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Commentary

Predictive Modeling of *Clostridium perfringens* Growth in Cooked Rice under Different Storage Conditions

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DESCRIPTION

Clostridium perfringens is a spore-forming, anaerobic bacterium commonly implicated in foodborne illnesses, particularly in foods that are prepared in bulk and subjected to improper storage practices. Among such foods, cooked rice has garnered attention due to its starch-rich composition and potential to support rapid bacterial growth when left at unsafe temperatures. In institutional kitchens and food service settings, rice is often cooked in large batches and held at ambient temperature for extended periods, creating favorable conditions for C. *perfringens* germination and multiplication. This study aims to develop a predictive model to estimate the growth kinetics of C. *perfringens* in cooked rice under various storage scenarios, providing a valuable tool for risk assessment and food safety management.

To achieve this, the study employed a controlled laboratory approach using sterile cooked rice samples inoculated with a known concentration of C. *perfringens* spores (approximately 10^2 spores/g). The rice samples were then subjected to four different temperature regimes: 15°C, 25°C, 35°C and 45°C, simulating common post-cooking storage conditions. Bacterial enumeration was carried out at regular intervals (0, 2, 4, 6, 8, 10 and 12 hours) using Tryptose Sulfite Cycloserine (TSC) agar under anaerobic conditions. The data were fitted into primary growth models, including the modified Gompertz and Baranyi models, to estimate lag phase duration, maximum specific growth rate and time to reach critical contamination thresholds (e.g., 10^6 CFU/g, commonly associated with illness onset).

The results showed clear temperature dependence in the growth behavior of C. *perfringens*. At 15°C, minimal growth was observed, with the population remaining largely static even after 12 hours. However, at 25°C, the bacteria exhibited a short lag phase and began to multiply exponentially after 4 hours, reaching unsafe levels by the 10th hour. At 35°C and 45°C, growth was significantly accelerated, with populations exceeding 10^6 CFU/g within 6 and 4 hours, respectively. The Baranyi model provided the best fit for most datasets, accurately capturing the transition from lag to exponential growth and allowing for robust predictions across the tested temperatures. These findings highlight the critical importance of temperature control in the post-cooking handling of rice, particularly in settings without strict time-temperature monitoring.

In addition to temperature, the study evaluated the effect of initial spore concentration and moisture content on bacterial proliferation. Higher spore loads (10^3 spores/g–10^4 spores/g) shortened the lag phase and led to faster population increases, emphasizing the need to prevent cross-contamination during pre-cooking handling. Moisture content also played a role; rice with higher residual water content supported faster germination and growth, especially at mid-range temperatures (25°C –35°C). These parameters were integrated into the predictive models to enhance their accuracy and applicability in real-world scenarios. By inputting initial contamination level, storage time and temperature, the model can estimate the potential risk of C. *perfringens* proliferation in a given batch of rice, aiding food safety managers in decision-making and control measures.

Validation of the model was performed by comparing predicted growth curves with experimental data from real-world kitchen simulations. Cooked rice was stored in common catering containers under ambient conditions typically observed in Italian school cafeterias and event catering setups. The model predictions closely aligned with observed data, with deviations of less than 0.5 log CFU/g, confirming its utility in operational risk assessment. The model's sensitivity and specificity also made it a practical tool for developing safe holding time guidelines and determining Critical Control Points (CCPs) in Hazard Analysis and Critical Control Points (HACCP) systems.

In conclusion, the predictive modeling of *Clostridium perfringens* growth in cooked rice under various storage temperatures provides vital insights for food safety management in bulk food preparation environments. The study confirms that time and temperature are key factors influencing the rapid growth of this pathogen, with serious implications for public health when rice is improperly stored after cooking. The validated model offers a scientific basis for developing evidence-based storage guidelines, including safe holding times and temperature thresholds,

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tailored to food service operations. As improper rice handling continues to be a recurring cause of foodborne outbreaks, especially in mass catering and buffet systems, predictive modeling emerges as an essential preventive tool. Incorporating such models into food safety protocols can significantly reduce the risk of C. *perfringens* related illnesses and promote safer food handling practices across various sectors of the food industry.