The Refrigeration Index Calculator
Explanatory Notes

The Predictive Model

The predictive model used in this calculator was developed by Dr Tom Ross and colleagues at the University of Tasmania. The model has been published:

> Ross, T., Ratkowsky, D. A., Mellefont, L. A. and T.A. McMeekin, T. A. (2003) Modelling the effects of temperature, water activity, pH and lactic acid concentration on the growth rate of Escherichia coli. Int.J.Food Microbiol. 82:33-44.

An evaluation of the model against data in the literature has also been published:

> Mellefont, L.A., McMeekin, T.A. and Ross, T. (2003) Performance evaluation of a model describing the effects of temperature, water activity, pH and lactic acid concentration on the growth of Escherichia coli. Int.J.Food Microbiol. 82:45-58.

The use of these models in hot boning applications and validation data has been described in an MLA publication that accompanies the Hot Boning Index Calculator CD ROM:

> Meat & Livestock Australia (2004) Validation of the chilling of hot boned manufacturing meat and primals. PRMS.020

Validation data for offals is described in an MLA publication titled:

> Meat and Livestock Australia (2006) Investigation of Microbiological growth on offal during cooling. PRMS.073e

The predictive equation follows:

$$\sqrt{r} = c \bullet (T-T_{min}) \bullet (1-\exp(d \bullet (T-T_{max}))) \bullet \sqrt{(a_w-a_{wmin})} \bullet \sqrt{(1-10^{(pHmin-pH)})} \bullet \sqrt{(1-10^{(pH-pHmax)})} \bullet \sqrt{(1-[LAC]/(U_{min} \bullet (1+10^{(pH-pKa)})))} \bullet \sqrt{(1-[LAC]/(D_{min} \bullet (1+10^{(pKa-pH)})))} \pm e$$

Where:

r = relative growth rate or specific growth rate (time-1)
c, d and **g** = fitted parameters
$\mathbf{a_w}$ = water activity
$\mathbf{a_{wmin}}$ = theoretical minimum water activity below which growth is not possible
T = temperature,
$\mathbf{T_{min}}$ = theoretical minimum temperature below which growth is not possible
$\mathbf{T_{max}}$ = theoretical maximum temperature beyond which growth is not possible
pH has its usual meaning
$\mathbf{pH_{min}}$ = theoretical minimum pH below which growth is not possible
$\mathbf{pH_{max}}$ = theoretical maximum pH beyond which growth is not possible
[LAC] = lactic acid concentration (mM)
$\mathbf{U_{min}}$ = minimum concentration (mM) of undissociated lactic acid which prevents growth when all other factors are optimal
$\mathbf{D_{min}}$ = minimum concentration (mM) of dissociated lactic acid which prevents growth when all other factors are optimal
pKa is the pH for which concentrations of undissociated and dissociated lactic acid are equal, reported to be 3.86
e = error

The values of the constants are:

Parameter	Estimate
C	0.2345
T_{min}	4.14
T_{max}	49.55
pH_{min}	3.909
pH_{max}	8.860
U_{min}	10.43
D_{min}	995.5
aw_{min}	0.9508
d	0.2636
Root Mean Square Error (RMSE) in $\sqrt{(1/(GT\ [h]))}$	0.0054

Model parameters for each product type

The RI Calculator allows the selection of a number of products. The parameters associated with each product types are indicated in the table below:

	pH	Lactate(mM)	aw
Carcase	6.5	51.7	0.993
Boxed trim	6.5	51.7	0.993
Lean Primal	5.4	86.5	0.993
Fat Primal	6.8	0	0.990
Offal	6.8	25	0.995
Mechanically separated meat	6.8	51	0.995

Lag phase

A lag phase may occur when a bacterium moves from one environment to another, especially if it has to adjust to a new environment. The hot boning work described above demonstrated a good correlation when 5 generations of lag were introduced to the equation. 5 generations of growth (1.5 $\log_{10}$) can be subtracted from the calculated refrigeration index in situations where a lag may occur.

The question 'the starting temperature is hot' determines whether a lag is applied. If the meat is hot or warm, then it is assumed that *E. coli* has recently been introduced to the meat surface and a 5 generation lag is allowed. If the meat is cold, then it is assumed that *E. coli* may already be present on the meat, has adjusted to the environment and is ready to grow as soon as the temperature rises.

Temperature

Temperature is the only parameter that can be entered by the user. Data may be entered manually, or cut and pasted from spreadsheets etc.

Future Development

As the industry gains experience with the RI Calculator, it is likely that modifications will be made to the way that the calculator functions. There may also be scientific advances that cause the basic calculations and parameters to be changed. Additional validation studies may suggest new parameters. Studies on carcase chilling, in which pH, a_w and temperature vary during the process may suggest new ways to utilize the power of the predictive model for monitoring the hygiene of meat processing.