



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

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## Keywords

Authenticity, Coffee, EA-IRMS,  
Food Fraud, Geographical Origin,  
Isotope Fingerprint, Labeling

## Goal

Trace the geographical origin of roasted 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 geographical origin. Investigating food origin and authenticity in laboratories is one of the key ways of monitoring and enforcing legislation for food integrity and labelling (EC Reg. No. 1169/2011) and product geographical indication/origin (EC Reg. No. 510/2006) and therefore protecting consumers and brands.

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

In this application note we show hydrogen and oxygen stable isotope measurements on roasted coffee samples measured with the Thermo Scientific™ EA IsoLink™ IRMS System. We were able to trace the origin of 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 coffee bean samples 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. The produced H<sub>2</sub> 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 measured samples, the sample weights correspond to 60–150 µg of H and 220–650 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 ( $\delta^2\text{H}$  and  $\delta^{18}\text{O}$ ) in coffee beans can be used to differentiate their geographical origin<sup>2,3</sup>. The *Coffea spp* plants, cultivated as the source of the coffee beans, carry an isotopic fingerprint associated with local-regional rainfall<sup>4,5</sup>, but can also be influenced by cultivation practices, soil processes and geological characteristics of the local area, altitude and proximity to the shoreline<sup>5</sup>. The oxygen and hydrogen isotope fingerprints in rainfall change with distance inland from the shoreline and with increasing altitude because the heavier isotopes are the first to be released from the clouds. This effect can be tracked in the oxygen and hydrogen isotopic fingerprints of plants and their fruits (e.g. coffee beans)<sup>2,5</sup>. For example, relatively high  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  values of coffee from Africa are likely the result of strong evaporation and condensation processes.

### Where does my coffee come from?

Twenty unique roasted coffee beans from 15 countries, including Asia, Africa and Central and South America, were analyzed. Figure 1 shows hydrogen and oxygen isotope fingerprints of roasted coffee beans and shows that they can be clearly differentiated at the continent scale. Furthermore, the oxygen and hydrogen data measured in this study are in very good agreement with previously published values for globally sourced coffee beans at the country level<sup>2,3,8</sup>, demonstrating that country of origin can be determined for 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 altitudes<sup>5</sup>.



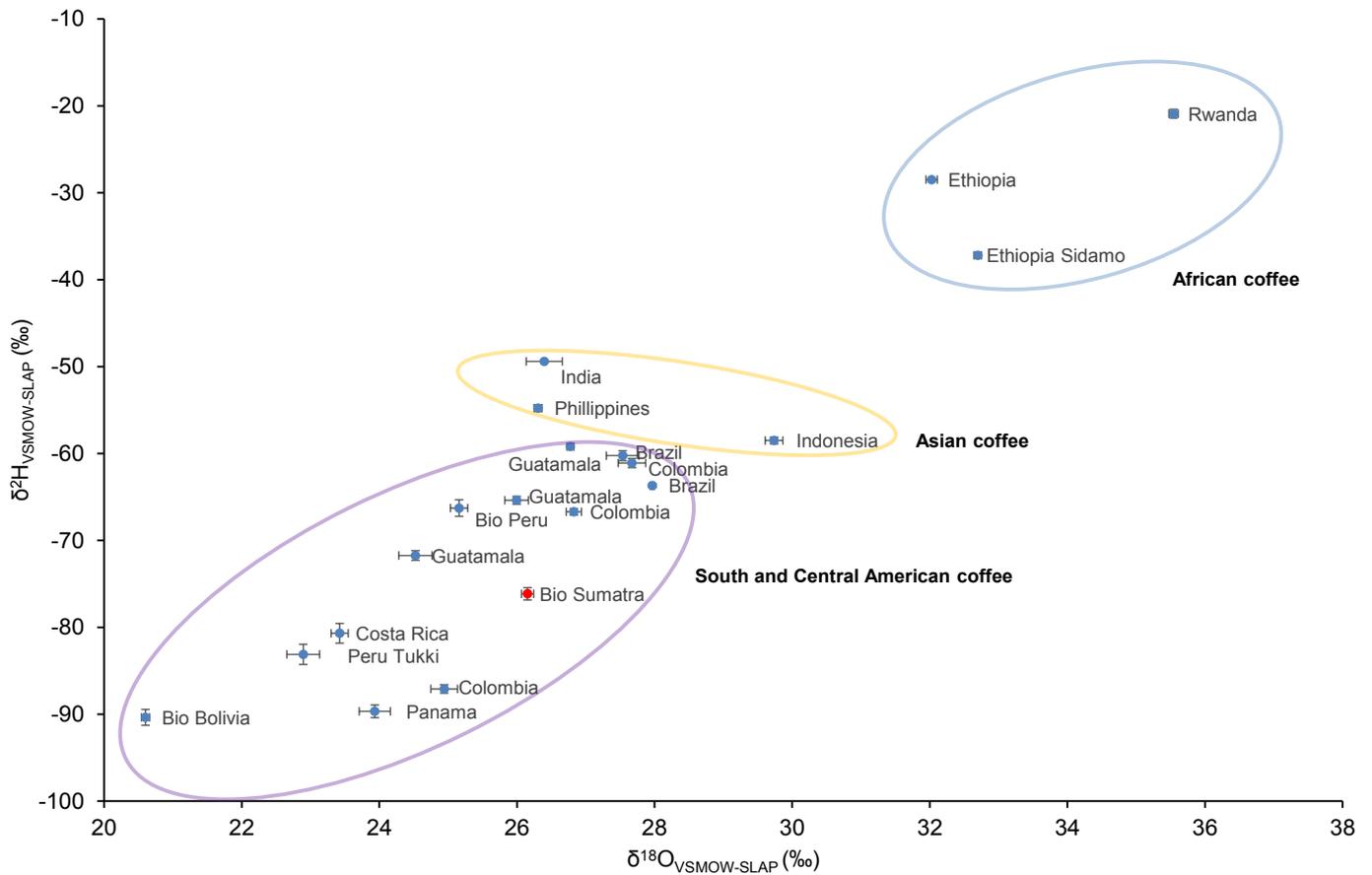


Figure 1. Hydrogen and oxygen isotope fingerprints of roasted coffee beans from Africa (blue), Asia (brown) and central and South America (purple).

### Identifying mislabeled coffee

The Bio Sumatra coffee measured 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<sup>2,3,6</sup>.

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



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

| Coffee Samples            | Country         | $\delta^2\text{H}_{\text{VSMOW-SLAP}}$<br>(‰)±1 SD | $\delta^{18}\text{O}_{\text{VSMOW-SLAP}}$<br>(‰)±1 SD |
|---------------------------|-----------------|----------------------------------------------------|-------------------------------------------------------|
| Asia                      | Indonesia       | -58.51±0.78                                        | 29.74±0.26                                            |
|                           | India           | -49.41±0.12                                        | 26.97±0.53                                            |
|                           | Phillippines    | -54.79±0.77                                        | 26.31±0.11                                            |
|                           | Bio Sumatra     | -76.15±1.42                                        | 26.15±0.18                                            |
| Africa                    | Ethiopia Sidamo | -37.20±0.61                                        | 32.70±0.11                                            |
|                           | Ethiopia        | -28.49±0.06                                        | 32.03±0.17                                            |
|                           | Rwanda          | -20.91±1.00                                        | 36.37±0.14                                            |
| South and Central America | Bio Peru        | -66.28±1.91                                        | 25.16±0.25                                            |
|                           | Bio Bolivia     | -90.36±1.83                                        | 20.60±0.12                                            |
|                           | Brazil          | -60.25±1.13                                        | 27.54±0.47                                            |
|                           | Brazil          | -63.70±0.44                                        | 27.97±0.06                                            |
|                           | Costa Rica      | -80.69±2.26                                        | 23.42±0.25                                            |
|                           | Colombia        | -87.09±0.97                                        | 24.94±0.39                                            |
|                           | Colombia        | -66.72±0.76                                        | 26.83±0.22                                            |
|                           | Colombia        | -61.10±1.05                                        | 27.67±0.40                                            |
|                           | Guatamala       | -65.39±0.90                                        | 26.00±0.34                                            |
|                           | Guatamala       | -71.74±1.12                                        | 24.53±0.48                                            |
|                           | Guatamala       | -59.21±0.31                                        | 26.78±0.10                                            |
|                           | Panama          | -89.67±1.46                                        | 23.93±0.45                                            |
|                           | Peru Tukki      | -83.11±2.32                                        | 22.89±0.48                                            |

## Summary

Hydrogen and oxygen isotope fingerprints are powerful tools to determine the country of origin of coffee beans and therefore assessing product label claims. 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 enable to 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 detect origin of food and beverage products (e.g. 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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