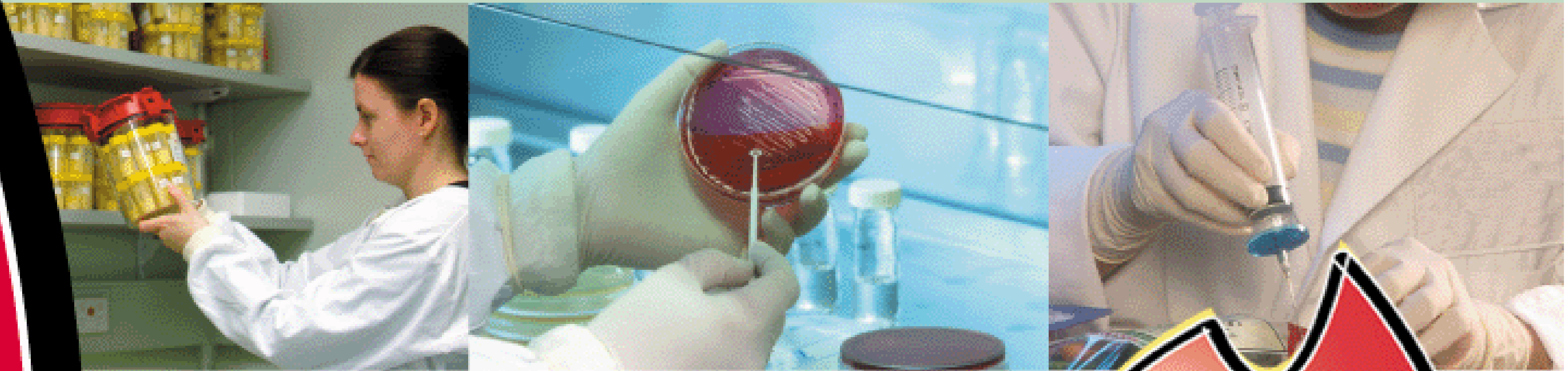


Australian Food Safety
Centre of Excellence

Food Safety: the essential ingredient

Microbial growth models and temperature monitoring technologies

Tom McMeekin, Nicholas Smale,
Ian Jenson & David Tanner

Australian Food Safety
Centre of Excellence

Food Safety: the essential ingredient

PREDICTIVE MICROBIOLOGY: THE CONCEPT

A detailed knowledge of microbial responses to environmental conditions, synthesised in a mathematical model, enables objective evaluation of processing, distribution and storage operations on the microbiological safety and quality of foods, by monitoring the environment without recourse to further microbiological analysis

The PROCESS of predictive microbiology: turning data into knowledge by *describing microbial population behaviour quantitatively*

In vitro
Environment
In vivo

- *temperature, pH, water activity,*
- *atmosphere composition,*
- *additives, food structure*
- *competition among organisms*

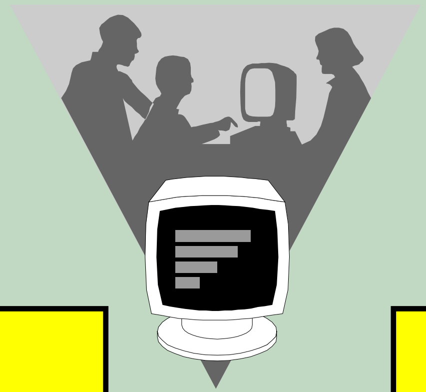
➔

➔

- microbial response
  - growth / no growth,
  - probability of growth,
  - lag time, doubling time,
  - time to reach a certain conc.
  - full growth / survival curves
  - (dynamic response)
  - metabolic production

The SCIENCE and TECHNOLOGY of predictive microbiology – monitor the environment without retrospective microbial counts

Predictive software



Biomathematics (mathematical models) ↔ **Bioinformatics (database)**

ComBase Consortium, 2003

FSA, UK

Institute of Food Research, Norwich, UK

US Department of Agriculture, Agricultural Research Service

Eastern Regional Research Center Wyndmoor, PA, USA

---

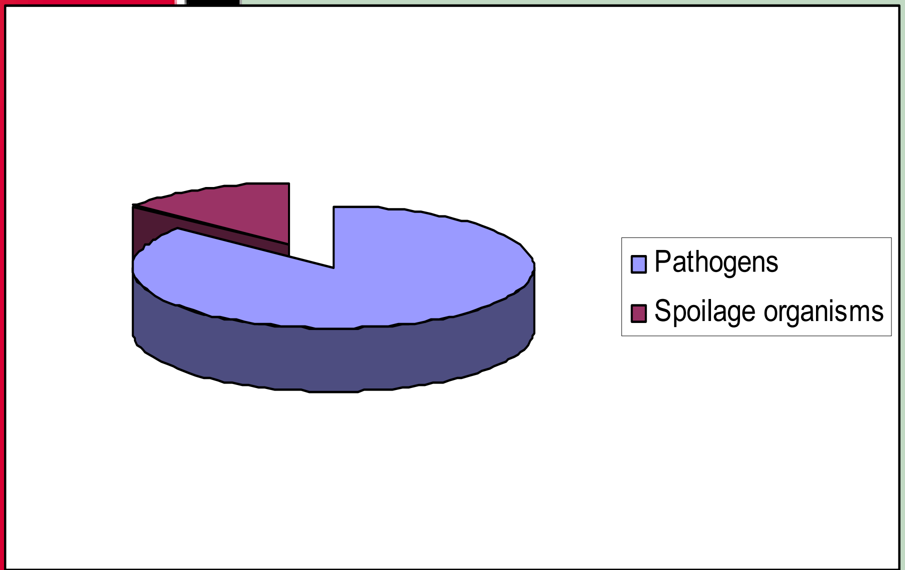
e-ComBase: 2yrs Accompanying Measures project to populate ComBase by data from Supporting Partners

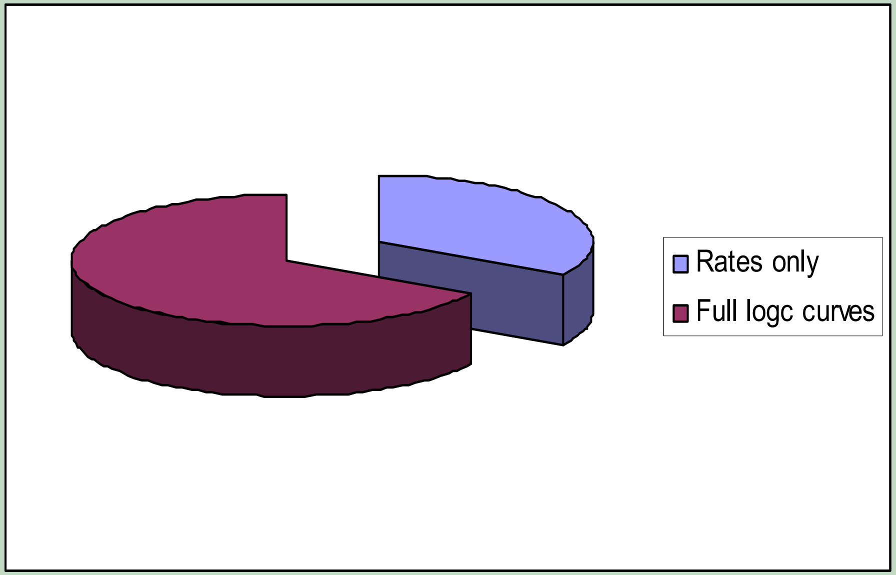
EC *Quality of Life and Management of Living Resources (QoL)*
Key Action 1 - Food, Nutrition and Health

Data in *ComBase*, October, 2005

≈ 30K records on pathogens;
≈ 5K on spoilage organisms;

2/3 full log-count curves
1/3 growth/death rates





Australian data added to ComBase – Feb 2006

- **Kinetic data : 5522 new records.**

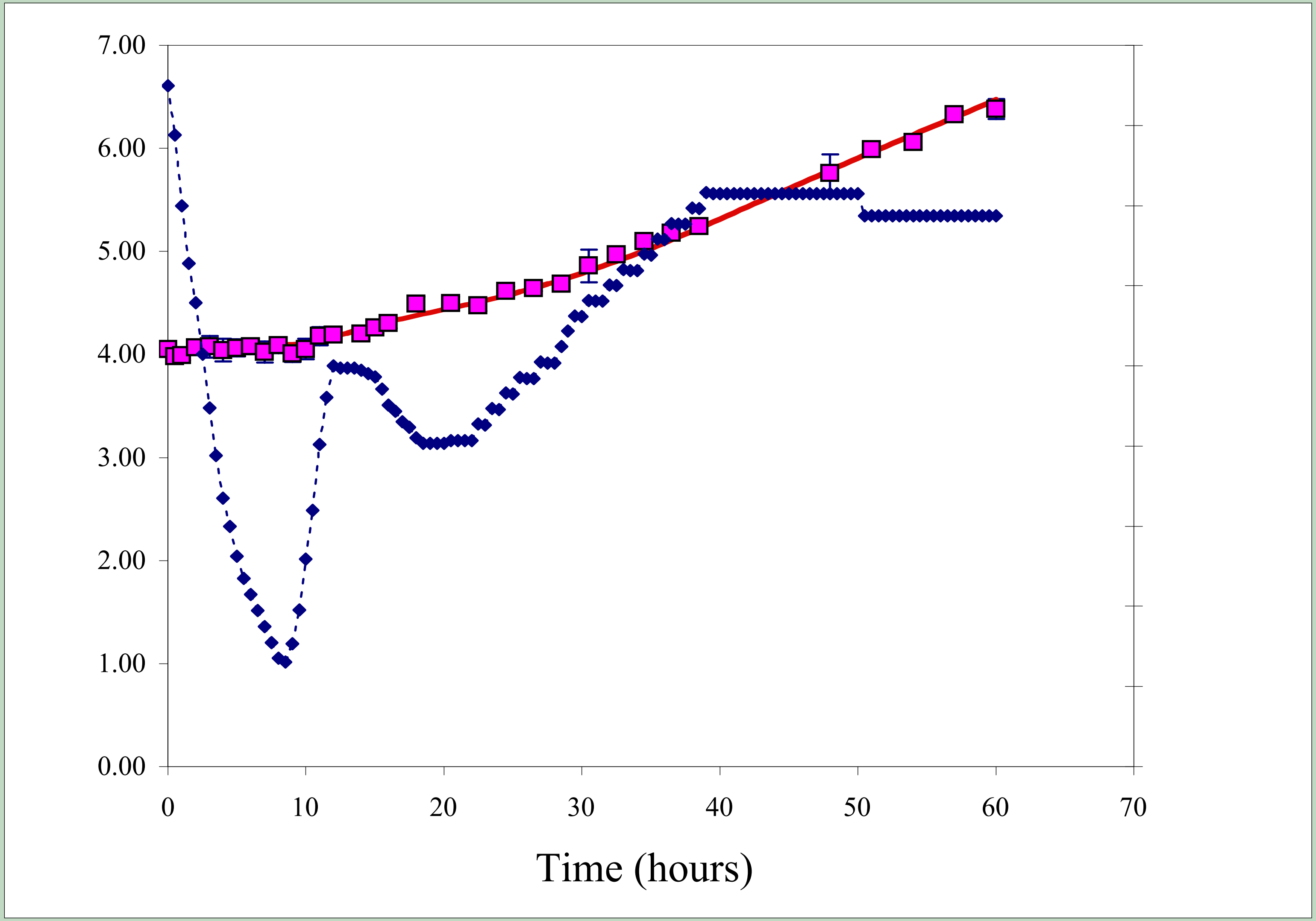
  Each record is a kinetic bacterial response to the environmental conditions (originally ComBase only incorporated this kind of data)

- **Probability of growth data: 2466 new records**

  Every record is a set of replicated realizations of an experiment. Hence, data corresponds to **6143** independent experiments

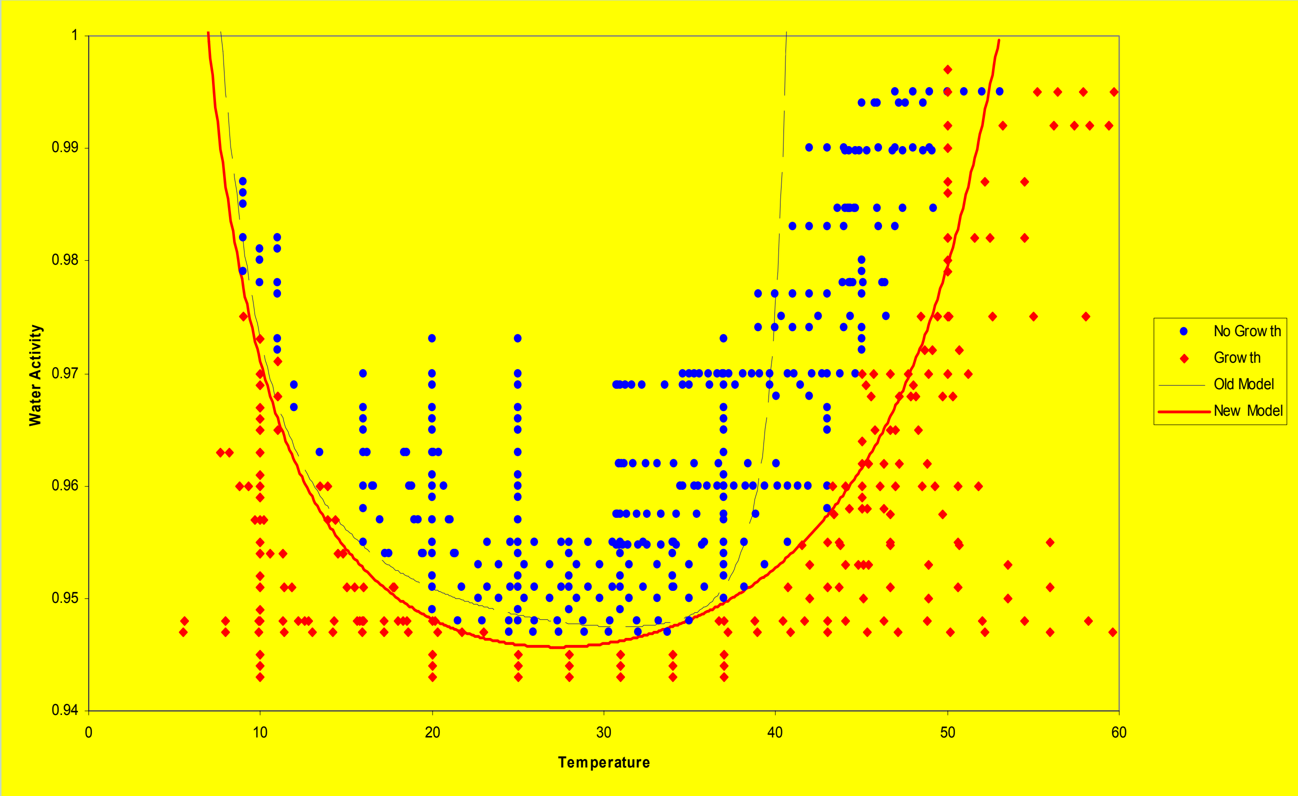
  ComBase has been extended by adapting its fields to store this data

E.coli growth with fluctuating a_w (12°C)

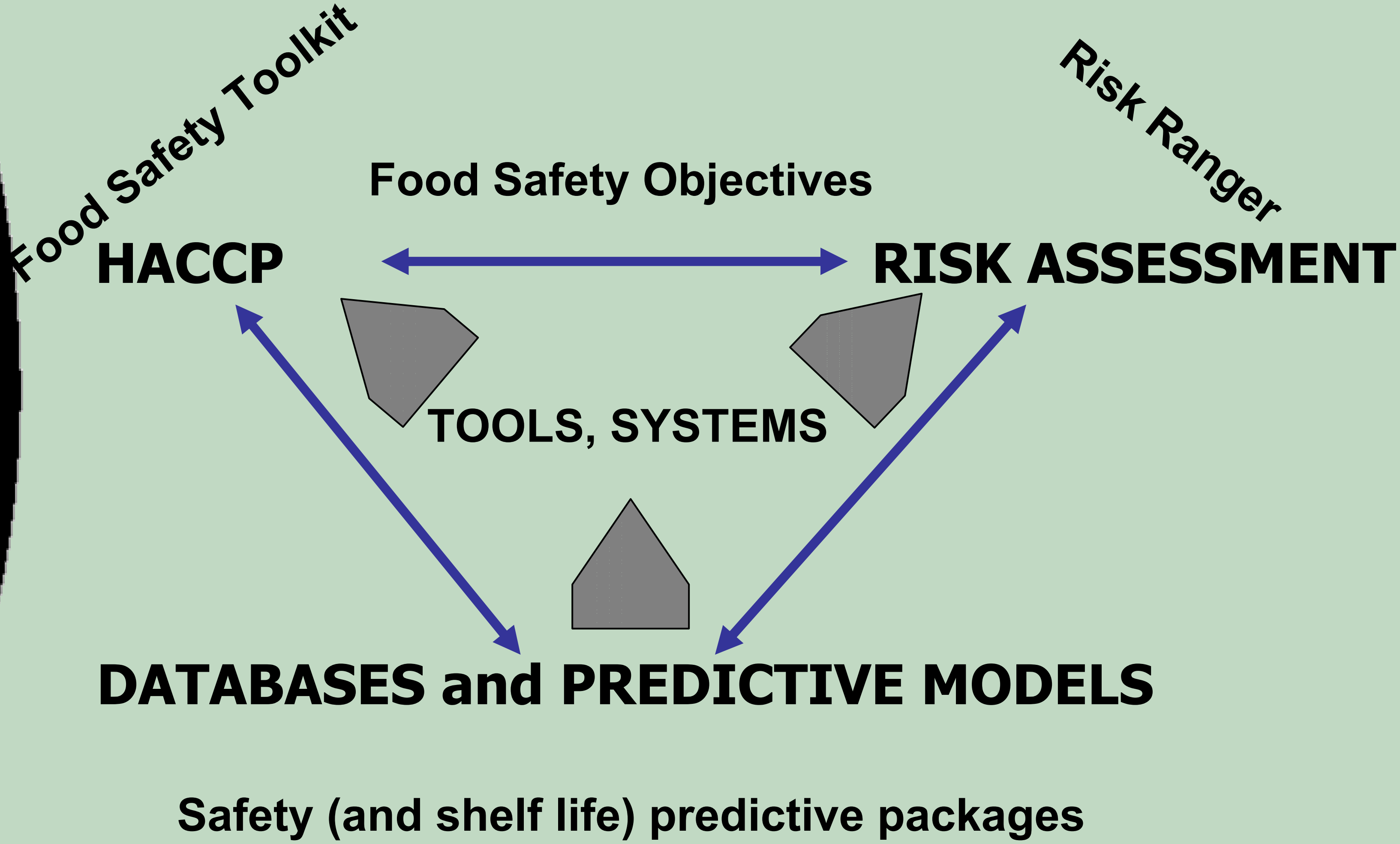


Formulation of safe foods using growth boundary models

- Quantifying the hurdle concept
  - *E. coli* boundary model for temperature and water availability



Systems and Technology to support Food Safety Management



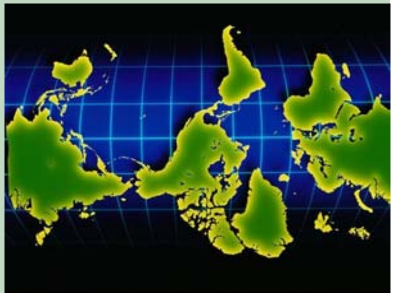
Regulatory and industry outcomes

A detailed knowledge of the microbial ecology of any product / pathogen combination :

- Supports regulations that are defensible and challenges unwarranted regulations
- Indicates the need for outcome based regulations
- Underpins the paradigms of food safety management enabling:
  - real time process management
  - prospective formulation of safe products and design of safe processes
  - determination of the hygienic equivalence of products and efficacy of processes
  - flexibility in meeting regulatory requirements

Drivers to develop systems and technologies to assure safety and shelf life of food in international trade

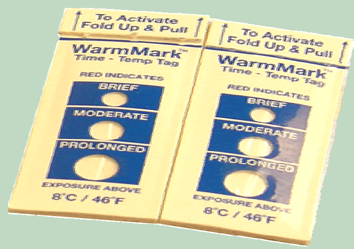
- The food industry operates in a global market place
- Reliance on transport for delivery of high quality products to distant markets
- Distances and voyage times to market from Australia are long
- Temperature variability in supply chains



What technology options are available?

- Track and trace technologies
  - Barcoding
  - Radio frequency identification (RFID)

- Environment monitoring technologies
  - Data loggers
  - Time-temperature integrators (TTI's)



Temperature loggers

- Temperature measurement, data storage, retrieval
- Predictive models allow critical analysis of the consequences for shelf-life and safety

- Case studies in *in situ* process management
  - Frozen dairy product
  - Meat carcass chilling
  - Fermented meat processing

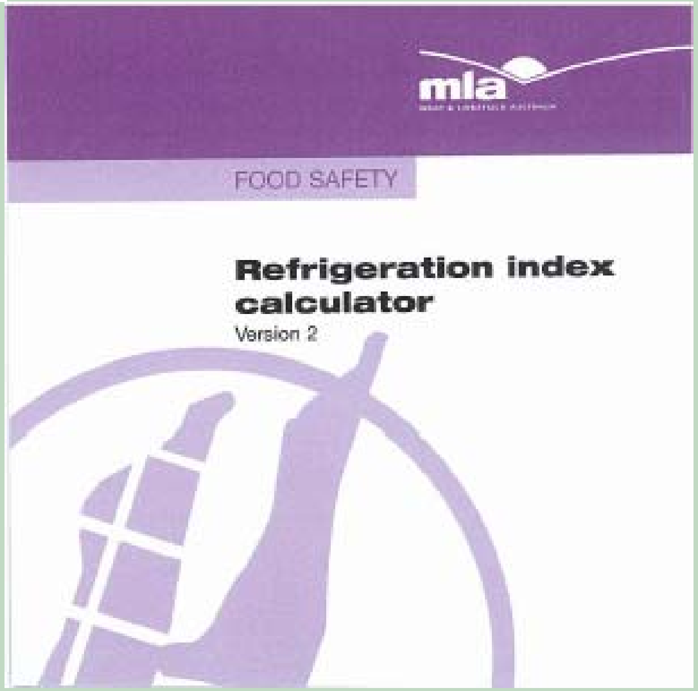
Frozen dairy product

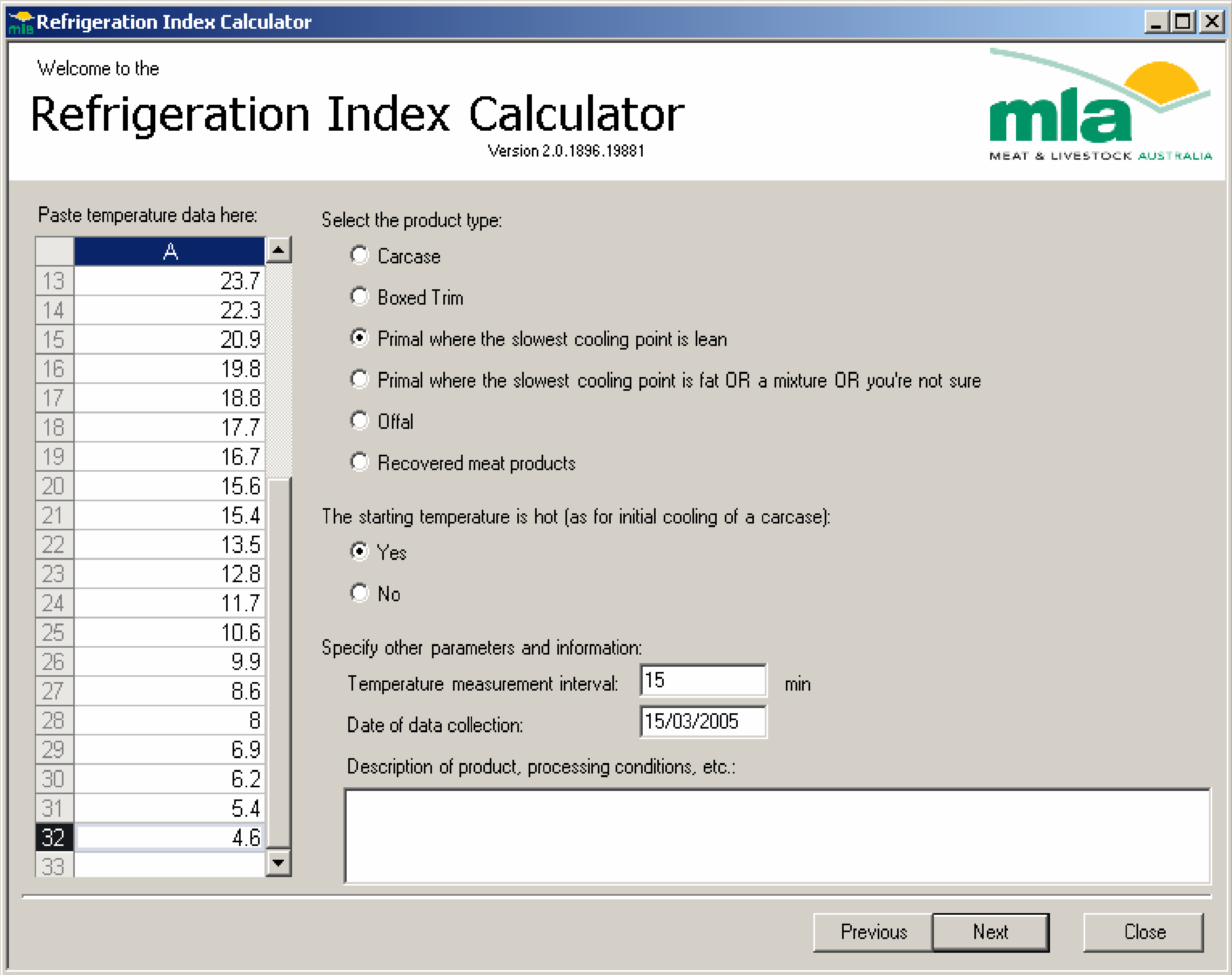
- **BACKGROUND:**
  - heat treated product, bulk packed, frozen
  - testing indicated the product exceeded specifications
  - inadequate cooling allowed growth of sporeformers
  - cooling profiles and microbiological test results compared with model predictions
- **COMPANY RESPONSE:**
  - numerous configurations trialed with temperature data logging and microbiology testing
  - predictive model used throughout to give assurance of the effectiveness of cooling rates
- **BENEFITS TO COMPANY:**
  - used cooling profiles to monitor process performance
  - early identification of unsatisfactory performance
  - product shipped on basis of cooling profile without the expense and delay of testing

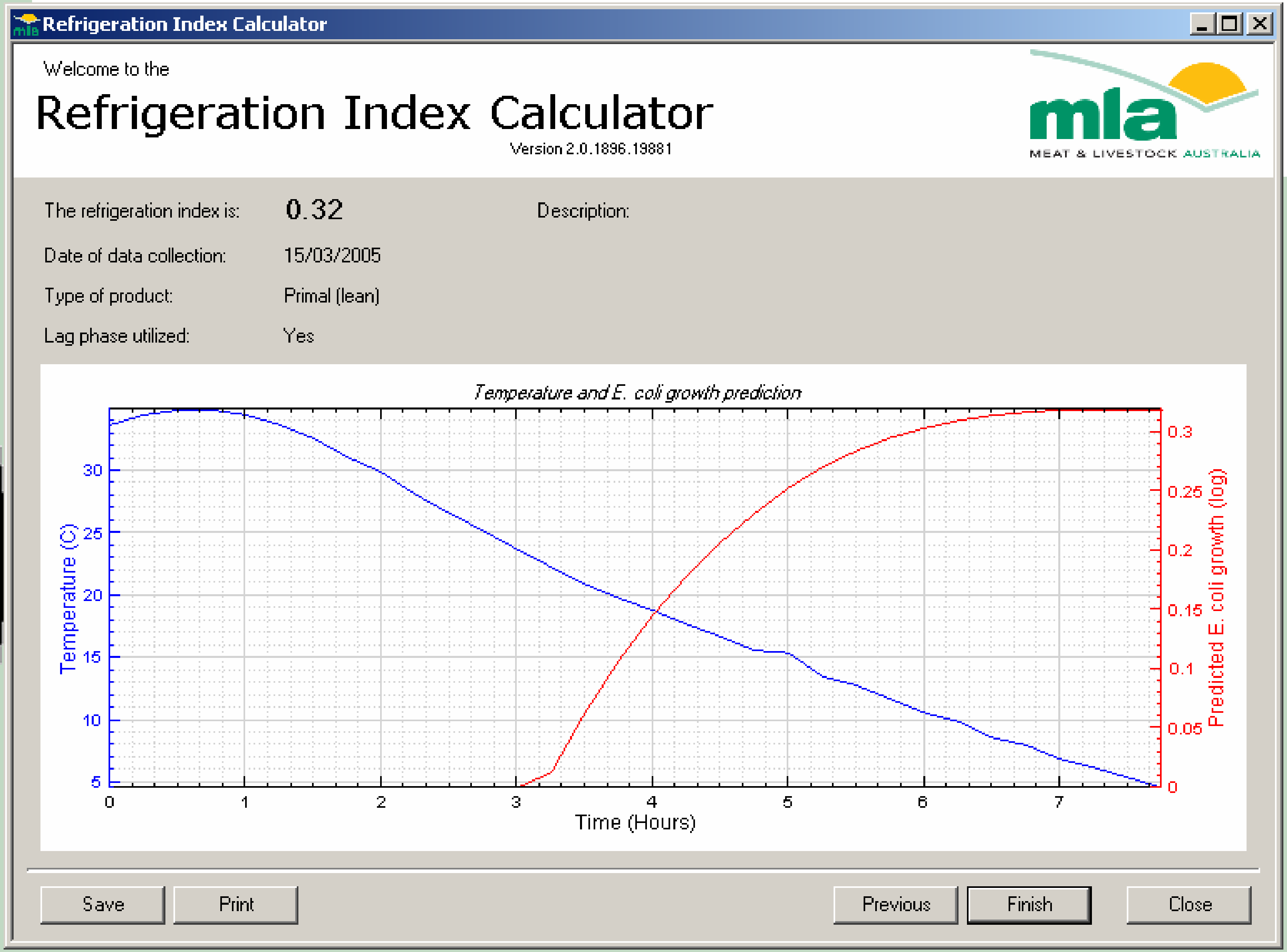
Meat carcass chilling

- *Issues:* safety of alternative processes (hot boning), weekend chilling, carcass rewarming, offal cooling
- *E. coli* "megamodel" for temperature, water activity, pH and lactate concentration
    - based on ~1000 observations, 1000 independent 'validation' data
    - more parameters, more applications
- Development: Ross *et al*. 2003 *Int. J. Food Microbiol.* 82: 33-44.
- Evaluation: Mellefont *et al*. 2003 *Int. J. Food Microbiol.* 82: 45-58.
- Application: Development, by AQIS, of a Refrigeration Index for carcass chilling in revised Export Meat Orders

Export Control (Meat and Meat Products) Orders 2005




Refrigeration Index Calculator
Welcome to the
Refrigeration Index Calculator
Version 2.0.1896.19881
mla
MEAT & LIVESTOCK AUSTRALIA
Paste temperature data here:
A
13 23.7
14 22.3
15 20.9
16 19.8
17 18.8
18 17.7
19 16.7
20 15.6
21 15.4
22 13.5
23 12.8
24 11.7
25 10.6
26 9.9
27 8.6
28 8
29 6.9
30 6.2
31 5.4
32 4.6
33
Select the product type:
Carcase
Boxed Trim
Primal where the slowest cooling point is lean
Primal where the slowest cooling point is fat OR a mixture OR you're not sure
Offal
Recovered meat products
The starting temperature is hot (as for initial cooling of a carcase):
Yes
No
Specify other parameters and information:
Temperature measurement interval: 15 min
Date of data collection: 15/03/2005
Description of product, processing conditions, etc.:
Previous
Next
Close

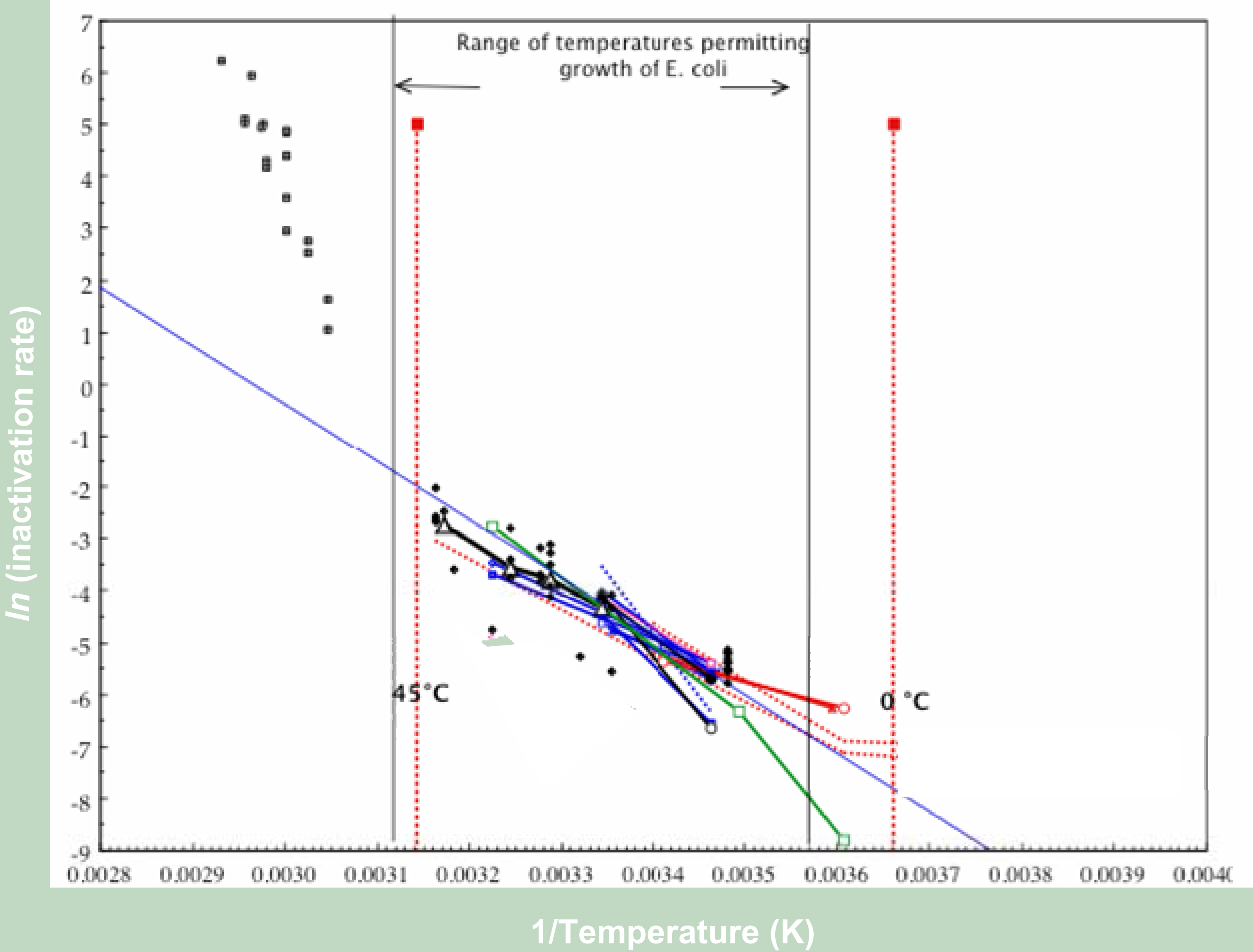

Refrigeration Index Calculator
Welcome to the
Refrigeration Index Calculator
Version 2.0.1896.19881
mla
MEAT & LIVESTOCK AUSTRALIA
The refrigeration index is: 0.32
Description:
Date of data collection: 15/03/2005
Type of product: Primal (lean)
Lag phase utilized: Yes
Temperature and E. coli growth prediction
Temperature (C)
Predicted E. coli growth (log)
Time (Hours)
0
1
2
3
4
5
6
7
5
10
15
20
25
30
0
0.05
0.1
0.15
0.2
0.25
0.3
Save
Print
Previous
Finish
Close

E. coli inactivation in uncooked fermented meat products

- severe EHEC outbreak in Oz in 1995
- national expert committee created to assess ‘process safety’, based on “3-log kill”
- impossible task due to lack of quantitative data
- industry funded a small project to look at data availability, build a model if possible
- data collated, synthesised, modelled

Outcomes

- literature review provides new insights
- model developed based on the published data
- model used to screen processes for approval (regulators), and to reassess processes (producers)
- dedicated project funded using broth modelling and evaluation in product
- original model confirmed, no improvement



Range of temperatures permitting growth of E. coli
45°C
0 °C
ln (inactivation rate)
1/Temperature (K)

MEAT & LIVESTOCK AUSTRALIA

E. coli Inactivation in Fermented Meats

Calculators to estimate the "log kill" of *E. coli* during production of fermented meats

Version 2.2 (1 August 2004). Developed for Meat and Livestock Australia by the Australian Food Safety Centre of

Australian Food Safety Centre of Excellence

An initiative of: national FOOD industry strategy

Supported by: Australian Government Department of Agriculture, Fisheries and Forestry

Click to Continue

Systematic analysis of the literature

- Ross (1999) Predictive Microbiology for the meat industry. Meat and Livestock Australia, Sydney, 196pp.

- Ross and Shadbolt (2001) Predicting *E. coli* inactivation in uncooked fermented meat products. Meat & Livestock Australia, 59pp. (cis@mla.com.au)

- Van Asselt and Zwietering (2006) A systematic approach to determine global thermal inactivation patterns for various food pathogens. Int. J. Food Microbiol. 107: 73-82.

- Adkin et al., (2006) Use of a systematic review to assist the development of Campylobacter control strategies in broilers. J. Appl. Microbiol. 100: 306-315.

Probabilistic modelling – an emerging trend

den Aantrekker et al. (2003). Estimating the probability of recontamination via the air using Monte Carlo simulations. Int. J. Food Microbiol. 87: 1-15.

Membre et al. (2006). A probabilistic modeling approach in thermal inactivation: estimation of postprocess *B. cereus* spore prevalence and concentration. J. Food Prot. 69: 118-129.

Tsutsui and Kasuga (2006). Assessment of the impact of cattle testing strategies on human exposure to BSE agents in Japan. Int. J. Food Microbiol. 107: 256-264.

Francois et al. (2006) Single cell variability of *L.monocytogenes* grown on liver pate and cooked ham: comparing challenge tests to predictive simulations. J.Appl.Microbiol. 100: 800-812.

Estimated economic benefits

Value of predictive microbiology to the Australian meat industry(source Meat and Livestock Australia)

	Value ($M) per annum
Hot boning	***15**
Weekend chilling	***30**
Refrigeration breakdowns	**7.5**
Cooling of cooked meats	**3***
Uncooked fermented meats	***30**
TOTAL	85.5

***Value calculated as a % of the market protected by predictive microbiology using 5% of the value of sales except for fermented meats where 20% is used based on the effect of past food~borne disease outbreaks on sales in this sector**

Application of predictive models with temperature loggers

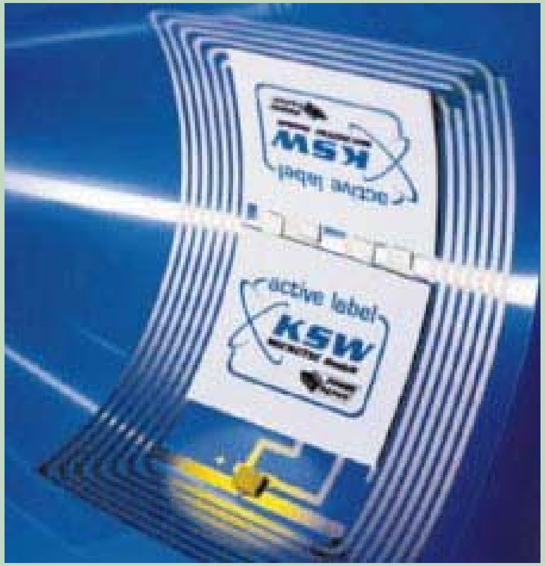
- The examples above normally use electronic temperature loggers which, for process control, present inherent problems in data recovery eg loss of information with non-return of loggers, retrospective analysis of information and manual examination for “progress reports”

Traceability

- Increasing interest in electronic chain traceability systems that communicate with finance software, business systems and work as an integrated part of production management

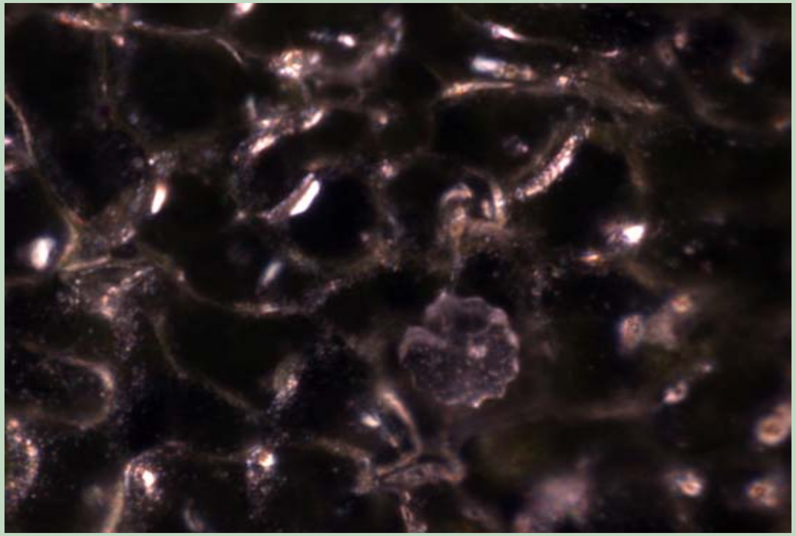
RFID ++

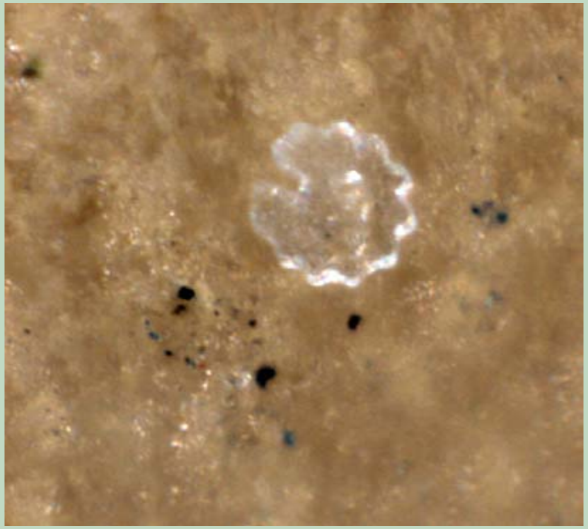
- Added functionality by incorporating sensors into tags to monitor:
  - Position
  - Temperature
  - Gases (incl. humidity)
  - Light



Microscopic, edible, information-dense, easily read, inexpensive, and, if necessary, t*hermosoluble* markers for foods, seeds, and drugs

www.burntsidepartners.com



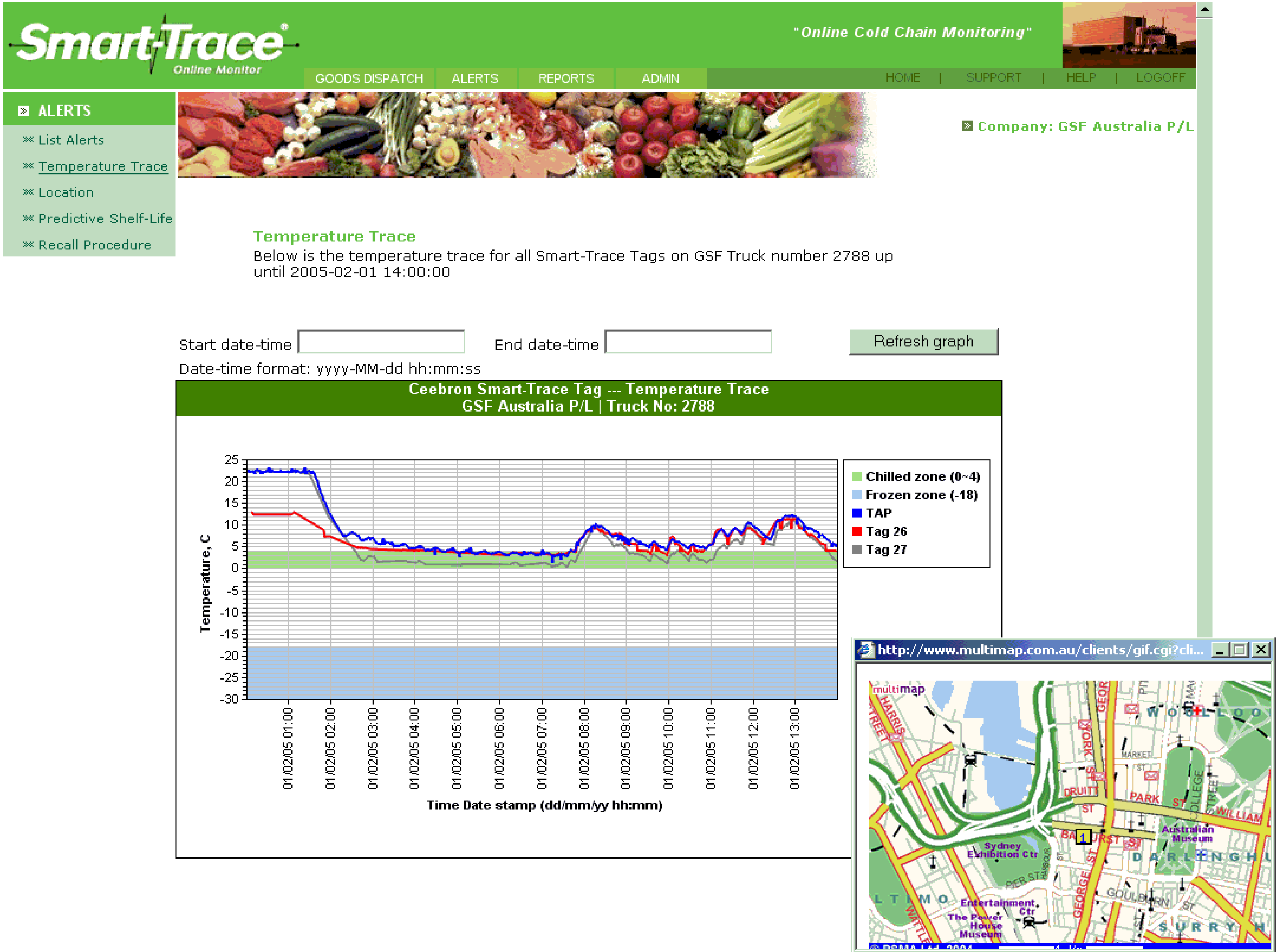


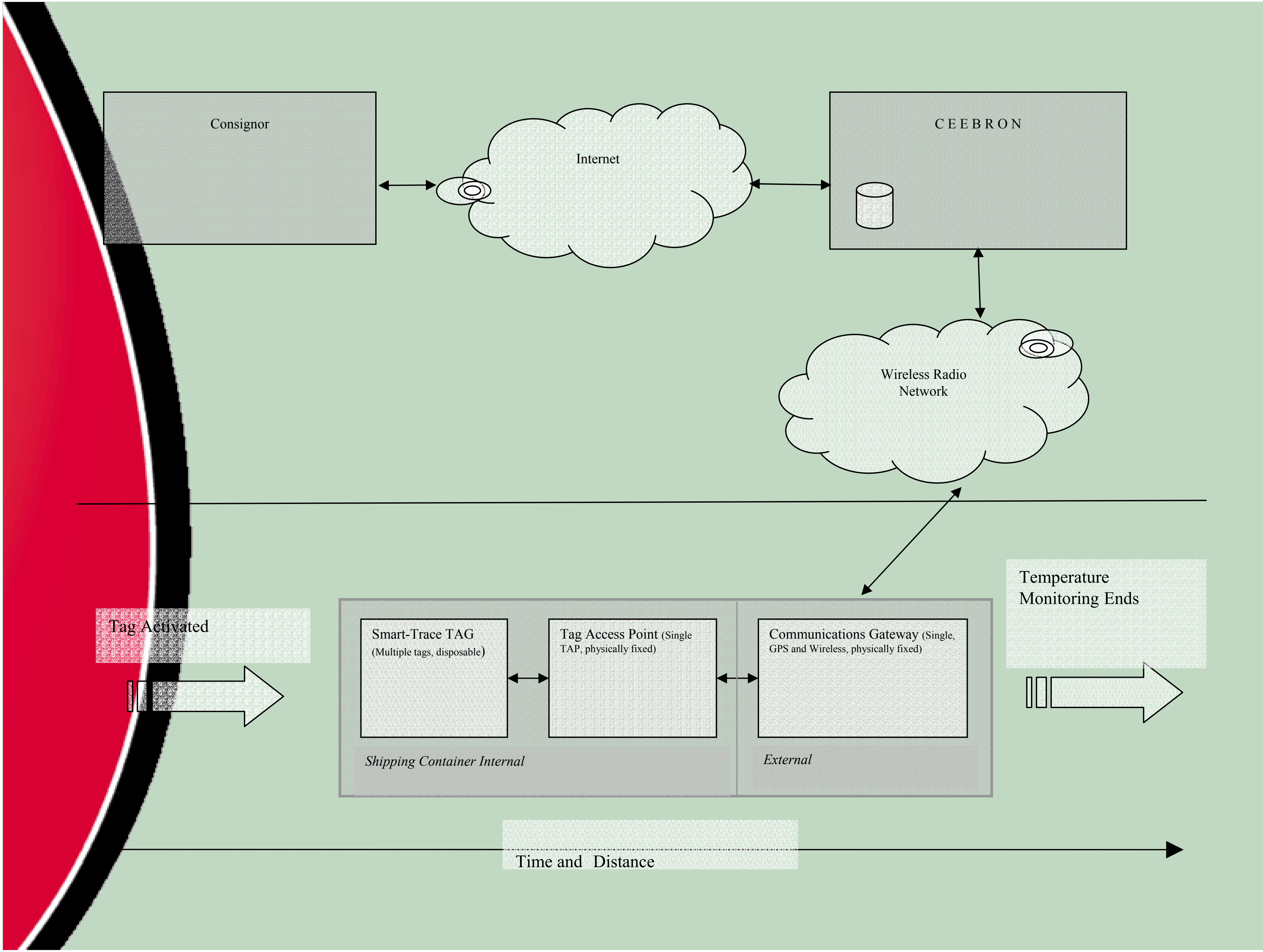
Application of predictive models with real time reporting

- Towards real time reporting by combining technological power with scientific precision
- Food safety management will achieve new levels of precision and flexibility when predictive models are integrated with radio frequency identification (RFID)/ad hoc wireless technology

Case study: Smart-Trace

- A wireless monitoring technology for the cold chain
- Real-time information availability
    - Product ID (EPC)
    - Product temperatures
    - Location (GPS)

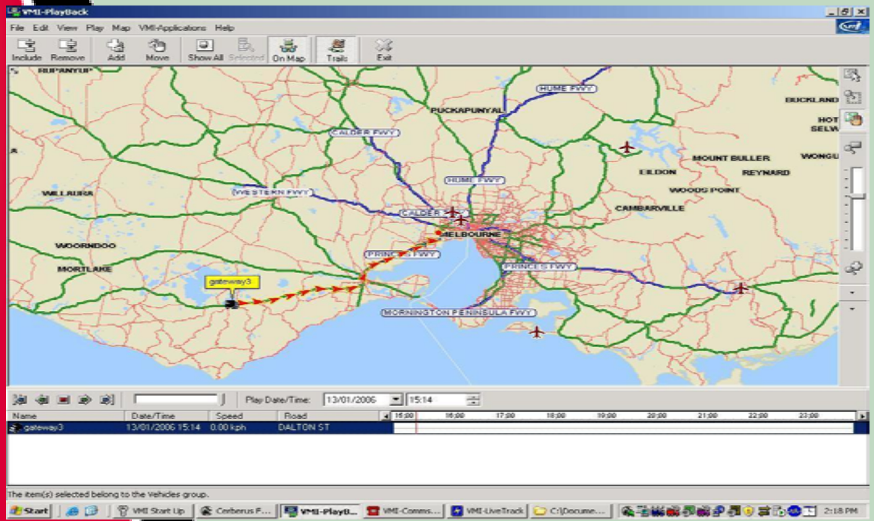

Smart-Trace®
Online Monitor
"Online Cold Chain Monitoring"
GOODS DISPATCH
ALERTS
REPORTS
ADMIN
HOME | SUPPORT | HELP | LOGOFF
ALERTS
List Alerts
Temperature Trace
Location
Predictive Shelf-Life
Recall Procedure
Company: GSF Australia P/L
Temperature Trace
Below is the temperature trace for all Smart-Trace Tags on GSF Truck number 2788 up until 2005-02-01 14:00:00
Start date-time
End date-time
Refresh graph
Date-time format: yyyy-MM-dd hh:mm:ss
Ceebron Smart-Trace Tag --- Temperature Trace
GSF Australia P/L | Truck No: 2788
Temperature, C
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
01/02/05 01:00
01/02/05 02:00
01/02/05 03:00
01/02/05 04:00
01/02/05 05:00
01/02/05 06:00
01/02/05 07:00
01/02/05 08:00
01/02/05 09:00
01/02/05 10:00
01/02/05 11:00
01/02/05 12:00
01/02/05 13:00
Time Date stamp (dd/mm/yy hh:mm)
Chilled zone (0~4)
Frozen zone (-18)
TAP
Tag 26
Tag 27
http://www.multimap.com.au/clients/gif.cgi?cli...
multimap
HARRIS STREET
GEORGE
YORK ST
DRUITT ST
PARK ST
WILLIAM
MARKET
COLLEGE STREET
Australian Museum
Sydney Exhibition Ctr
GOULBURN ST
PIER ST
Entertainment Ctr
The Power House Museum
W O O L L O O
D A R L I N G H
U L T I M O
S U R R Y H

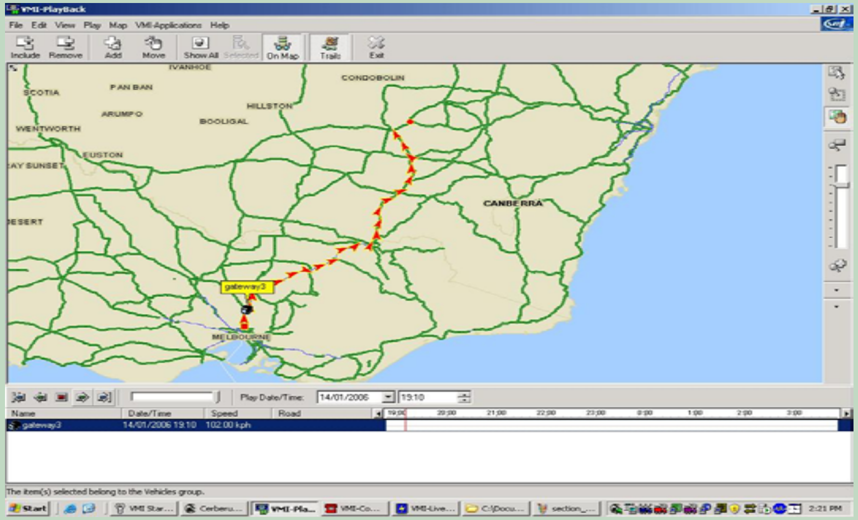

Consignor
Internet
CEEBRON
Wireless Radio
Network
Temperature
Monitoring Ends
Tag Activated
Smart-Trace TAG
(Multiple tags, disposable)
Tag Access Point (Single TAP, physically fixed)
Communications Gateway (Single, GPS and Wireless, physically fixed)
Shipping Container Internal
External
Time and Distance

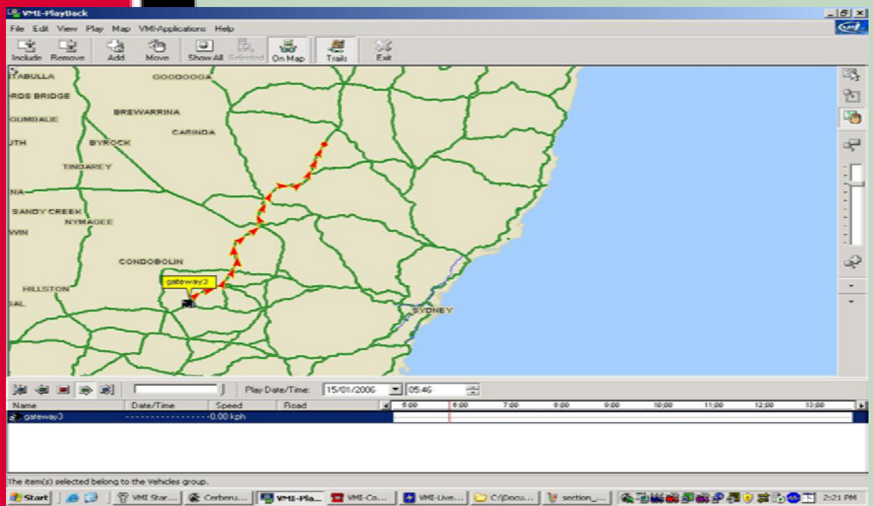
Case study: Smart-Trace

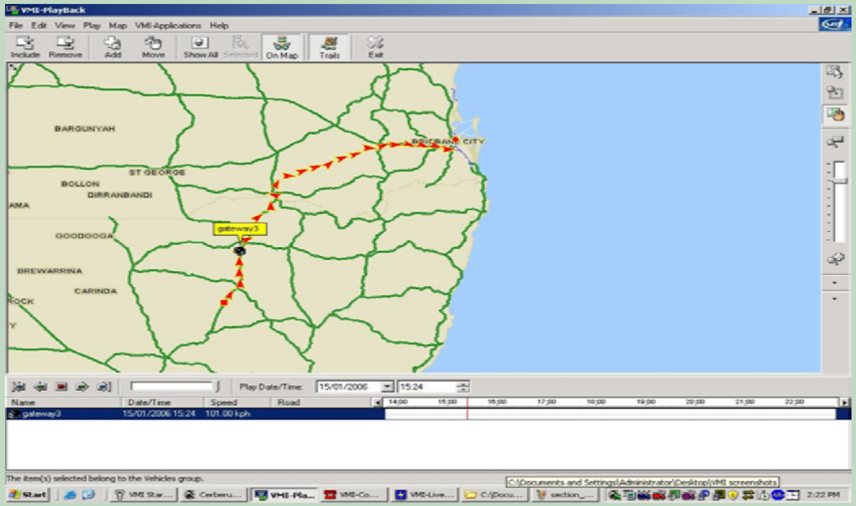
- Mesh network (ad hoc wireless network)
  - **P**latform **A**d-Hoc **W**ireless **N**etworking

Location Screenshots – Trial 1

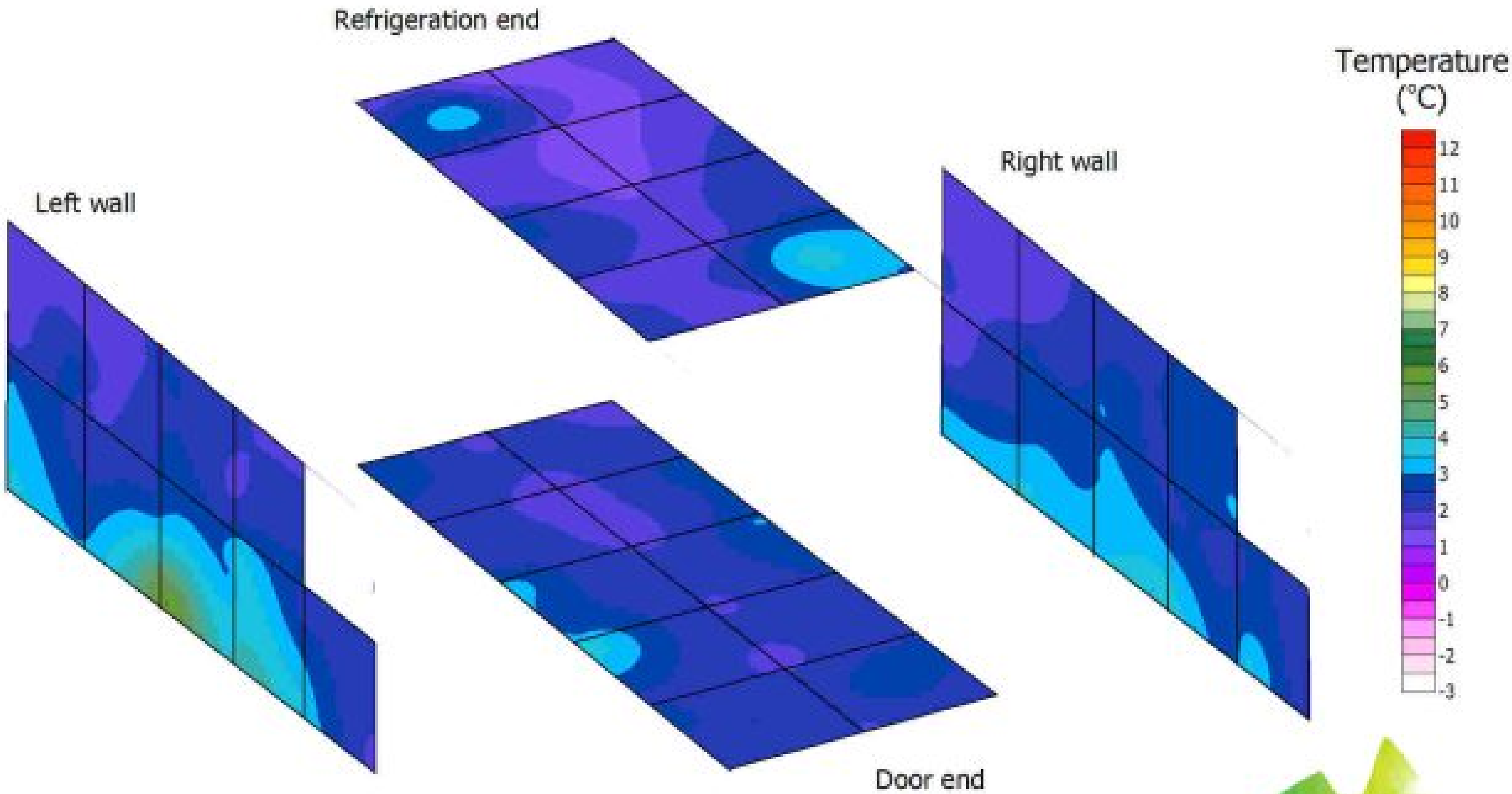









AUSTRALIA



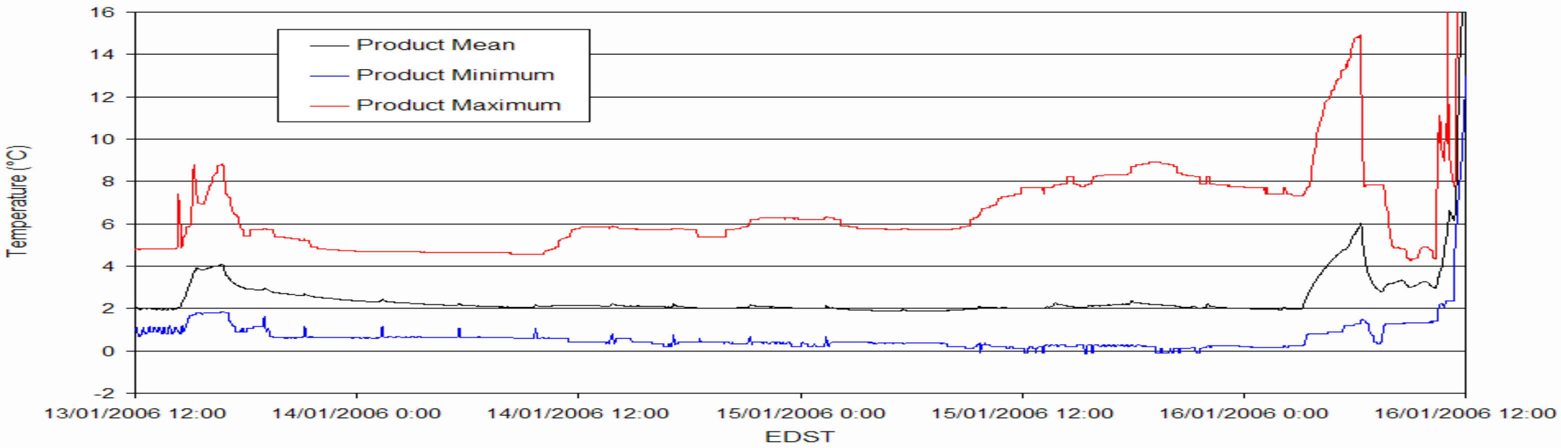
Ceebron

Smart-Trace Online Monitor

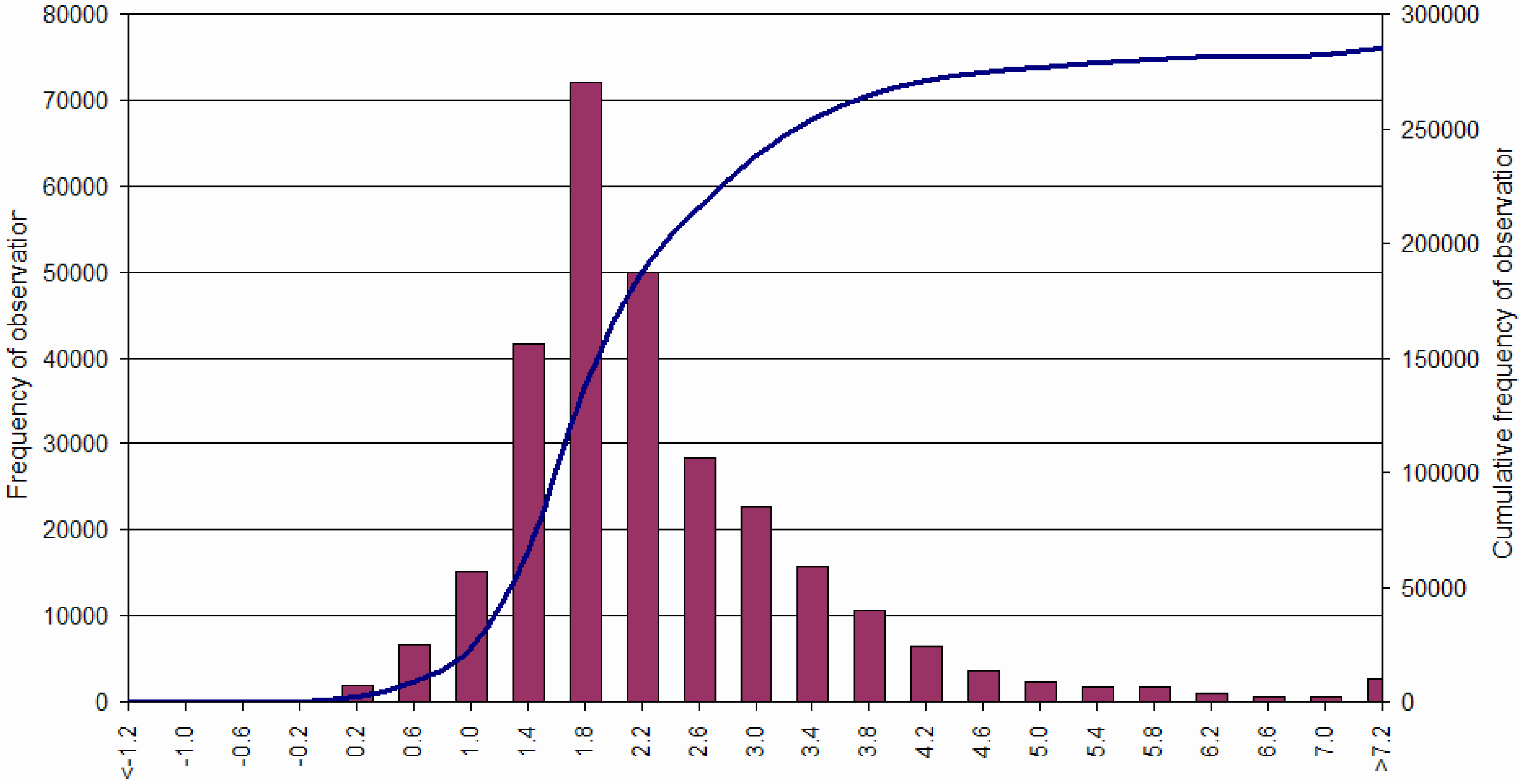
FOOD SCIENCE AUSTRALIA

A joint venture of CSIRO & the Victorian Government

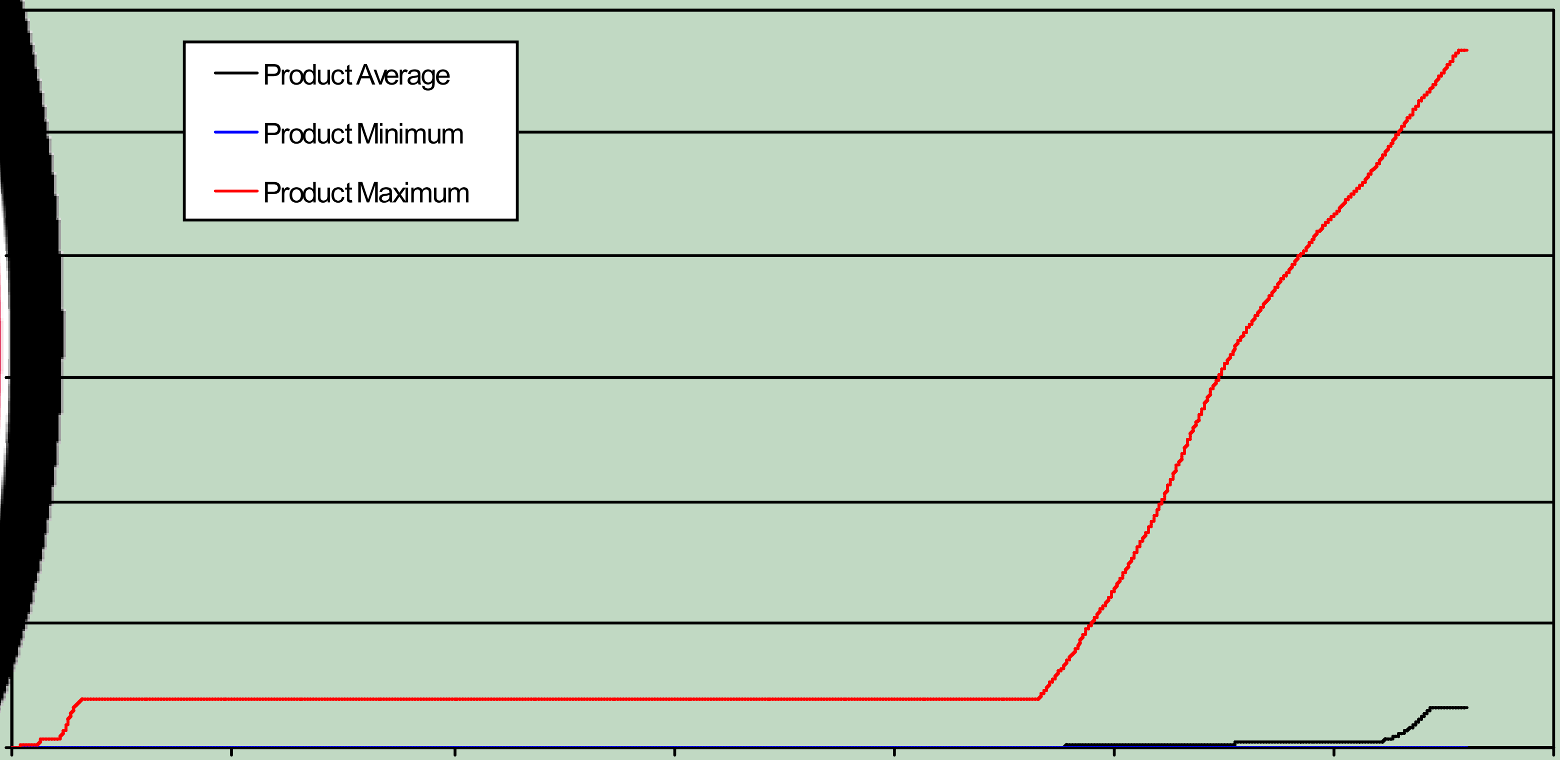
Average, minimum and maximum measured product temperatures



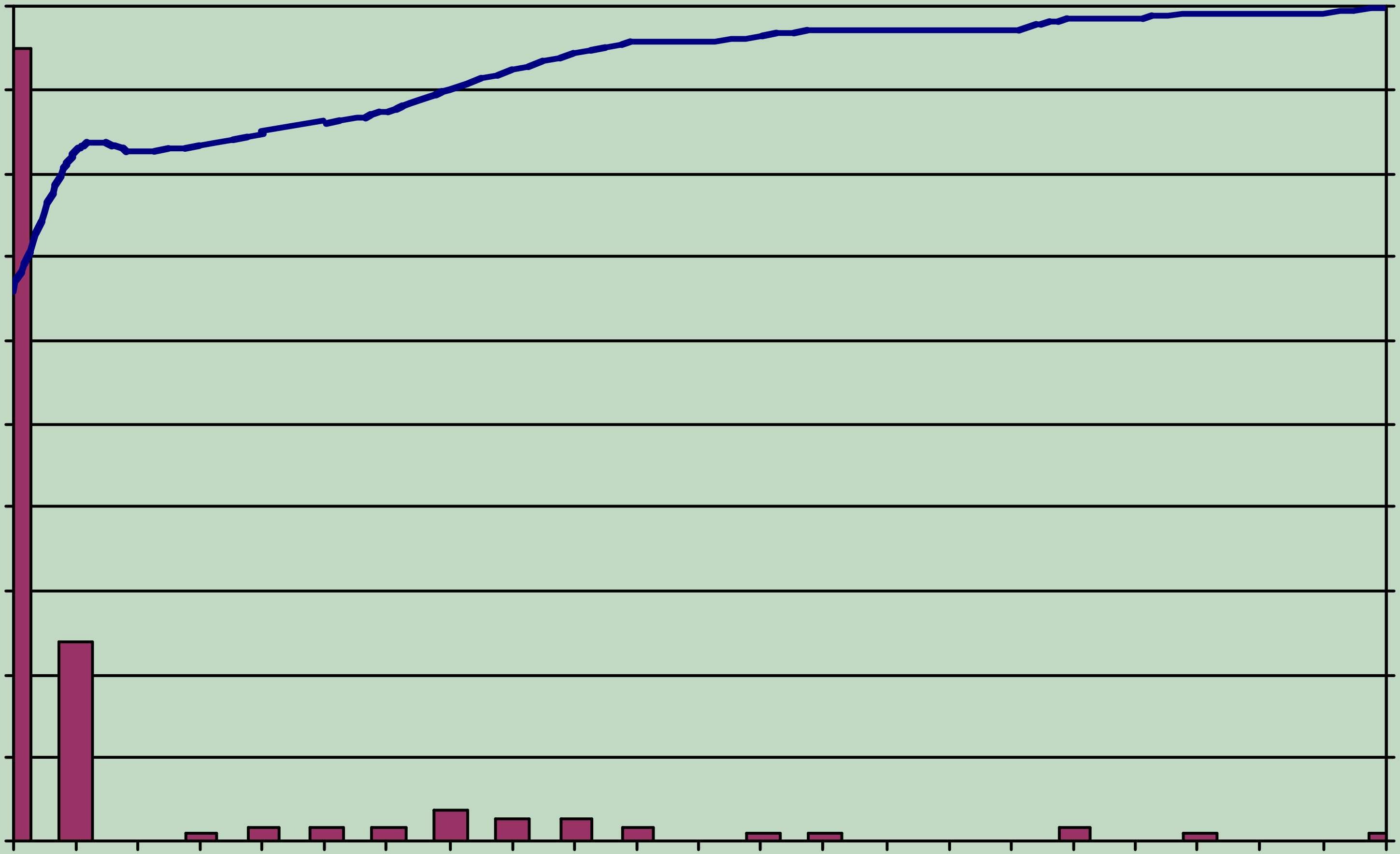
Frequency of observations of in-pallet temperatures

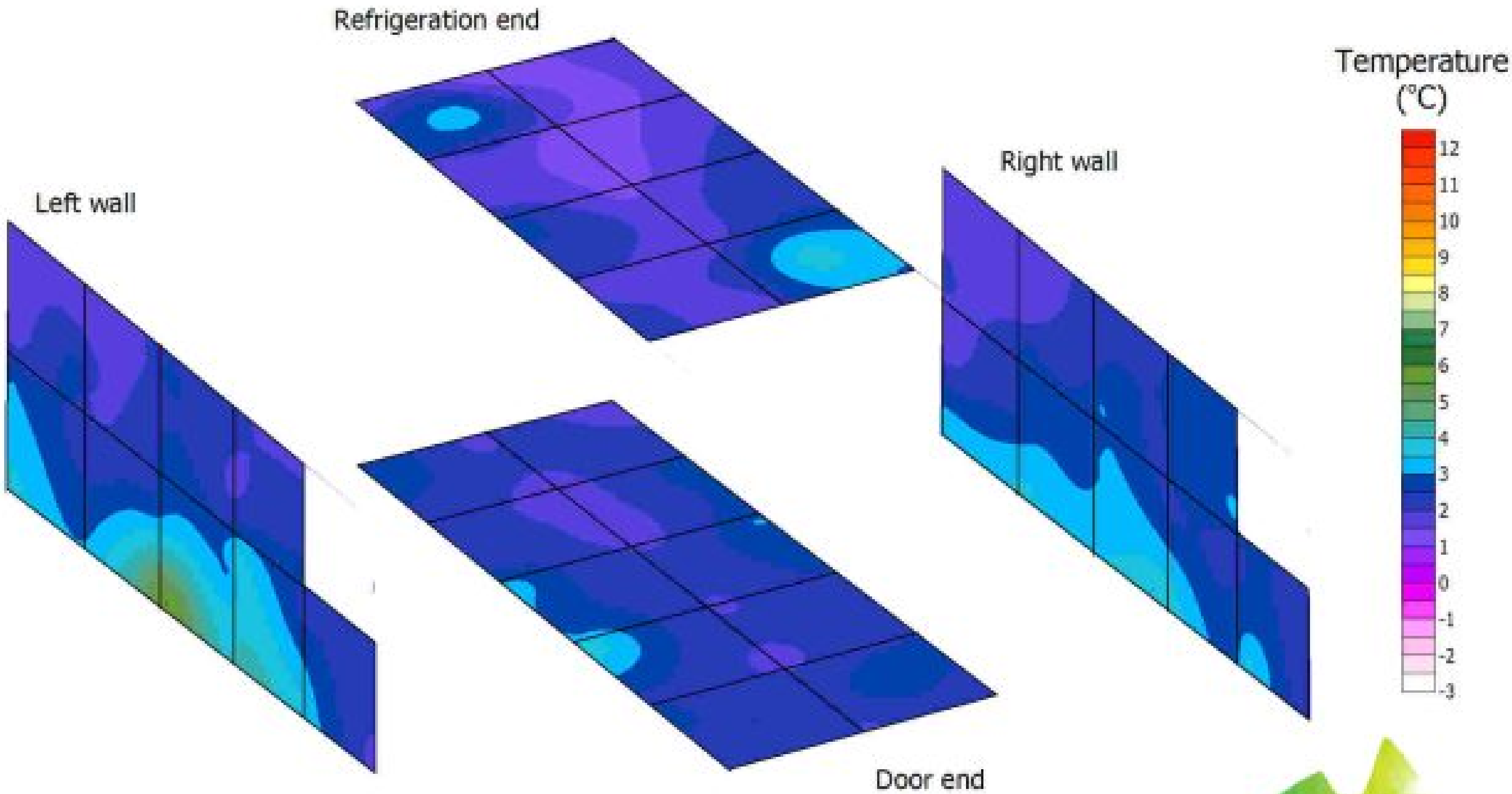


Average, minimum and maximum measured Refrigeration Index



Frequency of observations of Refrigeration Index





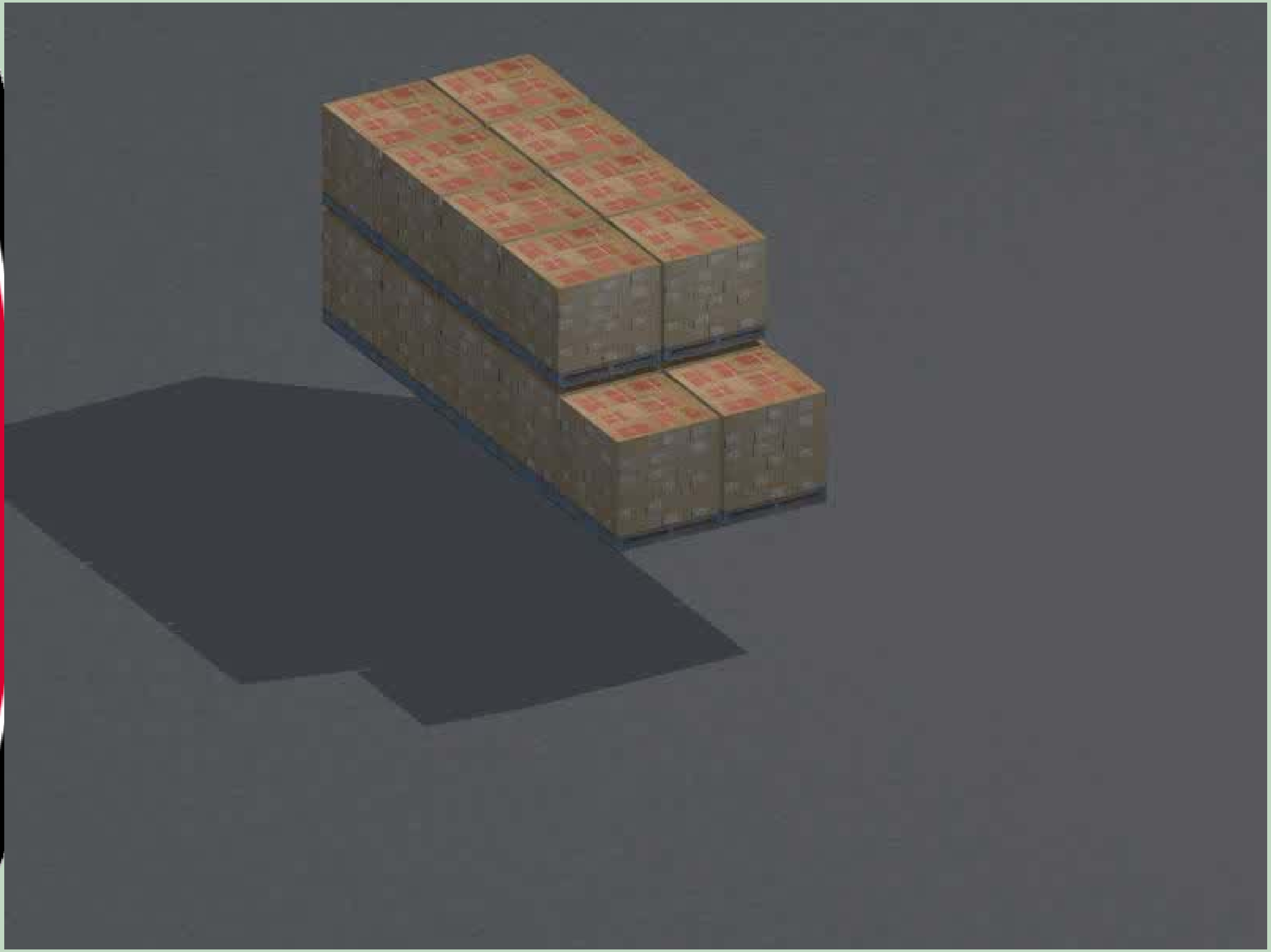
Ceebron

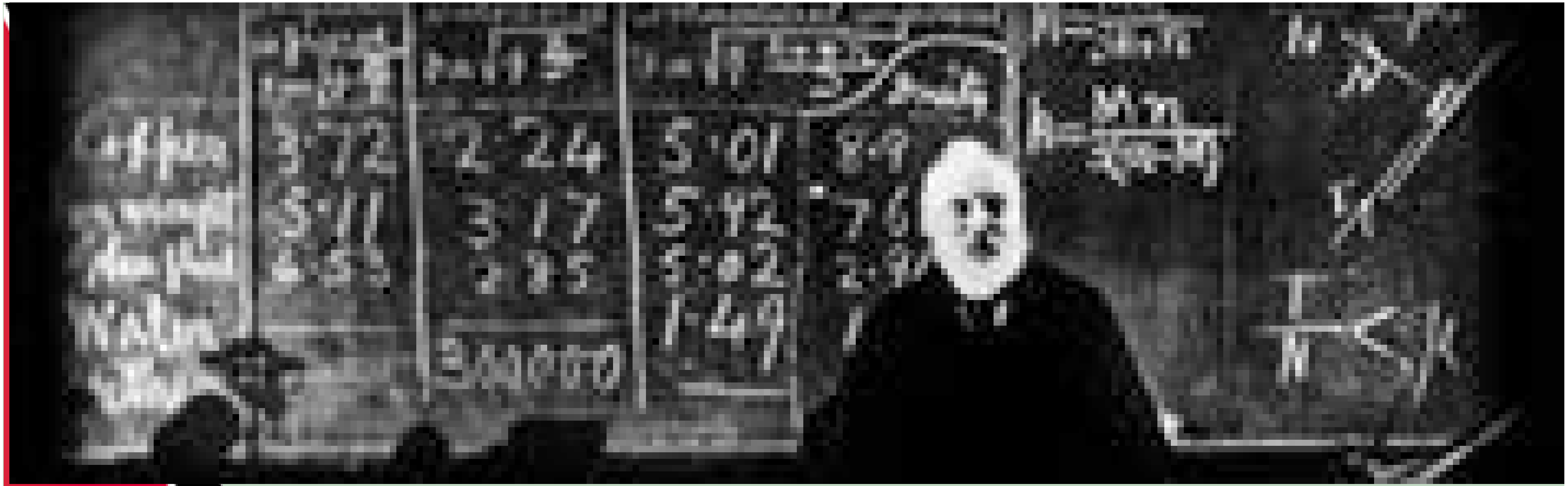
Smart-Trace
Online Monitor

FOOD
SCIENCE
AUSTRALIA

A joint venture of CSIRO &
the Victorian Government

Smart-Trace Field Trials Thermographics 1 video





”….when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot …. your knowledge is of a meagre and unsatisfactory kind;

"... it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science ….."

Lord Kelvin (William Thomson) 1824-1907

Sharing the vision:
Safe Food to the Nation and the World

Core Partners

TIAR
A centre of excellence in cool temperate agricultural research

national FOOD industry strategy

FOOD SCIENCE AUSTRALIA
A JOINT VENTURE OF CSIRO AND THE VICTORIAN GOVERNMENT

Australian Government
Department of Agriculture, Fisheries and Forestry

Core Members

DAIRY AUSTRALIA

GRDC
Grains Research & Development Corporation

mla
MEAT & LIVESTOCK AUSTRALIA

ozfoodnet

RIRDC
RURAL INDUSTRIES RESEARCH & DEVELOPMENT CORPORATION

SEAFOOD SERVICES AUSTRALIA

Tasmania
DEPARTMENT of PRIMARY INDUSTRIES, WATER and ENVIRONMENT

State Government Victoria
Department of Primary Industries

UTAS

Claudio Bittencourt, PhD Candidate
Olivia McQuestin, Research Assistant
Dr John Bowman, Molecular Biologist
Dr Lyndal Mellefont, Predictive Microbiologist
Dr Janelle Brow, Postdoctoral Research Fellow
Nazri Mohamed Naim, Honours Candidate
Kim Chang, Honours Candidate
Professor June Olley, Honorary Research Professor
Jimmy Choo, Honours Candidate
Lauri Parkinson, Laboratory Assistant
Alison Dann, PhD Candidate
Terry Pinfold, Honours Candidate
Mark De'Pannone, PhD Candidate
Sven Rasmussen,Research Assistant
Dr Susan Dobson, Quantitative Microbial Risk Analyst
Professor David Ratkowsky, Honorary Research Professor
Esta Kokkoris, PhD Candidate
Associate Professor Tom Ross, Predictive Food Microbiology
Joseph Finn, Honours Candidate
Dr Svetlana Shabala, Postdoctoral Research Fellow
Mark Jackson, Honours Candidate
Kathleen Shaw, PhD Candidate
Sally Jones, Executive Assistant
Julia Souprounov, PhD Candidate
Mandeep Kaur, PhD Candidate
Jimmy Twin, PhD Candidate
Roger Latham, Research Assistant
Wei Xiong, Masters Candidate
Shih Hui Lee, Masters Candidate
Donglai Zhang, Masters Candidate
Sia Wee Lee, Honours Candidate
Laura Maddock, Laboratory Assistant
Sharee McCammon, Research Assistant
Professor Tom McMeekin, Professor of Microbiology,
Co-Director, AFSCoE

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Food Safety: the essential ingredient