Towards Digital Twin Technologies for the Food Industry

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The food industry is increasingly called upon to modernize its production systems to enhance efficiency, reduce resource consumption, and align with sustainability goals. In this context, digital twins offer a promising solution to simulate, monitor, and optimize industrial processes. However, effective implementation of such tools requires a structured methodology supported by high-quality data and validated in real operational environments. This work presents a comprehensive and replicable approach to digital twin development, applied to a real industrial process. The case study focuses on the production of vegetable broth, particularly its thermal treatment phases, including sterilization and heat recovery. These stages are characterized by high energy demand and thus represent key targets for optimization. The methodology is structured in five main steps: (1) analysis of the production process and identification of critical phases; (2) acquisition of process variables through online and offline sensors, combined with technical documentation; (3) organization of the collected data into a coherent dataset; (4) application of a data reconciliation procedure to minimize measurement errors and enforce thermodynamic consistency; and (5) development of the digital twin using dynamic simulation software. Data reconciliation is a central step in this workflow. Given the absence of full sensor coverage and the inherent variability of industrial data, reconciliation was performed by formulating and solving a constrained optimization problem based on energy balances across the heat exchangers. This allowed the correction of raw data and the creation of a consistent and reliable input set for the digital twin. The final model was developed in AVEVA Dynamic Simulation, reproducing the real-time behavior of the plant under different operating conditions. The digital twin enables energy performance analysis, operational scenario testing, and process optimization. This study demonstrates that the combination of field data acquisition, data reconciliation, and dynamic simulation provides a robust foundation for implementing digital twins in food manufacturing. The proposed methodology, validated in a real industrial setting, is scalable and adaptable to similar thermal processes. It contributes to improved energy efficiency, reduced operational variability, and enhanced decision-making capabilities, fostering a more resilient and sustainable food industry.

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