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Tracing the geographical origin of green and roasted coffee with isotope fingerprints

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ABSTRACT

Coffee is one of the most popular beverages worldwide, sourced from different geographical regions and 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.

Roasted and green coffee beans have a fingerprint, a unique chemical signature that allows them to be identified: isotope fingerprints of carbon, nitrogen, sulfur, hydrogen and oxygen have been reliably used for origin, authenticity and product label claim verification.

In this poster, we report isotope measurements from green and roasted coffee beans measured using the Thermo Scientific™ EA IsoLink™ IRMS System. These data illustrate how isotope fingerprints can determine the origin of coffee beans. Consequently, it is evident that isotope fingerprint approach helps support legislation on food integrity and labelling (EC Reg. No. 1169/2011) and product geographical indication/origin (EC Reg. No. 510/2006) and therefore, protect consumers and brands.

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. This includes product mislabeling, in terms country of origin declarations and also product adulteration, meaning replacing a higher quality, original ingredient with one of lesser quality or extending a product by adding an adulterant.

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 the most popular beverages worldwide. Coffee beans from different geographical regions are imported through a commercial chain that usually involves several intermediates. To ensure that 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. 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.

ISOTOPES IN FOOD AND BEVERAGE ORIGIN AND AUTHENTICITY

Stable isotopes of **carbon, nitrogen, sulfur, oxygen and hydrogen** can be measured from food and beverage products, such as honey, cheese, olive oil, animal meat, milk powder, vegetables, wine, liquor, water and so forth, using isotope ratio mass spectrometry techniques. These stable isotope data can subsequently be interpreted to determine the origin, correct-labeling and trace adulteration of food and beverage products, as summarized in Table 1.

Table 1. Stable isotopes and their interpretation in food and beverage origin and authenticity.

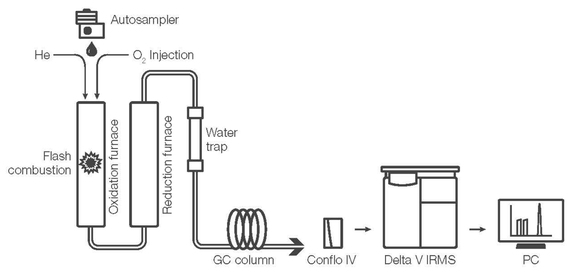
Stable Isotope	What is the biogeo-chemical interpretation?	What is an example of food fraud interpretation?	What products can be affected?
Carbon	Photosynthesis (C3, C4 and CAM pathways)	Adulteration (e.g. sweetening with cheap sugar)	Honey, liquor, wine, olive oil, butter
Nitrogen	Fertilizer assimilation by plants	Mislabeling (differentiate organic and non-organic)	Vegetables, animal meat
Sulfur	Local soil conditions, proximity to shoreline	Origin of product	Vegetables, animal meat, honey
Oxygen	Local-regional rainfall and geographical area	Watering of beverages, place of origin of product	Coffee, wine, liquor, water, sugar, animal meat
Hydrogen	Local-regional rainfall and geographical area	Watering of beverages, origin of product	Coffee, wine, liquor, water, sugar, animal meat

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 (Figure 1).

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 H_2 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.

Figure 1. EA IsoLink IRMS System configuration.



HYDROGEN AND OXYGEN ISOTOPE FINGERPRINTS IN COFFEE

The hydrogen and oxygen isotope fingerprints in coffee beans can be used to differentiate their geographical origin (Figure 2).[1,2,3] The Coffea plants, from which coffee beans are cultivated, carry a local-regional fingerprint primarily derived from the hydrological cycle (Figure 3), 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 shoreline[5].

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 $\delta^{18}O$ and $\delta^{2}H$ values of green coffee beans from Africa are likely the result of strong evaporation and condensation processes.

Figure 2. Map showing oxygen isotopic fingerprints of water in precipitation (Bowen, 2010: 168)[7].

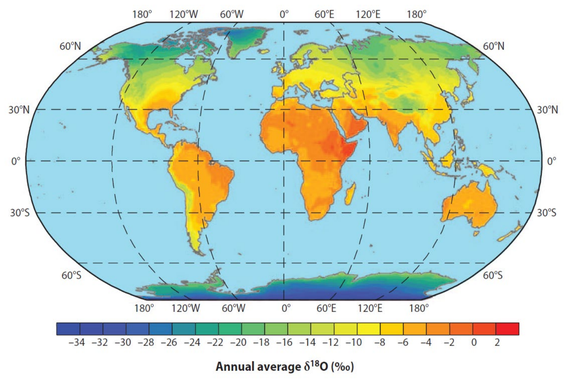
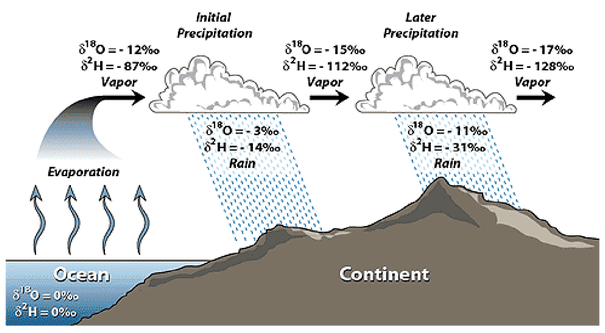


Figure 3. Changes in hydrogen and oxygen isotopes within the water cycle.



WHERE DOES MY COFFEE COME FROM?

Nineteen unique green coffee beans and twenty unique roasted coffee beans from 12 countries, including Asia, Africa and Central and South America, were analyzed to determine their geographical origin.

Figure 4 shows hydrogen and oxygen isotope fingerprints of green coffee beans and shows that they can be clearly differentiated at the continent scale. In addition, Figure 5 shows hydrogen and oxygen isotope fingerprints of roasted coffee beans and illustrates that they can be differentiated at the continent scale

Figure 4. Hydrogen and oxygen isotope fingerprints of green coffee beans from Africa (blue), Asia (brown) and central and South America (purple).

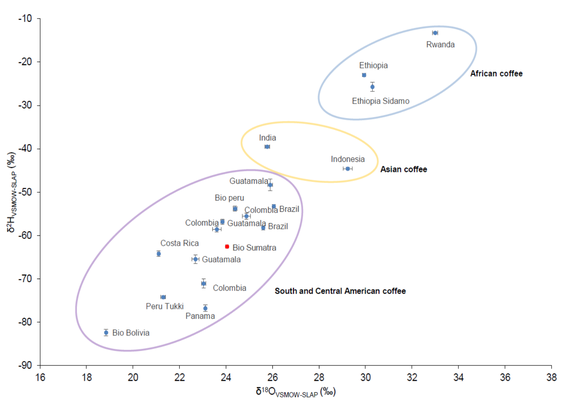
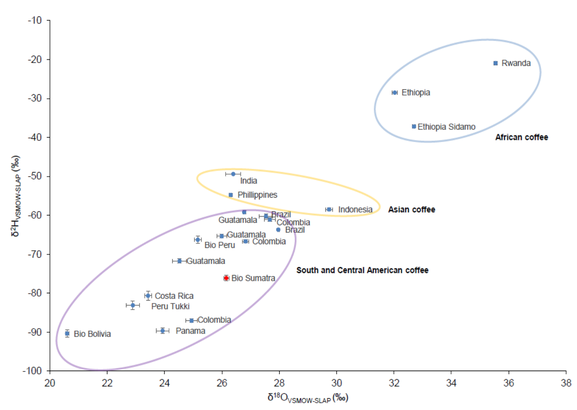


Figure 5. Hydrogen and oxygen isotope fingerprints of roasted coffee beans from Africa (blue), Asia (brown) and central and South America (purple).



IDENTIFYING MISLABELED COFFEE

The Bio Sumatra green and roasted coffee beans, are grouped with coffee from South and Central America rather than from Asia (Figures 4 and 5, 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, which has been identified from the hydrogen and oxygen isotope fingerprints of the coffee bean.

CONCLUSIONS

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;
- High throughput and low cost sample analysis;
- Complete automation, reducing user intensity;
- All-in-one flexibility to meet changing analytical requirements.

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- **AB30427**: EA-IRMS Tracing the geographical origin of green coffee beans using isotope fingerprints
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