Antoine Hubert is president and co-founder of Ynsect, an innovative company focused on insect genetics, insect zootechnical studies, insect biochemistry and products characterization, process engineering and sustainable value assessment.

Hubert was previously senior scientist at Total and Altran, where he managed programs on sustainable development applied to bioresources, soil remediation, waste-to-energy and recycled resources.

In 2007, he launched the non-profit WORGAMIC, which deals with food sustainability, urban agriculture and organic waste recycling.
Potential of Alternative Protein Sources: Focus on Insect Meal

Antoine Hubert
President
Ynsect
The increase of population...

France consumption from 1950:
- meat x 2
- cereal / 3
- leguminous / 7
... leads to **great challenges for feedstock industries**

- **Non-sustainable feed raw material**
  - Importation security
  - Forest biodiversity
  - Oceans biodiversity
  - Soja meal
  - Fish meal

- **Feedstock**

- **Feedstock residues polluting environment**
  - Eutrophisation
  - Soil
  - Potability
An issue of nitrogen flows and stocks

- Indicators:
  - Industrial fixation
  - Electrochemical fixation

- Processes:
  - Biological fixation
  - Decomposing fungi & bacteria

- Nutrition cycle:
  - N\(_2\) → NO\(_x\) → N\(_{organic}\) → NH\(_4^+\) → NO\(_2^+\) → NO\(_3^-\)

- Contamination:
  - Air contamination
  - Soil / water contamination

- Biological processes:
  - Bactéries nitrifiantes
  - Bactéries dénitrifiantes

- Fixation methods:
  - Industrial fixation
  - Electrochemical fixation

- Decomposing fungi & bacteria:
  - Decompose organic nitrogen into inorganic forms

- Nitrogen flow and stock issue:
  - An issue of nitrogen flows and stocks
Which solutions to increase protein availabilities?

1) Consuming less resources

2) Optimizing available resources to decrease nitrogen spillage/wasting

3) Increasing protein production (fixation and assimilation of nitrogen)

4) Find new resources out of current cycle
Solutions goes through resources diversification

Insects

Algae

Krill
Insect for Feed markets
Insects are 1st worldwide biodiversity (except bacteria)

Selected model species

- Mammals
  - 5,600 species estimated
  - 5,501 (98%) species discovered

- Birds
  - 10,500
  - 10,064 (96%)

- Reptiles
  - 12,000
  - 9,547 (80%)

- Amphibians
  - 15,000
  - 6,771 (45%)

- Fish
  - 45,000
  - 32,400 (72%)

- Crustaceans
  - 150,000
  - 47,000 (31%)

- Mollusks
  - 200,000
  - 85,000 (43%)

- Arachnids
  - 600,000
  - 102,248 (17%)

Insects
- 5,000,000
- 1,000,000 (20%)

Sources: IUCN; Arthur D. Chapman, Australian Biodiversity Information Service
Insects do have all diets for all organic matter bioconversion

From 5 to 200 millions years of « research » on digestion / bioconversion process

Source: ANR DANAC - INRA LBE
A potential good market acceptance thanks to actual use in pet food & naturality argument

- Fly maggot
- Mealworms
- Crickets
- Fish baits
- Zoo animals
- Household pets

Insect & PAP => low acceptance in Europe
Positive regulatory framework for the use of insect meals for animal feed in Europe

Regulatory framework

UE 1069/2009 C3 – updated 294/2013
UE 999/2001 – updated 56/2013

* Processed Animal Protein
# Insect meal composition

**Exemple of Molitor PAP**

## Whole insect meal

<table>
<thead>
<tr>
<th>Composition</th>
<th>P1</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Dry matter</td>
<td>93.44</td>
<td>g / 100 g</td>
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<tr>
<td>Ash</td>
<td>3.16</td>
<td>g / 100 g</td>
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<tr>
<td>Lipid</td>
<td>28.02</td>
<td>g / 100 g</td>
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<tr>
<td>Proteins</td>
<td>50.70</td>
<td>g / 100 g</td>
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<tr>
<td>Total carbohydrate</td>
<td>11.56</td>
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</table>

Source: Ynsect 2013

## Defatted insect meal

<table>
<thead>
<tr>
<th>Composition</th>
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<tbody>
<tr>
<td>Dry matter</td>
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<tr>
<td>Ash</td>
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<tr>
<td>Lipid</td>
<td>19.64</td>
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<tr>
<td>Proteins</td>
<td>60.60</td>
<td>g / 100 g</td>
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<tr>
<td>Total carbohydrate</td>
<td>9.39</td>
<td>g / 100 g</td>
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</tbody>
</table>

Source: Ynsect 2013
Industrial aspects
Technical constraints for use as fish feed

Good nutritional profile especially **protein profile**
But **high content in chitin**
⇒ Reduce insect meal digestibility
⇒ Good digestibility till **30% incorporation** (Turbot)
When chitin separated ⇒ digestibility > 95%

Good nutritional profile especially **lipid profile**
But **high content in polysaccharides**
⇒ Reduce algae meal digestibility
⇒ Good digestibility till **40% incorporation** (Tilapia)
When polysaccharides separated ⇒ digestibility > 95%

100% fish meal substitution by **krill meal** in diet without growth modification (Cod & Rainbow Trout)
But **high fluoride content** (1 000-6 000 mg/kg) + UE directive limitation + **chitin content**
⇒ **5 to 10 % incorporation** limit / palatability properties

Source: Médale & Koushik, 2009
Current world production & prices and potential in 2020

<table>
<thead>
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<th>COMMODITIES</th>
<th>2013</th>
<th>2020</th>
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<td>3000 T (30 000 T)</td>
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<td>3000 – 6000 €/T</td>
<td>1000 – 2500 €/T</td>
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<tr>
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<td>15 000 000 T</td>
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<td>500 – 9000 €/T</td>
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<td>10 000 T</td>
<td>50 000 – 100 000 T</td>
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<tr>
<td></td>
<td>3000 – 20 000 €/T</td>
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<tr>
<td></td>
<td>300 000 T</td>
<td>500 000 – 1 000 000 T</td>
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<tr>
<td></td>
<td>1000 – 10 000 €/T</td>
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</table>

<table>
<thead>
<tr>
<th>MOLECULES (PIGMENTS, DHA, EPA)</th>
<th>2013</th>
<th>2020</th>
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Conclusions
Conclusions

Proteins / Energy, same issues!

Protein needs very important & limited traditional resources
⇒ Protein transition

No miracle solution!
⇒ Smart feed grid
⇒ Protein mix

Still a long journey for sustainable and affordable protein sources
⇒ from molecules / niche market to commodities / mass market
Insect, microalgae and krill represent serious alternative feed sources

- Already used as complement (5-10%) for some fish species
- Source of oil too (algae)
- But
  - Prices still too high compared to fish feed
  - Quotas issues for krill
  - Farming challenge for macro-algae
  - Competition with food
  - Anti-nutritional factors issues (polysaccharides, fluoride…)

⇒ For bigger incorporation, need for cost efficient separation technologies
⇒ Decreasing meal prices with byproducts valorization + capacities scale-up
⇒ From Agriculture & Fisheries to Biorefinery
A progressive scale-up & industrialization backed up with powerful R&D is the key to success in this journey.

Industry development goes through cooperation: Producers start to get united for regulation lobbying, communication and R&D joint efforts.
Insect Biotech Pioneer

Providing innovative products & services from insects

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