The Use of HACCP in the Production of Meat and Poultry Products

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ABSTRACT

Meat and poultry products frequently have been implicated in outbreaks of foodborne illness. The risk of foodborne illness can be reduced through implementation of the hazard analysis critical control point (HACCP) concept. The basic principles of HACCP described by the International Commission on Microbiological Specifications for Foods are briefly reviewed. Examples are presented to describe how these principles can be used to produce meat and poultry products with improved microbiological safety and quality. The future acceptance of HACCP will depend on the resolution of certain issues.

Meat and poultry products are significant factors in foodborne illness. Foods containing meat and poultry were implicated in 54% of all the reported outbreaks of foodborne illness in the U.S. between 1968 and 1977 (4). This was later reported to be 33% of all reported outbreaks between 1977 and 1984 (5). Improvements in the preparation and handling of meat and poultry products could result in significant reductions in foodborne illness. The hazard analysis critical control point (HACCP) concept provides a systematic approach to achieve this end. If the goal of reduced foodborne illness is to be achieved, it is necessary to identify the errors which are involved in food preparation. Table 1 summarizes the major errors in food preparation as reported from three regions of the world: England and Wales, United States, and New South Wales, Australia (3,6,8). It should be noted that the most common errors in each region involved some aspect of time-temperature control. Usually a combination of factors was involved. For example, preparing foods too far in advance was a factor in 21-61% of the outbreaks in the three regions. While preparing foods too early does not, in itself, cause foodborne illness; if the food is recontaminated or if spores survive and the food is held at an improper temperature, then the growth of foodborne pathogens can occur and illness can result. The information in Table 1 consists of data for outbreaks from all foods in each region; however, the same errors do occur in outbreaks in which meat and poultry are implicated. This information should be used to direct educational and regulatory efforts to prevent future outbreaks. Certainly, HACCP systems for meat and poultry products must consider time and temperature as the two major factors that must be controlled. The purpose of this paper is to describe the use of HACCP to improve the microbiological safety and quality of meat and poultry products.

PRINCIPLES OF HACCP

There has been considerable evolution in the definitions and principles since HACCP was proposed at the National Conference on Food Protection (2); however, to minimize confusion, one reference source on HACCP will be used to introduce the concept. Some of the basic components of HACCP which were recently described by the International Commission on Microbiological Specifications for Foods (ICMSF) are summarized in Table 2 (7).

Developing the HACCP plan

Each process and the conditions of processing are unique to each establishment. Although it is possible to generalize, as will be done later in the examples with flow diagrams, HACCP plans must be customized to the unique conditions existing within each establishment. Furthermore, the plans must be updated as future changes are made in the process or the establishment.

The HACCP plan should be developed by a team of individuals representing certain disciplines (e.g., engineering, quality assurance, production, microbiology, sanitation). The team should include local personnel from the establishment because they will be the most knowledgeable about the actual conditions which occur during processing (e.g., variability and limitations of the process). Other reasons for involving local personnel include: a) the...
Improper cooling
Inadequate cooking
Improper reheating

**TABLE 1.** Major errors contributing to foodborne disease in three regions of the world.

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<tr>
<td>Improper reheating</td>
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<td>12</td>
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<tr>
<td>Inadequate cooking</td>
<td>15</td>
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<tr>
<td>Preparation too far in advance of serving</td>
<td>61</td>
<td>21</td>
<td>40</td>
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<tr>
<td>Improper warm holding</td>
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<td>16</td>
<td>15</td>
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<tr>
<td>Storage at ambient temperature</td>
<td>40</td>
<td>46</td>
<td>43</td>
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<tr>
<td>Improper cooling</td>
<td>32</td>
<td>46</td>
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The number of outbreaks in each region was 1044 in England and Wales, 1152 in the United States, and 44 in New South Wales, Australia. There were multiple errors in most of the outbreaks.

**TABLE 2.** Some basic components of a HACCP system as outlined by ICMSF.

- A hazard analysis is performed and potential hazards are identified and prioritized according to severity and risk.
- Critical points in the operation which permit control of the hazards are identified.
- Criteria (e.g., time, temperature, pH) are specified that indicate whether an operation is under control at a particular CCP.
- Rapid tests are used to monitor whether the CCPs are under control. The sampling frequency is determined by the severity and risk of the hazard.
- Corrective action is taken when monitoring results indicate the operation is not under control.
- Verification tests are used to check that the overall HACCP system is working and that all hazards have been identified.
- Records are maintained and reviewed. Records include action taken when criteria have not been met.

The process of developing a HACCP plan is educational and this opportunity for educating local personnel in food safety should not be overlooked; b) there will be a sense of local ownership for the plan if plant personnel participate; c) the plan must be understood and implemented by local personnel after the “experts” leave; and d) someone, most likely a local person, should be responsible for ensuring that the HACCP plan is properly updated. A HACCP plan which is mandated by outside sources will likely be poorly conceived, erroneous, and/or incomplete, regardless of the expertise involved.

One individual should be assigned the responsibility that the completed HACCP plan will achieve its stated objectives. To be successful, it is essential that the team be provided with adequate resources and all pertinent information. There must be an open free exchange of information by all members of the team. It may be desirable or, perhaps, even necessary to obtain outside advice during the development of the plan or for a final review of the plan. The qualifications of an “expert” is a significant issue but will not be addressed in this paper.

**Hazard analysis**

The first step toward establishing a HACCP plan in a meat or poultry plant is for the team to conduct a hazard analysis. Hazard has been defined as “the unacceptable contamination, unacceptable growth and/or unacceptable survival by microorganisms of concern to safety or spoilage and/or the unacceptable production or persistence in foods of products of microbial metabolism (e.g., toxins, enzymes, biogenic amines)” (7).

The purpose of the hazard analysis is to identify potential problems which could occur in an operation. More than one hazard may be associated with a step in an operation. Each hazard must be considered and controlled established to minimize or prevent its occurrence. Examples of potential hazards which might be identified in a meat or poultry plant include: raw materials with a history of causing microbiological problems; sites of contamination in the process; and the potential for microorganisms to survive or multiply during production, storage, distribution, or use.

As a minimum, the hazard analysis should question the effect of the following upon the safety and quality of the product: (a) raw materials; (2) characteristics of the food during and after processing; (c) the procedures used for processing; (d) packaging; (e) conditions of distribution; and (f) how the product is used. The analysis of hazards must be quantitative if it is to be meaningful. This requires two assessments for each potential hazard, namely, severity (e.g., spoilage of a food vs. botulism) and risk (e.g., one chance in a million vs. every time).

**Critical control point**

After the hazards have been identified, then procedures must be established for their control. The definition for critical control point (CCP) is of practical importance to the meat and poultry processor and regulator because it defines the limits of what should be achieved when a HACCP program is established. Experience indicates that there can be considerable debate over which steps in a process are CCPs, how and how well the CCPs can be controlled, and the level of confidence that the hazards can be prevented when the CCPs are under control.

Since the introduction of HACCP, the definition for CCP has changed markedly. As originally stated, “the critical control point is a concept adopted by the panel to describe the location(s) or point(s) in a food processing operation at which failure to prevent contamination can be detected by laboratory tests with maximum assurance and efficiency” (2). This narrow definition focused upon preventing contamination, such as from salmonellae, and the use of laboratory tests to detect failures if they occur. This original definition for CCP was modified by ICMSF in 1980 to “a location or a process which, if not correctly controlled, could lead to contamination with unacceptable growth” (14). Attempts to apply this definition to the control of salmonellae in a wide variety of products and processes led to a revised definition (9).

The current ICMSF definition for a critical control point is “a location, practice, procedure or process at which
control can be exercised over one or more factors which, if controlled, could minimize or prevent a hazard" (7). This new definition states in positive terms the value of a CCP and limits CCPs only to those steps in a process where some degree of control is possible. This definition is particularly suitable for fresh meat and poultry as well as ready-to-eat products. In particular, the definition allows for and encourages the adoption of CCPs to minimize contamination with enteropathogens during the slaughtering processes and the subsequent handling of raw meat and poultry. The definition is realistic in its recognition that there is a gradient in the ability to control a hazard. The gradient ranges from partial control to absolute control of a hazard. This led ICMSF to propose two general classifications of CCP based upon the level of confidence that hazards can be prevented.

A CCP1 will assure control while a CCP2 will minimize but cannot assure the control of a hazard. Both types of CCP are important and both must be controlled. The net result of the effort applied to controlling a CCP1 should be a high level of confidence that the hazard has been prevented. In the case of a CCP2, the risk of the hazard can be minimized, but elimination of the hazard cannot be assured. Conversely, at a CCP2 the risk of the hazard can be significantly higher if no attempt is made to control the hazard. Thus, every reasonable effort must be made to exercise control. Of course, the degree of effort applied will be influenced by the severity of the hazard and the risk of its occurrence. In situations where the severity of the hazard is high (e.g., botulism) and the ability to control the hazard cannot be assured (i.e., CCP2), the conditions of the process either must be modified so that control can be assured or the process should not be used.

Tables 3 and 4 provide examples of CCP1 and CCP2, respectively, in the preparation of meat and poultry products.

A definition for the term, control, as applied to HACCP has not been suggested to date. In this text and as used in ICMSF Book 4, control means managing the conditions of an operation to maintain compliance with established criteria. Thus, an operation is under control when the established criteria are being met. Within the context of HACCP, the net result of control at a CCP is to minimize or prevent the risk of one or more hazards.

Criteria

Table 3 provides examples of criteria which are used for monitoring CCPs. If the criteria are met, the hazards will be prevented or eliminated. For example, the USDA has established minimum criteria for time and temperature when cooking roast beef (13). These criteria are based upon achieving a 7-log destruction of salmonellae in the coldest area of the roast. This does not include the additional thermal destruction associated with the rather long heating and cooling periods during the cooking process. Thus, the criteria for time and temperatures are very conservative, and there should be no risk of salmonellae survival if the criteria are met. Similarly, the USDA has established specific time-temperature criteria for holding raw pork to assure trichinae destruction (12). The risk of enterotoxin production during the fermentation step for dry sausage production can be prevented if recommended criteria for time, temperature, and pH are met (1).

All the criteria suggested in Table 3 permit timely measurements for determining whether each of the processes is under control. The examples suggest that the criteria associated with a CCP tend to be specific, quantifiable, supported by research or the technical literature, and provide a yes/no response. There is usually an established history that the criteria can be met reliably with existing technology and the hazards can be prevented. One test of the level of confidence might be that, if requested by a customer, a signed letter of guarantee that a certain hazard does not exist could be issued.

The criteria for CCP2 can be of the same nature as described for CCP1 above. However, the CCP may be designated a CCP2 because the procedures available can minimize but not prevent the hazard, or there may be an unreliable history of compliance with the established criteria. An example of the latter is whether perishable meat or poultry products will be maintained below 4.4 or 7.2°C during storage, distribution, display, and in the home.

The criteria for CCP2 can also be based upon whether certain established practices are being followed correctly. In most of the examples in Table 4, compliance is measured visually by a person knowledgeable in the established procedures. There may be a human element involved which...
raises questions of consistency and the training and performance of new employees. Criteria which are based upon following certain procedures tend to be less specific, less quantifiable, dependent upon human judgment for measurement, based upon experience as opposed to research, and provide a yes/no response, but with some reservation. Experience normally indicates a very high level of compliance. Caution should prevail when signing a letter of guarantee that a potential hazard does not exist or will not occur.

**Monitoring and verification**

A key element of the HACCP system is the use of rapid measurements to monitor whether established criteria are being met at each CCP. Examples of rapid measurements used in the meat and poultry industry include visual observations and measurements for fat, moisture, pH, time, temperature, humidity, and air pressure or vacuum. These and other measurements can be used to assess whether established criteria are being met at each CCP. Since the results become quickly available, the data can be used to make adjustments during processing and, thereby, maintain continuous control of the operation. Measurements which require too much time to allow adjustments while an operation is in progress are not suitable for monitoring. Such measurements, however, can be useful for verification.

Verification has been defined as the use of supplementary information to check whether the HACCP system is working (7). Examples of measurements used for verification include microbiological assays; official methods for fat, moisture, protein; and tests to check the final internal temperature of cooked products (e.g., coagulation test, catalase test).

The use of monitoring and verification will be described in the following example. Recontamination of cooked meat and poultry products is a potential hazard that must be controlled. Control of the cooked product environment is a CCP which depends on many factors including plant layout, equipment design, employee practices, procedures used for handling product between cooking and final packaging, and cleaning and sanitizing the equipment and environment. Although each of these factors is important, in this example the focus will be limited to equipment sanitation as a factor influencing product shelf life.

Table 5 lists examples of measurements that are applicable for monitoring and verifying that equipment is acceptably clean for handling cooked meat and poultry products. The three rapid measurements most commonly used to assess whether equipment is satisfactorily clean rely upon the human senses for visual appearance, aroma, and touch. These observations give a rapid assessment but provide only limited confidence that the equipment is, in fact, microbiologically acceptable. Thus, it is common in commercial processing facilities to conduct further analyses for verification purposes.

Several procedures are commonly used in the meat and poultry industry to verify that equipment has been properly cleaned and sanitized. The procedures include microbiological assays of samples from equipment (e.g., swabs), product from various stages of processing (i.e., flow sheet samples), finished product, and testing the keeping quality of the finished product (i.e., does the product meet the expected shelf life). Other sources of information which are useful for verification include reports of inspections by regulatory agencies and others, such as representatives from the corporate staff and information from the field on product shelf life. All of these procedures and sources of information provide useful data to verify that the monitoring results have been providing a valid measure of equipment sanitation.

**Records**

A HACCP program is not complete without adequate documentation. Records of results obtained during the monitoring of CCPs must be retained for some appropriate length of time. The results must include action taken when the established criteria have been exceeded. For example, it may have been necessary to reprocess product, destroy product, or alter the manner in which the product is labeled, distributed, and used (e.g., reduce the sell-by-date on the package, distribute frozen instead of refrigerated, ship to a processor who can use the product in a manner where the defect does not pose a hazard). The results obtained from verification tests also must be retained. Ideally, data obtained during monitoring and verification should be summarized and used to follow trends so that problems can be anticipated.

Regulatory agencies will play a significant role in the use of HACCP in meat and poultry plants. It will be necessary that certain records be made available to regulatory officials for their review. Agencies also should have some responsibility for reviewing HACCP plans to assess whether there are flaws in the plan relative to the consideration of hazards, CCPs, criteria, monitoring, verification, and rec-

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**TABLE 5. Measurements for evaluating whether equipment is hygienically acceptable.**

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<td>visual</td>
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<td>aroma</td>
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<th>Verification measurements:</th>
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<tr>
<td>Microbiological assays</td>
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<td>samples from equipment (e.g., swabs)</td>
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<td>flow sheet samples</td>
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<tr>
<td>analysis of finished product</td>
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<td>shelf life tests</td>
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<tr>
<td>Records and reports</td>
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<tr>
<td>reports from regulatory agency and corporate staff inspections</td>
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<td>information from the field on product shelf life</td>
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EXAMPLES OF THE USE OF HACCP IN THE MEAT AND POULTRY INDUSTRY

Flow diagrams can be very useful when developing a HACCP program to describe a process, identify sites of contamination, identify steps in the process where control can be exercised, and provide an estimate of the degree of control which can be expected. This helps management understand the process, including where the potential problems exist, and, depending upon their severity and risk, how to allocate resources to control the hazards. This information also can be used to help document a HACCP plan and facilitate inspections and the review of processes by regulatory personnel.

A few examples of the use of flow diagrams and application of HACCP to meat and poultry processing appear in Fig. 1–4. A detailed discussion for three of the flow diagrams (Fig. 1, 2, 4) appears in chapters 10 and 11 of ICMSF Book 4 (7). The discussion for Fig. 3 appears in a WHO-ICMSF report (9). Continuing with its desire to place HACCP on a more quantitative basis, ICMSF proposed two general categories according to the risk that contamination can occur. The terms, major and minor, were selected for this purpose and are used throughout Fig. 1–4.

Slaughtering process

In the first example, the slaughtering process for cattle, sheep, goats, and horses is described from the point of holding the live animals through chilling of the carcasses. The slaughtering process in Fig. 1 lists three CCPs, only one of which is a CCP1. The skinning and eviscerating steps are major sites of contamination and if these procedures are conducted in a correct manner, the degree of contamination can be reduced. The chilling process was assigned a CCP1 because this step is effective in restricting the growth of pathogens. At the time ICMSF Book 4 (7) was being developed, the significance of Listeria monocytogenes was uncertain. The risk for growth of L. monocytogenes during the chilling step remains unclear.

Roast beef

In Fig. 2, an example of a process for manufacturing roast beef is outlined. Five CCPs are listed where the control of hazards can be exercised. The cooking step is listed as a CCP1 because meeting certain minimum time-temperature requirements can assure the destruction of enteropathogens (e.g. salmonellae). In this example, chilling prevents the growth of surviving sporeformers, but the method of chilling in the example cited involves immersing the bags of cooked roast beef in cold water. This can result in contamination through openings where defective seals occur. The major site of contamination to the cooked product occurs when the bags are opened to drain away excessive meat juices and the bags are resealed or a new bag is applied. The general process outlined in Fig. 2 also is applicable to certain poultry products.

Dry sausage

In Fig. 3, an example of a process for producing fermented dry sausage is outlined. This example was developed to discuss the control of salmonellae in a WHO-ICMSF document (9). In that report, the destruction of salmonellae was reviewed in terms of the wide variety of products and processes used throughout the world. Within this context, the fermentation step was considered a CCP2 for the control of salmonellae. The technology currently exists for producing these products with a very high level of confidence that salmonellae will be destroyed. This technology includes applying appropriate controls over the formulation, fermentation, and drying steps in the process. In the course of applying this technology, traditional characteristics of some varieties of dry sausage might change.

As mentioned in the criteria section, multiplication and enterotoxin by Staphylococcus aureus can occur in uncontrolled fermentations for dry and semi-dry sausage production. This problem has been reported only in the United States where higher fermentation temperatures have been used more widely. Since this potential hazard can be prevented with a high level of confidence, a CCP1 can be
Figure 2. Flow diagram for production of roast beef.

Figure 3. Flow diagram for production of fermented sausage.

Figure 4. An example of a process for producing canned hams which are subsequently sliced and packaged as sliced ham. In this example, the cooking process was identified as the only CCP1. The time-temperature of heating assures the destruction of nonsporeforming pathogens and spoilage organisms. The degree of contamination occurring during the slicing and packaging steps strongly influences the ultimate rate of spoilage of the packaged product. The temperatures encountered during storing and distribution also influence the shelf life. Slicing, packaging, and storing/distributing are CCP2s because control can be exercised, but absolute control cannot be assured. Experience indicates that some contamination with spoilage flora will occur, and some degree of subsequent temperature abuse is likely. The rate of spoilage of the packaged product will be influenced by the degree of contamination and the temperatures that will be encountered. The process outlined in Fig. 4 is generally followed for producing many cooked, cured, and noncured poultry products. One difference is that poultry products are normally cooked in a casing or pouch rather than a metal container.

Adjusting conditions to reduce the risk of hazards

When manufacturers of ready-to-eat meat and poultry products perform a hazard analysis, five factors within their control should be considered for reducing the risk of microbiological hazards (Table 6). First, the processing procedure must be designed and controlled to eliminate hazards whenever possible. Second, the characteristics of a product should be modified to improve its microbial stability during processing and during subsequent storage, distribution, and use. Third, contamination must be prevented between the time when products are processed (e.g., cooked) and when they are packaged. Fourth, appropriate packaging design and labeling information should be used to instruct consumers in proper handling of the product (e.g., keep refrigerated). Fifth, a combination of as many factors as possible should be used (10). Examples of product characteristics (the second factor above) which can be modified to reduce the risk of microbiological hazards are listed in Table 7 (11).
The use of HACCP for Listeria control

At the present time, no greater microbiological issue faces the meat and poultry industry than that of the potential pathogen, L. monocytogenes. Table 8 summarizes ten factors which can help prevent contamination of cooked meat and poultry products with L. monocytogenes. HACCP can be an effective system to control Listeria. A lack of adequate technology and the prevalence and characteristics of L. monocytogenes combine to make it difficult to eliminate this potential pathogen from the cooked product environment of meat and poultry processing establishments. For the present, a realistic assessment is that the control of L. monocytogenes in the cooked product environment is a CCP2. This assessment and recognition of the potential severity of the hazard (i.e., listeriosis with a high rate of fatality among certain segments of the population) means that greater effort must be applied to minimize the risk of post-process contamination than has ever been applied, heretofore, in this industry.

Additional information for the control of Listeria during the production of ready-to-eat meat and poultry products is available through the American Meat Institute (P.O. Box 3556, Washington, DC 20007). The available information includes a written guideline for Listeria control, a video on equipment design, and a video for training employees in proper hygiene practices.

THE FUTURE ACCEPTANCE OF HACCP

The concept of HACCP is applicable to a wide variety of problems which we face in our daily lives. It is, after all, a common sense approach to preventing problems. In the case of food operations, technical knowledge is required to anticipate and prevent problems. The HACCP system requires the involvement of experts who must reduce technical information to a form that nontechnical persons can apply to their operation. HACCP is the best system currently available for improving the microbiological safety of food. It is not...
unexpected that HACCP is being embraced by various groups as a means to prevent foodborne illness. Will there be long term acceptance of HACCP or will HACCP be viewed as a fad and be rejected in the future? The following are some issues that must be considered.

- There continues to be a nonuniform understanding of HACCP both domestically and internationally. The intent of ICMSF Book 4 is to describe the HACCP concept and encourage its use to improve the microbiological safety and quality of foods. The definitions and principles evolved from extensive debate over a period of several years. Whether future efforts by others will result in documents which are in agreement with ICMSF Book 4 (7) remains to be seen.

- There is a misunderstanding or an unrealistic expectation that the application of HACCP will prevent all problems. This is, in part, due to a failure to recognize or accept the reality that only partial control of a hazard is possible at certain CCPs (i.e., CCP2). The current, revised ICMSF definition for CCP reflects this concern.

- The “expert” can be a weak link in the system. The fact that several experts will often provide different opinions raises questions of credibility and confidence in the overall system.

- Most outbreaks of foodborne illness are due to errors in homes and food service establishments. Can the HACCP concept be effectively incorporated into the educational process for food handlers in these situations?

- Will the acceptance of HACCP result in decreased foodborne illness? If not, will the failure be assigned to inadequacies of HACCP as a system for prevention or to improper implementation of HACCP.

- How much time will be required to train inspectors and industry personnel with one common understanding of HACCP? How long will it take to convert to a HACCP based control system, including the adoption of new HACCP based regulations? Will HACCP survive this transition period? Perhaps, the educational process and procedures for implementation should be subjected to HACCP to assure a smooth, timely transition.

- Can HACCP be incorporated into state and federal regulations? HACCP deals with the uniqueness of each operation, whereas, regulations tend to be generic in scope.

- Will HACCP be accepted by food inspectors and the public? Under a HACCP based control system, the focus and method of inspection will change from traditional methods. Inspections might be limited to certain aspects of a food process. Without a certain amount of freedom to inspect other areas, this can lead to a perception that HACCP results in reduced inspection and loss of regulatory control even though the intent of HACCP is just the opposite.

- The acceptance of HACCP requires some degree of mutual trust between the regulator and the regulated. Can this be resolved to the satisfaction of both parties and the public?

- HACCP requires that processors assume greater responsibility for assuring control, thus leaving regulators with a greater emphasis on verification. The impact of this change would be greatest in USDA inspected facilities.

- Verification is one aspect of HACCP. Thus, end-product testing is performed when appropriate. Producer-buyer and producer-regulator disagreements over end-product testing will not disappear with the adoption of HACCP. Differences of opinion will exist over the degree to which HACCP can replace the need for end-product testing. This will be an issue for foods in both domestic and international commerce.

- Even with the acceptance of HACCP, it is predicted that the historical debate over microbial criteria (numbers and types of microorganisms) will continue. The debate, however, will expand to include hazards, risks, CCPs, monitoring, and the ability to control at certain CCPs. Will this encourage or hinder the adoption of microbiological criteria?

- The application of HACCP to numerous nonsafety issues (e.g., net weight) can result in a complex system in which the focus on safety is lost. This dilutes the value of HACCP as a system for assuring the control of hazards that are of the greatest severity. This lack of focus increases the likelihood that limited resources will be diverted from controlling CCPs of greatest concern to safety. For this reason, some have proposed that HACCP be limited to safety issues. For example, a formal “HACCP Plan” might need to be developed as a regulatory requirement for assuring safety. Yet, the HACCP concept remains the best approach to assuring consistency and preventing major problems of all kinds (e.g., spoilage). HACCP is a powerful tool which should be used for preventing all problems where the potential hazards have a high degree of severity.

- Control systems continue to evolve. While HACCP is now being considered for adoption on a fairly wide scale, will a newer, better system be developed in the future? Is HACCP the system for beyond the year 2000?

REFERENCES


Korkeala et al., con't. from p. 794

Figure 1. The boundary of the maximum growth (38.4°C) of the Lactobacillus strain A210 (A) and the respective boundary (39.3°C) of its thermoresistant isolate (B). The thermoresistant isolate was obtained from the colony at 39.3°C marked by the arrow (A). The temperature gradient in both runs was the same.

strains except for strain A1. Strain A1 may be earlier selected to tolerate a higher temperature. The greatest increase in maximum growth temperature was found for strain C1, whose thermoresistant isolate was able to grow at a temperature 4.2°C higher than the parent strain.

According to the present results, the maximum growth temperature of lactobacilli seems not to be a stable character. The same was also found by Ståhl and Olsson (8), who have reported facultatively and obligatorily thermophilic variants in mesophilic Bacillus megaterium strains. However, the significance of this interesting phenomenon is not known and needs further study.

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REFERENCES


