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Editorial: Machine learning and predictive microbiology: enhancing food safety models

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Editorial on the Research Topic
Machine learning and predictive microbiology: enhancing food safety models

The goal of food safety is to ensure that the food provided to consumers does not represent a health risk due to the presence of chemical, physical, or biological hazards. In particular, microbial growth, whether from spoilage or pathogenic microorganisms, can reduce shelf life and pose a health hazard. The composition, physical properties, and chemical properties of a food product can either promote or inhibit microbial growth; also, food processing methods can favor or restrain microbial proliferation. The response of microorganisms to food composition, processing, or storage conditions will determine their growth capacity. However, traditional microbial growth models, which are often used in laboratory settings, do not always translate well to real-world food environments due to the unique conditions present in food systems. In this context, predictive microbiology has emerged as a valuable tool, enabling researchers to predict the behavior of pathogenic and spoilage microorganisms in food systems based on growth results obtained under controlled conditions (Kumar et al., 2024).

The food industry is constantly modifying processing conditions, developing or enhancing more efficient preservation methods, and creating new food products. In all these scenarios, the use of predictive microbiology can help select the best conditions to increase shelf life and reduce the risk of pathogen contamination. Even when predictive models are utilized in the food industry as a complement to quality control programs, such as HACCP (Hazard Analysis and Critical Control Points), numerous challenges remain in this research field. The development of new primary predictive models is an ongoing task, as new variables can be incorporated and new statistical and mathematical methods become available. Typically, predictive models examine the growth of an organism under controlled conditions; however, the impact of its interactions with other organisms present in the food environment is often overlooked. Additionally, the initial physiological state of the microorganisms needs to be taken into consideration (Koseki et al., 2021). The incorporation of new information provided by the "omics" sciences, particularly functional genomics, can also improve predictions of microbial growth in foods. Tools such as data mining or machine learning can utilize up-to-date information on microbial growth in food systems to generate more comprehensive predictive models (Taiwo et al., 2024).

In the present Research Topic, the combination of preservation methods is reported to be effective in extending the shelf life of food products. In Chen et al., the antimicrobial effects of lemon essential oil, both alone and in a nanoemulsion were tested against common foodborne pathogens (*Escherichia coli, Staphylococcus aureus,* and *Listeria monocytogenes*). The effects were also tested on the shelf life of fresh-cut kiwifruit, showing that the increase in shelf life was related to the antimicrobial and antioxidant effects of the nanoemulsion. In another study, the effect of lactic acid bacteria (LAB) inoculants on the quality of oat silage was investigated, seeking to reduce the concentration of biogenic amines and thereby improve product safety (Huang and Jia). Although these contributions do not contain predictive models in their content, they serve as examples of cases in which predictive microbiology can provide information on food safety throughout the processing chain.

On the other hand, in Hernandez-Figueroa et al., different predictive models are used to analyze the effect of thyme essential oil on the *in vitro* growth of *Aspergillus flavus* and *Penicillium citrinum*. The essential oil was studied in combination with different pH concentrations and water activities, using a full factorial experimental design. The authors suggest that by using different modeling approaches, it is possible to identify the mechanisms of action of moderate antimicrobials and their combinations. The construction and validation of a tertiary model for *Salmonella* growth in chicken liver was presented by Oscar, with data obtained from Most Probable Number (MPN) analysis under different conditions of dose, time, and temperature. Polynomial regression was used to construct the secondary and tertiary models, which were then validated with experimental data. The author emphasizes the importance of developing tertiary models that can be used in the food industry.

The incorporation of novel strategies to manage data, such as data mining, neural networks, and machine learning, presents an opportunity to achieve the goals of predictive microbiology. A better understanding of the physiological stages of microorganisms in food systems, along with the changes in growth conditions at different stages of the food management chain, can also provide a more accurate view of the effects of processing on food preservation and safety. However, several questions remain to be answered in this field.

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References

Koseki, S., Koyama, K., and Abe, H. (2021). Recent advances in predictive microbiology: theory and application of conversion from population dynamics to individual cell heterogeneity during inactivation process. *Curr. Opini. Food Sci.* 39, 60–67. doi: 10.1016/j.cofs.2020.12.019

Kumar, V., Ahire, J. J., and Taneja, N. K. (2024). Advancing microbial food safety and hazard analysis through predictive mathematical modeling. *The Microbe* 2:100049. doi: 10.1016/j.microb.2024.100049

Taiwo, O. R., Onyeaka, H., Oladipo, E. K., Oloke, J. K., and Chukwugozie, D. C. (2024). Advancements in predictive microbiology: integrating new technologies for efficient food safety models. *Int. J. Microbiol.* 2024:6612162. doi: 10.1155/2024/6612162