

The Role and Future of Predictive Microbiology in Food

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1. Background knowledges
2. The most important application
3. Future expectations

The background

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

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

The background

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”

Model types

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

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):

$$T = 25^{\circ}\text{C}$$

$$\text{pH} = 7.0$$

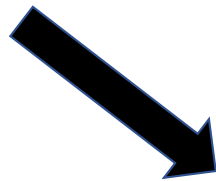
$$a_w = 0.999$$

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 $a_w = a_3$

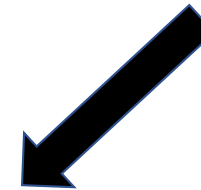


Condition B: μ_b
T = b_1 , pH = b_2 , and $a_w = b_3$



Condition C/D...

$\mu_c, \mu_d...$



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).

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