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Authenticity and Origin Control of Fragrance and Cosmetic Ingredients Using Isotopic Methods

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The higher production costs associated with plant-derived raw materials—and the extraction and purification of these natural substances compared to their synthetic counterparts—create significant opportunities for counterfeiting.
To determine whether an ingredient is of natural or synthetic origin, detect ingredient substitution, and identify the geographical and/or botanical origin of products, stable isotope ratios of bio-elements—hydrogen, carbon, nitrogen, oxygen, and sulfur—and/or the site-specific natural isotope fractionation (SNIF) of hydrogen and carbon are analyzed in fragrance, and cosmetic products using isotope ratio mass spectrometry (IRMS) and nuclear magnetic resonance (NMR) spectroscopy.
Various biological, biochemical, physical, and chemical processes cause fractionation of individual isotopes, resulting in unique isotopic signatures. The application of these techniques to both bulk materials and specific compounds (e.g., aroma constituents) therefore enables precise assessments of product authenticity and traceability.
A well-known example is vanillin, which is extracted from the bean of the CAM plant Vanilla and can cost up to $4,000 per kilogram. Its $\delta^{13}C$ and $\delta^{2}H$ values provide clear indicators of whether the substance is natural, biotechnologically derived, or fully synthetic. The reliability of SNIF-NMR in verifying the authenticity of vanillin is further enhanced by combining both ^{2}H and ^{13}C isotopic profiles.
In the cosmetics sector, isotopic techniques are employed to detect the illegal addition of shark-derived squalene and squalane into olive-derived products, even at concentrations as low as 10%. Similarly, the $\delta^{13}C$ values of specific components of *Rosa damascena* Mill.—one of the most expensive essential oils on the global market—can reveal adulteration with cheaper oils. For instance, atypical $\delta^{13}C$ values of geranyl acetate may indicate the presence of a natural but less expensive oil from a C_4 plant such as *Cymbopogon martinii* (palmarosa), a known adulterant of *Rosa damascena* essential oil.
Numerous additional examples highlight the effectiveness of these techniques in authentication: bis(methylthio)methane (BMTM) from *Tuber magnatum* (white truffle), linalool and linalyl acetate from essential oils of various plants including *Lavandula angustifolia* (lavender), as well as estragole, methyl eugenol, and *trans*-anethole from *Pimpinella anisum* (anise) and *Foeniculum vulgare* (fennel) seeds.
As consumer demand for transparency and natural authenticity continues to rise, stable isotope techniques are increasingly positioned as essential tools for quality control, traceability, and certification within the aroma and cosmetic industries.