The Process Hygiene Index (PHI) in Meat Processing

This Bulletin gives an overview of how the Process Hygiene Index (PHI), an application of predictive microbiology, can be used to improve confidence in the safety of meat.

INTRODUCTION

Consumers expect food to be safe to eat. An incidence of food-borne disease, especially when publicized by the press, can result in a loss of consumer confidence. Such confidence can be difficult to regain.

Microbes and Meat

Meat at slaughter is sterile. Thus it should, in theory, be possible to prepare safe meat by preventing disease-causing organisms from contaminating meat during processing and storage. In reality, this does not happen because intensive handling procedures are used to produce meat products.

Pathogenic organisms can be found everywhere in the environment. For example, they may be on workers' skin and clothes, on animal hides and fleeces, in water and on machinery. Therefore, the best way to ensure meat safety is to prevent contaminating organisms from developing to levels that can cause disease.

Bacterial Growth

Bacteria grow and multiply on the meat surface at a rate determined by the organisms' physiology. Important factors that help determine the rate of growth on fresh meat are the availability of water and nutrients, and the temperature. Fresh meat provides a moist and nutritious environment for bacteria, so growth can be controlled by drying (reducing the availability of water) and/or cooling the meat.

Temperature tends to be the most important factor used to control the growth of both pathogenic organisms and spoilage organisms on fresh meat. This is because it is difficult to ensure that all contaminated surfaces of a nonuniform product like a carcass will dry enough to prevent growth.

Generally speaking, bacteria grow faster as the temperature rises, and the faster they grow, the sooner they can reach numbers that can result in disease or spoilage. For example, a food poisoning bacterium such as *Salmonella* can reproduce about 20 times faster at 35°C than at 10°C.

Thus, the use of hygienic processing techniques to minimise initial bacterial numbers, then cooling meat quickly and maintaining low storage temperatures, will maximise food safety and storage potential.

To have confidence in the product, the effectiveness of these "control" techniques needs to be measured. This can be done by manually counting bacteria at the end of a process and comparing the numbers with counts taken at the start of the process. This procedure will tell you the overall bacterial growth during the process and whether final numbers are too high to be safe. However, manual counting methods are slow and are not particularly precise when samples are taken from products that have a variable covering of bacteria (e.g. carcasses). As well, this method does not assess how much the contaminating bacteria grow during each processing step, so it tells nothing about how each step might be contributing to the overall microbial load on the meat.

An alternative method is to use predictive microbiology in the form of the Process Hygiene Index (PHI). This method is being used more and more by industry today.

WHAT IS PHI

The PHI method allows us to assess the potential growth of a microbial indicator organism, in this case *Escherichia coli*, during each step in a process. The PHI is a numerical value, calculated from temperature data of a product in a process and a model for *E. coli* growth at various temperatures. The organism *E. coli* was chosen because its time-temperature growth pattern is similar to that of *Salmonella* and other mesophilic pathogens. The temperature history is taken with a probe and electronic datalogger.

The higher the PHI value, the greater the potential of the process being evaluated to allow the growth of *E. coli* (and therefore of mesophilic pathogens). For example, a PHI of 0 indicates no potential for growth, whereas a PHI of 10 indicates a potential for 10 generations of growth (i.e. an *E. coli* cell has the potential to divide 10 times).

PHI starts at zero and has no upper limit. The higher the PHI, the higher the risk that contaminating pathogens, if present, can grow to dangerous levels.

For each process being evaluated, PHI-based guidelines can be referred to, to indicate if the PHI value calculated indicates that the process is hygienically acceptable.

GUIDELINES

Each process has a PHI level above which growth potential is too high for safety. There is no absolute level. For each process, the maximum acceptable PHI is determined by the likely level of contamination at the start of the process and the probability of pathogen growth after the process. For example, three-class sampling plans have been developed for lamb processing, beef processing, general carcass cooling and offal processing.

HOW IS A PROCESS EVALUATED?

- The process to be evaluated is defined.
- A product temperature history is collected for the process.
- The temperature history is converted into a PHI value.
- The PHI value is checked against standards and guidelines.

DEFINE THE PROCESS

For PHI to be useful, we need to know where the first opportunity is for bacterial contamination of the product and the point at which mesophilic pathogen growth is no longer a risk (i.e., the point at which the product temperature falls below 7°C). A good way to do this is by using a flow diagram to describe the process. This can form part of an overall HACCP programme. (See MIRINZ bulletin No. 40 for a discussion of HACCP.) Below is an example of a flow diagram for a process that produces vacuum-packaged legs from lamb carcasses.

The process may be one-phase or two-phase. Two-phase processes include a boning operation. For example, carcass cooling is a one-phase operation, whereas carcass cooling followed by boning and vacuum packaging of legs, such as in the example below, is a two-phase operation. In two-phase operations, the first phase contains a risk of aerobic pathogen growth; the second phase can involve either aerobic growth (e.g., unwrapped cuts) or anaerobic growth (e.g. vacuum packaged cuts).

When a process involves an aerobic phase followed by an anaerobic phase, there will be a short lag period between the phases while the bacterial cells adjust their metabolism.

COLLECT A TEMPERATURE HISTORY

An electronic data logger is used to obtain a produ temperature history for the process. Before use, the logger is set up using MIRINZ DLOG or AP1 software. AP1 software is better for two-phase processes because it allows these processes to be identified and processed more easily.

At the moment, two makes of logger can be conveniently used with PHI software. These are the Delphi logger (uses MIRINZ DLOG and AP1 software) and the SAPAC logger (uses DLOG built into SAPAC software).

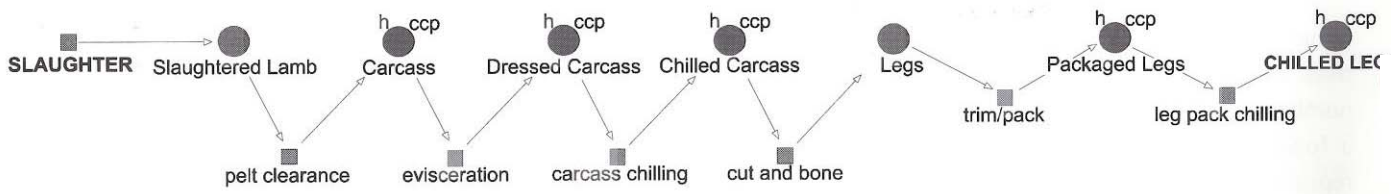
To evaluate the hygienic acceptability of a process, the worst-case is examined. If the worst case is hygienically acceptable, then all variations will also be acceptable.

To collect worst-case data, the datalogger measures the temperature of the slowest cooling site on the product that is also susceptible to bacterial contamination. This gives a picture of a process's maximum potential to allow microbial growth.

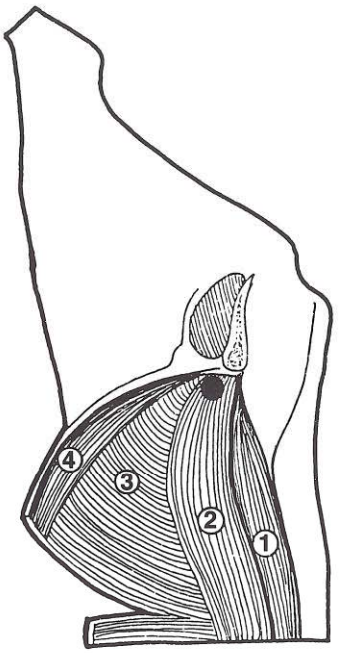
For example, for beef side cooling, the temperature history is collected at a site adjacent to the aitch-bone pocket, whic is the slowest cooling surface site. For carcass cooling, suc as cooling of lamb carcasses, temperature is measured within the body cavity as a site adjacent to the 5th lumbar vertebra. (Deep tissues, which cool more slowly than surface tissues, are not monitored for PHI, because intact deep tissue from healthy animals is sterile at slaughter, and therefore there is no potential for microbial growth.)

The monitored unit (side or carcass) is positioned at the warmest site within the chiller, or if this is not known, a number of units are monitored, representing a cross-section of the chiller load.

In a two-phase process, the probe is removed from the carcass at boning and placed next to packaged product at the thermal centre of a carton, which will be the slowest cooling site in the carton.



HACCP flow diagram for the production of chilled lamb legs.



The aitch-bone pocket (dark circle), the site used to record the temperature history of the slowest cooling surface site for beef sides. 1 psoas minor muscle; 2 psoas major muscle, 3 external oblique muscle, 4 straight abdominal muscle.

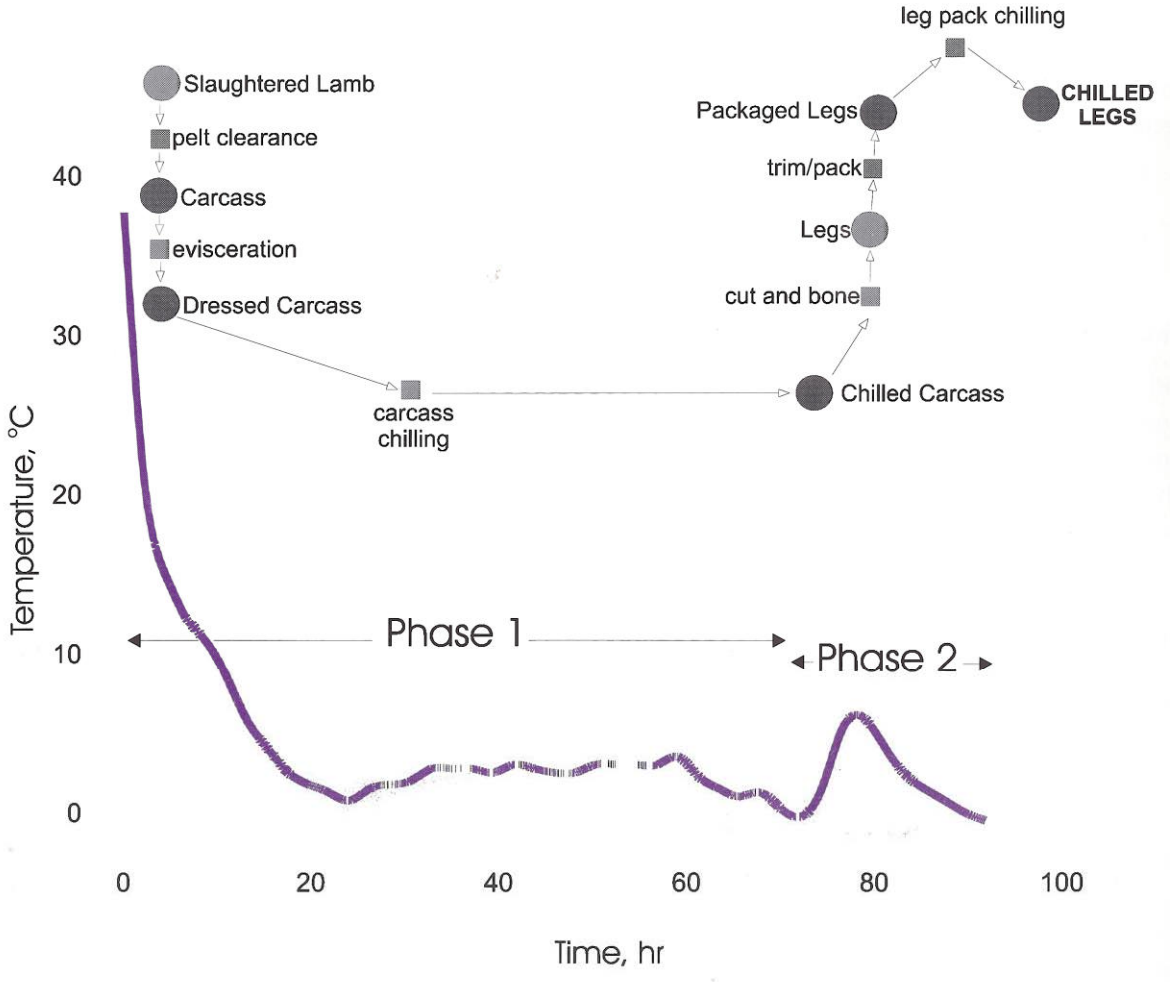
Thus, whatever the process, the warmest part of the product that is susceptible to microbial contamination is the site that must be monitored.

CONVERT THE TEMPERATURE HISTORY INTO A PHI VALUE

The temperature data are down-loaded from the logger to a personal computer. The figure below shows just such a temperature trace for a two-stage operation. Superimposed above this trace are the HACCP steps for the same process. These steps are not drawn by the software, and have been included simply for comparative purposes.

If DLOG software is used, the PC produces a temperature trace. The user then identifies the start and end of the process (on the trace), after which the software calculates two PHI values - one for an anaerobic process the other for an aerobic one. The user considers the process and decides which of the two types of PHI value is appropriate.

If AP1 software is used, the computer will 'know' what process is being evaluated (i.e., one-phase, two-phase aerobic, two-



Temperature trace for a two-stage operation, with the HACCP steps for the operation shown at the top, for comparison.

phase anaerobic), because the user defines the process when the logger is set up. The user identifies the start and finish time for each phase and the computer produces a PHI for the whole process.

With either software, PHI values can be calculated for parts of a process by redefining the start and end of the process and recalculating the PHI.

CHECK PHI VALUES AGAINST STANDARDS AND GUIDELINES

The PHI produced for any process is checked against criteria developed for that process. PHI criteria may be determined 'in-house' or may be part of a standard produced by a regulatory body.

With in-house criteria, the guidelines are established according to the processor's knowledge and requirements of the process. An existing standard, for a similar product, could be used for developing in-house criteria.

In-house criteria can be set for a variety of commercial reasons, whereas regulatory criteria are set to ensure food safety.

USES FOR PHI

In addition to establishing if a process has a potential for *E. coli* proliferation that is within certain guidelines, the PHI technique can be used for:

- comparing processes (e.g. chiller runs)
- assessing the effect of process modifications on microbial growth potential
- HACCP applications

INAPPROPRIATE APPLICATIONS OF PHI

PHI is not a method to calculate actual bacterial growth on product. A PHI value reflects the **maximum potential** for a process to allow the growth of *E. coli* and similar organisms. There may be reasons why actual *E. coli* growth is lower. For example, some product may have a pH unfavourable for maximum growth, other product may dry sufficiently to retard growth. Also, with hygienic processing, most product within the process is not likely to be contaminated with *E. coli*.

SUMMARY

PHI assesses the hygienic performance of a process, by indicating that processes' potential to allow the growth of a typical mesophilic pathogen. It does not predict the actual growth that may occur on the monitored product.

PHI values are calculated for the worst-case. The product temperature history used to calculate the PHI is collected at the warmest place on product likely to carry microbial contamination.

To assess the hygienic efficiency of a process, the PHI val calculated can be compared to guidelines, developed either in-house or by regulatory authorities.

FURTHER READING

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