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Editorial: Identification and control of the geographic origin of plant materials: Investigation of ambient influences and environmental selection

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Editorial on the Research Topic
Identification and control of the geographic origin of plant materials: Investigation of ambient influences and environmental selection

Control of the claimed geographic origin of plant commodities like food and timber has become an important task, as the origin of these commodities is relevant with respect to several issues. We can consider, for example, the implications for foods that carry a recognized Geographical Indication/ Protected Designation of Origin (GI/PDO). GI/PDO foods often have significantly higher prices than the same food, growing or produced in non-specific areas (e.g., sparkling wine from Champagne (France) as opposed to sparkling wine from a non-specific area; fruits, vegetables, and spices from certain regions, e.g., Saffron La Mancha (Spain), Blue Mountain Coffee (Jamaica), etc.).

Another issue related to the geographic origin is food traceability, which refers to the need of determining the geographical origin of food, and it way "from farm to fork". Food traceability helps to locate the origin of contaminated, adulterated, and/or faked food, when it has been found in markets and needs to be traced back to its (geographic) origin. Food traceability is also important to verify commodities/ products from a given region, which trade/importation have been banned for some issue related to health, pollution, etc., or to fight customs fraught.

Besides the topic of food traceability, the control of provenance of wood also is an important issue, in particular with respect to the protection of national parks and primeval forests, fighting illegal logging, and all of its accompanying consequences. Control of timber origin is not limited to developing (tropical) countries but carried out globally. Furthermore, wood is used in many ways since ancient times (from construction materials to tools, paper, veneer, instruments and even jewelry), thus there are a multitude of interests to investigate its geographic origin. The method of choice for the identification and verification of geographic origin covers a wide range of research: isotopic composition, multielemental profiles, genetic variation, and many others generically named "fingerprinting". Generally, there are two main approaches used to identify the geographical origin of food/ wood:

Environmental influences (including geology)

Most of the methods applied investigate differences in the plant composition, from major compounds to trace elements, resulting from the influence of the respective ambient environment. These influences are archived in the plant materials e.g., variations in element concentrations due to differences in soil and bedrock, irrigation water, fertilizers, and emissions (either natural or anthropogenic), among many other influences. As a consequence of these differences, the geographical origin of plants can be determined using the above mentioned fingerprinting methods.

Variations in isotope ratios can result from a multitude of influencing factors (e.g., the influence of climate and weather on H- and O- isotopes in the water, but also agricultural practice, with or without synthetic fertilizers, etc.). Namely, the influence of the geographical area, including soil, irrigation water, natural emissions (volcano, etc.), in addition to anthropic factors, like use of fertilizers, emissions from vehicles, industries and residential plots can produce characteristic isotopic (H, C, N, O, S, Pb and Sr isotopes, among others) and elemental fingerprints.

Research of isotope ratios of non-conventional elements has been started to be also applied for investigations on the geographic origin of plants. However, the processes influencing the isotope ratios of these elements are extremely diverse, and in most cases not yet sufficiently investigated.

Variations in concentrations of organic compounds in plant material are usually caused by a plant's reaction to ambient influences and are thus also environmentally driven. The analytical techniques as NMR, GC-EA-IRMS and LC-EA-IRMS are producing an increasing amount of information on isotopic changes in organic molecules, which, added to the isotopic and multielemental fingerprint, should produce a more accurate evaluation of the geographical origin in plants and plant-based materials/food. Infrared-related and NMR screening techniques are also widely applied in both targeted and untargeted metabolomics studies. The relevant advantage of these techniques consists in the high number of compounds that are simultaneously determined in a single run, (potentially) enabling the discrimination of the geographical origin of a commodity by using suitable chemometric methods.

Genetic/molecular relatedness of individuals

Molecular analysis related to geographic origin base on the assumption that geographically nearer individuals are usually more closely related to each other than distant individuals. Investigated are either the plant or animal of interest itself, or its associated microbiome that are the microorganisms associated to a plant or animal. These microorganisms can be of endogenous or exogenous origin. Among the endogenous microorganisms, endosymbiotic bacteria and fungi in plant roots are very suitable. Soil is most often used from exogenous sources, or specifically rhizosphere, which represents a very close connection between the soil and the roots of plants. In the rhizosphere, a very high metabolic activity takes place, and the microbial diversity is several times higher than in the surrounding soil. Methods based on the molecular fingerprint of associated microorganisms are therefore used to trace the geographical origin of plant material. With the development of more sophisticated next-generation sequencing techniques, the capture of individual microorganisms and their subsequent differentiation between two or more geographical locations is at a better level than a few years ago.

Special issue contributions

Most of the articles published in this volume (eight of nine) belong to the first group and report differences between different geographic origins resulting from the respective environmental conditions. The article by Bhagat et al., describes a feasibility study to utilize the plant microbiome for discrimination of geographic origin.

Two articles are dealing with the control of geographic origin of tropical timber: The paper related to stable isotope ratio analysis of timber to protect two forest concessions in Gabon by Watkinson, Rees, Gwenael, et al., establishes an approach for the origin assessment of forest products and timber from two distinct sites. The samples were analyzed for their isotope patterns. The results of this pilot study indicate that the ^{34}S ratio to have a significant discrimination potential for the origin of the timber samples from Gabon.

The study by Watkinson, Rees, Hofem, et al., on the stable isotope ratio of timber from two islands of the Solomon Islands is regarded as a baseline for future isotope studies on

timber of this geographic origin. As the Solomon Islands are currently deforested at an alarming pace, measures for the control of geographic origin are urgently required. However, further studies on this topic are still necessary, as certain features, e.g., species-related differences in sulfur isotopes require scientific explanations.

Three articles report on the provenance, or provenance-related (influence of storage) issues, of food (saffron and cucumbers), and identification and differentiation of dietary supplements from algae: The paper by Kejžar et al., describe a survey of 18 commercial algae products collected on the Slovenian market. Their characterization was performed based on the elemental profile, isotope content, and antioxidant potential. The sample differentiation was performed through chemometrics [Principal Component Analysis (PCA)], but did not result in a complete discrimination of different micro-algae types or different geographic origins, thus additional data are required for this purpose. The article by Bhagat et al., presents a feasibility-study successfully differentiating the geographic origin of three saffron (to be precise: the microbiome of the crocus corms of crocus sativus, saffron are the filaments of the crocus flower) samples by analysis of the microbiome associated with these samples, thus using molecular (instead of environmental) markers for the investigation of geographic origin. Even though only a very low number of samples were investigated, the results are promising and request further studies of this approach. The article by Horacek and Papesch, deals with potential changes in the isotopic composition of vegetable foods (cucumber) due to storage of the goods. They report significant changes, even though during saleable conditions of the goods the variations remained insignificant. Although these results probably cannot directly be translated to other plant food commodities, this study documents that storage of (plant) food under non-ideal conditions might lead to changes in the isotopic pattern, which needs to be considered when evaluating the authenticity of product claims.

Four articles investigate the provenance of wine: Leder et al. and Griboff et al. apply a combination of isotope ratios and element concentrations for the discrimination and control of geographic origin of wine. Both studies identify $\delta^{18}O$, in addition to the elemental concentration of Sr, Mg and Na as geographic origin-relevant parameters. but disagree on the relevance of others, e.g., $\delta^{13}C$, which was relevant in the study about Croatian, but irrelevant in the study comparing Argentine and Austrian wines. Griboff et al., also identify many elements as markers of geographic origin, while Leder et al., report that the elemental composition is mainly influenced by oenological practice. This matter needs further investigation, even though the particular bedrock geology of Argentina should explain, at least partially, the observed differences in element concentrations. In Horacek et al., a comparison of $\delta^{13}C$ and $\delta^{18}O$ of wine samples of two vintages from Central and Southeastern Europe and Argentina has been published. They show a quite good differentiation among the European samples, but a rather incomplete one of the Argentinean wine samples. These data show that wine samples of distant geographic origins still might possess similar $\delta^{13}C$ and $\delta^{18}O$ values, requiring additional data to construct a reliable fingerprint to differentiate wines from diverse areas (e.g., the multielemental concentrations presented by Griboff et al.).

Muñoz et al., report on the differences of fruit yield and phenolic profiles of wines, produced from two clone types, from different geographic locations within the Mendoza area in Argentina. They found notable differences related to altitude between these investigated two clone types, including differences in the phenolic profiles. The results indicate that fruit yield and the phenolic composition of wines are influenced by the environment, in addition to the plant material and their interaction, resulting in higher concentration of some specific phenolic compounds at lower temperatures and higher altitude.

Author contributions

MH wrote the manuscript. DM, KO, SH, and DW contributed parts of the manuscript and revised an earlier version. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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