadequacies of the traditional system of post mortem meat inspection, which focuses on visible lesions and carcass defects, but largely fails to address the public health risks associated with the symptomless carriage of foodborne human pathogens in meat animals and subsequent contamination of carcass meat. In considering this deficiency, Hathaway and McKenzie (1991) supported the application of HACCP principles in the abattoir and emphasised the importance of exchanging information between farm and abattoir to reinforce the preventive nature of the HACCP approach. The extent to which the HACCP system is being applied in British abattoirs and the current role of the Official Veterinary Surgeon (OVS) in hygiene assessment will be considered in the present paper.

Within the context of the European Union, abattoirs must conform to meat hygiene directives that necesssitate costly structural changes. Compliance with these requirements has been a major burden on the industry and, in itself has not improved the microbiological standard of the meat (Mackey and Roberts 1990). By making such changes, however, it can be argued that a suitable environment is being created for hygienic meat production. The next phase in hygiene control must be to optimise the procedures and practices used in the abattoir and cutting plant. Progress in this direction will be discussed in the following sections.

Hygiene control in red meat abattoirs

An outline of the HACCP system for red meat production is given by the International Commission on Microbiological Specifications for Foods (ICMSF 1988). In the case of beef, for example, critical control points (CCPs) in abattoirs include chilling (CCP1) and skinning, eviscerating and transporting (CCP2). A more detailed, generic HACCP plan for beef is described by the National Advisory Committee on Microbiological Criteria for Foods, US Department of Agriculture (NACMCF 1993). However, a proper HACCP programme must be designed by the individual company or abattoir for their own production process, and should focus on food safety rather than including other considerations, such as product quality and animal welfare, which tend to result in too many CCPs.

The UK Committee on the Microbiological Safety of Food (Report 1991) made a number of recommendations for improving abattoir performance, most of which could be regarded as Good Manufacturing Practices (GMP, Snijders 1988). These included using a freshly sanitised knife for bleeding each animal, adopting the practices, where appropriate, of tying and bagging the anus and sealing the oesophagus, and improving the cleaning and disinfection of slaughter equipment.

As a means of encouraging the Meat Industry to adopt a risk analysis approach to hygiene control, the Ministry of Agriculture has recently introduced the Hygiene Assessment System (HAS) for abattoirs (Simmons et al. 1995). The system provides a means of recognising those good hygiene and management practices which contribute to the production of hygienic meat. Results from the HAS have been used to monitor abattoir performance and to identify any premises where regulatory action may be needed. A similar system is being used in meat cutting plants.

The hygiene assessment, which is carried out by the OVS, takes the form of a score sheet that lists the main areas in hygiene control. Thus, for red meat abattoirs, there are five separate sections covering Ante-mortem, Slaughter and Dressing, Personnel and Practices, General Conditions and Management, and Maintenance and Hygiene of Premises. Up to 11 categories are included in each section. Scores are awarded in each category and are added to give a sub-total for the section. A conversion factor is then applied so that the section has a weighted figure that reflects its relative risk in relation to product safety. Results for all sections are added together to give an overall figure for the abattoir as a whole. With red meat abattoirs, 75% of the total score is accounted for by Ante-mortem, Slaughter and Dressing, and Personnel and Practices. Recent experience in applying the HAS, up to the end of November 1994, was presented to the UK Parliament (Hansard 1995) and results are shown in Table 1. The table indicates the variation in performance from one abattoir to another and suggests that those at the lower end of the scale were not using GMP or properly applying HACCP principles.

Table 1
Initial performance of abattoirs in England and Wales according to th Official Hygiene Assessment System (Hansard 1995)

Score bands	Total no. of abattoirs	Abattoir type: fully approved	low throughput*	temporarily derogated**
21-30	3	0	0	3
31-40	19	1	1	17
41-50	89	4	3	82
51-60	103	15	11	77
61-70	84	17	11	56
71-80	49	25	4	20
81-90	23	15	3	5
91-100	4	3	1	0

* No more than 20 animals per week.

** Structural requirements in Regulations to be met within a specified period.

To determine the relationship between HAS scores and the microbiological condition of carcasses at the end of the slaughterline, a study was made of 11 beef abattoirs in the UK (Hudson et al. in press). On each of five visits to individual premises, 10 carcasses were sampled at four diferent sites to obtain total viable counts (TVC) at 30 °C and counts of presumptive coliform bacteria. HAS scores were also determined and ranged from 11 to 84, again showing wide variation in abattoir performance. A significant negative correlation (P<0.001) was found between mean HAS scores and mean TVC for each abattoir (Table 2), but not with coliforms. Mean TVC varied from $\log_{10}$ 2.79 to 3.78 cfu/cm^2. According to the advisory scale of Mackey and Roberts (1990), 24% of counts were in the "Excellent" category, with counts not exceeding $\log_{10}$ 3.0 cfu/cm^2. The remaining 76% were classed as "Good" (between $\log_{10}$ 3.0 and 4.0 cfu/cm^2). However, the latest study proposed a more stringent scale to encourage even higher levels of attainment.

Table 2
Relationship between mean total viable counts (TVC) and the Hygiene Assessment System (HAS) scores for each abattoir visit

Total viable count ($\log_{10}$/cm^2)	HAS score: 10	20	30	50	60	10	80	Total
1.50-1.99	-	-	-	-	-	-	1	1
2.50-2.99	-	-	-	-	8	3	1	12
3.00-3.49	-	2	4	12	5	4	1	28
3.50-3-99	3	1	2	4	-	-	-	10
≥4.00	1	-	2	1	-	-	-	4
Total	4	3	8	17	13	7	3	55

As would be expected, hygiene control in red meat abattoirs is strongly influenced by the skill and care of the operatives in handling carcasses. In the HAS, the categories concerned with Slaughter and Dressing and Personnel and Practices have proved of greatest value in determining trends in carcass contamination (Hudson et al. in press).

HACCP and the poultry processing plant

As in other countries, poultrymeat production in the UK is often highly intensive and processing rates of 6,000 carcasses per hour or more are common. At the larger plants many of the stages in processing are automated and therefore hygiene performance is related more to the type of equipment being used than to the way in which operatives carry out their tasks. The intensive nature of the process and the design of the machinery tend to favour extensive microbial cross-contamination (Mead 1989) with *Salmonella*, experience suggests that processing results in approximately a five-fold increase in the proportion of positive birds.

Despite this problem, a basic HACCP scheme for poultry production and processing has been described (ICMSF 1988); again, this must be adapted for each individual establishment. The generic scheme is clearly relevant to any major changes in carcass contamination. Chilling is the only CCP1 because it prevents any significant microbial growth during processing. On the other hand, scalding and spray-washing are CCP2s because, when these processes are properly controlled, carcass contamination is reduced. Careful setting of eviscerating machines minimises gut breakage and hence microbial contamination at this stage (CCP2). However, cross-contamination of carcasses occurs continuously throughout the process and cannot be prevented by any known means. The problem is most acute during scalding, plucking and evisceration and is favoured by the close proximity of carcasses. Thus, cross-contamination can occur even when there is a net reduction in the microbial load on the birds. Although CCPs to control gross contamination can be identified, there appear to be no CCPs in the basic process that would prevent cross-contamination with small numbers of microorganisms. Thus, GMP are needed throughout the process to limit the spread of any foodborne pathogens present. Examples are thorough cleaning and disinfection of equipment post processing, use of super-chlorinated process water at various stages and attention to the hygiene of personnel.

In a study that attempted to reduce cross-contamination during processing, Mead et al. (1994) utilised a readily identifiable, non-pathogenic strain of *Escherichia coli*, which was used experimentally to inoculate carcasses, equipment or working surfaces. The spread of the organism was followed both before and after introducing additional control measures, which included the use of chlorinated water sprays to prevent an accumulation of organisms on equipment, increasing chlorine concentrations in process water and eliminating all unnecessary carcass contact surfaces. The results showed that cross-contamination could be reduced or even prevented at some points in the process. For example, the operative responsible for manual neck skin cleaning and inspection prior to carcass chilling was a vehicle for cross-contamination (Table 3). Introducing hand rinsing in chlorinated water after handling of one carcass and before touching another reduced the spread of the marker.

Similar control measures were applied at the same processing plant in an attempt to reduce contamination of carcasses with naturally occurring campylobacters (Mead et al. 1995). It was found that approximately 95% or birds from 15 flocks yielded *Campylobacter*-positive neck skin samples after bleeding, but processing reduced levels of contamination by 10–1000-fold and contamination was significantly lower ($P<0.001$), following the changes in the process. On its own, the improvement was relatively slight, but could be enhanced by measures to reduce campylobacter carriage in the live bird.

Table 3

Spread of a marker organism during manual neck-skin cleaning and inspection at a poultry processing plant

		Without hand rinsing			With hand rinsing		
Trial no.:		1	2	3	1	2	3
Inoculated carcass		*6.3	6.9	6.3	6.3	6.1	6.2
Carcass no.	10	4.2	4.7	4.2	1.8	2.7	3.1
	25	3.9	3.2	4.1	1.7	2.8	3.1
	50	3.9	1.6	3.0	-	1.4	1.1
	100	3.1	1.7	2.9	-	1.3	-
	200	2.5	1.1	1.1	-	-	-
	300	1.9	-	1.4	-	-	-
	400	1.5	1.4	1.9	-	-	-
	500	**-	-	0.9	-	-	-

*Log_{10} cfu/g of neck skin ** Below detection level (<0.6)

A recent report on the UK Poultry Meat Industry (Report 1996) called for constant attention to all critical points in the poultry meat supply chain and regarded the application of HACCP principles as the key management regime through which significant improvements in pathogen carriage rates could be achieved. The HAS described earlier as a means of auditing slaughterhouse hygiene has also been adapted for use in poultry processing plants. Although the approach is the same as that used for red meats, there are differences in the method of poultry production and type of equipment employed, so both the component categories and their respective weightings have been changed accordingly. This means less emphasis on Personnel and Practices and more on Processing to reflect the influence of the process itself on carcass hygiene.

Developments in abattoir machinery

The Committee on the Microbiological Safety of Food (Report 1990) clearly recognised that the slaughter processes used for both red and white-meat animals will inevitably lead to the spread of microorganisms during meat production. The problem is more acute with poultry because the processing equipment has been designed to maximise throughput and efficiency rather than safeguarding product hygiene. Although the machines frequently incorporate sprays of chlorinated water, these do not substitute for a proper cleaning process. In the Report on Poultry Meat (Report 1996) the need is recognised for development of more hygienic machinery and for the Poultry Industry to replace outdated equipment as soon as improved designs become available. To a lesser extent, there are similar problems with some of the equipment involved in red meat production e.g. that used for cleaning pig carcasses after singeing (Report 1991).

Further improvements in hygiene control may depend upon the introduction of new equipment, involving fresh concepts, particularly for poultry. While some progress has been made in this direction, hygiene control is not usually the highest priority for either equipment manufacturers or meat producers. Equally, there are no specific requirements in EU legislation relating to the type of equipment that should be used.

Despite the lower priority given to hygiene control in poultry processing, several new developments have appeared in recent years. These include multi-stage, counterflow scalding, a new type of evisceration system, better equipment for cleaning live-bird delivery crates and cleaning-in-place systems for eviscerating machines, conveyor belts etc. All except the last-mentioned are gradually being adopted within the Industry.

Multi-stage, counterflow scalding ensures that birds leave the system in the cleanest water and microbial contamination on the birds is reduced by a further 60% (Zwanikken 1993). Also, water in the component tanks can be changed, as required, while processing is ongoing. The new type of eviscerating equipment provides more controlled opening of carcasses and transfer of the viscera to a separate, parallel line. This process results in lower level of carcass contamination.

An improved type of crate for live-bird delivery is now available and crates can be cleaned with a soaking process that loosens dried-on faeces. The final stage incorporates a sanitising agent so that dirty, contaminated crates can be eliminated as a source of cross contamination between different poultry flocks.

Carcass decontamination

There is an extensive literature on possible methods for decontaminating carcasses of both red and white meat animals. Most experimental studies have involved various kinds of chemical treatment, although some of the substances used would appear to be unsuitable for commercial application, because of possible health hazards from meat residues or tainting effects on the product. Poultry meat, in particular, is highly susceptible to changes in colour and flavour from chemical treatment. There is a further problem in the European Union, where only water of potable quality is allowed to come into contact with carcass meat and no chemical treatment has yet been sanctioned. The reluctance on the part of the regulators to do so reflects their concern that such treatment may be used to conceal poor hygiene control in the slaughter process. From the viewpoint of the HACCP concept, however, terminal decontamination would provide a CCP at the most appropriate stage to overcome the problem of carcass contamination. At present, this cannot be prevented by GMP or any other means. Therefore, decontamination should be regarded as complementary to good hygiene and not a substitute for it.

Although treatments involving water at ca 8 °C or brief exposure to superheated steam have been investigated, the immediate interest in decontamination centres on the use of certain organic acids such as acetic, citric and lactic acids and trisodium phosphate (TSP). Lactic acid and TSP appear to be the main contenders and either is acceptable for food use in the USA. Lactic acid has the advantage that it is naturally present in muscle as a metabolite. Application to both red and white meat by spray or immersion are being considered and it is recognised that the effectiveness of treatment will depend on the method of application, the concentration used, the time and temperature of treatment and the extent to which microbial attachment to meat surfaces has occurred (Snijders et al. 1985). The treatment can be expected to reduce or even eliminate organisms such as *Salmonella* spp., which generally occur in only low numbers.

Lactic acid has both bactericidal and bacteriostatic properties and is effective against various pathogenic and spoilage bacteria. An initial reduction in microbial numbers of up to two $\log_{10}$ units can be expected and eventually may be greater due to a delayed effect (Smulders and Woolthuis 1985). The antimicrobial action of TSP is less well understood. It may be partly a pH effect, since active solutions are highly alkaline. In the case of poultry, at least, TSP treatment removes a very thin fat coating from the skin and allows removal of microbial contaminants by subsequent washing (P. Coppen, pers. comm.). Few studies have made a direct comparison of lactic acid and TSP under identical test conditions. The results of such a comparison, using chicken drumsticks artificially inoculated with a strain of *Salmonella enteritidis* PT4, are shown in Table 4. The table indicates that TSP was slightly more effective under the test conditions and showed a delayed effect after holding the drumsticks at 4 °C for 24 h. In these experiments, the salmonella counts involved a resuscitation procedure to optimise recovery of any damaged cells.

Table 4

Effects of lactic acid and trisodium phosphate treatment on *Salmonella enteritidis* PT4 inoculated onto chicken skin (Kanellos and Mead, unpublished)

	Log$_{10}$ decrease in count:	
Treatment	Before storage	After storage at 4° C for 24 h
Water	0.0	0.0
Lactic acid	0.5	0.7
Trisodium PO_4	0.8	1.7

Immersion time 15 sec. at ambient temp.: lactic acid, 1.5%; TSP, 12%. Treatment was followed by a standard washing procedure. Figures are means of two trials in each case.

For poultry processing, only super-chlorination of process water is widely used in the UK to control microbial contamination during slaughter operations. The benefits of the treatment are well known, as are the limitations, but the use of chlorine in processing is not permitted in all countries.

When added to the factory water supply, chlorine eliminates organisms such as spoilage bacteria that may present and restricts the build-up of bacteria on equipment and working surfaces. Chlorine has little direct effect on carcass contamination because, in contact with the bird, it is rapidly inactivated. Addition of chlorine to chill water prevents carcasses from being seeded with spoilage bacteria that would otherwise accumulate in the chilling system, and destroys any foodborne pathogens in the water. The primary value of chlorine is in controlling microorganisms in the processing environment, not as a carcass decontaminant.

HACCP for processed meats

Among the variety of processed meat products available in the UK and elsewhere, those of greatest concern in relation to food safety are ready-to-eat products that may be consumed without any further heat treatment. The essential steps in carrying out a hazard analysis have been summarized by Tompkin (1990). These include (i) establishment of a processing procedure to eliminate all relevant hazards; (ii) formulation of a product with adequate microbial stability during processing, storage, distribution and use; (iii) prevention of post-processing recontamination; (iv) use of appropriate packaging and inclusion of labelling to inform the consumer about handling requirements; (v) a combination of as many control factors as possible. For these products, CCPs may involve e.g. addition of salt and/or nitrite, cooking, chilling or drying to a known water activity value. For cooked products, a suitable time-temperature regime should ensure the destruction of all non-sporing pathogens and spoilage bacteria.

Probably the pathogen that is most difficult to exclude from ready-to-eat items is *Listeria monocytogenes*. An example of listeria contamination in a further-processing factory producing a chicken dish is given in Table 5. Listerias can be found in various niches and may be present on the floor, from where they can contaminate other sites as well as the product itself. It has been estimated that an effective control plan may take up to two years to implement properly (Tompkin 1992). Even then, total elimination of the organisms is unlikely. In the UK, low levels of listeria are to be expected in a proportion of all ready-to-eat meat and poultry products, and are presently accepted as safe.

Table 5

Listeria contamination in further processing of chicken (Hudson and Mead, unpublished)

Type of sample	No. tested	No. positive
Processing environment	28	7 (floor, tank wheels, conveyors)
Hands of operatives	2	0
Boots	1	1
Chill holding room	4	1 (floor)
Chill storage	8	1 (floor)
Meat at different stages	3	0
Sauce added to product	2	1
Final product	3	3

Species present: *L. monocytogenes* and/or *L. innocua.*

Conclusions

The application of the HACCP concept to food safety control is being actively promoted by regulatory authorities in the UK and is aimed at all stages in the food chain. Nevertheless, it must be recognised that the HACCP approach has some limitations, especially in relation to the processes used for slaughter animals, that lack any means of destroying foodborne pathogens. Also, HACCP systems will not prevent all hazards associated with food consumption and, clearly, some are more easily prevented than others. For example, salmonellas are more readily eliminated from processed meats than listerias. Only time will tell whether widespread application of HACCP principles will have a beneficial impact on the rising incidence of human food poisoning. Most foodborne illness is due to mishandling of foods in homes and catering establishments, and successful education of food handlers in these situations is likely to be the key factor.

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