Multi-Analytical Tracing of Soybean Origin Using Elemental and Metabolomic Profiling

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ABSTRACT:
Soybean (*Glycine max*) is a critical global commodity and a major source of protein for both human consumption and animal feed. Amid growing concerns over environmental sustainability and deforestation, regulatory initiatives such as the 2023 EU Deforestation Regulation (EUDR) have highlighted the need for reliable tools to verify the geographical origin of soy and ensure transparency across supply chains. This study applies a multi-analytical approach combining elemental and metabolomic fingerprints to investigate the global and regional provenance of soybean.

Over 330 samples were collected from major producing countries, including Brazil, the United States, Argentina, India, China, Canada, and Paraguay. Elemental profiles obtained via inductively coupled plasma mass spectrometry (ICP-MS) were analysed using multivariate statistical models, achieving over 98% classification accuracy for country of origin. Specific elements were identified as key contributors to geographical differentiation. A second stage focuses on intra-country differentiation within Brazil, where 250 samples from five different regions revealed clear elemental profile differences, indicating potential for robust intra-country discrimination. To enhance this regional analysis, untargeted metabolomics profiling with liquid chromatography–quadrupole time-of-flight mass spectrometry (LC-QTOF-MS) was incorporated, aiming to refine the discrimination of Brazilian soybeans. This complementary dataset support data fusion strategies that combine elemental and metabolite datasets. This metabolomics dataset was also explored for mycotoxin screening, contributing to broader assessments of soybean quality and safety.

These combined analytical methodologies aim to contribute to the development of robust analytical methodologies for soybean origin authentication, offering practical tools for industry stakeholders and policymakers in meeting emerging global sustainability regulations.

KEYWORDS:
Soybean traceability, elemental profiling, metabolomics, data fusion, geographical origins