The Growth Model

Introduction

The growth model estimates the potential growth of mesophilic (cold intolerant) bacteria from a meat cooling process, from the end of slaughter and dressing (post mortem examination point) until the meat temperature falls below 7°C.

The growth model was derived from experiments looking at the growth of meat-processing related *Escherichia coli* (*E. coli*) strains in a broth matrix at different constant temperatures (Reichel et al: 1991, Lowry et al: 1989, Gill:1984). *E. coli* was chosen as it was considered to have similar growth characteristics as other mesophilic bacteria.

The potential growth is calculated by splitting the cooling process into a number of distinct time periods, calculating the number of generations of cell growth for each time period and then summing the number of generations over all the time periods to calculate the generations of growth for the whole cooling process. For time periods monitored with a temperature logger, processors typically use time periods of 2 minutes or less.

The PHI value is then determined by converting the generations of growth into the index value.

Growth Models: Cell Growth

The PHI growth models are functions of time, temperature (**T**) and the presence of oxygen (Kemp *et al*. 2009).

The generations of cell growth per hour (**G**) for **aerobic growth** (Figure 1) is given by:

$G = (0.0513T - 0.17)^2$	when **T** is between 7 and 30°C
$G = (0.027T + 0.55)^2$	when **T** is between 30 and 40°C
$G = 2.66$	when **T** is between 40 and 47°C
$G = 0$	when **T** is less than 7°C or above 47°C

Generations per hour for **anaerobic growth**, which is likely to occur once a product is vacuum-packed or bulk packed into cartons (Figure 1) is given by:

$G = (0.0433T - 0.15)^2$	when **T** is between 7 and 30.5°C
$G = (0.0163T + 0.676)^2$	when **T** is between 30.5 and 40°C
$G = 1.77$	when **T** is between 40 and 45°C
$G = 0$	when **T** is less than 7°C or above 45°C

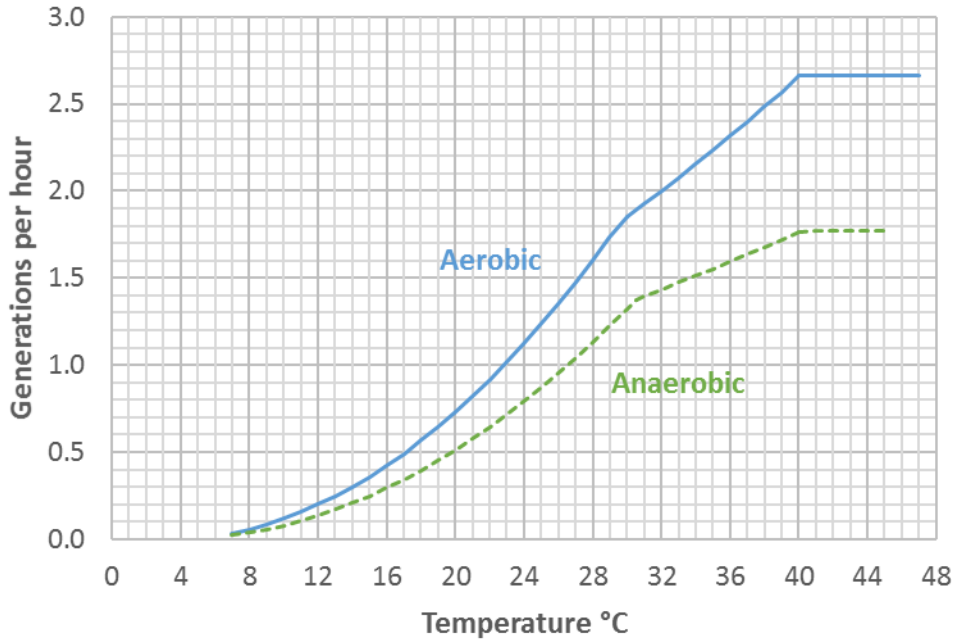

Figure 1: PHI *E. coli* growth models

Initial lag phase of growth

The transition of the *E. coli* cells to the meat surface during dressing of the carcass, may cause a temporary period of no cell growth (lag phase in growth). In the model, this period of time following dressing where no cell growth occurs is set to 30 minutes. This is equivalent to approximately one generation of cell growth.

This lag phase duration was derived from experiments using freshly slaughtered meat undergoing a typical meat cooling profile (Mills 2019), as well as meat experiments from the literature (Dickson 1992, Ingham 2007, Smith 1985). An example of the supporting experimental data is shown in

Figure 2 and a summary of literature information can be found in Pattis (2017).

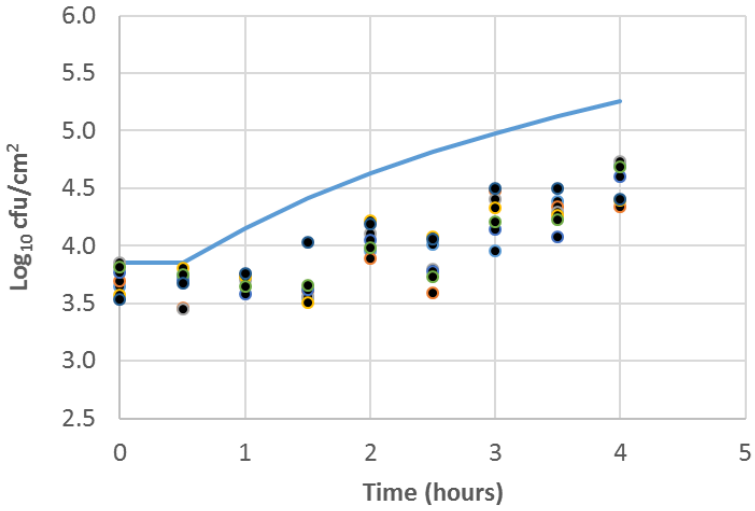

Figure 2: Comparison of experimental *E. coli* growth (black dots) with the predicted generations of growth from the experimental time-temperature profile (blue line). The predictions include a lag phase of 30 minutes.

Duration of aerobic to anaerobic lag phase

The transition from an aerobic to an anaerobic state may also induce a temporary period of no cell growth (lag phase). The lag time as given by Reichel et al. (1991) is given in Table 1 or can be calculated from:

Lag = exp(4.17 – 0.245**T**) hours, when temperature **T** is between 7 and 25°C[1].

At temperatures below 7°C there is no growth and above 25°C the lag time is considered too short to consider.

Table 1: Aerobic to anaerobic lag time for growth (Adapted from Reichel et al. 1991)

T (°C)	8	12	15	17	19	21	22	23	24	25
Lag (h)	11	3.4	1.7	0.9	0.6	0.4	0.3	0.2	0.2	0.1

[1] An exponent (exp) is the inverse of the natural log (Ln).

Calculating the Process Hygiene Index

For each cooling time-temperature profile, the growth model estimates the potential growth of mesophilic (cold intolerant) bacteria from the end of slaughter and dressing (post mortem examination point) until the meat temperature falls below 7°C.

To convert the potential growth to an index value, a scaling factor of $\frac{1}{14}$ is applied. This scaling factor was chosen to normalise the growth model output, such that the performance criteria maximum value is equal to 1.

References

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