

Multiparametric analytical approaches for the characterization of agri-food supply chains

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Traceability represents a fundamental aspect of agri-food supply chain management, ensuring transparency, product authenticity, and compliance with quality and safety regulations. It allows the reconstruction of a product's history through all stages of production, transformation, and distribution, providing essential information on its origin and characteristics. The PhD project aims to develop and apply advanced analytical methodologies to achieve an objective and comprehensive characterization of agri-food products, with a specific focus on the dairy supply chain and the production of Gorgonzola PDO cheese.

The proposed methodological approach combines untargeted and targeted analytical techniques to obtain complementary information on the chemical composition of food products along the supply chain. Untargeted analyses, including SPME-GC/MS, LC-DAD, LC/MS, and ^1H NMR, provide broad chemical fingerprints, enabling the detection of volatile and non-volatile compounds related to product composition, transformation, and quality. Targeted analyses, such as SPME-GC/IRMS, LC-IRMS, ICP-OES, ICP-MS, and MC-ICP-MS, focus on specific chemical markers, particularly isotopic and elemental compositions, that are directly linked to the product's geographic and environmental origin.

Two categories of indicators will be investigated to achieve effective traceability: direct (primary) and indirect (secondary) indicators. Direct indicators include isotopic ratios ($^{87}\text{Sr}/^{86}\text{Sr}$, $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, $\delta^{18}\text{O}$, $\delta^{34}\text{S}$) and elemental profiles, which provide reliable markers of geographic provenance. Indirect indicators, on the other hand, derive from extended compositional analyses based on chemical, physicochemical, and microbiological parameters, which can distinguish products sharing the same origin or production process from those of different provenance.

This PhD project will concentrate on the dairy sector, starting from milk as the raw material and extending to the final Gorgonzola cheese. The analyses will include the study of fatty acid profiles, sugar content, proteins, ash, and possible off-flavours using untargeted instrumental techniques such as HS-SPME-GC/MS and NMR. Emphasis will be placed on the determination of light isotopes ($\delta^{13}\text{C}$, $\delta^{15}\text{N}$, $\delta^{34}\text{S}$) in amino acid fractions of milk and cheese, with isotopic measurements performed in collaboration with the Jožef Stefan Institute (Ljubljana).

The goal of this research is the development of an objective traceability model capable of verifying product authenticity and determining its geographic origin through a robust integration of multi-analytical data. This integration will be achieved using chemometric and statistical tools, such as principal component analysis (PCA) and partial least squares (PLS), which allow identification of recurring patterns, similarities, and outliers among samples. By combining advanced analytical chemistry and data science, this multiparametric approach will contribute to strengthening consumer confidence, promoting product quality and integrity, and enhancing the value of local agri-food territories.