Glycoalkaloids in Potatoes

Trade Consultation Forum
17 June 2016
In September 2015, CFS was notified of a food poisoning case
- two persons from the same household
- after eating cooked potatoes
  - tongue numbness
  - burning sensation in mouth

Glycoalkaloid was detected
- in the raw potato sample
- in a urine sample of one of the victims
Glycoalkaloids in Potatoes

Solanaceae family
• glycoalkaloids
• defence against herbivores, pests and diseases
• naturally produced

Glycoalkaloids
• Sugar + alkaloid
  ➢ \( \alpha \)-chaconine
  ➢ \( \alpha \)-solanine
Glycoalkaloids in Potatoes

Chaconine: Sugar + alkaloid

Diagram:
- L-Rhamnose
- L-Glucose
- Alkaloid
Glycoalkaloids in Potatoes

Solamine: Sugar + alkaloid

- L-Galactose
- L-Glucose
- L-Rhamnose
- Alkaloid
Two toxic mechanisms
(1) disrupt of cell membrane
- adversely affect intestinal permeability
- nausea, vomiting, stomach and abdominal cramps, and diarrhea
  (1/2 to 12 hours after ingestion)

(2) interfere the message transmission between nerve cells
  - neurological effects (i.e. drowsiness, apathy, restlessness, shaking, confusion, weakness, and disturbed vision)
Glycoalkaloids in Potatoes

Distribution

Glycoalkaloid contents in different parts of a potato plant, in order from highest to lowest concentration (mg/kg, not drawn to scale)
# Glycoalkaloids in Potatoes

<table>
<thead>
<tr>
<th>Plant part</th>
<th>Typical glycoalkaloids content (mg/kg, fresh weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowers</td>
<td>2150-5000</td>
</tr>
<tr>
<td>Sprouts</td>
<td>2000-9970</td>
</tr>
<tr>
<td>Leaves</td>
<td>230-1450</td>
</tr>
<tr>
<td>Berries</td>
<td>180-1350</td>
</tr>
<tr>
<td>Roots</td>
<td>180-850</td>
</tr>
<tr>
<td>Stems</td>
<td>23-33</td>
</tr>
<tr>
<td>Commercial cultivars of tubers</td>
<td>10-150</td>
</tr>
</tbody>
</table>
Glycoalkaloids in Potatoes

Generally accepted safe upper limit

A bitter taste and a burning sensation in the mouth

Some consumers can taste the bitterness

Commercial cultivars (10 – 150 mg/kg)

Low levels (below 100 mg/kg) may produce desirable flavours
## Glycoalkaloids in Potatoe tubers

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<th>Plant part</th>
<th>Typical glycoalkaloids content (mg/kg, fresh weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial cultivars of tubers</td>
<td></td>
</tr>
<tr>
<td>• Skin (2-3% of tuber)</td>
<td>10-150</td>
</tr>
<tr>
<td>• Peel (10-12% of tuber)</td>
<td>300-640</td>
</tr>
<tr>
<td>• Flesh</td>
<td>150-1070</td>
</tr>
<tr>
<td>Sprouts</td>
<td>12-100</td>
</tr>
<tr>
<td></td>
<td>2000-9970</td>
</tr>
</tbody>
</table>

- **Sprouts**
  - 300-640
  - 150-1070
  - 12-100

- **‘Eye’ (Area where the sprouts develop)**

- **Suberized ‘skin’**
  - 1.5 mm layer

- **Peel**

- **Tuber flesh**
Glycoalkaloids in Potatoe tubers

Distribution of glycoalkaloids
• the whole potato tubers
• concentrate
  ➢ sprouts
  ➢ peel (a small 1.5 mm layer immediately under the skin)
  ➢ the area around the potato ‘eyes’

Way to reduce
• peeling of potatoes greatly reduces
  the levels of glycoalkaloids present
Local study by the CFS (2006)

Glycoalkaloids in Flesh and Peel of Various Potatoes (mg/kg)

<table>
<thead>
<tr>
<th>Variety</th>
<th>α–solanine</th>
<th></th>
<th>α–chaconine</th>
<th></th>
<th>Glycoalkaloids (Whole potato)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flesh</td>
<td>Peel</td>
<td>Flesh</td>
<td>Peel</td>
<td></td>
</tr>
<tr>
<td>New Potato</td>
<td>ND</td>
<td>120</td>
<td>ND</td>
<td>200</td>
<td>72</td>
</tr>
<tr>
<td>Russet</td>
<td>ND</td>
<td>20</td>
<td>ND</td>
<td>70</td>
<td>26</td>
</tr>
<tr>
<td>Red-skinned</td>
<td>ND</td>
<td>30</td>
<td>ND</td>
<td>110</td>
<td>36</td>
</tr>
<tr>
<td>Yellow-skinned 1</td>
<td>ND</td>
<td>100</td>
<td>ND</td>
<td>300</td>
<td>88</td>
</tr>
<tr>
<td>Yellow-skinned 2</td>
<td>ND</td>
<td>60</td>
<td>ND</td>
<td>200</td>
<td>60</td>
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</tbody>
</table>

ND: not detected; Limit of Detection (LOD) = 10 mg/kg
## Local study by the CFS (2006)

Glycoalkaloids in sprouts and flesh of potatoes (mg/kg)

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<th>Variety</th>
<th>α–solanine</th>
<th>α–chaconine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flesh</td>
<td>Sprout</td>
</tr>
<tr>
<td>Sprouted red-skinned potato</td>
<td>ND</td>
<td>3500</td>
</tr>
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ND: not detected; Limit of Detection (LOD) = 10 mg/kg
Glycoalkaloids in Potatoes

Commercial cultivars of tubers
• vary between 10 and 150 mg/kg
• most beneath 100 mg/kg

Bitter varieties
• four wild potato species in Mexico (S. polytrichon, S. stoloniferum, S. ehrenbergii, S. cardiophyllum)
• considerable high levels (1080 – 5540 mg/kg)
Factors affecting the levels of glycoalkaloid

- cultivars
- cultivation and management

- stresses after harvest
  - injury
  - light
  - storage temperature
Factors affecting the levels of glycoalkaloid

Cultivars
• most important
• considerable variation among cultivars
• genetically controlled
• commercial cultivars vary between 10 and 150 mg/kg

Lenape variety (1960s)
• for pest resistance: *Solanum tuberosum* × *Solanum chacoense*
• breeders and professionals — ended up with severe nausea
• high alkaloid content (300 mg/kg)
• was not released for commercial planting
Factors affecting the levels of glycoalkaloid

Cultivation and Management
- stresses during growth
  - unusual weather (cold, hot, rainy, dry)
  - unusual insect attack

- in 1986, 11 people became ill
- 66% Magnum Bonum samples exceeded 200 mg/kg
- a sales ban on such potatoes
- unusually cold and rainy growing season is partly responsible
Factors affecting the levels of glycoalkaloids

Cultivation and Management

- stresses during growth
  - unusual weather (cold, hot, rainy, dry)
  - unusual insect attack
- degree of maturity
  - immature tubers have higher metabolism
  - have higher glycoalkaloid
  - e.g. “new” potatoes

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Factors affecting the levels of glycoalkaloid

Injury
• pest infestation
• mechanical injury
• stimulate glycoalkaloids production

Light
• prolonged exposure
  ➢ chlorophyll synthesis
  ➢ ‘greening’ of the tuber
• stimulate glycoalkaloids production
• independent reactions but occur at the same time
Factors affecting the levels of glycoalkaloid

Storage temperature
• elevated temperature
  ➢ promote sprouting
• low temperature (≤ 7°C)
  ➢ promote conversion of starch to sugar

Increase in sugar
• darken during cooking
• produce acrylamide
Factors affecting the levels of glycoalkaloid

Reducing sugars + Asparagine
(glucose or fructose) (amine acid)

>120°C

Acrylamide

Low storage temperature (< 7°C)
- promote conversion of starch to sugar
- cooking (>120°C) may increase amount of acrylamide
Storing potatoes in the refrigerator can result in increased acrylamide during cooking. Therefore, store potatoes outside the refrigerator, preferably in a dark, cool place, such as a closet or a pantry, to prevent sprouting.

– US Food and Drug Administration

Do not store potatoes below 8 °C (low temperature storage can increase the components that contribute to acrylamide formation). – Health Canada
Factors affecting the levels of glycoalkaloid

Advice (storage temperature) from other authorities:

Do not store potatoes in the refrigerator as this increases sugar levels (potentially increasing acrylamide production during cooking). Keep them in a dark, cool place. – European Food Safety Authority

For some fruits that need to ripen, keeping them in the fridge can affect the taste. The most important food not to keep in the fridge are potatoes, when these are stored in the fridge the starch in the potato is converted to sugar. When baked or fried these sugars combine with the amino acid asparagine and produce the chemical acrylamide, which is thought to be harmful. – UK Food Standards Agency
Factors affecting the levels of glycoalkaloid

Advice (storage temperature) from other authorities:

Don’t store potatoes at temperatures below 8°C because this can increase the components that prompt acrylamide formation.
– Food Standard Australia New Zealand

Keep them in a dark place, handle them gingerly and protect them from being bumped against; otherwise they are vulnerable to the formation of solanine, a toxic substance. If the pantry is also cool, you can retard softening and sprouting as well. Otherwise room temperature works just fine.
– National Food Agency, Sweden
Regulatory control

Codex
• not established any safety standard

Generally accepted safety upper limit is 200 mg/kg of potato

Health Canada
• established a maximum level for glycoalkaloids
  ➢ 200 mg/kg total glycoalkaloids (fresh weight)
• this level applies to all commercially sold potatoes
Regulatory control

The National Food Agency, Sweden
• Regulations on Certain Foreign Substances in Food (2002)

<table>
<thead>
<tr>
<th>Substance</th>
<th>Food</th>
<th>Maximum level, mg/kg</th>
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<tr>
<td>Glycoalkaloids, total level of solanidine glycosides (α-chaconine, α-solanine etc.)</td>
<td>Potatoes, raw and unpeeled</td>
<td>200</td>
</tr>
</tbody>
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(Source: FAOLEX - legislative database of FAO Legal Office)

The Federal Office of Consumer Protection and Food Safety (Germany)
• considers amounts up to 200 mg/kg in potatoes for safe
Advice to Trade

Handling
• know the cultivars, maturity ("new" potatoes)
• handled with special care

Light
• display in areas with low light intensity
• shut lights off at night over the potatoes
• cover with brown paper sacks.
• packing in paper bags or in plastic bags that are opaque on one side.

Temperature
• Keep potatoes cool and dry
Reference


Retail Handling of Fresh Potatoes (Agriculture Victoria)
(Updated: August 2010 and 2013)

Toxic Glycoalkaloids in Potatoes (Centre for Food Safety)(November 2015)
Thank you