



EA-IRMS: Tracing the geographical origin of green coffee beans using isotope fingerprints

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Keywords

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Goal

Trace the geographical origin of green coffee beans using hydrogen and oxygen isotope fingerprints.

Introduction

Complexities in the food supply chain from the production site through to the consumer have presented significant, and at times relatively easy, opportunity for economically motivated fraudulent activities to occur but be undetected. As food products from certain regions attract a higher price on the market, this can lead to economically motivated fraud through product mislabeling. This means replacing a higher quality, original ingredient with one of lesser quality, extending a product by adding an adulterant and product mislabeling, including misrepresenting product origin and ingredients. Collectively, this affects consumer confidence, product brand reputation and may have a positive, or negative, impact on manufacturer revenue, depending on the source and objective of adulteration. Consequently, there is an increase in retailer and consumer demand to see proof that food products are what the label claims them to be, including origin, and ingredient verification. Investigating food origin and authenticity in laboratories is one of the key ways of monitoring and enforcing legislation for food integrity and labelling (EC Council Regulation No 1169/2011) and protecting consumers and brands.

Coffee is one of the most popular beverages worldwide. Coffees from different geographical regions are imported through a commercial chain that usually involves several intermediates. To ensure that green coffee beans come from their labelled locations, laboratories need an analytical tool for geographical origin discrimination with a special emphasis on the country of origin. Green coffee beans have a fingerprint, a unique chemical signature that allows them to be identified: isotope fingerprints have been reliably used for origin, authenticity and product label claim verification.

In this application note we show hydrogen and oxygen isotope measurements on green coffee beans measured with the Thermo Scientific™ EA IsoLink™ IRMS System. We were able to trace the origin of green coffee beans based on unique trends observed from their isotopic fingerprints.

Analytical configuration

For hydrogen and oxygen analysis, around 800 µg of dried, cryo-milled green coffee beans were weighed into the silver capsules and introduced into the pyrolysis reactor of the EA IsoLink IRMS System from the Thermo Scientific™ MAS Plus Autosampler. The reactor is held at 1450 °C and consists of an outer ceramic tube and an inner glassy carbon reactor with a helium carrier gas flow via a bottom feed connector. The produced H₂ and CO gases were separated using a 1 m 5Å molecular sieve packed GC column held isothermally at 70 °C. After separation, the gases were transferred to a Thermo Scientific™ Delta V™ Isotope Ratio MS via the Thermo Scientific™ ConFlo IV™ Universal Interface. For our samples, the sample weights correspond to 50–177 µg of H and 201–689 µg of O across all samples analyzed. Hydrogen and oxygen isotope ratios were calibrated against SLAP and VSMOW. Analysis time is less than 5 minutes, using 1 liter of helium per sample.

Hydrogen and oxygen isotopic fingerprints of coffee

The hydrogen and oxygen isotope fingerprints in coffee beans can be used to differentiate their geographical origin^{1,2,3}. The *Coffea* plants, from which coffee beans are cultivated, carry a local-regional fingerprint primarily derived from the hydrological cycle, which is associated with local-regional rainfall^{4,5}, but can also be influenced by cultivation practices, soil processes and geological characteristics of the local area, altitude and proximity to the shoreline⁵. The oxygen and hydrogen isotope fingerprints change in rainfall as you move further inland from the shoreline and with increasing altitude because the heavier isotopes are the first to be released from the clouds^{2,5}. This effect can be tracked in the oxygen and hydrogen isotopic fingerprints of plants and their fruits (e.g. green coffee beans)^{3,6}. For example, relatively high δ¹⁸O and δ²H values of green coffee beans from Africa are likely the result of strong evaporation and condensation processes.

Where does my coffee come from?

Nineteen unique green coffee beans from 12 countries, including Asia, Africa and Central and South America, were analyzed to determine their geographical origin. Figure 1 shows hydrogen and oxygen isotope fingerprints of green coffee beans and shows that they can be clearly differentiated at the continent scale. Furthermore, the oxygen and hydrogen data measured in this study correlate with previously published values for globally sourced coffee beans at the country level^{2,3,6}, demonstrating that country of origin can be determined for green coffee using isotope fingerprints. The differences evident in hydrogen and oxygen isotope fingerprints of different coffee beans from the same country, specifically Colombia and Guatemala (Figure 1 and Table 1), are likely related to the different altitudes where these coffee beans were grown. Higher altitudes mean that hydrogen and oxygen isotopes are lighter compared with lower altitudes⁵.



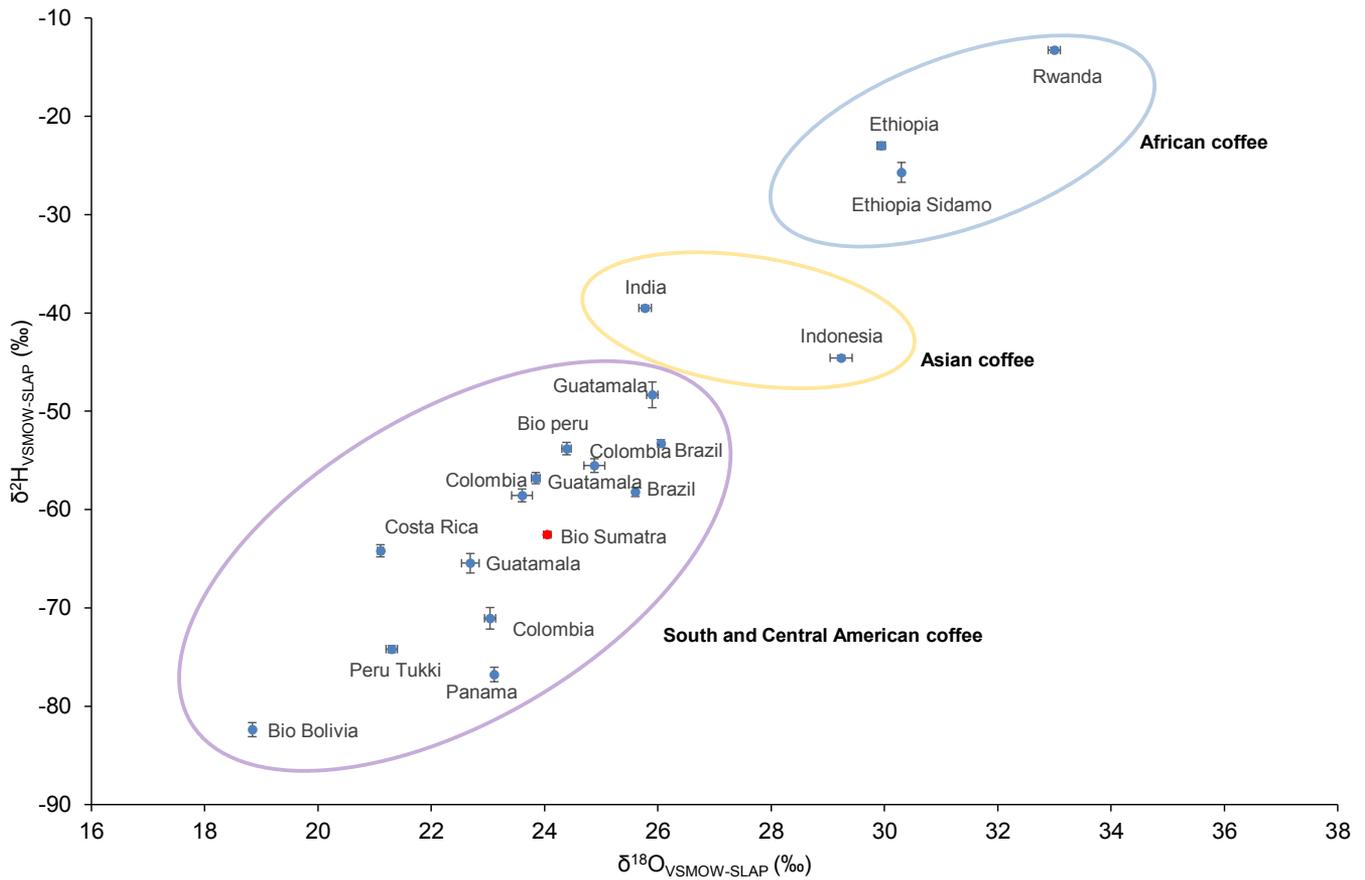


Figure 1. Hydrogen and oxygen isotope fingerprints of green coffee beans from Africa (blue), Asia (yellow) and central and South America (purple).

Identifying mislabeled coffee

The Bio Sumatra coffee measured here is grouped with coffee from South and Central America rather than from Asia (Figure 1, red marker). It was expected that this sample would correlate with our data (e.g. Indonesia) and previously published data^{2,3,6}.

This anomaly is an indication that the coffee labeled as originating from Sumatra may not be a correct label declaration and has been identified from the hydrogen and oxygen isotope fingerprints of the green coffee bean.



Table 1. The hydrogen and oxygen isotopic fingerprints of green coffee beans from Asia, Africa and South and Central America analyzed in triplicate.

Green coffee samples	Country	Mean $\delta^2\text{H}_{\text{VSMOW-SLAP}}$ (‰)±1SD	Mean $\delta^{18}\text{O}_{\text{VSMOW-SLAP}}$ (‰)±1SD
Asia	Indonesia	-44.57±0.76	29.23±0.58
	India	-39.49±0.80	25.77±0.33
	Bio Sumatra	-62.55±0.71	24.05±0.19
Africa	Ethiopia Sidamo	-25.70±3.03	30.03±0.06
	Ethiopia	-22.99±1.11	29.94±0.22
	Rwanda	-13.27±0.79	33.00±0.32
South and Central America	Bio Peru	-58.80±1.89	24.39±0.25
	Bio Bolivia	-82.38±2.15	18.84±0.08
	Brazil	-53.26±1.10	26.50±0.08
	Brazil	-58.20±1.40	25.60±0.11
	Costa Rica	-64.19±1.85	21.10±0.15
	Colombia	-55.53±2.09	24.88±0.55
	Colombia	-71.06±3.29	23.04±0.29
	Colombia	-58.56±1.94	23.60±0.55
	Guatamala	-56.80±1.71	23.84±0.23
	Guatamala	-48.33±3.93	29.50±0.30
	Guatamala	-65.64±2.98	22.69±0.47
	Panama	-76.77±2.21	23.11±0.08
	Peru Tukki	-74.19±1.05	21.30±0.30

Summary

Hydrogen and oxygen isotope fingerprints are powerful tools to determine the country of origin of green and roasted coffee beans and therefore assessing product label and retailer claims⁷. Verifying the correct labeling of food products is important for consumer confidence, brand reputation and producer revenue alongside reducing fraudulent activities. To achieve this, laboratories require a robust, automated analytical technique that provides unique and conclusive answers that verify the authenticity, origin and correct labeling of food products. This can be achieved analyzing the oxygen and hydrogen isotopic fingerprints with the EA IsoLink IRMS System.

By using the EA IsoLink IRMS System, laboratories gain:

- the ability to trace the origin of food and beverage products, such as green coffee beans, using isotope fingerprints;
- fast and low cost sample analysis;
- complete automation, reducing user intensity;
- all-in-one flexibility to meet changing analytical requirements.

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