Development of Technique for Estimation of Geographical Origin of Food Using Stable Isotope and Trace Element Analyses

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Outline

1. Brief Introduction of Food Authenticity
2. Explain Some of Results (Beef and Whisky)
3. The combined use of multiple analytical method to improve the accuracy
Food fraud is a big problem in Japan

Food Authenticity Problems

• Mislabeling
• Addition of inferior products to premium products

There is a need for analytical method to check where our food come from!
### Analytical Approach to Food Authenticity

**Identification of Cultivar**
- DNA Analysis

**Discrimination of Cultivation Area**
- **Stable Isotope Analysis**
  - $\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$, $\delta^{2}D$
  - $^{15}N/^{14}N$ → Soil nutrition
  - $^{13}C/^{12}C$ → Carbon fixation process
  - $^{18}O/^{16}O$ → Local groundwater

- **Trace Element Analysis**
  - Li, Mg, Al, K, Ca, Mn, etc.
  - Soil: the geological profile is unique
  - Plant: reflecting the soil composition in which plant is grown
Isotopes are defined as atoms of the one element that differ in the number of neutrons percent in their Nuclei.
Stable Isotope Ratio

$^{13}\text{C}/^{12}\text{C}$, $\text{D}/\text{H}$, $^{15}\text{N}/^{14}\text{N}$, $^{18}\text{O}/^{17}\text{O}/^{16}\text{O}$

Difference in Mass between isotopes of same element

The lighter isotope is more reactive, hence is concentrated in reaction products and substrate are enriched with the heavier isotope.

(Fry, Stable Isotope Ecology, 2006)
Isotope Analysis for Food Fraud
( Carbon· Nitrogen· Oxygen· Hydrogen )

Light element isotope ratios in organism are reflected to their growth environments (e.g. diet, fertilizer, geographical origin).

Each element will provide different information.

<table>
<thead>
<tr>
<th>Isotope Ratio</th>
<th>Main Factor</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{13}\text{C}/^{12}\text{C}$</td>
<td>C3 and C4 plan</td>
<td>Addition of Sugar, Diet</td>
</tr>
<tr>
<td>$^{15}\text{N}/^{14}\text{N}$</td>
<td>Trophic Level, Fertilizer</td>
<td>Diet, Organic</td>
</tr>
<tr>
<td>$^{18}\text{O}/^{16}\text{O}$</td>
<td>Evaporation, condensation, precipitation</td>
<td>Geographical Origin</td>
</tr>
<tr>
<td>D/H</td>
<td></td>
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Multi-Element Stable Isotope Ratios = “Fingerprint”
Heavier isotopes (D and $^{18}$O) preferentially fall out of precipitation first, leaving a residual cloud mass that is isotopically depleted.

Oxygen and hydrogen isotope ratios in organism is mainly reflected to those of drinking water.
Global Map of Oxygen Isotope Ratios of Precipitation

Weighted Annual $\delta^{18}O$

Variation
$-30 \sim -2\%$

IAEA Database (2002)

Oxygen and hydrogen isotope ratios in Organism

Geographical Data
Where are your food products from?

Where’s the beef . . . from?
Case 1: Geographical Origin of Beef

Geographical Parameter

δ¹⁸O (%)

δ¹³C (%)

Grass-fed

Corn-fed

AUS

USA

JPN
Fake whiskies cost the industry approximate 10% in sales per year. 

The local source water is used during whisky production.

Case 2: Geographical Origin of Whisky
To improve the accuracy of discrimination of the geographical origin...

The combined use of multiple analytical methods is needed to improve the accuracy of discrimination of the geographical origin of agricultural products.
Thank you for your attention!