Rapid Detection of Processed Uranium in Food

Council on Ionizing Radiation Measurements and Standards

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Gaithersburg, MD

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Goal

Develop a method to test food for uranium contamination in the aftermath of an incident involving processed uranium

• Method must be simple
• Able to be used by non-radiological laboratories
• No need for licensed material (spikes, tracers, etc.)
• Fast/easy sample preparation
  – Applicable for emergency response
  – High throughput
Uranium

- $^{238}\text{U} \sim 99.27\%$
- $^{235}\text{U} \sim 0.7198\%$
- $^{234}\text{U} \sim 0.0050\%$
- $^{238}\text{U}/^{235}\text{U}$ natural ratio $\sim 138$
- $^{235}\text{U}$ enrichment 3-5 % for power and $\sim 90\%$ for military applications
Radiochemical Methods

• Traditional radiochemistry methods are employed to measure alpha, beta, and gamma emitting radionuclides
  – Alpha and beta emitters are more challenging to measure
  – Often must separate elements and isotope
ICP-MS

• Technique is very common in analytical labs
• Relatively simple sample prep
Traditional ICP-MS Methods for Uranium

• Often used for geochemistry
  – Extremely detailed studies
  – Very little error
  – Thermal-ionization mass spectrometry (TIMS) and multiple-collector ICP Mass Spectrometry

• Used by Health Physicists and for bioassay
  – “Dilute and shoot” methods developed by CDC
  – Sector Field-Mass Spectrometry (SF-ICP-MS)

• Quadrupole ICP-MS
  – cheaper instrument, but widely used
  – Organic material must be removed

Typical Quadrupole ICP-MS Procedures for Uranium

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  • Can not be stored (made then destroyed after each use)

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– Microwave heating
– Cool, quench HF with aqueous Boric Acid
– Microwave heating
– Cool, inject into ICP-MS
– Excellent results but suboptimal for emergency response

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Proof of Principle

• Reference materials measured on multiple days

• Known ratios for $^{238}\text{U}/^{235}\text{U}$:
  - CRM U500 1.0003
  - CRM U970 0.0054
  - SRM4321C 137.82

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Standard Deviation</th>
<th>Observed bias %</th>
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<tbody>
<tr>
<td>CRM U500 (N = 5)</td>
<td>0.9998</td>
<td>0.0024</td>
<td>-0.05</td>
</tr>
<tr>
<td>CRM U970 (N = 5)</td>
<td>0.0053</td>
<td>0.0001</td>
<td>-1.0</td>
</tr>
<tr>
<td>SRM4321C (N = 5)</td>
<td>138.87</td>
<td>1.55</td>
<td>0.76</td>
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</tbody>
</table>
Method

• 5 g food in Teflon Beaker

• Acid leach with 10 mL high purity nitric acid

• Heat
Can We “Dilute and Shoot”

• No!
• Error up to 60 % for pome fruits and stone fruit
  • Residual organic content
• OK for water (≈ 0.06 % error)
Method

- 5 g food weighed in Teflon Beaker
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- Heat
- Filter through plug DGA resin plug
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• Heat

• Filter through plug DGA resin plug
  – Elute with concentrated nitric acid first
  – Strip column with 5 % nitric acid

• Collect and inject into ICP-MS
Intended use

• Fresh fruits, vegetables, dairy

• 25 different types of fruit and vegetables were analyzed in triplicate. Maximum deviation from known ratio: ± 3%
  – Required no spikes, tracers, or correction
  – Any laboratory with ICP-MS capability could perform this analysis

• How sensitive is this measurement for the detection of $^{235}$U?
% Change in $^{238}\text{U} / ^{235}\text{U}$ Ratio with 1.2 picogram spike in 5 g Food
Limitations

- Cereal grains: E.g. Wheat, rice, breakfast cereal, pasta
- Fats from food of animal origin: E.g. Butter, lard, oil
- High Starch and/or protein: E.g. lentils, beans
- High oil content: E.g. Tree nuts, Peanut butter, tahini
- High sugar, low water: E.g. raisins, dried apricots

This method is for use during emergency. Fresh foods are more germane.
Conclusions

• Developed a quadrupole ICP-MS method capable of interrogating uranium fingerprint

• Method not limited to radiochemical laboratories

• Simple, user friendly

• Potential automation with in line HPLC/Ion Chromatography
Acknowledgements

- WEAC laboratory members
- CFSAN collaborator
- Audience for listening