Process Hygiene Index

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Introduction

The following text is based on a document supplied by The Meat Research Institute of New Zealand. It describes how to apply the PHI values calculated by Temprecord.

Microbes and meat

Meat at slaughter is sterile (Gill, 1979). Microbes that can cause food poisoning and/or spoilage begin their activities after contaminating the exposed surfaces of meat. A typical organism often found associated with meat is Escherichia coli. This organism is an important pathogen. It also has growth characteristics that are similar to other mesophilic pathogens (viz. organisms that grow well in warm environments) such as the salmonellae. Measuring the ability for E. coli to grow on meat is therefore a useful indication of the potential for mesophilic pathogens to grow generally.

Bacterial growth

Bacteria grow and multiply on the meat surface at a rate determined by physiological capacity and the availability of water, space and nutrients. Fresh meat provides a moist and nutritious environment for bacteria to grow on. This means that bacterial growth will be effectively limited only by the cells physiology. Having said this, meat surface drying is sometimes used to control growth. However, it is difficult to prove effective application of drying on a non-uniform product such as fresh meat.

Furthermore, the effect of drying is difficult to quantify. It should be assumed then, unless proven otherwise, that there will always be areas on the surface of meat that can allow unrestricted growth of bacteria. Control is then best effected by manipulating the physiological growth capacity of the organisms. This is best done using temperature.

Generally speaking, bacteria grow faster as the temperature rises. The faster they grow, the faster they can reach numbers that can result in disease or spoilage. Thus, by minimizing initial bacterial numbers (using hygienic processing techniques), cooling meat quickly, and maintaining low storage temperatures food safety and storage potential will be maximized. To have confidence in the product such techniques need to be ‘measured’. Initial bacterial numbers can be minimized by good manufacturing practice and assessed by classical microbiological techniques. The ability for the bacteria to grow during processing can be assessed by re-assaying meat at the process end. This is, however, a slow process and does not give an indication as to how each processing step contributes to the overall microbial bio-load. An alternative method uses predictive microbiology in the form of the Process Hygiene Index (PHI).

The Process Hygiene Index

PHI is a means of assessing the potential growth of a microbial indicator organism during a process. The PHI is a numerical value that is equivalent to the growth of a microbial indicator organism (E. coli) over a process temperature history collected by an electronic data-logger. The higher the index value, the greater the potential for E. coli growth. For example, an index of 0 (zero) indicates no growth potential, 10 indicates a potential for 10 generations of growth (i.e. an E. coli cell has the potential to reproduce 10 times).

EXAMPLE

Bacterial Growth Statistics

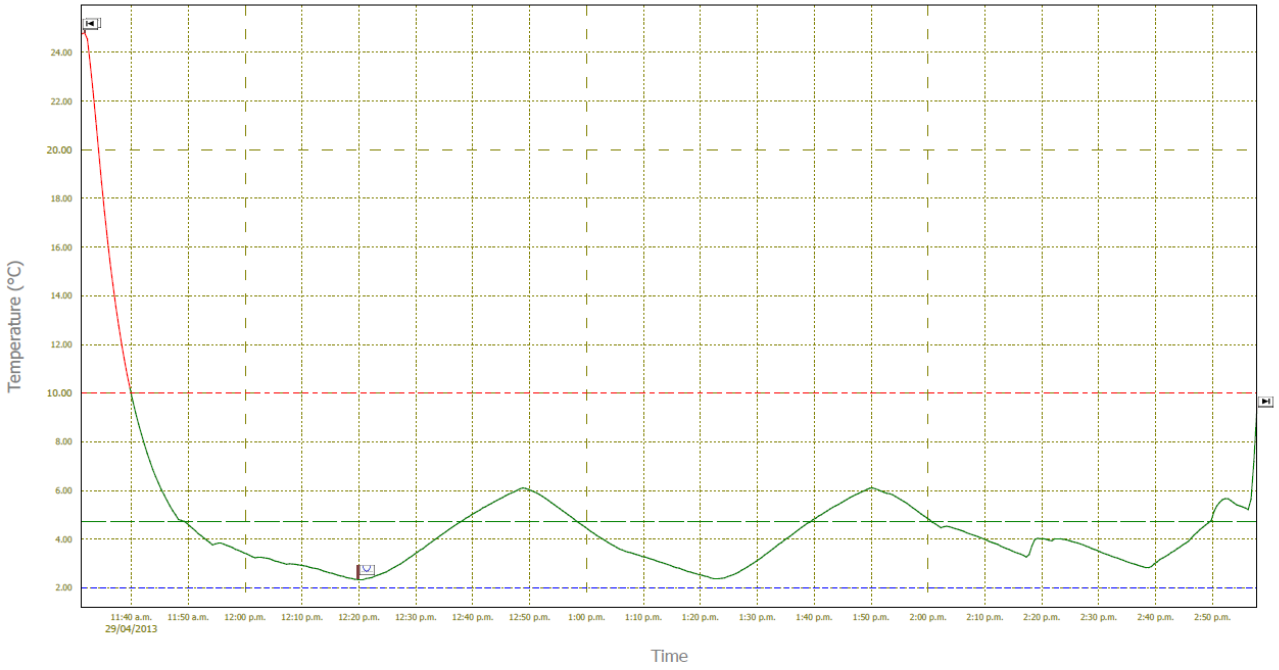
The following growth statistics pertain to the data between the start and end markers (samples 1 through 414). The results are from methods supplied by the Meat Industry Research Institute of New Zealand (MIRINZ). These growth statistics are a guide only and do not represent any actual measured growth.

Start Marker is at sample	1	(Monday, 29 April 2013 11:31:16 a.m., 24.76 °C)
End Marker is at sample	414	(Monday, 29 April 2013 2:57:46 p.m., 9.24 °C)
Anaerobic Growth	0.1 generations	
Aerobic Growth	0.1 generations	
Anaerobic Growth with Lag	0.0 generations	
Aerobic Growth with lag	0.0 generations	

Graph

Serial Number
User Data 1
User Data 2
User Data 3
User Data 4
User Data 5

S0063487
Sample Report - Ambient to fridge temp



The probe

A special probe is manufactured for use in PHI applications. The logger probe is tapered and composed of Teflon. This allows easy insertion and retrieval from product (especially after freezing when other materials may stick). Teflon also is a poor conductor of heat so the probe tip, which contains the sensor, will allow a faithful measurement of the local temperature.

Positioning the probe

The probe is positioned to measure temperature at a site that reflects the process's greatest ability to allow bacterial growth. This means that the logger's probe must be attached to the warmest meat surface site (where bacterial contamination occurs) and the monitored meat must follow the process through its warmest path. Deep tissue temperature, whilst warmer than the surface during the initial carcass cooling phase, is NOT used because deep tissue is sterile and bacterial growth does not therefore need to be considered. If the warmest path is not known, or is variable, a number of samples (e.g. carcasses) are monitored that are representative of the load. For a carcass the slowest cooling site is adjacent to the aitch-bone pocket (bovine) or within the cavity adjacent to the 5th and 6th lumbar vertebrae (ovine). After cold boning, the probe should be placed on the surface of a small cut, which has the ability to re-heat at the fastest rate. After warm/hot boning a large cut is used because it will cool the slowest. After packaging (including offals) the probe is placed at the thermal centre of the load (e.g. between two cuts at the centre of a box in the centre of the load). Further specifications can be tailored for your own process or obtained from the appropriate regulatory literature.

Types of processes

Before calculating a PHI process an operator must decide what type of process they have monitored. This involves two considerations. Firstly, is the process one or two-phase? Secondly, is the process aerobic, anaerobic, or a mixture of the two?

One-phase or Two-phase?

Processes such as carcass cooling and offal cooling are termed 'single phase' processes because they are composed of a single cooling period containing no periods where product is handled requiring removal of the temperature logger. A temperature history is collected simply by attachment of the probe to the slowest cooling site. For surface sites, the probe is inserted into a stainless-steel disc which is then pinned to the meat surface using a non-heat conducting (i.e. Teflon®) staple. The logger should be placed with the product as soon as possible. There may be regulatory requirements relating to your process describing when and where probes are placed. For carcass cooling, the surface temperature should be above 25° C at the beginning of the process and below 7° C at the end (which is the minimum temperature for E. coli growth). At the end of the process the logger is interrogated and a PHI produced. Note that 2 models of disc are available - one for beef and one for mutton.

Temprecord expresses PHI values both with and without lag. This lag refers to the period of time that bacteria need to adjust to a new environment before they can start to grow. For use with fresh meat processing DO NOT USE VALUES EXPRESSED AS 'WITH LAG'. This is because bacteria that contaminate meat are considered to have resolved their lag phase by the time process monitoring is commenced.

When a single-phase process is followed by a second operation the overall process is termed 'two-phase'. An example is where a carcass is cooled (first phase), boned and the packaged cuts chilled (second phase). During this operation the temperature logger is used to measure the first phase as described for the single-phase operation. The logger is then removed for the boning operation and then placed with the packaged product to continue the monitoring process. There may be a regulatory limit on the maximum length of time the logger can be absent from the product between the phases (e.g. one hour for carcass/cuts assessment). The PHI value for a two-phase process can be calculated as follows:

Remember that you must have the Statistics option 'Show Growth Statistics' checked in order for Temprecord to display PHI statistics.

Uses for PHI

In addition to establishing if a process allows 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 allowing microbial growth.
- HACCP (Hazards Analysis Critical Control Points) 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 unfavorable for maximum growth, some product may dry sufficiently to retard growth, while other product within the process may not be contaminated with E. coli.

Further Information

Remember that you must have the Statistics option 'Show Growth Statistics' checked in order for Temprecord to display PHI statistics.

1. In Graph View, mark the start and end of the first phase of cooling. You can do this quickly by positioning the sample cursor at the start of the first phase of cooling and pressing F7. Then position the cursor at the end of the first phase of cooling and press F8.
2. Switch to Statistics View. Temprecord will then show a value for the PHI for the first phase. The expressed PHI will either be for aerobic growth (e.g. carcass cooling) or anaerobic growth (e.g. offal cooling- although this will be a one-phase process only).
3. Repeat step 1. for the second phase of cooling.
4. Repeat step 2. for the second phase. The PHI will be either for anaerobic growth (e.g. warm-boned bulk packed meat or vacuum packaged cuts) or aerobic growth (e.g. unwrapped cuts).
5. Manually calculate the potential for aerobic growth during the inter-phase period. This is done by firstly choosing the maximum temperature occurring at either the end of the first phase or the start of the second phase and then calculating the amount of potential aerobic growth for the inter-phase period using the following formula, used by the PHI software algorithm and presented in the paper of Reichel et. al. (1991).

   Y = (0.0513x - 0.17)2, when x is between 7 and 30°C

   Y = (0.027x + 0.55)2, when x is between 30 and 40°C

   Y = 2.66, when x is between 40 and 47°C and

   Y = 0 when x is <7°C or >47°C

Example:

If the first phase ends at 7° C and the second phase starts 0.75 hr later at 12° C, you need to

calculate 0.75 hours aerobic growth at 12° C.

((0.0513 x 12) -0.17)2 = 0.2 generations potential growth per hour.

The inter-phase PHI is therefore 0.75 x 0.2 = 0.15

6. The three PHI values (first phase, second phase and inter-phase) are then added together to give a process PHI.

7. For two-phase processes that contain an aerobic first phase followed by an anaerobic second phase, results that are marginally (e.g. within 0.2 generation) above specified upper limits for the process, can be recalculated taking into consideration the short aerobic-to-anaerobic lag period during which cells cease to grow while converting their metabolisms to anaerobic respiration. This method is described in Reichel et al. It is a tedious process to accomplish manually and may not significantly influence your result - however it is an option for those operators who want to keep their results faithful with those generated by MIRINZ AP1 software (presently incompatible with Temprecord loggers). A future release of Temprecord will produce a PHI value for a two-phase process and will calculate the lag automatically.

Further Notes (provided by MIRINZ - the Meat Industry Research Institute of New Zealand)
Growth of micro organisms is measured in the number of times they multiply. If they stop multiplying, then they are considered to have stopped growing. If the part of the product where any E.coli are located is below 7degC they will stop growing/multiplying. A PHI of 3.5 doesn't mean 3.5 Log per hour; it means 3.5 generations/hour. A generation is a doubling, a Log is a factor of ten. So starting with one cell, a generation of growth will give us 2 cells, whereas a Log growth will give us 10 cells.

The PHI only tells you the number of generations of growth that would occur if the product is at that temperature for one hour. If the temp is changing with time then you have to work out the number of generations of growth in separate time steps. For example, the first hour is 37degC so the PHI might be 6 generations / hr for that hour, the second hour at 35degC so the PHI = 4.8 generations / hr for that hour. If we add the two hours of growth together, we get 10.8 generations (these PHI figures are just made up).

We can extend this to minutes too: If at 37degC for 1 minute gives PHI of 6 generations / hr then must be (6/60) = 0.1 generations / minute, then at 35degC for 1 minute gives PHI of 4.8 generations / hr then must be (4.8/60) = 0.08 generations / minute. Hence in the two minutes we have 0.18 generations of growth.

To convert generations to a straight multiplication factor, just multiply by 2 to the power of the number of generations.

For example, 10 generations = 2 to the power of 10 = 1024. So the number of microorganisms has increased by a factor of 1024. You can see that this is about the same as 3 Logs, 10 to the power of 3 = 1000.

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The Future

MIRINZ and Temprecord International Ltd. are continuing to develop and improve software and hardware for extending the scope of the PHI. In addition to pursuing this application of predictive microbiology for food safety, they are also working on a similar application for predicting the growth of spoilage organisms. This will allow processors to monitor and optimize storage processes to minimize the growth of spoilage organisms and thus maximize the storage life of chilled products.

References/Further reading

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