Risk Assessment of Aflatoxins

NOV. 30th 2017

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Outline of Presentation

Contents

I. How important is aflatoxin
II. Food standard for aflatoxin
III. Risk Assessment
IV. Risk Management
V. Recommendation
Aflatoxins in food: an unavoidable problem

Aflatoxins
Northern Europe
Afla n.a.; ZON 25%; DON 71%; FUM n.a.; OTA n.a.

Eastern Europe
Afla 51%; ZON 46%; DON 61%; FUM 31%; OTA 55%

North Asia
Afla 15%; ZON 63%; DON 83%; FUM 51%; OTA 25%

Central Europe
Afla 19%; ZON 41%; DON 64%; FUM 51%; OTA 20%

North America
Afla 21%; ZON 14%; DON 50%; FUM 27% OTA 21%

Southern Europe
Afla 33%; ZON 14%; DON 36%; FUM 56%; OTA 41%

South East Asia
Afla 71%; ZON 37%; DON 34%; FUM 55%; OTA 28%

South Asia
Afla 88%; ZON 14%; DON 22%; FUM 56%; OTA 49%

South America
Afla 15%; ZON 28%; DON 21%; FUM 76%; OTA 16%

Southern Europe
Afla 33%; ZON 14%; DON 36%; FUM 56%; OTA 41%

Africa
Afla 58%; ZON 8%; DON 17%; FUM 58%; OTA 42%

Middle East
Afla 37%; ZON 0%; DON 11%; FUM 67%; OTA 50%

North America
Afla 50%; ZON 14%; DON 50%; FUM 27%; OTA 21%

Southern Europe
Afla 33%; ZON 14%; DON 36%; FUM 56%; OTA 41%

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Afla 71%; ZON 37%; DON 34%; FUM 55%; OTA 28%

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Africa
Afla 58%; ZON 8%; DON 17%; FUM 58%; OTA 42%

Middle East
Afla 37%; ZON 0%; DON 11%; FUM 67%; OTA 50%
Difuranocoumarin derivatives produced by the fungi *Aspergillus flavus* and *Aspergillus parasiticus*
- Aflatoxins are secondary fungal metabolites.
- Aflatoxin types include B1, B2, G1, G2.
- B1 is most prevalent and toxic aflatoxin.

Aflatoxin has received considerable attention due to their significance in agricultural loss and human health.

Aflatoxin is epidemiologically implicated as carcinogen in humans and an environmental contaminant which is widespread in nature, therefore chronic toxicity is of greater concern than acute toxicity.

Major source of exposure: cereals, peanuts/nuts, spices etc.

How to control aflatoxins?
Aflatoxins?

Aflatoxin exposure throughout the food chain

- **Biological factors**
  - Susceptible crop
  - Toxigenic fungi

- **Environmental factors**
  - Temperature
  - Moisture
  - Mechanical injury
  - Damage by insect / damage

- **Harvesting factors**
  - Crop maturity
  - Temperature
  - Moisture

- **Storage**
  - Temperature
  - Moisture

- **Distribution & Processing**

- **Food**

- **Feed**

- **Animals**
  - Animal
  - Animal origin food (meat, milk, egg, etc.)

- **Humans**

- **Aflatoxin exposure from food intake**

- **Aflatoxin exposure**
How important is aflatoxins?

- Deaths and disability adjusted life years (DALYs)
- African Region (AFR)
- Southeast Asia Region (SEAR)
- Western Pacific Region (WPR)
- Eastern Mediterranean Region (EMR)
- Europe (EUR)
- Americas Region (AMR)

- Years lived with disability (YLD),
- Years of life lost (YLL)

WHO report on global burden of foodborne diseases, aflatoxin is one of the main issues.

Gibb et. al. (2016).
Permitted maximum levels of aflatoxins vary greatly, depending on whether the country imports or exports the affected commodities. Very strict regulation can be costly.

<table>
<thead>
<tr>
<th>Target food</th>
<th>Classification</th>
<th>Comparison target country or organization (μg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B1+B2+G1+G2</td>
<td>15.0</td>
</tr>
<tr>
<td>Cereals, legumes, peanuts, nuts and their simple processed products (grinding, cutting, etc.)</td>
<td>15 (Groundnuts, almonds, hazelnuts, Brazil nuts and pistachio)</td>
<td>4.0 (All cereals and all products derived from cereals) 10.0 (Maize and rice) 15.0 (Groundnuts), 15.0 (Almonds, pistachios and apricot kernels) 15.0 (Hazelnuts and Brazil nuts) 10.0 (Other tree nuts)</td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.0 (All cereals and all products derived from cereals) 5.0 (Maize and rice) 8.0 (Groundnuts), 12.0 (Almonds, pistachios and apricot kernels) 8.0 (Hazelnuts and Brazil nuts) 5.0 (Other tree nuts)</td>
</tr>
<tr>
<td>Groundnuts (peanuts) and other oilseeds and processed products</td>
<td>B1+B2+G1+G2</td>
<td>15.0</td>
</tr>
<tr>
<td></td>
<td>4 (Groundnuts and processed products) b)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>2 (Groundnuts and processed products) b)</td>
<td></td>
</tr>
</tbody>
</table>
## Regulatory limits for aflatoxins-2

<table>
<thead>
<tr>
<th>Target food</th>
<th>Classification</th>
<th>Korea</th>
<th>Codex</th>
<th>EU</th>
<th>USA</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soy sauces/pastes, red pepper powder and curry powder</td>
<td>B1+B2+G1+G2</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20 (All food)(^d)</td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>15 (Brazil nuts, groundnuts and processed products, pistachio)(^d)</td>
</tr>
<tr>
<td>Nutmeg, turmeric, dried pepper, dried paprika and natural species containing these</td>
<td>B1+B2+G1+G2</td>
<td>15</td>
<td>-</td>
<td>10.0 (Capsicum spp., Piper spp, nutmeg, ginger, turmeric)</td>
<td>-</td>
<td>5.0 (Capsicum spp., Piper spp, nutmeg, ginger, turmeric)</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>B1+B2+G1+G2</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10 (All food)(^d)</td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Dried fruits</td>
<td>B1+B2+G1+G2</td>
<td>15</td>
<td>-</td>
<td>10</td>
<td>4.0 (Products intended for direct human consumption)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>10</td>
<td>-</td>
<td>5</td>
<td>2.0 (Products intended for direct human consumption)</td>
<td></td>
</tr>
<tr>
<td>Infant foods, follow-up foods, cereal foods for infants and young children, other foods for infants and young children</td>
<td>B1</td>
<td>0.1</td>
<td>-</td>
<td>0.10 (Including Dietary foods for special medical purposes intended specifically for infants)</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Exception of Ground nuts (peanuts) and other oilseeds for crushing for refined vegetable oil production  
\(^b\) Exception of Crude vegetable oils destined for refining and refined vegetable oils  
\(^c\) Sum of B1, B2, G1 and G2  
\(^d\) Sum of B1, B2, G1 and G2
Risk Assessment

Hazard Identification
(toxicology, epidemiology)

Implementing policies and providing management plans.

Hazard Characterization
(toxicology, epidemiology)

Implementing policies and providing management plans.

Exposure Assessment

Implementing policies and providing management plans.

Risk Characterization

Implementing policies and providing management plans.

Establishing Standards

Appropriate protection level (food contaminants et al.)

Priority setting

Implementing policies and providing management plans.

Reducing Risk

Perception differences through risk communication
Flowchart of Risk Assessment in NiFDS

Chemicals

Intentional use chemicals (pesticides etc)

- Chronic
- Acute

Carcinogenicity?

- Yes
- No

Genotoxicity?

- Yes
- No

Hazard Characterization

Unavoidable chemicals

- Chronic
- Acute

Carcinogenicity?

- Yes
- No

Genotoxicity?

- Yes
- No

Hazard Characterization

Exposed assessment

- BMDL
- NOAEL, BMDL, TDI, PTWI, PTMI

Risk Characterization

Type 1
Type 2
Type 3
Type 4
Type 5
Type 6
Type 7
Type 8
Type 9

Table 1
Table 2
Table 3
Table 4
Table 5
Table 6
Table 7
Table 8
Table 9

Stop using (Ban)

Risk Characterization

- Type 1
- Type 2
- Type 3
- Type 4
- Type 5
- Type 6
- Type 7
- Type 8
- Type 9

Table 1
Table 2
Table 3
Table 4
Table 5
Table 6
Table 7
Table 8
Table 9
LD50 0.5 mg/kg for duckling
LD50 60 mg/kg for mouse
Binds to nucleic acids in some species
Difficult to assess for humans

Liver cancer in most species

Some evidence humans are at lower risk than other species

One of most potent mutagenic and carcinogenic substances known

B1 (AFB1) most common, most studied, most toxic

Toxicity varies by species

Death usually from liver damage
Aflatoxin B₁

Cytochrome-P450

Aflatoxin B₁-8,9-epoxide (exo and endo)

DNA-adducts

DNA repair

Microsomal epoxide hydrolase (?)

Aflatoxin B₁-8,9-dihydrodiol

Protein binding

Mutation

Toxicity

Cancer

Physiological pH

Dialdehydic phenolate

Aflatoxin B₁ aldehyde reductase

Aflatoxin B₁ dialcohol

Excretion

Glutathione S-transferase(s)

Aflatoxin B₁-Glutathione conjugate

Excretion

Fernanda et al. (2016).
<table>
<thead>
<tr>
<th>Country</th>
<th>Region</th>
<th>AFB1 intake (ng/kg b.w./day)</th>
<th>Liver cancer rate/year&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Liver cancer rate/60 years&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenya&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Highland</td>
<td>4.2</td>
<td>14</td>
<td>840</td>
</tr>
<tr>
<td></td>
<td>Midland</td>
<td>6.8</td>
<td>43</td>
<td>2,580</td>
</tr>
<tr>
<td></td>
<td>Lowland</td>
<td>12.4</td>
<td>58</td>
<td>3,480</td>
</tr>
<tr>
<td>Swaziland&lt;sup&gt;c&lt;/sup&gt;</td>
<td>High veldt</td>
<td>14.3</td>
<td>35</td>
<td>2,100</td>
</tr>
<tr>
<td></td>
<td>Middle veldt</td>
<td>40.0</td>
<td>85</td>
<td>5,100</td>
</tr>
<tr>
<td></td>
<td>Lebombo</td>
<td>32.9</td>
<td>89</td>
<td>5,340</td>
</tr>
<tr>
<td></td>
<td>Low veldt</td>
<td>127.1</td>
<td>184</td>
<td>11,040</td>
</tr>
<tr>
<td>Transkei&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Four districts</td>
<td>16.5</td>
<td>91</td>
<td>5,460</td>
</tr>
<tr>
<td>Mozambique&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Manhica-Mangud</td>
<td>20.3</td>
<td>121</td>
<td>7,260</td>
</tr>
<tr>
<td></td>
<td>Massinga</td>
<td>38.6</td>
<td>93</td>
<td>5,580</td>
</tr>
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<td></td>
<td>Inhambane</td>
<td>77.7</td>
<td>218</td>
<td>13,080</td>
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<tr>
<td></td>
<td>Inharrime</td>
<td>86.9</td>
<td>178</td>
<td>10,680</td>
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<tr>
<td></td>
<td>Morrumbene</td>
<td>87.7</td>
<td>291</td>
<td>17,460</td>
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<tr>
<td></td>
<td>Homoine-Maxixe</td>
<td>131.4</td>
<td>479</td>
<td>28,740</td>
</tr>
<tr>
<td></td>
<td>Zavala</td>
<td>183.7</td>
<td>288</td>
<td>17,280</td>
</tr>
<tr>
<td>China&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Guangxi B</td>
<td>11.7</td>
<td>1,754</td>
<td>105,240</td>
</tr>
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<td></td>
<td>Guangxi B</td>
<td>90.0</td>
<td>1,822</td>
<td>109,320</td>
</tr>
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<td></td>
<td>Guangxi C</td>
<td>704.5</td>
<td>2,855</td>
<td>171,300</td>
</tr>
<tr>
<td></td>
<td>Guangxi D</td>
<td>2,027.4</td>
<td>6,135</td>
<td>368,100</td>
</tr>
</tbody>
</table>

<sup>a</sup> Age-adjusted annual incidence of liver cancer for men per one million individuals. The age distributions of the population groups studied did not deviate significantly from each other. In the study from China, the incidence of HBsAg carriers was 23% of all members of the cohort and in the study from Swaziland and (presumably) Kenya it was 21–28%, whereas no information was found for Mozambique. The calculation of the lifetime liver cancer rate (last column) assumed a lifespan of 60 years.

<sup>b</sup> Peers et al. (1976) as corrected by Carlborg (1979).

<sup>c</sup> Peers and Linsell (1977).

<sup>d</sup> Van Rensburg et al. (1985).

<sup>e</sup> Yeh et al. (1989).
## Hazard Characterization

**BMD10 and BMDL10 on the development of liver cancer in rats by exposure to AF B1**

<table>
<thead>
<tr>
<th>Model</th>
<th>Log (likelihood)</th>
<th>AIC</th>
<th>Accept</th>
<th>BMD10 (µg/kg b.w./day)</th>
<th>BMDL10 (µg/kg b.w./day)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BMDS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamma</td>
<td>75.52</td>
<td>Yes</td>
<td>0.47</td>
<td>0.23</td>
<td></td>
</tr>
<tr>
<td>Logistic</td>
<td>73.54</td>
<td>Yes</td>
<td>0.45</td>
<td>0.34</td>
<td></td>
</tr>
<tr>
<td>Log-logistic</td>
<td>75.52</td>
<td>Yes</td>
<td>0.48</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>Log-probit</td>
<td>75.50</td>
<td>Yes</td>
<td>0.48</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>Multistage</td>
<td>75.61</td>
<td>Yes</td>
<td>0.44</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Multistage-Cancer</td>
<td>73.64</td>
<td>Yes</td>
<td>0.42</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Probit</td>
<td>73.52</td>
<td>Yes</td>
<td>0.41</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>Weibull</td>
<td>75.56</td>
<td>Yes</td>
<td>0.46</td>
<td>0.21</td>
<td></td>
</tr>
<tr>
<td>Quantal-Linear</td>
<td>78.24</td>
<td>No</td>
<td>0.14</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td><strong>PROAST</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamma</td>
<td>-34.76</td>
<td>Yes</td>
<td>0.47</td>
<td>0.23</td>
<td></td>
</tr>
<tr>
<td>Logistic</td>
<td>-34.77</td>
<td>Yes</td>
<td>0.45</td>
<td>0.34</td>
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<tr>
<td>Log-logistic</td>
<td>-34.76</td>
<td>Yes</td>
<td>0.48</td>
<td>0.26</td>
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<tr>
<td>Log-probit</td>
<td>-34.75</td>
<td>Yes</td>
<td>0.48</td>
<td>0.28</td>
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<tr>
<td>Two-stage</td>
<td>-34.82</td>
<td>Yes</td>
<td>0.42</td>
<td>0.34</td>
<td></td>
</tr>
<tr>
<td>Weibull</td>
<td>-34.78</td>
<td>Yes</td>
<td>0.46</td>
<td>0.21</td>
<td></td>
</tr>
<tr>
<td>LVM: E2</td>
<td>-34.76</td>
<td>Yes</td>
<td>0.41</td>
<td>0.31</td>
<td></td>
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<tr>
<td>LVM: H2</td>
<td>-37.04</td>
<td>No</td>
<td>0.20</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

* Wogan et al., 1974
## Toxicity information for major mycotoxins

<table>
<thead>
<tr>
<th>Mycotoxin</th>
<th>Units</th>
<th>TDI</th>
<th>TDI***</th>
<th>IARC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aflatoxin B1</td>
<td>NOT ESTABLISHED</td>
<td></td>
<td>BMDL_{10} = 170 ng/kg bw/day</td>
<td>GROUP 1</td>
</tr>
<tr>
<td>Aflatoxin M1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ochratoxin A</td>
<td>PTWI*</td>
<td>1.0</td>
<td>0.11 μg/kg bw./week</td>
<td>GROUP 2B</td>
</tr>
<tr>
<td>Fumonisin</td>
<td></td>
<td>2.0</td>
<td>1.65 μg/kg bw/day</td>
<td>GROUP 2B</td>
</tr>
<tr>
<td>Patulin</td>
<td></td>
<td>0.4</td>
<td>0.4 μg/kg bw/day</td>
<td>GROUP 3</td>
</tr>
<tr>
<td>Deoxynivalenol</td>
<td></td>
<td>1.0</td>
<td>1 μg/kg bw/day</td>
<td>GROUP 3</td>
</tr>
<tr>
<td>Zearalenone</td>
<td></td>
<td>0.5</td>
<td>0.4 μg/kg b.w./day</td>
<td>GROUP 3</td>
</tr>
</tbody>
</table>

* PTWI: Provisional tolerable weekly intake (ng/kg bw/week)
** TDI: Tolerable daily intake (ng/kg bw/day)
*** As designated by the National Institute of Food Drug Safety Evaluation
**Dietary Exposure Assessment**

- **Aflatoxin contamination**
  - 10,443 samples from 300 products during 2012-2015
  - analyzed by HPLC and LC-MS/MS

- **Food consumption**
  - the Korea National Health and Nutrition Examination Survey (KNHANES, 2011–13)
  - the mean and extreme intake (P95) by age

- **Body weight**
  - calculated using the MIMS/MAP 3.0 & Oracle 10g programs

\[
\text{Aflatoxin contamination in food (µg/g)} \times \text{Food consumption (g/day)} = \text{Aflatoxins exposure (ng/kg bw/day)}
\]

\[
\text{Body weight (Kg)}
\]
Dietary Exposure Assessment

Number of food samples tested for aflatoxins

- Grains and grain-based products: 1562
- Corn and corn-based products: 267
- Nuts and nut-based products: 734
- Cereals: 155
- Nuts and seeds: 342
- Pastes: 565
- Spices: 162
- Vegetables: 33
- Wheat flours: 116
- Fruits: 399
- Fruit(derived): 223
- Noodles: 478
- Snacks: 625611
- Bread and rice cakes: 193
- Tofu and milk: 162
- Coffee: 49
- Mushroom: 15
- Chocolate: 3
- Preserves: 8
- Processed meat products: 166
- Oils and fats: 217
- Tea: 7
- Alcohol: 221
- Beverages: 255
- Kimchi: 270
- Pickled foods: 408
- Canned foods: 3
- Raw processed convenience foods: 15
- Instant/processed foods: 2
- Processed milk products: 93
- Livestock products: 2
- Raw materials in common use for foods and medicines: 3
- Other foods: 15

Number of samples
Samples were analyzed using high-performance liquid chromatography (HPLC) and mass spectrometry (MS), according to the CODEX HPLC or HPLC/MS/MS method, while “nondetects” were evaluated using ND (0) and ND (limit of detection, LOD).
Dietary Exposure Assessment

Data Management System in NiFDS

Collection program of hazardous substances monitoring DB &
(MIMS, Monitoring Information Management System)
(MAP, Monitoring database and Assessment Program)
Dietary Exposure Assessment

Data Management System in NiFDS

SNA: Food-Hazard network analysis

GIS: Contamination Map (eg, Total Afl.)
### Concentrations of aflatoxin in food

<table>
<thead>
<tr>
<th>Category</th>
<th>No. of samples</th>
<th>LC %</th>
<th>Concentration range (LB / UB) (µg/kg)</th>
<th>Mean</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
<th>LC: left-censored data (values below the limit of detection)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grains and grain-based products</td>
<td>1562</td>
<td>92</td>
<td>-</td>
<td>0.09/0.23</td>
<td>0/0.04</td>
<td>0/0</td>
<td>74.86/74.86</td>
<td></td>
</tr>
<tr>
<td>Corn and corn-based products</td>
<td>267</td>
<td>91</td>
<td>-</td>
<td>0.10/0.21</td>
<td>0/0.08</td>
<td>0/0</td>
<td>4.55/4.55</td>
<td></td>
</tr>
<tr>
<td>Pulse and pulse-based products</td>
<td>734</td>
<td>96</td>
<td>-</td>
<td>0.02/0.09</td>
<td>0/0.02</td>
<td>0/0</td>
<td>7.25/7.25</td>
<td></td>
</tr>
<tr>
<td>Nuts and nut-based products</td>
<td>938</td>
<td>93</td>
<td>-</td>
<td>0.10/0.18</td>
<td>0/0.03</td>
<td>0/0</td>
<td>12.20/12.20</td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>155</td>
<td>86</td>
<td>-</td>
<td>0.03/0.22</td>
<td>0/0.05</td>
<td>0/0</td>
<td>1.26/1.26</td>
<td></td>
</tr>
<tr>
<td>Nuts and seeds</td>
<td>342</td>
<td>93</td>
<td>-</td>
<td>0.04/0.15</td>
<td>0/0.02</td>
<td>0/0</td>
<td>6.62/6.62</td>
<td></td>
</tr>
<tr>
<td>Pastes</td>
<td>922</td>
<td>88</td>
<td>-</td>
<td>0.10/0.23</td>
<td>0/0.03</td>
<td>0/0</td>
<td>10.61/10.61</td>
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</tr>
<tr>
<td>Condiments and sauces</td>
<td>565</td>
<td>86</td>
<td>-</td>
<td>0.04/0.17</td>
<td>0/0.06</td>
<td>0/0</td>
<td>6.85/6.85</td>
<td></td>
</tr>
<tr>
<td>Spices</td>
<td>151</td>
<td>88</td>
<td>-</td>
<td>0.34/0.66</td>
<td>0/0.23</td>
<td>0/0</td>
<td>9.51/9.51</td>
<td></td>
</tr>
<tr>
<td>Vegetables</td>
<td>162</td>
<td>98</td>
<td>-</td>
<td>0.01/0.14</td>
<td>0/0.07</td>
<td>0/0</td>
<td>1.44/1.44</td>
<td></td>
</tr>
<tr>
<td>Wheat flours</td>
<td>171</td>
<td>96</td>
<td>-</td>
<td>0.02/0.13</td>
<td>0/0.02</td>
<td>0/0</td>
<td>1.20/1.20</td>
<td></td>
</tr>
<tr>
<td>Fruits (dried)</td>
<td>399</td>
<td>94</td>
<td>-</td>
<td>0.02/0.19</td>
<td>0/0.07</td>
<td>0/0</td>
<td>3.20/3.20</td>
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<tr>
<td>Food for infants and young children</td>
<td>223</td>
<td>98</td>
<td>-</td>
<td>0/0.07</td>
<td>0/0.07</td>
<td>0/0</td>
<td>0.14/0.16</td>
<td></td>
</tr>
<tr>
<td>Noodles</td>
<td>478</td>
<td>98</td>
<td>-</td>
<td>0.01/0.13</td>
<td>0/0.02</td>
<td>0/0</td>
<td>1.08/2.18</td>
<td></td>
</tr>
<tr>
<td>Snacks</td>
<td>625</td>
<td>97</td>
<td>-</td>
<td>0.01/0.17</td>
<td>0/0.04</td>
<td>0/0</td>
<td>2.12/2.18</td>
<td></td>
</tr>
<tr>
<td>Bread and rice cakes</td>
<td>611</td>
<td>98</td>
<td>-</td>
<td>0/0.05</td>
<td>0/0.02</td>
<td>0/0</td>
<td>2.16/2.18</td>
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</tr>
<tr>
<td>Tofu and muk</td>
<td>193</td>
<td>95</td>
<td>-</td>
<td>0.05/0.10</td>
<td>0/0.0</td>
<td>0/0</td>
<td>1.16/1.16</td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>162</td>
<td>96</td>
<td>-</td>
<td>0.03/0.06</td>
<td>0/0.03</td>
<td>0/0</td>
<td>3.27/3.27</td>
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<tr>
<td>Mushroom</td>
<td>1</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Chocolate</td>
<td>49</td>
<td>98</td>
<td>-</td>
<td>0/0.17</td>
<td>0/0.02</td>
<td>0/0</td>
<td>0.06/2.18</td>
<td></td>
</tr>
<tr>
<td>Preserves</td>
<td>15</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Processed meat products</td>
<td>3</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Oils and fats</td>
<td>8</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>166</td>
<td>93</td>
<td>-</td>
<td>0.04/0.14</td>
<td>0/0.02</td>
<td>0/0</td>
<td>1.36/2.18</td>
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</tr>
<tr>
<td>Alcohol</td>
<td>3</td>
<td>100</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Beverages</td>
<td>217</td>
<td>98</td>
<td>-</td>
<td>0/0.05</td>
<td>0/0.02</td>
<td>0/0</td>
<td>0.7/0.7</td>
<td></td>
</tr>
<tr>
<td>Kimchi</td>
<td>1</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Pickled foods</td>
<td>6</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Canned foods</td>
<td>3</td>
<td>100</td>
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<td>-</td>
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</tr>
<tr>
<td>Raw processed foods</td>
<td>221</td>
<td>82</td>
<td>-</td>
<td>0.02/0.07</td>
<td>0/0.02</td>
<td>0/0</td>
<td>1.67/1.67</td>
<td></td>
</tr>
<tr>
<td>Instant/convenience foods</td>
<td>255</td>
<td>95</td>
<td>-</td>
<td>0.01/0.10</td>
<td>0/0.03</td>
<td>0/0</td>
<td>1.46/2.18</td>
<td></td>
</tr>
<tr>
<td>Starches</td>
<td>15</td>
<td>87</td>
<td>-</td>
<td>0.06/0.21</td>
<td>0/0.03</td>
<td>0/0</td>
<td>0.68/0.96</td>
<td></td>
</tr>
<tr>
<td>Other foods</td>
<td>270</td>
<td>87</td>
<td>-</td>
<td>0.04/0.12</td>
<td>0/0.04</td>
<td>0/0</td>
<td>4.65/4.65</td>
<td></td>
</tr>
<tr>
<td>Processed milk products</td>
<td>408</td>
<td>98</td>
<td>-</td>
<td>0/0.06</td>
<td>0/0.01</td>
<td>0/0</td>
<td>0.71/0.71</td>
<td></td>
</tr>
<tr>
<td>Livestock products</td>
<td>2</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Raw materials in common use for foods and medicines</td>
<td>93</td>
<td>94</td>
<td>1.07/1.14</td>
<td>0/0.03</td>
<td>0/0.01</td>
<td>93.44/93.44</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a): not calculated where all data were left-censored or the number of data was very limited
## Dietary Exposure Assessment

### The average and high consumer exposure to aflatoxin by age class

<table>
<thead>
<tr>
<th>Population groups</th>
<th>Estimates exposure for average consumer&lt;sup&gt;a&lt;/sup&gt; (ng/kg b.w./day)</th>
<th>Estimates exposure for high consumer&lt;sup&gt;b&lt;/sup&gt; (ng/kg b.w./day)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LB</td>
<td>UB</td>
</tr>
<tr>
<td>All population</td>
<td>0.263</td>
<td>1.105</td>
</tr>
<tr>
<td>Adults&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.255</td>
<td>1.056</td>
</tr>
<tr>
<td>1~2 years</td>
<td>0.614</td>
<td>3.049</td>
</tr>
<tr>
<td>3~6 years</td>
<td>0.537</td>
<td>2.502</td>
</tr>
<tr>
<td>7~12 years</td>
<td>0.375</td>
<td>1.657</td>
</tr>
<tr>
<td>13~19 years</td>
<td>0.242</td>
<td>1.060</td>
</tr>
<tr>
<td>20~64 years</td>
<td>0.252</td>
<td>1.052</td>
</tr>
<tr>
<td>65 &lt;</td>
<td>0.273</td>
<td>1.085</td>
</tr>
</tbody>
</table>

<sup>a</sup>Average intake is based on average occurrence and average consumption.

<sup>b</sup>High consumer is based on average occurrence and 95<sup>th</sup> percentile consumption.

<sup>c</sup>20 < group
Dietary Exposure Assessment

Daily aflatoxin exposure in each food group

![Graph showing daily aflatoxin exposure in various food groups.](image)
Dietary Exposure Assessment

Contribution of each food to dietary exposure of aflatoxins

Contribution to aflatoxin exposure using LB concentration in all population

Contribution to aflatoxin exposure using UB concentration in all population
Dietary Exposure Assessment

Foods with high contamination & exposure level (Group I)

- Glutinous rice (roasted)
- Soybean sauce
- Barely tea
- Soybean (roasted)

Graph showing the relationship between exposure concentration (ug/kg bw/day) and concentration (ug/kg) with a logarithmic scale for Ln(Con., ug/kg).

Legend:
- Nuts and nut-based products
- Nuts and seeds
- Grains
- Grain-based products
- Fruits (dried)
- Fruits
- Snacks
- Other foods
- Kimchi
- Tea
- Pulse
- Pulse-based products
- Tofu and muk
- Noodles
- Wheat flours
- Mushrooms
- Bread and rice cakes
- Raw processed foods
- Cereals
- Oils and fats
- Processed meat products
- Corn and corn-based products
- Corn
- Processed milk products
- Beverages
- Preserves
- Vegetables
- Pickled foods
- Seasoned foods
- Alcohol
- Instant/convenience foods
- Special purpose foods
- Condiments
- Coffee
- Canned foods
Korean Diet is different from Western-style Diet

Grain (Rice etc) consumption = 300g/day
Risk Characterization

Low possibility of hazardous effects related to aflatoxin exposure through food intake

The aflatoxin risk from food intake: the margin of exposure (MOE) method

\[ \text{BMDL}_{10} (\mu\text{g/kg bw/day}) \]
\[ \text{MOE} = \frac{\text{BMDL}_{10}}{\text{Daily exposure (\mu\text{g/kg bw/day})}} \]

The mean daily exposure for total aflatoxin: 0.0011 \( \mu\text{g/kg bw/day} \)

BMDL\(_{10} \) for aflatoxin: 0.170 \( \mu\text{g/kg bw/day} \)

Koreans maintaining an average diet were assessed to have a low possibility of hazardous effects related to aflatoxin exposure.

Nevertheless, because aflatoxins are carcinogenic and genotoxic, their levels in food should be continuously monitored and minimized following the ALARA principle.
Risk Characterization

Comparison of Exposure Levels with Foreign Countries

- BMDL10 170 ng/kg b.w./day

<table>
<thead>
<tr>
<th>Country</th>
<th>Exposure Level (ng/kg b.w./day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hong Kong</td>
<td>5</td>
</tr>
<tr>
<td>France</td>
<td>0</td>
</tr>
<tr>
<td>China</td>
<td>10</td>
</tr>
<tr>
<td>Korea</td>
<td>15</td>
</tr>
<tr>
<td>Europe</td>
<td>20</td>
</tr>
<tr>
<td>Australia</td>
<td>25</td>
</tr>
<tr>
<td>America</td>
<td>30</td>
</tr>
</tbody>
</table>
Risk Management

Reduction strategy

Home
- Keep cereals and processed products in cool dark place
- Maintain a balanced diet
- Check the expiration date and discard the moldy food
- Be careful when storing nuts
- Purchase from trusted retailers

Industry
- Apply GAP/GMP/HACCP to minimize mycotoxin contamination
- Select a reliable supplier when purchasing food ingredients
- Preservation conditions (cool, dark place, dry place) based on first-in-first-out
- Maintain raw material supply and demand records
Food safety practices throughout the food chain
Thank you for your attention