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# ARTIFICIAL INTELLIGENCE AND BIOMARKERS FOR THE EARLY DIAGNOSIS OF SUBCLINICAL MASTITIS IN DAIRY COWS: A REVIEW

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**Abstract**: Subclinical mastitis is one of the most economically important forms of mastitis in dairy cattle: it shows no overt clinical signs, yet reduces milk yield and quality and increases the risk of progression to clinical disease. Conventional diagnostic methods, such as bacteriological culture, somatic cell count, and the California Mastitis Test, are limited by turnaround time, cost, subjectivity, or moderate accuracy. This review synthesizes two complementary and rapidly evolving lines of research: novel milk and blood biomarkers(e.g., acute-phase proteins, enzymes, antimicrobial peptides, and microRNAs) and artificial intelligence (AI)-based approaches using data from automatic milking systems, spectroscopy, and infrared thermography. Although several individual biomarkers and AI models have shown good diagnostic performance under research conditions, each remains limited in specificity, cost, or generalizability across farms and pathogens. We discuss the current state of the art, the potential of integrated biomarker AI frameworks, and the key challenges (data standardization, model interpretability, and field validation) that must be addressed before such tools can be reliably applied under commercial farm conditions.

## Introduction

- Subclinical mastitis is the most common and economically important form of mastitis in dairy cows. It reduces milk yield and quality without visible signs (Halasa et al., 2007). Conventional diagnostic methods remain the reference but are slow, costly or subjective (Ruegg, 2017).
- Milk and blood biomarkers may allow earlier detection (Ceciliani et al., 2012), while sensor data from automatic milking systems support continuous monitoring (Hogeveen et al., 2010) and the training of AI prediction models (Ebrahimi et al., 2019).
- This review examines the potential of biomarkers and AI-based tools, alone and combined, for the early diagnosis of subclinical mastitis under farm conditions.

## Results and discussions

- Conventional methods, namely somatic cell count, the California Mastitis Test and bacteriological culture, remain the reference in practice, but their use is limited by turnaround time, cost and subjectivity (Viguier et al., 2009; Ruegg, 2017).
- Proposed alternatives include biomarkers such as acute-phase proteins (Eckersall et al., 2001), cathelicidins (Addis et al., 2016) and microRNAs (Zong et al., 2022), as well as infrared thermography (Polat et al., 2010) and machine learning models (Ebrahimi et al., 2019).
- Integrating these approaches is the most promising route to early and reliable diagnosis under commercial farm conditions.
- **Scheme 1** summarizes the main strategies for the early diagnosis of subclinical mastitis, a condition that has no clinical signs yet causes substantial economic losses (Halasa et al., 2007).




**Scheme 1.** Main strategies for the early diagnosis of subclinical mastitis in dairy cattle

## Conclusions

1. Conventional methods remain essential for confirming subclinical mastitis, but they are not well suited to early, rapid and objective detection on farm.
2. Milk and blood biomarkers can reveal intramammary inflammation before conventional indicators change, although their specificity and cost still limit routine use.
3. Artificial intelligence applied to sensor, spectral and thermographic data enables continuous, non-invasive monitoring, provided that models are validated across different farms.
4. A combined biomarker–AI approach could support earlier, targeted intervention, reduce production losses and promote more prudent antimicrobial use in dairy herds.