AI-driven forecasting of heat stress effects on dairy production using TSMixer neural network

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Introduction

Heat stress, intensified by climate change, represents a major challenge for the dairy industry. Advances in Artificial Intelligence enable the projection of future conditions based on historical data, offering crucial resources to tackle heat stress impacts.

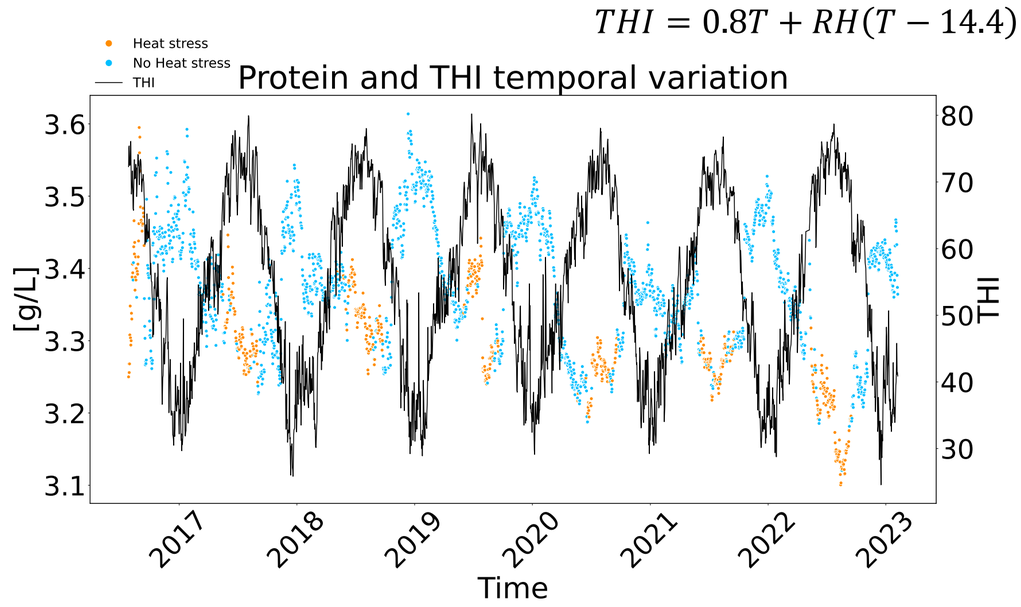
This study investigates and forecasts the impact of microclimatic conditions on milk production in dairy cows using data collected from Automatic Milking Systems (AMS) in a commercial dairy farms with an average herd of 200 cows. Over a period of 6 years and 7 months, we analyzed temporal relationships among milk yield, protein, fat content, ambient temperature, and the Temperature-Humidity Index (THI).

We introduced the Time-Series Mixer (TSMixer) architecture to forecast long-term trends in milk production and quality at high temporal resolution. TSMixer accurately predicted daily values of milk yield, protein, fat, and milk temperature over two-month time spans. It outperformed a baseline model which describes average seasonal trends over the year.

THI effect on milk quality and production

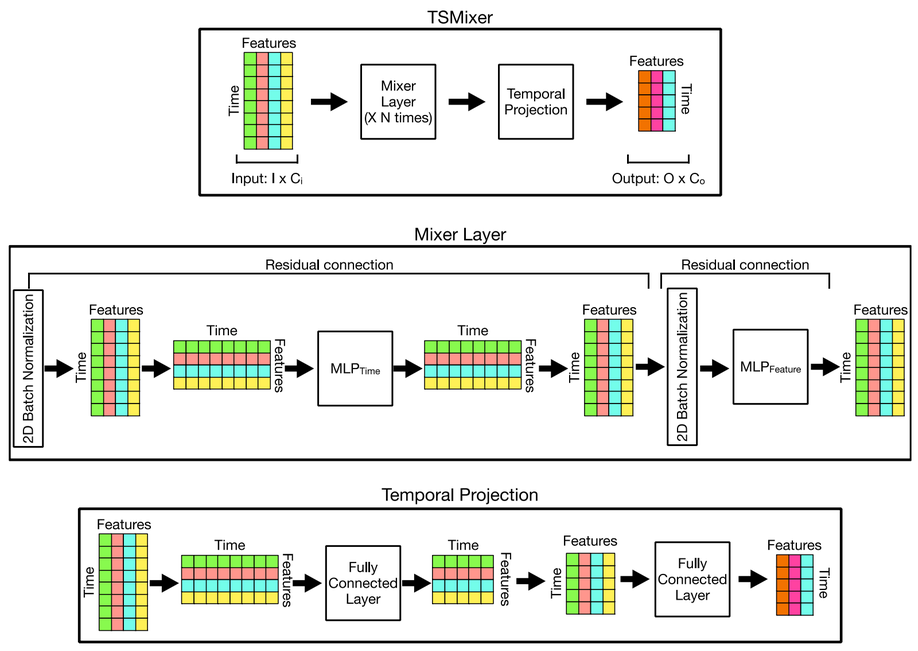
Protein and THI negative correlate, with protein values reaching their minima in corrispondence of heat stress conditions.

$$THI = 0.8T + RH(T - 14.4) + 46.4$$

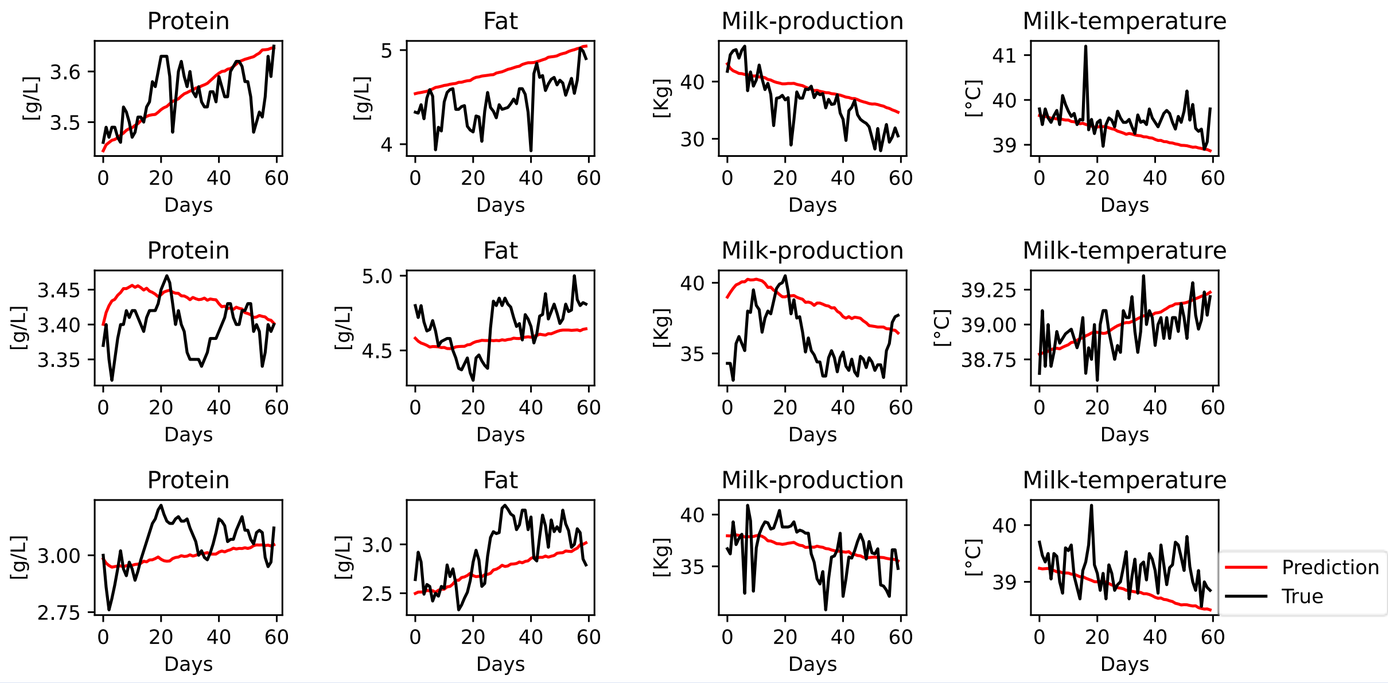


TSMixer predictions on milk quality and production

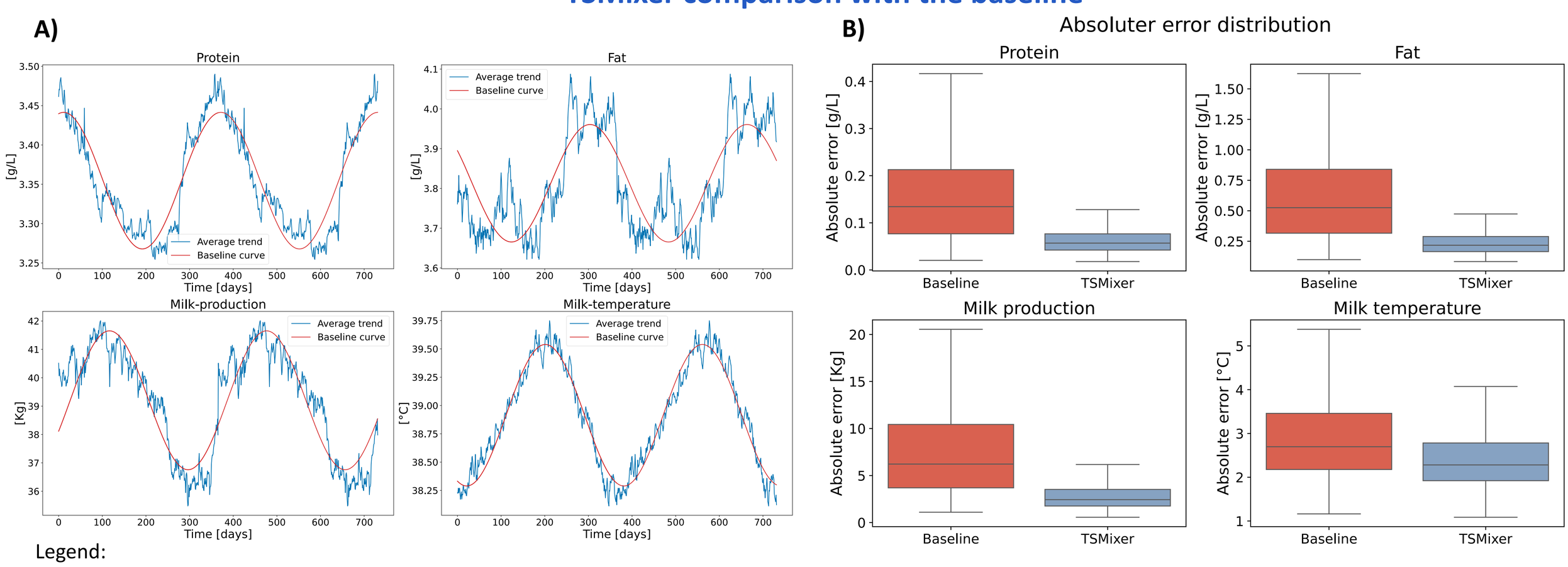
TSMixer architecture



TSMixer predictions examples



TSMixer comparison with the baseline



Legend:

A) Baseline model for seasonal periodicity

B) Baseline vs TSMixer absolute error: TSMixer performs better than the baseline model

Conclusion

This study presents an innovative approach to understanding and forecasting the impact of microclimatic conditions on milk production using AMS data. By combining statistical analysis with deep learning techniques, we demonstrated that microclimatic variables, particularly THI, significantly influence milk composition, with notable time-lag effects.

The proposed use of TSMixer enables long-horizon predictions of key milk traits, outperforming traditional baseline models. Its lightweight architecture makes it suitable for real-time integration into automated dairy systems, supporting proactive and data-driven management.

Zanchi, M. et al. (2025). Influence of microclimatic conditions on dairy production in an Automatic Milking System: Trends and Time-Series Mixer predictions. *Computers and Electronics in Agriculture*, *229*, 109730.

Paper QR Code