Harnessing NMR metabolomic fingerprinting for enhanced geographical identification and quality of milk and coffee

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Abstract

Geographical identification of food products, such as milk and coffee, is crucial for ensuring quality and authenticity, as well as promoting local traditions. In recent years, various technical innovations have emerged that employ metabolomic and fingerprinting approaches to distinguish products based on their geographical origin. These methods not only enhance traceability but can also contribute to the valorization of local productions, making them more competitive in the global market.

One of the most promising approaches is the use of nuclear magnetic resonance (NMR) spectroscopy for metabolomic fingerprinting. In one of our studies (Tenori et al., 2018), this non-destructive and rapid method, allows us to distinguish milk from different farms (97% accuracy), revealing significant differences in metabolic profiles. This technique is based on the analysis of metabolites present in milk, which can vary depending on factors such as animal diet and farming practices. Moreover, in a subsequent study (Meoni et al., 2020), we demonstrated that NMR can be used to compare human breast milk with infant formula and that different formula milk producers can be accurately recognized using the metabolomic fingerprint of milk samples, further highlighting the importance of this approach in ensuring the quality and traceability of dairy products.

Subsequently, we also explored how grazing affects the metabolic profile of cow's milk, demonstrating that farming practices can have a direct impact on milk quality (Niero et al., 2022). These findings can be used to develop marketing strategies highlighting geographical origin and sustainable practices, contributing to a greater valorization of local dairy products.

In the context of coffee, we applied the same approach to analyze *Coffea Arabica* beans from different varieties and post-harvest treatments in Nicaragua (Meoni et al., 2021). The results showed that metabolomic fingerprinting is effective for the classification and recognition of varieties, suggesting that such techniques can be used to guarantee the authenticity of coffee and to promote local varieties. This is particularly relevant in a global market where quality and origin are increasingly important for consumers.

Indeed, chemical analysis using NMR offers numerous advantages for the geographic recognition of food products. Firstly, NMR allows for highly detailed metabolomic fingerprinting, which can reveal significant differences in the chemical profiles of food products. Moreover,

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it is a non-destructive technique that requires little to no sample preparation, making it particularly suitable for analyzing these products. Another significant advantage of NMR is its ability to provide quantitative information about the metabolites present.
In conclusion, integrating advanced techniques such as NMR metabolomic fingerprinting into the food supply chain represents a unique opportunity to improve the geographical identification of products like milk and coffee. These innovations not only guarantee authenticity and quality but can also contribute to the greater competitiveness of local products in the global market while supporting rural economies and promoting faster and more sustainable agricultural practices and analytical techniques.

Keywords: Geographical identification, Authenticity, NMR, Fingerprinting, Metabolomics, Milk, Coffee