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Food Specification Maps for European Mineral Water: an interactive demonstration of the TraceTool

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Food fraud

Blenheim Palace mineral water bottles 'filled with tap water'

Exclusive bottles of luxury "mineral water" from Blenheim Palace were filled with ordinary tap water by a businessman, a court heard.

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Landowner Ralph Searle, 58, put the mains tap water in the Blenheim bottles in a scene reminiscent of Del Boy Trotter’s activities in television’s Only Fools and Horses.

A court heard Searle had won a contract to bottle and sell water for office coolers from the Duke of Marlborough's Blenheim Palace estate in Oxfordshire.

But he was caught filling the bottles with tap water and other water from a spring at his farm 150 miles away in Wales.

More than 50 of his customers complained that the water in bottles at their offices had a “funny taste” compared to their usual Blenheim Mineral Spring Water.

Trading standards investigators raided Searle’s plant to find “Blenheim” bottles filled with both tap water and water from his farm in the Black Mountains near Carmarthen, South Wales. The court heard the sodium and sulphate content in the water did not match the “high standards” of the Duke of Marlborough’s top of the range mineral water.
Food fraud

HOW THE PUBLIC CAN BE DECEIVED

MEAT
- Selling non-organic meat as organic.
- Adding excessive water to meat without declaring it.
- Selling meat unfit for human consumption.
- Adding beef and other meat to 100% pork sausages.
- Selling 'lean' meat that contains as much fat as standard.
- Substituting Parma ham with a cheaper product.

FISH
- Selling farmed fish as wild.
- Mislabelling the geographic origin.

FRUIT AND VEGETABLES
- Selling conventional produce as organic.
- Giving the wrong geographical origin.
- Selling cheaper varieties of potato as an expensive variety such as King Edwards.
- Adding GM soya beans to conventional beans, without declaring them.

EGGS
- Selling battery farm eggs as free-range.

CHEESE
- Using cow's milk rather than buffalo milk to make mozzarella.

OLIVE OIL
- Dyeing it dark green with chlorophyll to make it look like extra virgin.
- Diluting olive oil with cheaper hazelnut oil.

ORANGE JUICE
- Diluting it with inferior quality juice.
- Adding beet sugar to sweeten 'natural' orange juice.

COFFEE
- Adulterating highly sought-after arabica beans with cheaper varieties.

ALCOHOL
- Selling counterfeit versions of big brands, which can include dangerously high levels of methanol.
- Watering down spirits.
- Substituting cheap varieties for expensive premium brands in bars.
- Adding extra sugar during wine making to increase alcohol content.

RICE
- Using cheap varieties to bulk up expensive basmati rice.

www.thisismoney.co.uk
Food fraud

Costs of food fraud:

- Global food fraud is estimated to be worth 50 b$ on an annual basis
- U.K. food fraud is estimated to be worth 70 m£ to 7 b£ annually
- Fraud figures are expected to rise as a result of economic turn-down

True figures are difficult to assess

- Product verification is cost and time intensive
- Verification methods are still under development
- Swindlers are getting more and more inventive
Food fraud

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TRACE project (2005 – 2010)

Main goals:

- Providing cheap tools for the verification of food origin and authenticity
- Develop a food trace traceability standard (TraceCore XML)
- Dissemination of result to a broader audience; public awareness and perception
TRACE project WP1/15/16

WP1/WP15 (Food Origin Mapping)

Sampling campaign in Europe (500 - 2100 samples per commodity)
Soil & surface water, Mineral water, Cereals, Olive oil, Honey, Chicken, Lamb & Beef

Analysis (bulk, extractions, defatted material)
Trace elements, stable isotopes ($\delta^2H$, $\delta^{18}O$, $\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$) and $^{87}Sr/^{86}Sr$

WP16 (Food Specification Modeling)

Database with sampling information and analytical results
+ Digital information about climate and geology (GIS maps)

Food specification maps
**Food specification maps**

Two approaches for the verification of food origin:

1. **Database approach**
   - Specifications from a dedicated database
   - Requires data/specs from all producers
   - Not very cost effective
   - Not necessary the result of local factors; needs regular update
   - Works best for limited number of well defined producers

2. **Food specification approach**
   - Specifications based on relation between geo-climatic factors and food composition
   - Predicts specs for unsampled areas
   - Cost effective
   - Based on “static” local factors
   - Works also for many LOCAL producers
# Food specification maps

WP16 progress towards food specification maps:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mineral water</th>
<th>Wheat</th>
<th>Chicken</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta^{2}H / \delta^{18}O$</td>
<td>Annual min. temperature</td>
<td>Relation with climate not yet understood</td>
<td>Relation with climate not yet understood</td>
</tr>
<tr>
<td>$^{87}Sr / ^{86}Sr$</td>
<td>Regional / local geology</td>
<td>Local geology</td>
<td>Geology + feed</td>
</tr>
<tr>
<td>$\delta^{13}C$</td>
<td>(disturbed by industrial CO2?)</td>
<td>Moisture conditions and drought stress</td>
<td>Feed composition (C3/C4 plants)</td>
</tr>
<tr>
<td>Trace elements</td>
<td>Relation with geology not well understood</td>
<td>Na-concentrations might reflect sea-spray</td>
<td>not yet understood</td>
</tr>
<tr>
<td>$\delta^{15}N / \delta^{34}S$</td>
<td>not yet understood</td>
<td>not yet understood</td>
<td>not yet understood</td>
</tr>
</tbody>
</table>

Outstanding data analysis & modeling: Olive oil, lamb and beef, and further evaluation of honey data
**Food specification maps**

**Food specification maps**: Maps that predict the isotopic and/or trace element specifications of food commodities for any required production location.

Specifications are based on the 95% confidence limits of the predicted value for some parameter at some location \(x, y\).

Combination of specifications for different parameters (par) for each \(x, y\):

\[
S_A(x, y) = c\ell^-_{par1} < \text{par1}(x, y) < c\ell^+_{par1} \quad \& \quad c\ell^-_{par2} < \text{par2}(x, y) < c\ell^+_{par2} \quad \& \quad \ldots \quad c\ell^-_{parN} < \text{parN}(x, y) < c\ell^+_{parN}
\]

Where \(c\ell^+\) and \(c\ell^-\) are the individual 95% confidence limits.

**Because specifications are defined as an interval (\(c\ell^-\) to \(c\ell^+\)), which overlap with other specifications, a certain measured isotope value in some food commodity will always comply to a number of \(x, y\) locations, or area, on the map → this area is called “specification area”**
Food specification maps

Combined specification areas for $\delta^2H$, $\delta^{18}O$ and $^{87}\text{Sr}/^{86}\text{Sr}$

The combined specification area (in green) applies to a cross-section which is smaller than the individual specification areas
Food specification maps

Does the sample comply to the specifications with 95% confidence?

<table>
<thead>
<tr>
<th>Sample:</th>
<th>Specifications (x,y):</th>
<th>Complies?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta^{2}\text{H}$ = -110 ‰</td>
<td>-105 ‰ &lt; $\delta^{2}\text{H}$ &lt; -125 ‰</td>
<td>TRUE</td>
</tr>
<tr>
<td>$\delta^{18}\text{O}$ = -12 ‰</td>
<td>-11 ‰ &lt; $\delta^{18}\text{O}$ &lt; -13 ‰</td>
<td>TRUE</td>
</tr>
<tr>
<td>$^{87}\text{Sr}/^{86}\text{Sr}$ = 0.716</td>
<td>0.707 &lt; $^{87}\text{Sr}/^{86}\text{Sr}$ &lt; 0.714</td>
<td>FALSE</td>
</tr>
</tbody>
</table>

Multiple comparisons for independent hypothesis testing:

$$\alpha_{\text{overall}} = 1 - (1 - \alpha_{\text{single comparison}})^{N\text{comparisons}}$$

Specifications have an individual $\alpha$-error of 5% and 3 comparisons:

$$\alpha_{\text{overall}} = 14.3\%$$

→ Testing multiple hypothesis increases the chance of false positives → correction needed
→ Situation gets worse for correlated variables (e.g. $\delta^{2}\text{H}$ and $\delta^{18}\text{O}$)
Food specification maps – mineral water

TRACE mineral water sampling in Europe:

- ~650 samples
- Different geology
- Different climate zones

Analysis:

- $\delta^2\text{H}/\delta^{18}\text{O}$
- $^{87}\text{Sr}/^{86}\text{Sr}$
- $\delta^{34}\text{S}$
- Trace elements
- Major composition
- Tritium
Food specification maps – mineral water

Prediction model Sr-isotopes in mineral water

Geological map Europe

Reclassified map

Reclassification

<table>
<thead>
<tr>
<th>New classes</th>
<th>2.5perc</th>
<th>97.5perc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cenozoic</td>
<td>0.708</td>
<td>0.715</td>
</tr>
<tr>
<td>Mesozoic</td>
<td>0.708</td>
<td>0.722</td>
</tr>
<tr>
<td>Paleozoic</td>
<td>0.708</td>
<td>0.723</td>
</tr>
<tr>
<td>Paleozoic-Precambrian</td>
<td>0.708</td>
<td>0.739</td>
</tr>
<tr>
<td>Intrusives</td>
<td>0.708</td>
<td>0.728</td>
</tr>
<tr>
<td>Volcanics</td>
<td>0.704</td>
<td>0.714</td>
</tr>
</tbody>
</table>

Specification map for Sr-isotopes in mineral water
Food specification maps – mineral water

Prediction model Sr-isotopes in mineral water (upper and lower range)

87Sr/86Sr

**lower values**

- <all other values>
- 0.704
- 0.708

**upper values**

- <all other values>
- 0.714
- 0.715
- 0.722
- 0.723
- 0.728
- 0.739
**Food specification maps - mineral water**

Prediction model $\delta^2\text{H}$ and $\delta^{18}\text{O}$ in mineral water

$\delta^{18}\text{O}$ in global precipitation versus mean annual temperature. European mineral water in black

Currently: Prediction model European mineral water = isotope model global precipitation (Van der Veer et al., 2008)
Food specification maps - mineral water

$\delta^2H$ and $\delta^{18}O$ in mineral water

$\delta^{18}O$ in global precipitation versus mean annual temperature (grey). European mineral water in black

Currently: prediction model European mineral water = isotope model global precipitation (Van der Veer et al., 2008)

$\delta^{18}O = -6.5 \pm 0.8 \%$
Food specification maps - mineral water

δ²H and δ¹⁸O in mineral water

δ¹⁸O in global precipitation versus mean annual temperature. European mineral water in black

In pink the area where values range between -6.5 +/- 0.8 ‰ = specification area
**TraceTool**

The TraceTool is a webapplication that was developed to facilitate working with a combination of food specification maps, and to disseminate the food specification approach to a broader audience.

**What can you do (mineral water):**

* **Retrieve predicted values for a certain production area**
  → Compare with measured values to verify acclaimed production area

* **See how specific a combination of specifications is**
  → Where do similar values occur? What is the extent of specification area?

* **Uncertainty of the map values**

**Future work:**

* Improve existing mineral water models
* If possible, add models for mineral water
* Extend with models for other food commodities
At last

This talk would not have been possible without the huge effort of many researchers in WP1, WP15 and WP16.

JIFSAN is thanked for the invitation and organization.
Interactive demonstration TraceTool