The Role and Future of Predictive Microbiology in Food

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14/12/2021

Contents

The background

- The “one health” approach
- Food as transmission vehicles
- Foodborne outbreaks:

  E.g. The group B *Streptococcus* outbreaks caused by freshwater fish

1. The trend of food consumption

- **Demands of customers**:
  - Fresher and more natural
    - E.g., raw milk cheese

- **Globalized food supply chain**:
  - Longer and more complex
  - Imported food

2. Burdens of Foodborne outbreaks

- Pose health and economic burden to the individual and public health systems
- Harm the reputation of food companies and countries in competitive global markets
- Result in food waste

3. Transmission of antimicrobial resistance

- Vehicle: contaminated food, especially meat products
- Transmit multidrug-resistant pathogens from farm to fork
  - Key reservoirs of “superbugs”: food animals

Demand: reliable and effective food safety management!

Predictive microbiology

- Interdisciplinary: mathematics + microbiology
- **Definition: Predictive microbiology is about describing the population behaviour of microorganisms in response to the environmental properties of foods over time with mathematic equations.**
- **Premise**: "the responses of populations of microorganisms to environmental factors are reproducible"

(Ross et al., 2014; Ross et al., 1999)

Model types

- **Kinetic models: the ‘rate’**
  - **Growth rate**
  - Death (inactivation) rate
- **Probabilistic models: the ‘likelihood’**
  - Probability of growth
  - Probability of toxic formation

(Ross et al., 2014)

Food matrix as a ‘nutrition broth’

Environmental parameters:

- *Extrinsic parameters:*
  - Storage temperature (T)
- *Intrinsic parameters:*
  - Water activity (a_w)
  - pH
  - Other components in foods
  - …

Model development

Growth rate

- Classic two-step approach
  - Primary models
  - Secondary models
    - Tertiary models (combinations of primary and secondary models)

Example: ComBase https://www.combase.cc/index.php/en/

- Developed by U.S. Department of Agriculture and other academic institutions
- Supported by USDA
- A suit of primary and secondary models
- An internet-based interface
- Repository for growth data

Example: ComBase https://www.combase.cc/index.php/en/

The interface of ComBase predictor

- User-friendly
- Choose target bacteria
- Adjust parameters
- Get growth data (e.g., growth rate)

Example: ComBase https://www.combase.cc/index.php/en/

Step 1: Primary model

Condition A (a fixed condition):

T = 25°C

pH = 7.0

a_w = 0.999

Example: ComBase https://www.combase.cc/index.php/en/

Step 2: Secondary model

- Containing over 60,000 records of bacterial growth

Condition A: μ_a
$T = a_1$, $pH = a_2$, and $a_w = a_3$

Condition B: μ_b
$T = b_1$, $pH = b_2$, and $a_w = b_3$

Condition C/D…

μ_c, μ_d…

Parameters “fitted”

Secondary model

Empirical model *VS.* Mechanistic model

- Purely empirical model

- Semi-mechanistic model

  (e.g., square-root type)

- Purely mechanistic model ?

Application: supporting food safety management

✓Predictive microbiology supports **two levels** of food safety management.

Industry level: microbial food safety management

Traditionally,

- ✗ **Hazard-based approach:**
  - ✗ **Regulatory inspection and sampling regimes**

- ✓ **Risk-based approach**

Industry level

Predictive microbiology

Providing "scientific supports" for estimating the behavior of pathogens in food chain

✓ **QMRA**
(Quantitative Microbial Risk Assessment)

✓ **HACCP**
(Hazards Analysis Critical Control Points)

Implement of HACCP (Hazards Analysis Critical Control Points) plans in Hong Kong

- Hong Kong *v.s*. developed countries
  - Wet market

- Hong Kong to follow international trend

Government level

- **Regulation**
  - **Most of countries:** regulatory inspection and sampling regimes
    - Time-consuming, expensive, and opportunistic
  - Regulation based on predictive model as a better alternative

Government level

- **Regulation**
  - **Australia: a tool, "refrigeration index"** :
    - Regulate and monitor the effectiveness of refrigeration process of exported meat.
      - By regulating the increase of *Escherichia coli* in meat.
    - Cost-effective.
      - By 2008, the implementation reaching a benefit:cost ratio of 11:1.
  - **Hong Kong**: criteria for microbial limits are still based on regulatory inspection and sampling regimes (i.e., Aerobic Colony Count level).

(Federal Register of Legislation, 2021; McMeekin, 2008; Centre for Food Safety, 2017)

The future expectations

- Model development for certain food products
  - Involve more explanatory variables in models
- **Shift from empirical model to mechanistic model**
  - Systems-biology approach

Understanding on microorganisms

- Use bioinformatic (e.g., artificial intelligence) to simplify empirical model development
- **Standardization of predictive microbiology**

Modelling techniques

Take home message

- **Predictive microbiology**
  - A quantify approach of food microbiology with mathematical modelling
  - Imperfect but effective tool applied in food industry
  - ! Empowering the risk-based food safety management strategies