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Review

The role of microbiological testing in systems for assuring the safety of beef

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Abstract

The use of microbiological testing in systems for assuring the safety of beef was considered at a meeting arranged by the International Livestock Educational Foundation as part of the International Livestock Congress, TX, USA, during February, 2000. The 11 invited participants from industry and government research organizations concurred in concluding that microbiological testing is necessary for the implementation and maintenance of effective Hazard Analysis Critical Control Point (HACCP) systems, which are the only means of assuring the microbiological safety of beef; that microbiological testing for HACCP purposes must involve the enumeration of indicator organisms rather than the detection of pathogens; that the efficacy of process control should be assessed against performance criteria and food safety objectives that refer to the numbers of indicator organisms in product; that sampling procedures should allow indicator organisms to be enumerated at very low numbers; and that food safety objectives and microbiological criteria are better related to variables, rather than attributes sampling plans.

Keywords: Microbiological sampling; Beef; HACCP; Food safety

1. Introduction

It is now generally acknowledged that traditional meat inspection procedures cannot assure that consumers will not be exposed to infectious doses of meat-borne pathogens (Tompkin, 1990). Consequently, meat inspecting authorities around the world

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are currently encouraging or mandating the implementation of Hazard Analysis Critical Control Point (HACCP) systems for meat production processes. Although full systems of that type must encompass physical and chemical as well as microbiological hazards, the latter hazards are the major concern with meat (Gill, 1998).

The Food Safety and Inspection Service (FSIS) of the US Department of Agriculture (USDA) has been to the fore in the current effort to improve the microbiological safety of meats in general, and raw beef in particular, through the implementation of HACCP systems for meat plant processes (USDA, 1996). The arrangements for developing, documenting and verifying HACCP systems for the production of raw beef products differ considerably among countries. Despite the differences, the advocated procedures are all fundamentally similar in that it is recommended or required that a HACCP system be developed only after a plant is deemed to meet a number of 'pre-HACCP requirements'; HACCP systems are based on the inspection of product and equipment for visible contamination, and subjective assessments of the microbiological effects of individual operations within production processes; and attention is focused particularly on the performance of carcass dressing processes at slaughtering plants (CFIA, 1994; Soul, 1996; USDA, 1996). However, most regulatory authorities do not require microbiological testing of raw beef.

Australia and New Zealand are two of the few countries where microbiological testing is required. In those countries, testing programmes have been jointly developed by industry and regulatory agencies, for food quality as well as food safety purposes, with historical data from industry being incorporated into national data bases at the beginning of testing programmes (MLA, 1998; Hathaway et al., 1999). The primary objective of the testing is to verify the control of processes at meat plants. Failure to meet microbiological standards precipitates investigative activities aimed at improving control over processes. These activities may or may not involve the regulatory authority, depending on the type and degree of failure, and condemnation of product or stopping of processing are not seen as appropriate responses to failures to meet standards. Microbiological testing is also required by the USDA. That testing too is aimed in the first instance at process control, but it is related to food safety only, and regulatory responses that include rejection and recall of product, and stopping of processing are emphasized in the testing programme.

The microbiological testing and regulatory responses mandated by the USDA affect plants outside as well as within the USA, as plants in other countries which export beef to the USA must perform the same or equivalent testing of their products. Moreover, irrespective of national requirements, individual customers for raw beef are increasingly specifying that they receive only product that has been subjected to some forms of microbiological testing, while manufacturers of ground, raw beef products, such as hamburger patties, are increasingly subjecting the product they receive to microbiological tests. Such voluntary testing by commercial parties tends to involve the use of procedures similar to those required by the USDA, as the world's meat industry has been widely advised of those procedures in relation to trading with and within the USA.

The increasing demand for the microbiological testing of beef has led many involved with the beef industry to reconsider current testing programs and procedures. For a better understanding of the directions of thinking on those matters, the International Livestock Congress arranged for a discussion of microbiological testing in relation to the safety of beef, between an invited group from industry and government laboratories. All members of the group were active in developing, implementing and/or studying HACCP systems for the meat industry. This paper provides a summary of the arguments that were advanced during the discussion, and reports the unanimous conclusions of the group about the appropriate collection and use of microbiological data in relation to systems for assuring the safety of beef.

2. The need for microbiological testing

All meat-inspecting authorities recommend that the safety of raw beef be assured by the use of HACCP systems, and that HACCP systems be developed by assessment and control of the visible contamination of product and control of plant conditions during processing. If meat safety can indeed be assured by systems of control that are based on subjective assessments of the hygienic condition of product and the hygienic effect of processing conditions, then microbiological testing may be only

peripheral in systems for assuring the safety of meat. The relationship between visible and microbiological contamination of meat must therefore be considered.

It seems obvious to most people that visible contamination is likely to be associated with microbiological contamination, so actions to prevent the deposition on, or to remove visible contamination from product and equipment are likely to enhance the microbiological condition of product. In support of that assumption, it has been shown that the numbers of total aerobic bacteria on carcasses can be progressively reduced when dressing processes are routinely controlled by reference to the visible contamination of product and with the strict observance of Good Manufacturing Practices (Bolton et al., 1999; Hudson et al., 1996).

Despite that, the assumption that all actions which help to prevent the visible contamination of product also help to prevent microbiological contamination is not necessarily true. For example, the visible contamination of carcasses during skinning operations is usually greater when animals have dirty rather than clean hides at the time of slaughter (Van Donkersgoed et al., 1997), and washing of animals before slaughter can substantially reduce visible contamination of carcasses. However, such treatments may have little or no effect on the microbiological conditions of carcasses (Schnell et al., 1995; Byrne et al., 2000). Thus, although most of the bacteria found on the dressed beef carcasses are commonly derived from the hide and deposited on the meat during skinning operations, it is the way these operations are performed rather than the state of the hide that usually determines the extent of the microbiological contamination (Gill et al., 1998).

Nor can it be assumed that treatments for removing visible contamination will necessarily improve the microbiological condition of product. To give examples, trimming, vacuum cleaning and vacuum cleaning while simultaneously applying hot water and/or steam are all treatments used commercially which are effective for removing visible contamination from carcasses. Also, all these treatments have been shown to be effective for removing bacteria from meat in experimental circumstances (Dorsa, 1997). Despite that, all three treatments are largely ineffective for reducing the numbers of bacteria on carcasses when they are applied as routine operations in commercial carcass dressing processes (Gill and Bryant, 1997; Gill et al., 1996).

Cleaning treatments are microbiologically ineffective because, while visible contamination may indicate likely sites of microbiological contamination, the absence of visible contamination does not necessarily indicate that microbiological contamination is little or absent. Thus, spot treatments to remove visible contamination leave untouched far larger, visibly clean areas, some of which may well be heavily contaminated with bacteria. In addition, cleaning may redistribute visible filth as small, inconspicuous particles from larger, easily perceived, point sources.

Inspection for visible contamination can then direct attention to possible sources of microbiological contamination, and help identify improper performance of particular operations in meat plant processes. Moreover, where relationships between visible and microbiological contamination can be established, microbiological contamination may well be conveniently controlled by reference to the visible contamination of equipment or product. However, microbiological data are required to correlate microbiological contamination with visible soiling; to identify the microbiological effects of individual operations or processes; and to confirm or reject suspected sources of microbial contaminants on product. Therefore, some form of microbiological testing is essential if the microbiological condition of beef is to be assured, rather than assumed from non-microbiological qualities, which may or may not reflect the microbiological condition of product.

3. The purposes of microbiological testing

Microbiological testing can be used for surveying the microbiological condition of product, for deciding between acceptance or rejection of batches of product, or for purposes related to the implementation and maintenance of HACCP systems.

3.1. Surveillance testing

Nationwide surveillance testing has been carried out in many countries to obtain microbiological data from which to set regulatory policies and performance standards for meat plant processes. Such data have also been used to compare the hygiene conditions of product from different countries, for decisions on whether or not the meat inspection processes in each can be considered equivalent; and

data from replicated or continuing surveys have been used to discern the microbiological effects of regulatory initiatives (McNamara, 1995; Vanderlinde et al., 1998). Unfortunately, it is doubtful that the surveillance testing reported to date has been of much use for these purposes.

Various studies have indicated that there may well be substantial regional and seasonal variations in the prevalence in cattle of pathogenic bacteria, notably *Escherichia coli* 0157:H7 (Shere et al., 1998). There may then be large variations in the numbers of such organisms on beef. Surveillance testing which is carried out without regard to such possibilities is likely to give results which are more misleading than enlightening. At present, knowledge is lacking as to whether or not the beef produced within any country can be assumed to carry a microbial population of consistent composition and distribution until it is affected, in a desired manner, by the initiatives of some regulatory authority. In these circumstances, it is impossible to draw meaningful conclusions from comparisons of surveillance data collected in different countries and/or at different times. Nor are comparisons aided by the use of different sampling plans, different microbiological methods, and different procedures for data analysis, in different places at different times.

Even if surveillance data can ultimately provide some realistic description of the microbiological condition of beef within a country, it is doubtful that such data should be used for setting microbiological standards for products. There is much evidence that, within any country, there are great differences in the microbiological conditions of carcasses produced at different beef packing plants (Gill et al., 1998; Roberts et al., 1984). Consideration of composite data from many plants is likely to lead to the setting of performance criteria which reflect the worst rather than the best performances. Certainly, superior performance will not be recognized, far less rewarded.

To improve the microbiological safety of meat, it seems necessary for regulatory activities to encourage all plants to move towards the production of beef of the best possible microbiological condition, rather than towards some dubiously adequate, mean condition. To do that, it would seem necessary to identify the microbiological conditions of product from individual plants, and to set microbiological standards by reference to the median performance; but, in addition, to set Food Safety Objectives by reference to the best performances (Van Schothorst, 1998). Then, as improvements are obtained, the standard for process acceptance can move progressively towards the Food Safety Objectives.

Thus, surveillance testing is necessary for a variety of regulatory purposes. However, testing must be based on sound understanding of the factors that affect the microbiological condition of meat, and it must be structured to obtain data that are related unambiguously to the matters of interest. Where understanding is lacking, investigative studies are required before a program of surveillance testing is designed. Certainly, surveillance data should not be collected on the basis of convenient but unverified assumptions, such as the microbiological homogeneity of beef produced within all the plants supervised by a single regulatory authority. Nor should surveillance data collected for one purpose be subsequently used to answer questions that the surveillance program was not designed to address, and for which the data are not appropriate. In addition, surveillance testing will not contribute directly, and may not contribute at all, to controlling the microbiological condition of product. Therefore surveillance testing cannot be considered essential for assuring the microbiological safety of beef.

3.2. Acceptance testing

Testing of batches of meat to determine whether, or not, a pathogen is present in the product, or an indicator organism is present in unacceptable numbers, seems to many the appropriate form of testing for assuring the safety of beef. Unfortunately, such an approach is generally confounded by the practical limitations on sample collection and analysis, and the distribution of bacteria on or in meat, which prevent confident discrimination between acceptable and unacceptable product.

Until meat is ground, bacteria are present on only the surfaces of carcasses, cuts or pieces of manufacturing beef (Gill, 1979). Bacteria are not spread evenly over the product. Instead, their distribution generally approximates the log normal (Hildebrandt and Weiss, 1994a). That is, the set of $\log_{10}$ values for the bacteria recovered from each sample in a group of random samples will have a normal distribution with, commonly, a standard deviation of about 1 log

unit (Brown and Baird-Parker, 1982). Thus, there are very large variations in the numbers recovered from individual samples from the same batch. Consequently, even if the bacteria being sought can be recovered from nearly all samples, more than 20 samples are required to make some reasonable estimate of the mean numbers present in the product (Jarvis, 1989). If the bacteria are few, as is the case with most pathogens, the chance of recovering the bacteria being sought from any sample is very low (Hildebrandt et al., 1995). It is generally impractical to obtain enough samples from each batch to realistically estimate even the numbers of total aerobic bacteria present in the product, far less to detect with any certainty a pathogen present in small numbers. As a result, a negative finding for a pathogen such as *Escherichia coli* 0157:H7 gives no assurance that the organism is not present in a batch, although customers for beef commonly believe that it does.

A further difficulty with batch testing as a means of assuring product safety is that it is essentially incompatible with the operation of a HACCP system. The incompatibility arises because a HACCP system is a special case of quality assurance by process control, in which the quality to be assured is safety.

It has been recognized for many years that batch testing of a final product is an unsatisfactory way of assuring product quality, as it does not prevent the manufacture of sub-standard product. Nor does it assure that some faulty product is not passed to customers, unless every item is individually tested for all possible faults. The alternative is control of the production process, which can not only prevent the manufacture of sub-standard product but can also be used to progressively improve the product (Marquardt, 1984). It is explicitly recognized that process control, if properly implemented, must displace end product testing (Schilling, 1983). Otherwise, the process will be operated to only meet with the end product tests, which do not assure that all product is satisfactory. Thus, if end product testing is superimposed on a HACCP system as the means of making decisions on product safety, it will lead to the acceptance of inadequate control of the process and failure to obtain the progressive improvement of product safety that is certainly needed for raw beef.

For these reasons, batch testing of product is not an appropriate or effective means of assuring the microbiological safety of raw beef.

3.3. HACCP implementation

A HACCP system for controlling microbiological contamination must be based on appropriate microbiological data.

When developing a HACCP system to obtain product of specified microbiological quality from a process, it is first necessary to ensure that the process is being operated consistently, as by definition an inconsistent process cannot be controlled. Next, microbiological data must be obtained to identify the points in the process where hazards originate, or where hazards are reduced or eliminated. That is, the points at which possibly hazardous bacteria are deposited on or removed from the product. Those must be designated Critical Control Points, which are Type 1 if the hazardous contamination can be wholly prevented or eliminated, but Type 2 if the contamination can be only minimized or substantially reduced. Whichever type is identified, Standard Operating Procedures must be implemented and maintained to control the operations at each Critical Control Point. The microbiological efficacy of the Standard Operation Procedures must be validated by appropriate microbiological testing. The microbiological condition of product leaving the controlled process must be determined and documented. Periodic testing of the product leaving the process should be part of the procedure for verifying that the process is under control.

Thus, microbiological testing is a necessary part of HACCP implementation, as testing must be used to investigate the microbiological effects of the operations in or affecting a process, to validate the procedures adopted for controlling microbiological contamination, and to verify the maintenance of control over the microbiological condition of product.

Such are the proper and necessary uses of microbiological testing for assuring the safety of beef.

4. Sampling procedures

The scale and scope of microbiological sampling in relation to HACCP system implementation and maintenance is likely to vary with differences in facilities and equipment, the scales of processes, and the types of products involved. However, the neces-

sary characteristics of the procedures that are used for collecting and processing microbiological samples for HACCP purposes can be identified.

With HACCP, as with other process control systems, it is desirable to use established statistical methods for selecting samples and evaluating the data that describe process performance (Ryan, 1989). Methods of evaluation generally require that sampling yields numerical values rather than a statement of the detection or failure to detect some quality in each sample. Certainly, a negative finding for some quality in most samples gives very limited information about process performance.

As their numbers on beef are usually low, pathogens are recovered infrequently from beef and can then only be detected rather than enumerated. Thus, testing for pathogens provides little information of use for the implementation and maintenance of HACCP systems. Instead, microbiological testing for HACCP purposes must involve the enumeration of indicator organisms.

Indicator organisms are groups of bacteria that are indicative for the possible presence of organisms of concern, such as pathogens. Although it is possible within any particular process that numbers of a pathogen are an invariant fraction of the numbers of a specific group of indicator organisms, in general there is no necessary relationship between indicator and pathogen numbers. However, it can be generally assumed that the possible numbers of a pathogen are less than the numbers of the organisms indicative for it, and that reduction in the numbers of the indicator organisms will produce some similar reduction in the numbers of any pathogen with which the indicator organisms are associated.

As different indicator organisms indicate the possible presence of different pathogens, and may point to different origins of microbiological contamination, and also because there is no consistent relationship between the numbers of one group of indicator organisms and those of another, it is desirable that process performance be evaluated by reference to several rather than just one type of indicator organism. Indicator organisms that have been used in the assessment of meat plant processes include total aerobic counts, coliforms, Enterobacteriaceae, generic *E. coli*, fecal streptococci and aeromonads (Gill et al., 1999a; Mackey and Roberts, 1993), while listerias and enterococci have also been suggested for that purpose (Gill and Jones, 1995; Ingham and Schmidt, 2000).

As the numbers of indicator organisms can only establish the upper limits for pathogen numbers, the use of indicator organisms for process evaluation implies that actions should be taken to progressively reduce their numbers to the lowest level possible. Thus, whatever the numbers present at the inception of a HACCP system, if control is successful it should eventually be necessary to count indicator organisms at very low numbers. Ideally, indicator organisms should be counted at numbers down to 1 cfu in a sample of the maximum practical size.

For carcasses, cuts and equipment surfaces, very large areas can be sampled by swabbing. As bacterial numbers are properly considered as log values, delimitation of exact areas for swabbing is unnecessary, because log values will be essentially unaffected by modest variations in the actual area sampled (Gill and Jones, 1998). With at least carcasses, the numbers of bacteria recovered by different sampling methods, such as excision or swabbing with cellulose acetate sponge or medical gauze, are similar (Gill and Jones, 2000). Moreover, swab sizes and diluent volumes do not have to increase with increases in the surface area sampled. Thus, surface swabbing must be the preferred technique for sampling meat whenever it is practicable and demonstrably possible to recover substantial fractions of the bacteria present in sampled areas.

When the numbers of bacteria in samples are few, they are preferably enumerated by Most Probable Number techniques, which can be more sensitive than plating procedures because large volumes of samples or sample preparations can be tested. In the case of swab samples, the whole volume of the diluent used with each can be filtered through a hydrophobic grid membrane filter (Brodsky et al., 1982). Following incubation of the filter on a selective agar to allow growth of the bacteria retained on it, the numbers of an indicator organism can be determined at the ideal level of 1 cfu/sample.

As with water, milk and other foods, the demonstration of a process being operated to yield a product which carries very low numbers of indicator organisms would provide surety of the product's microbiological safety. For example, available data indicate that commercial carcass production processes can be operated to give beef carcasses sides

with log mean numbers of total aerobic bacteria < 2 log cfu/cm^2, and log mean numbers of generic *E. coli* < 0 log cfu/1000 cm^2 (Gill et al., 1999b).

5. Sampling plans

Microbiological sampling must be conducted and the collected data assessed by reference to some sampling plan. Making decisions on the basis of the collected data may involve the consideration of attributes or variables.

Microbiological sampling of meat has usually been considered with reference to attributes acceptance plans, and the USDA has specified plans of that type for evaluating the performances of meat plant processes (USDA, 1996). In attributes acceptance plans for indicator organisms, bacterial numbers are not considered as such. Instead, each sample is regarded as having an attribute of the numbers recovered being above or below one or two specified numbers (Hildebrandt and Weiss, 1994b). In a two class attributes acceptance plan, each sample is assigned to one of two groups depending on whether the numbers of bacteria recovered from it are above or below a number (M, the Safety or Quality Limit) deemed to be the maximum for acceptable samples. In a three-class plan, three groups of samples are defined by specification of a maximum number (m, the Good Manufacturing Practice limit) for bacteria in unconditionally acceptable samples and a second, larger, number (M) which is the Safety, or Quality Limit. Then, samples yielding bacteria in numbers between the two specified numbers ($M - m$) are marginally acceptable.

In addition to specifying the number or numbers of bacteria by which samples are classified, an attributes plan of either type must specify the number of samples (n) required for a decision. In a two-class plan, the number (c) of unacceptable samples which can occur in a set of n samples without the product being rejected must be specified also. In a three-class plan, both the number (c_{m}) of marginally acceptable and the number (c_{M}) of unacceptable samples which can occur in a set of n samples without the product being rejected must be specified, although c_{M} is commonly set at zero.

When applied to the acceptance or rejection of batches, the number of samples specified for decision are usually small, often as few as five, because of practical consideration. The likelihood of accepting defective batches is consequently high (ICMSF, 1986). When applied for process evaluation, as in the USDA regulations, the number of samples used for decision can be much larger, because samples can be progressively collected from all the product emerging from a process over lengthy periods of time, if necessary. However, whatever the size of the set of samples used for decision about the acceptability or otherwise of a process, an attributes plan can do no more than group processes as acceptable or unacceptable. This broad grouping conceals the variability between the samples from a process.

The simplistic grouping of processes as acceptable or unacceptable militates against improvement of all but the very worst of processes, as there is no way of discriminating between the various performances of processes that are deemed acceptable. Moreover, if a process is deemed unacceptable, the attributes data can give no indication of the cause of failure despite the need for action to improve the process. Further, any evening of the distribution of bacteria as product proceeds along a process, as a result of mixing in operations such as grinding and blending, can reduce the fraction of, or even eliminate, unacceptable samples although the numbers of bacteria in the product remain the same (Kilsby and Pugh, 1981). Or, when numbers are low, reduction in the variability of the distribution of the bacteria may bring the numbers in all samples below the detection limit of the analytical method used, and so give the illusion that the product has been freed of the bacteria. Such spurious improvements of the microbiological condition of product can lead to gross misunderstanding of the microbiological effects of a process and the microbiological condition of the product.

It is therefore apparent that attributes sampling is not a suitable tool to use with HACCP systems. In contrast, variables sampling plans are compatible with HACCP systems, and the numerical data obtained can be used for statistical control purposes (Kilsby, 1982). Variables sampling schemes assume that the distribution of microorganisms in a food is predictable. In the case of raw meat, the log values of bacterial counts are assumed to have a normal distribution. Because of this, the statistics based on

the normal distribution may be used for data analysis and making decisions.

When product moving through or emerging from a process is sampled at random, the data can be used to estimate the mean ($\bar{x}$) and standard deviation (s) of the log values of the bacterial counts obtained at each stage of the process. From those statistics, the log of the arithmetic mean ($\log A$) can be calculated by application of the formula $\log A = \bar{x} + \log_n 10.s^2/2$ (Kilsby and Pugh, 1981). Those statistics can be used to establish whether or not the numbers or distributions of bacteria change as a result of the process, and actions to improve control can be directed towards the operations with the greatest microbiological effects (Gill and Jones, 1997). That is, control can be centered in Critical Control Points which have been identified objectively (Gill and McGinnis, 1999). Moreover, the variability of the contamination can be discerned from the sets of numerical data, which should prompt action to prevent the occasional production of heavily contaminated product (Smelt and Quadt, 1990). The prevention of sporadic, heavy contamination of product is necessary, as such product may well be the major risk to consumers' health.

When using variables data to decide whether the microbiological quality of the product from a process is acceptable or not, a Safety or Quality limit (V) for the log numbers, and the percent fraction (p) of the product in which V may be exceeded, but which can be tolerated in acceptable product, can be specified (Kilsby et al., 1979). The desired, lowest probability (P) of rejecting unacceptable product and the number of samples (n) to be collected for making a decision can be specified also. Then, for any specified values of p, P and n, a factor (k_1) can be calculated such that product is unacceptable in terms of the values set for V and p when $\bar{x} + k_1 s > V$. Tabulated values for k_1 are available in the literature (Kilsby et al., 1979). Thus, the desired degree of safety assurance can be established in the sampling plan. In addition, variables plans can be designed to handle censored values (Marks and Coleman, 1998). That is, to deal with results that are above or, more usually in microbiological sampling, below the detection limit of the analytical method.

Also, numerical data allow the ranking of process performances, so that Food Safety Objectives can be set by reference to the best performances, and product of superior microbiological quality can be selected by customers when they consider there is need for enhanced safety of the product they receive. In addition, regulatory authorities, customers or other parties would have the option of directly verifying that a process meets its documented performance standards by the collection and analysis of sets of samples from product leaving the process.

It is therefore desirable that microbiological criteria for raw beef production processes which are based on attribute sampling plans be abandoned, and replaced by criteria based on variables sampling plans; and that such plans are used to determine hygienic performances and the consistence of performances at CCPs within processes, as well as to evaluate the conditions of product leaving processes.

6. Conclusions

During January 1999, the American Meat Science Association organized a symposium for the discussion of the role of microbiological testing in beef food safety programs. The conclusions of the participants were that the main purpose of microbiological testing should be the implementation and maintenance of effective HACCP systems; that testing for indicator organisms is necessary for that purpose, with the microbiological performances of processes being assessed against appropriate Food Safety Objectives; that testing for pathogens would be of little or no use for HACCP purposes or the reliable detection of unsafe product; and that actions by the industry to enhance the safety of raw meat must be supplemented by proper handling of product during the preparation of meals (AMSA, 1999). However, much of the discussion centered on batch testing for pathogens and attributes sampling plans, rather than on matters relating to HACCP implementation. In view of that and the increasing uncertainty about the value of current testing (Bjerklie, 2000), further consideration of microbiological testing in relation to systems for assuring the safety of beef seemed desirable.

In the event, the conclusions of the group convened by the International Livestock Commission were broadly agreeable with, but in some respects extended the conclusions arrived at during the

AMSA symposium. The conclusions of the group were:

1. The purpose of microbiological testing in relation to the safety of beef is the implementation and maintenance of effective HACCP systems. In fact, the group considered that appropriate microbiological testing is essential if HACCP systems are to be effective, as demonstrably effective systems cannot be based on inspection procedures alone.
2. Microbiological testing for HACCP purposes must involve the enumeration of indicator organisms rather than the detection of pathogens. The group agreed on the inutility of testing for pathogens in procedures for implementing and maintaining HACCP systems.
3. The efficacy of process control should be assessed against appropriate performance criteria and Food Safety Objectives. However, whereas the conclusion from the AMSA symposium indicated that Food Safety Objectives should refer to pathogenic organisms, the group concluded that Food Safety Objectives should refer to the numbers of indicator organisms in product, to maintain the relationship between Food Safety Objectives and HACCP procedures.
4. Sampling procedures should allow indicator organisms to be enumerated at very low numbers. Then, Foods Safety Objectives comparable with microbiological standards for water or milk could be sought. Attainment of such objectives would serve to greatly mitigate the ill effects of mishandling during meal preparation, which can never be entirely avoided. Food Safety Objectives and other microbiological criteria should be related to appropriate variables sampling plans. The performances of HACCP systems should not be related to attributes sampling plans, as in current USDA requirements for microbiological sampling or as suggested in the symposium conclusions, because attributes plans are not suited to measuring the effectiveness and variability of process control systems.

The group considered that the recommended approach to microbiological testing will have to be adopted if efforts to improve the safety of beef are to be redirected, from actions that may often be only cosmetic, to ones that will progressively reduce the risks from the microbiological hazards associated with beef.

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