# PREDICTIVE MICROBIOLOGY

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**Keywords**: Contaminant, temperature, microbial growth, food pathogens, food safety, generation time, mechanistic model, microbial contamination, microbial food quality, microbial risk, predictive microbiology, simulation, microbial growth models, water activity

## Contents



## Summary

The management of microbial risks in foodstuffs needs an exact knowledge of microorganisms and of their behavior in these products. This knowledge is classically obtained from a limited number of experiments because of the time required and the cost.

For these reasons, a mathematical simulation is used more and more often, in tandem with experimentation, to describe the theoretical dynamics of a microbial population under various conditions (product formulation, industrial process, storage conditions, and so on).

The quality and the credibility of the simulation results depend on the rigor used to build and use the models. In general, two groups of models are distinguished: the primary models describing the variation of the number of cells, or the microbial density with respect to time; and the secondary models describing the effect of environmental factors (temperature, pH) on the parameters of the primary model.

Different models were proposed in the literature and used by microbiologists. Some are more convenient and more in agreement with the needs of food microbiologists and food hygienists. These models were validated successfully in foodstuffs in complex situations (thermal variation, acidification, and so on).

## 1. Introduction

In the food industry, the control of microbial food quality is an obligation, from the raw material stage to the point of sale. This concern is not only linked with regulations, but it has become a fundamental demand of consumers, who want to buy safe and healthy products that keep their nutritional and sensorial properties.

Nevertheless, an increase in the outbreaks caused by foodborne pathogenic microorganisms has been observed. The reasons are numerous: aging of the population, increase in vulnerable population, modifications of industrial and commercial practices, modification of consumption lifestyle, increase in transcontinental travel, and the development of detection techniques.

Therefore, manufacturers are obliged to develop their knowledge of pathogenic microbial hazards to improve their risk analysis. This knowledge is usually based on experimental methods. These consist of the study of the behavior of a given contaminant population in a given product under different environmental situations (e.g., temperature and duration of storage). Nevertheless, because of the delay and the cost, this usual approach is always based on a limited set of experimental scenarios of risk conditions (limited number of breaks of cold chain, contamination level, microbial strain studied, and so on). This fuzzy knowledge of hazard obliges producers to maximize their safety margins (e.g., important heat treatments). This may be incompatible with improvement of nutritional properties of foods.

For this reason, microbiologists and hygienists would like to improve their approach by using new tools for modeling and simulation. Some models have been proposed and used with the aim to describe the effect of temperature and heat treatments on microbial destruction. But it is only since the end of the 1980s that the first mathematical tools have been built to simulate the complete behavior of microbial flora (growth, lag, and decrease phases) in food products under process conditions. This approach, called Predictive Microbiology, has no authority to replace the experimental approach, but it is used to complete and to lead it.

## 2. General Principles and Microbial Dynamics

Food processing may be described as a succession of steps, from the input of raw materials to the distribution and consumption of the product (Figure 1). Different steps can be identified as critical from the microbiological point of view. At each of these steps, microbial contamination or multiplication can occur. If we consider that a contamination occurs at a given initial level during one of these critical steps, predictive microbiology consists of a simulation of the behavior of this contamination, from the starting point to a given time, taking into account variations of process conditions. Hence, from a general point of view, four major objectives may be identified:

1. This approach allows the microbial hazard to be predicted, which improve the choices used to prevent and to control the risk;
2. Predictive microbiology allows quantification of the risk, so as to improve accuracy of the data gathered;

3. Predictive microbiology is used to optimize experimental design, which allows the spread of the investigation domain, and reduces delay and cost;
4. This approach is supportive of debate, which improves communication between experts and managers.

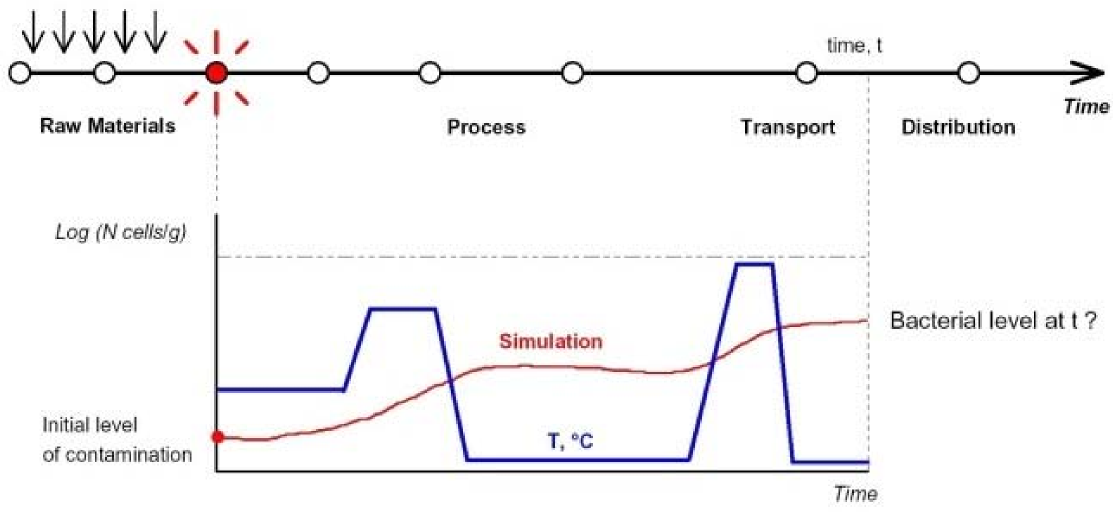


Figure 1. General principle of Predictive Microbiology in the food quality context

The objective of Predictive Microbiology is to be able to forward microbial dynamics by using mathematical models. Before studying the different models and formulations proposed, it is important to consider the classical behavior of the microbial population.
As shown in Figure 2, the evolution of the logarithm of the microbial cells' density under constant environmental conditions may be classically described in four main phases, which are:

1. The lag phase, which may be considered as an adaptation phase between an initial physiological state and a growth state, in a growth condition, and a delay of decrease in unfavorable conditions.
2. The growth phase characterized by a linear portion if the logarithm of the variable (biomass, number, or concentration of cells) is represented versus time. This dynamical step is close to an exponential phase, and is classically described from the slope value called maximum specific growth rate, $\mu_{max}$ (time$^{-1}$), defined as follows:

$$\mu_{max} = \frac{\ln x_2 - \ln x_1}{t_3 - t_2}$$
$$\mu_{max} = 2.303 \frac{\log_{10} x_2 - \log_{10} x_1}{t_3 - t_2} \quad (1)$$

3. The breaking and stationary phases may have several origins linked to high cell density in growth conditions (lack of nutrients, acidity, and so on), or to the apparition of a stable density of resistant cells in unfavorable conditions.

4. The decrease phase that appears when the medium and the conditions become too unfavorable. This phase is usually close to an exponential decrease of the density.

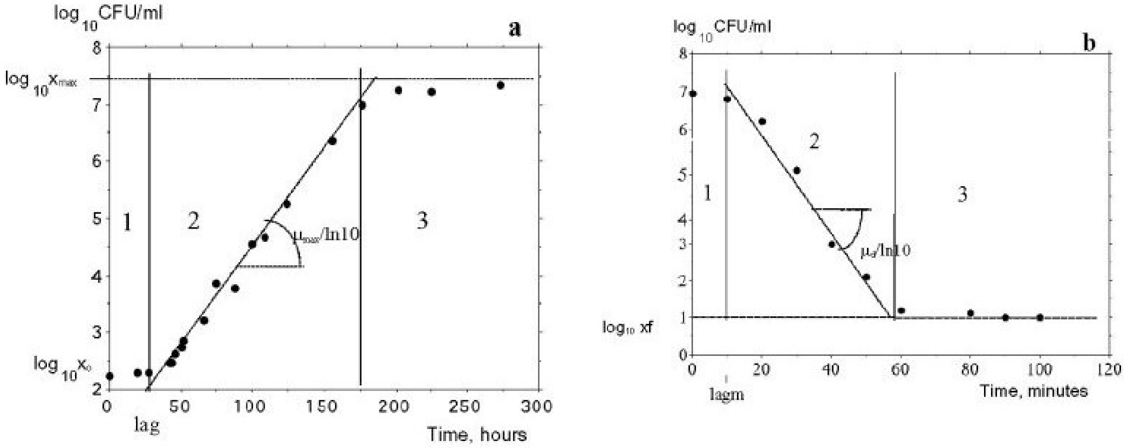


Figure 2. Different phases of dynamical behavior of *Bacillus cereus* and *Listeria monocytogenes* in a laboratory medium at 58.5 °C log *x*, logarithm of the microbial density; $x_O$, inoculum; $x_{max}$, maximum density; $xf$, the final survivals density; $\mu_{max}$ and $\mu_d$ respectively, the maximum specific growth rate and the maximum specific decrease rate.

Step 1: lag phases (growth, lag; decrease, lagm); Step 2a. exponential growth; Step 2b. exponential decrease; 3. stationary phases

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### Biographical Sketch

**Dr. Laurent Rosso** is Coordinator of Research and Technical Support of the French Food Safety Agency in Maison-Alfort, France, and Deputy Director in charge of the coordination of research, expertise, and technical support. He received his Ph.D. in biometry, applied to quantitative and predictive microbiology. Dr. Rosso has been active for eight years in applied research in the food industry. He is a well-known expert, both nationally and internationally, in the field of predictive microbiology applied to microbial risk assessment and management in foods. Dr. Rosso is the author of many scientific publications and an organizer and lecturer of several international scientific events.