The Role of Science in Enhancing Food Safety and Stability

K.S. Gobius

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ILSI SEA Region 6th Asian Conference on Food and Nutrition Safety (Nov 2012)
http://www.ilsi.org/SEA_Region/Pages/ViewEventDetails.aspx?WebId=4D540914-EEE6-40E4-89EB-0B73BA3D76C1&ListId=478BE3CB-581B-4BA2-A280-8E00CCB26F9C&ItemID=66
Outline

- Global Food Megatrends & Food Safety Challenges
- A Paradigm Shift in Risk Management
- Solutions from Innovative Science
- Future Needs
Food Is One Of Our Great Pleasures......

Various sources, Google Images
Global Food Industry is a huge complex business worth more than US$4 Trillion

*Food import-export (5-value) fluxes in 1998
József Baranyi, Zoltán Lakner, Maria M. Ercsey-Ravasz and Zoltán Toroczkai (personal Communication)
Food Science & Preservation Technology - A Remarkable Achievement

- Biology, Cell biology
- Biotechnology
- Chemistry
- Computer Science
- Genomics
- Materials Science
- Microbiology
- Nutrition
- Physics
- Sensory Science
- Toxicology
Over the next 40 years we will need as much food as we have eaten in the last 500 years.
The Coming Famine (Julian Cribb)

Peak Gas & Oil

Peak Phosphate

Water Crisis

Demand

Population

Global Yield Growth Slowing

Global R&D Spend on Ag Science Reduced

(Various sources, Julian Cribb)
Megashock: Population Health

Australian’s expenditure on health not sustainable

**Health and aged care costs to rise from $84 billion in 2003 to $246 billion in 2033**

Ageing population
Obesity increasing
Increased chronic disease

One-third of chronic disease and injury in Australia is attributable to diet and lifestyle related risk factors.
Megashock: Biosecurity & Food Safety

- Release
- Escape
- Contaminant
- Travel
- Corridor
- Migration

E. coli outbreak cases by country

- Europe's food poisoning outbreak saw 250 million euros in losses and 2,700 people affected. The outbreak began on May 2. German officials are still searching for the source of the contamination.

Graph: Imports 2007-08

- A$B

- 1991: -92
- 1993: -94
- 1995: -96
- 1997: -98
- 1999: -99
- 2001: 00
- 2003: 02
- 2005: 04
- 2007: 06
- 2008: 08
Going Without Food is Not a Pleasure

<table>
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<tr>
<th>Year</th>
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<td>2002</td>
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<td>2007</td>
<td>140</td>
</tr>
<tr>
<td>2008</td>
<td>150</td>
</tr>
</tbody>
</table>

*The real price index is the current price index adjusted to the World Bank's producer price index (PPI).*

**Economists fear repeat of 2008 food crisis**

Coffee, soybeans, and other global food prices have hit 2-year highs, with some experts predicting the situation could spiral out of control. "It's a perfect storm," said Dr. Andrew, "with a perfect storm of supply problems and demand pressure." The FAO Food Price Index has been rising steadily, reaching record levels in recent months.

**Source:** www.datadiary.com.au Images various sources, Google Images
Pathways to address the food security challenge?

- Reducing the demand trajectory
  - Reduce waste along the food value chain
  - Develop “smart biofuel” policies and technologies
  - Improve food, nutrition and health outcomes

- Filling the production shortfall
  - Expanding the land footprint
  - Intensifying existing land use
  - Closing yield gaps
  - Raising resource use efficiency and better managing risks
  - Breaking yield ceilings through new technologies

- Avoiding losses from the current production level
  - Maintaining pest and disease resistance
  - Avoiding soil and water degradation
  - Adapting to unavoidable climate change
  - **Avoiding disruptions through food safety/biosecurity issues**
  - Limiting the loss of existing agricultural land (e.g. to urbanisation)

(Keating and Carberry et al, CSIRO)
# Factors in the Emergence of Pathogens

- Microbial adaptation and change
- Human susceptibility to infection
- Climate and weather
- Changing ecosystems
- Human demographics and behaviour
- Economic development and land use
- International travel and commerce
- Technology and industry
- Breakdown of public health measures
- Poverty and social inequality
- War and famine
- Lack of political will
- Intent to harm

Morens *et al.*, 2004
Globalisation of Food Supply = New Opportunities for Microorganisms

(Adapted from Dawkins, 1996, 'Climbing Mount Improbable')
Rate of new diseases identified increasing

Unknown etiology for 80% of foodborne illnesses; 64% of deaths
1978 – new disease identified every 10-15 years
1988 – new disease identified every 8-9 years
Today – new disease identified every 14-16 months

Sources: Mead et al., 1999; Cynthia Johnson, USDA.
Reforms to Managing Food Safety

Command & Control
Prescriptive
Point Testing
Constraint to Innovation

Risk based
Flexible
Through Chain
Supports Innovation
More Complex
Trends in technology, trade and consumption likely to impact on microbial food safety

High Certainty of Impact

- Development & Implementation of Control Measures
- Regulatory measures
- Increased consumption of meat and poultry
- Increased consumption of fresh produce
- Doubling of Global Food Trade

Low Certainty of Impact

- Decreases Global Foodborne Disease
- Increase in Convenience foods Refrigerated foods & Extended shelf-life
- Improved Detection & Monitoring Technologies

Quested et al, 2010
Fresh Produce Safety

Includes over 300 separate commodities

Food safety often relies on prevention of contamination, the weakest form of hazard control

- Control of pathogen growth is insufficient
- No practical “kill” step currently available

Leafy greens 5 million bags a day, 18 billion/year

Dave Gombas
204 people from 26 states infected with outbreak strain

*E. coli* O157: H7 Isolated from 13 packages of DOLE spinach;

“DNA fingerprints” of all 13 matched the outbreak strain;

Eleven packages with lot codes consistent with a single facility on a single day

102 (51%) hospitalized ; 31 (16%) developed hemolytic uremic syndrome (HUS)

Three confirmed deaths

$170 million in lost sales, millions more in settlements
**E. coli** Outbreak in Germany

- Traced to Bean sprouts organic farm in Northern Germany
- Causative Agent, *E. coli* 0104:H4
- Over 4000 cases across 16 countries, most in Germany
- 909 haemolytic uraemic syndrome (HUS)
- 52 deaths
- Most costly ever outbreak
- Business cost so far >210 million Euros
- Medical costs (based on US estimates likely to be $3.5 billion)
- Likely contamination source, Fenugreek seeds from Egypt

![Image of E. coli bacteria]

![Map of E. coli outbreak cases by country]

http://www.smartdraw.com/specials/images/examples/ecoli-outbreak-germany-map.png

10.1056/nejmoa1106483 nejm.org
In HPT processing accurate temperature control is essential

- Heat retention aids (e.g., insulated carriers) are not completely effective and need validation

Thermocouple issues

- Usually fail after a limited number of runs
- Readings may be disturbed by internal heaters, if present

Wireless monitoring systems needed

- Temperature mapping of empty carriers/vessels ...
- ... also filled carriers
- Tracing of process temperature for records and/or validation
- Assistance in regulatory approval
The system = pressure resistant shell + data logger

The shell
Highly stress resistant
Low specific heat capacity
• heat sink effect minimal
High thermal conductivity

The data logger
Wireless temperature logger
Temperature range 0°C ≤ T ≤ 130°C
Measurement intervals ≥ 1 s
Memory: 4,000 logs per run

Prototype
stable for more than 200 runs
P = 600- 800 MPa
and
T ≤ 130°C

New design
No clamps required

Thermo-Egg and Diving Bells – Tools to assist in developing HPT processes
Fabrication of “Diving Bell” monitoring tool

- Synergy of spore inactivation with pressure, or potential protection, is still not completely proven

- “Thermo-Egg” → “Diving Bell”
  - The fact that the Thermo-Egg can be placed in a HPT process, while its inside is not subjected to pressure brought up the idea of filling it with spore samples rather than a temperature logger
  - Two shells were manufactured with identical dimensions, but one including a channel through which pressure could be transmitted
  - Both “diving bells” can be placed next to each other in a HPT process; the inside, i.e., the spore samples, will be subjected to very similar temperature profiles, with the important difference that one sample will also be subjected to high pressure, while the other sample remains at atmospheric pressure

- Compression heating issue?
The Design

Channel for pressure transmission

Thermo-Egg and Diving Bells – Tools to assist in developing HPT processes
Comparison of temperature profiles

Thermo-Egg and Diving Bells – Tools to assist in developing HPT processes

\[ T_{100, \text{open}} = 7.3 \text{ min} \]
\[ T_{100, \text{closed}} = 7.9 \text{ min} \]
Ongoing work

• Conduct spore inactivation studies for various bacterial spores of interest (spoilage organisms, pathogens)

• Characterise synergy (pressure/temperature) for inactivation of bacterial spores
Thermal Processing

Interrogate physiological state by flow cytometric (FCM) profiling

Equivalent thermal processes
Thermal Processing
Couple FCM with 3D-Structured Illumination Microscopy, chemical analyses, ‘omic’ techniques, etc
Atmospheric-Pressure Plasma Treatment of Food
Two Food Types Targeted

1. Nuts (almonds, etc)
   - Work underway

2. Powders (milk powder, flour, spices)
   - Early phase research
   - Explosion prevention will require maintaining oxygen content lower than ambient
We used an existing helium plasma torch, with extensive modifications to allow treatment of a larger surface area and to ensure safety.

**Plasma Treatment of Almonds: Initial Experiments**

Original plasma jet system

System modified for treatment of nuts

High-voltage electrode

Nut in helium atmosphere
Plasma Treatment of Almonds: Initial Experiments

Even plasma contact with nut surface demonstrated.

There was no inactivation of *E. faecium* on almond surfaces under the conditions examined (30 W, 350 kHz He-plasma, 1 min treatment).

The lack of inactivation was expected for a helium plasma.
Atmospheric Air Plasma System Development

- An atmospheric air plasma has been produced using a different power supply (higher voltage)
- Test almonds innoculated with *E. faecium*
- We have a strong expectation of success
  - Reactive nitrogen and oxygen species are the key to plasma disinfection
- Testing of apparatus is almost complete
- Disinfection experiments initiated
- Additional air plasma systems are now being tested, so we will have a range of options
Conclusions

• Global food drivers and megashocks complex
• Food safety public health & food security issue
• Rate of emergence of new issues increasing
• Solutions through *science* are essential
• Detection and management of new issues critical
• Codex RM framework will expedite development of control measures & new risk based processes
• Validated application of innovations in food processing are critically required
Thank you

Kari Gobius
Theme Leader Food Safety and Stability
CSIRO Animal, Food and Health Sciences

+61 7 3214 2036
Kari.Gobius@csiro.au

Martin Cole
Chief
CSIRO Animal, Food and Health Sciences

+61 2 9490 8465
Martin.Cole@csiro.au