Risks associated with the consumption of mass-reared insects?
FAO estimates that:

- The world needs to increase its food production by 70% in 2050 to serve a global population of 9 billion.
- Animal feed production is competing for resources (land, water and fertilizer) with human food and fuel production, urbanization and nature.
- 70% of world’s agricultural land is already directly or indirectly dedicated to meat production.

Can we still produce sufficient animal protein?
Mealworm
Grasshopper
Wax moth
Buffalo worm
The Insect Cookbook

Our future?

Inside a Japanese ornamental bug store
Industrial-scale processing for insects

Designs a circular economy

Source: M. Peters, personal communication, 2012.

Feed conversion

Efficiencies of production of conventional meat and crickets

- **Percentage of animal edible**
  - Cricket: 80%
  - Poultry: 55%
  - Pork: 55%
  - Beef: 40%

- **kg feed/kg edible weight**
  - Cricket: 18 g CO₂/kg growth
  - Poultry: 2850 g CO₂/kg growth
  - Pork: 8 kg feed/kg meat
  - Beef: 2 kg feed/kg meat

*Source: van Huis, 2013.*

Housefly (Musca domestica)

Jagran BV has developed a concept to grow at industrial-scale larvae fed with organic waste such as GFT waste, sludge, restaurant waste and even manure.

- Due to specific amino acids, lipids, enzymes and other components in the long term even more sophisticated applications are foreseen for human nutrition and pharma.
- End of 2013 demo factory line of AEB and Jagran BV.
Bioconversion of 1000 kg of fresh manure from dairy cows yields about 13 litres of biodiesel, and about 17 kg of high-quality protein powder for animal feed to replace soya and fish meal.

Novel protein sources

• Collecting from the wild;
• Semi-domestication;
• Buying from the market/the internet;
• Mass-rearing.
Background

In 2012 NVWA received mandates from the ministers of Agriculture (EZ) and Health (VWS) to assess the microbiological, chemical and parasitological risks arising from consuming mass-reared insects as food and feed.

In 2014 EFSA received a request from the European Commission (EFSA mandate number M-2014-0150).

(Un)-intentional consumption

Dutchman consumes annually up to 500 grams of insect protein (Marcel Dicke, Dec 2010).

Americans consume 900 grams of insects/ year subconsciously (Factsheet, Ohio University).

**Chocolate**
- 60 insect fragments 100 gram

**Fruit juices**
- 5 or more (fruit)fly eggs per 250 ml

**Peanut butter**
- 30 insect fragments per 100 gram

**Macaroni**
- 225 insect fragments per 225 gram

State of the Art

To the best of our knowledge, no toxicological studies involving whole edible insects or insect derived protein(s) have been carried out in human subjects or in experimental animals.
Risk assessment NVWA-BuRO

Discussions with experts of edible insects (WUR) and members of the Dutch Insect Breeders Association (VENIK) on the topic of rearing insects.

Systematic literature review.

Human consumption:
- mealworm beetle (*Tenebrio molitor*)
- lesser mealworm beetle (*Alphitobius diaperinus*)
- European migratory locust (*Locusta migratoria*)

Feed consumption:
- Housefly (*Musca domestica*)
- Black soldier fly (*Hermetia illucens*)

Extensive (peer) review.
Mandate

The Dutch assessment covers the main steps from production chain up to consumption including processing.

<table>
<thead>
<tr>
<th>Food</th>
<th>Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insect species</td>
<td>Insect species</td>
</tr>
<tr>
<td>Nutrient medium(^1)</td>
<td>Organic waste(^2)</td>
</tr>
<tr>
<td>Laying eggs</td>
<td>Laying eggs</td>
</tr>
<tr>
<td>Growing larvae</td>
<td>Growing larvae</td>
</tr>
<tr>
<td>Harvest by sieving</td>
<td>Harvest by sieving</td>
</tr>
<tr>
<td>Gut emptying</td>
<td>Gut emptying</td>
</tr>
<tr>
<td>Cleaning</td>
<td>Cleaning</td>
</tr>
<tr>
<td>Freezing</td>
<td>Freezing</td>
</tr>
</tbody>
</table>

\(^1\)Bran mixed with flour or ground chicken feed, supplemented with carrots, potatoes and water;
\(^2\)Regulation (EC) 1069/2009, animal by-products (former foodstuffs or VVM)
Production flowchart

Microbiological hazards

• Pathogenic microorganisms may be present in the production environment or in the insects’ feed – and thus could also be present in untreated larvae or insects.

• The packaging information indicates a shelf life of 52 weeks. However, there are no known studies of whether the product is safe throughout this 52-week period.
**Microbiological hazards**

- Small-scale studies have shown that the aerobic total viable count and the maximum permissible concentration of *Enterobacteriaceae* in fresh insects exceed the process hygiene criteria for the raw materials used in meat preparations (65% > 10^3 CFU/g).

<table>
<thead>
<tr>
<th>Product</th>
<th>Number</th>
<th>&lt;10^3</th>
<th>10^3-10^4</th>
<th>10^4-10^5</th>
<th>&gt;10^5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locust</td>
<td>17</td>
<td>59%</td>
<td>18%</td>
<td>24%</td>
<td>-</td>
</tr>
<tr>
<td>Lesser mealworm</td>
<td>17</td>
<td>24%</td>
<td>6%</td>
<td>41%</td>
<td>29%</td>
</tr>
<tr>
<td>Mealworm</td>
<td>18</td>
<td>11%</td>
<td>17%</td>
<td>28%</td>
<td>44%</td>
</tr>
<tr>
<td>Mealworm snack</td>
<td>3</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>35%</td>
<td>13%</td>
<td>29%</td>
<td>23%</td>
</tr>
</tbody>
</table>

NVWA, 2010
Microbiological hazards

- A ten-minute heat treatment reduced the aerobic total viable count ($< 10^6$ CFU/g) and concentration of *Enterobacteriaceae* ($< 10^3$ CFU/g) to values in compliance with the proposed process hygiene criteria.

Table 7. Average microbiota of whole, fresh and heat-treated mealworms (Klunder et al. 2012)

<table>
<thead>
<tr>
<th>Colony forming units (CFU/g)</th>
<th>Fresh</th>
<th>Cooked (10 min.)</th>
<th>Roasted (10 min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of aerobic bacteria</td>
<td>$5.0 \times 10^7$</td>
<td>$&lt;50$</td>
<td>$&lt;50$</td>
</tr>
<tr>
<td><em>Enterobacteriaceae</em></td>
<td>$6.3 \times 10^6$</td>
<td>$&lt;10$</td>
<td>$160$</td>
</tr>
<tr>
<td>Bacterial spores</td>
<td>130</td>
<td>$&lt;10$</td>
<td>40</td>
</tr>
</tbody>
</table>

Chemical hazards

• It is unclear exactly how much chitin (N-acetyl-D-glucosamine) insects reared contain, and whether there are any health risks associated with an intake of more than 2.7 grams of chitin per day. Depending on the percentage of chitin involved (estimated at 6%), the intake of a daily portion of 45 grams of freeze dried insects is not a cause for concern in terms of public health.

• Given the current production methods, these insects are unlikely to be exposed to toxic substances through their diet or through the surroundings in which they are reared.
Taxonomy
Crossreactivity

$sIgE$ from shrimp allergic patients react with mealworm proteins
Immunoreactivity

Reactive proteins were identified as tropomyosin and arginine kinase.

1 Soluble proteins (tris)
2 Dialysed (extract 1)
3 Difficult to solubilize proteins (urea)

Tropomyosin
Arginine kinase

Verhoeckx & van Broekhoven Food and Chemical Toxicology (2014)
Allergic hazards

- Mealworm proteins bind to IgE from shrimp allergic patients.
- Binding of mealworm proteins with IgE causes an immunological response in basophils.
- Reactivity with IgE from grass pollen, peanut, egg, milk or fish allergic patients was not observed.
- Possibility cannot be excluded that, after eating mealworms, sensitive individuals may experience sensitisation and allergic reactions.
Allergenicity testing

Allergy Risk assessment strategy for novel proteins

New protein (source)
- History of human exposure (work/food)
- Relationship: Taxonomy, Homology
- Identification proteins in source
- Information on usage: raw, matrix, processing

Research material: Extract(s), GMP

Research protocol, METC

Cross reactivity
- Sera known allergy with new protein
- Immuno-blot
- ELISA
- CAP/ISAC

Identification proteins

Functional Cross reactivity
- Sera known allergy with new protein

Basophil activation test

Skin prick test

Provocation

Cross reaction
- Sera new allergy with known allergen
  - In vitro
  - In vivo

New allergy
- Sera new allergy with new protein
  - In vitro
  - In vivo

Sensitising potency

History Sensitisation
- Screening (interview and/or serology)
  - Working population
  - Targeted people with symptoms

Identification reactive proteins in source (potential new allergens)

No history
- New TNO method (under development)
Research in progress

- Food challenge testing for mealworm in shrimp allergic patients (n=16) (in progress);
- Assessment of the sensitizing potency of mealworm among insect breeders (n=21) (in progress).
- Are there insects without tropomyosin and arginine kinase?

Knowns/unknowns:
- The possibility cannot be excluded that, after eating mealworms, sensitive individuals may experience sensitisation with allergic reactions (severity) comparable to shrimp proteins.
- There are no clinical records showing that shrimp allergic patients may experience sensitisation to house dust mites.
Conclusions

➢ Chemical, microbiological and parasitological risks of consuming insects can be sufficiently well controlled through the use of adequate production methods.

➢ Sensitive individuals may experience sensitisation and allergic reactions.

➢ The staff of insect rearing facilities may develop hypersensitivity or allergic reactions as a result of exposure to insects (or to insect body parts).

➢ If the expected intake of dried or freeze dried, whole insects exceeds 45 grams per day, the risk of chitin intake should be reassessed.
BON APPÉTIT

JP/NRC 01-11-2014