

Improving food safety using AI

By creating an AI tool based on bacterial sequence for predicting virulence and disinfectant resistance.

The Listeria problem in dairy

Listeria monocytogenes is a persistent foodborne pathogen which poses a risk to both consumers and the industry. Outbreaks linked to Listeria have led to increased safety standards, yet traditional testing methods for bacterial contamination provide limited insights. Standard microbiological techniques detect *L. monocytogenes* but lack the ability to differentiate between strains of varying virulence or assess resistance to disinfectants used in dairy facilities. Consequently, there's often a lack of essential information when making sanitation and risk-management decisions.

Developing an AI tool

Recognizing these limitations, this project aimed to enhance the capabilities of the dairy industry in managing *Listeria contamination*. By combining whole genome sequencing (WGS) data and machine learning (ML) technology, 'LisPred' was designed to predict two critical characteristics of *L. monocytogenes*: (1) virulence potential, which indicates how likely the strain is to cause illness, and (2) disinfectant tolerance, reflecting the strain's ability to resist standard cleaning agents. These predictions help quality assurance teams make more informed decisions about the level of risk and the required response to contamination.

How the AI tool works

LisPred utilizes ML algorithms trained on a large dataset of WGS data from *L. monocytogenes* isolates (Figure 1). The tool is capable of processing both raw sequencing reads and assembled genomic data. By analyzing and training on specific genetic markers associated with virulence and disinfectant tolerance, LisPred offers predictions with high accuracy for virulence and disinfectant resistance. The tool classifies strains into low, medium, or high risk for virulence and categorizes disinfectant resistance as either sensitive or tolerant.

For food safety professionals, this classification offers a clear, actionable insight into the level of

threat posed by *L. monocytogenes* strains. If a high-virulence strain that is tolerant to disinfectants is detected, teams can prioritize the incident, adjust sanitation protocols, and implement more stringent cleaning measures to eliminate the risk.

Accessibility and usability

LisPred is designed for wide accessibility across different technical backgrounds. This tool is available in stand-alone version and web-based tool. The stand-alone version is available as snakemake pipeline and docker image. The stand-alone options are for users with programming experience and intend to analyze data in-house. The web-based option is for users with limited computational skills, which is an intuitive point-and-click web interface hosted by the Center for Genomic Epidemiology at DTU. This version requires no advanced technical knowledge, making it ideal for fast, on-demand analysis.

Why WGS and AI?

Advances in WGS and ML have transformed how the food industry can assess and manage bacterial contamination. While traditional methods can confirm the presence of pathogens, they lack the resolution to evaluate a strain's specific traits, such as its potential severity or resistance to disinfectants. With WGS, it is now possible to achieve strain-level identification, revealing the unique features encoded in each bacterium's genome. By applying ML, LisPred analyzes these genomic characteristics to predict virulence and disinfectant resistance reliably.

Using WGS data in this way provides companies with high-resolution information on bacterial contaminants, enabling quicker and more effective responses. As the cost and time required for WGS continue to decrease, incorporating genomic data into routine testing is increasingly feasible, especially with user-friendly tools like LisPred that helps with the data interpretation process.



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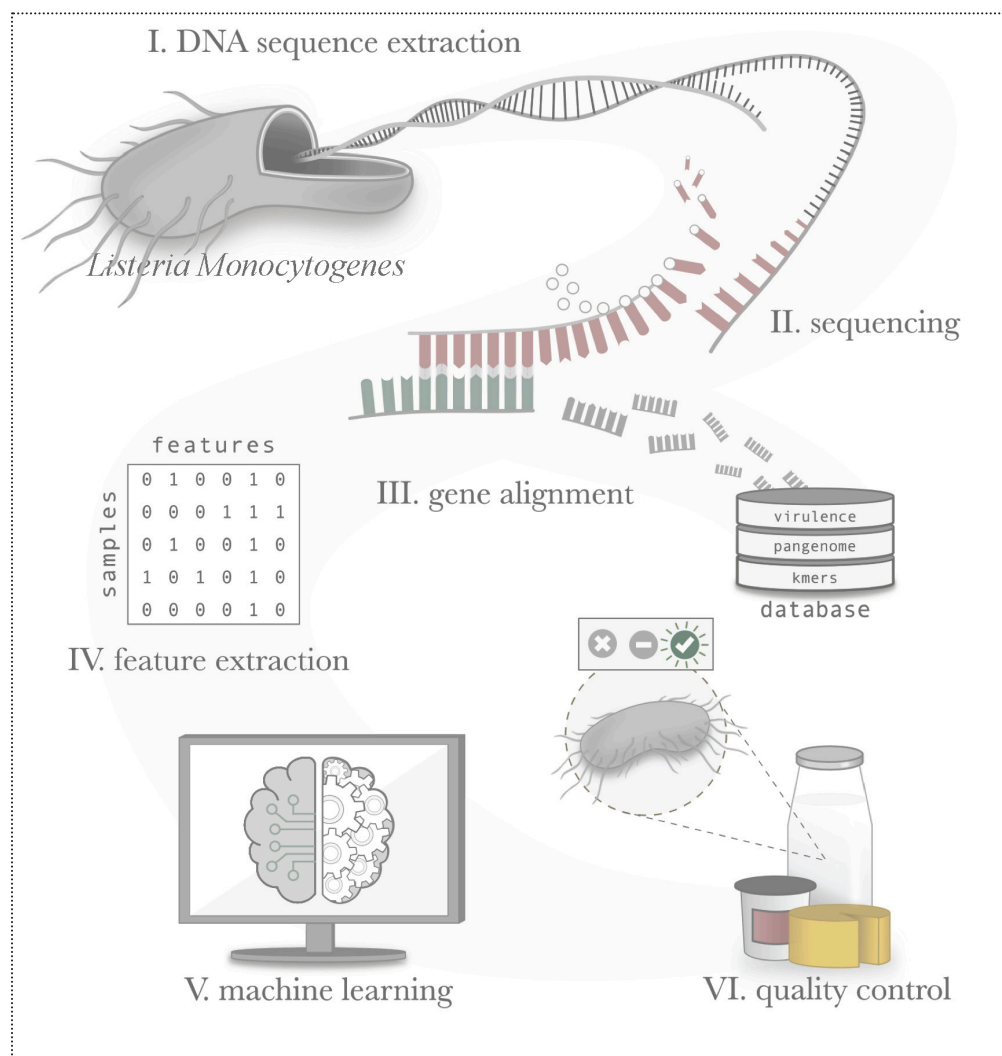


Figure 1 A concept picture for WGS-ML tool development

How can the industry benefit from this research?

By implementing LisPred, the Danish dairy industry can leverage cutting-edge technology to strengthen food safety efforts against *Listeria*. The tool's predictive capability for virulence and disinfectant tolerance equips food industry with actionable insights that improve risk assessment and response strategies. This ensures that sanitation efforts are precisely matched to each contamination incident, resulting in safer products and a more efficient quality control process. Overall, this project contributes to a safer and more resilient dairy sector, with the potential to set new standards for food safety worldwide.

Abstract

Funded by the Danish Dairy Research Foundation, this project has developed a machine learning tool that utilizes sequencing data to assess the virulence and disinfectant tolerance of *Listeria*

monocytogenes strains. This innovative tool is designed to improve food safety practices within the dairy industry by allowing food industry to assess contamination risks more effectively and make informed choices on cleaning protocols. ●

PROJECT FACTS

Project title: Improving food safety using WGS and machine learning

Project manager: Senior Researcher Pimplapas Leekitcharoenphon, DTU Food, Technical University of Denmark

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Project period: 2020 – 2024

Objective: To develop an WGS-AI tool for improving food safety by predicting virulence level and disinfectant resistance with *Listeria monocytogenes*.

PROJECTS RELATED TO THE DANISH DAIRY RESEARCH FOUNDATION