ENVIRONMENTAL ASSESSMENT OF INNOVATIVE PLANT-BASED PROTEIN-RICH FOOD PRODUCTS TOWARDS A MORE SUSTAINABLE FOOD CONSUMPTION

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Institut für Energie- und Umweltforschung Heidelberg (Germany)
food accounts for 30% of the EU GHG emissions

animal products represent > 50% of the total EU water footprint

will create innovative, high quality, protein-rich food crops and products, to sustain human health, the environment, and biodiversity

30% of the human-induced biodiversity loss is related to livestock production

agriculture accounts for 94% of total EU NH3 emissions
PROTEIN2FOOD: project steps

WP 1: AGRICULTURE
- Chick Pea
- Lentil
- Faba Bean
- White Lupin
- Andean Lupin
- Buckwheat
- Quinoa
- Amaranth

WP 2: PROCESSING
- Dry Fractionation
- Wet Fractionation
- Flakes
- Defatted Flakes
- Defatted Flours
- Endosperm Flours
- Wholemeal Flours
- Isolates
- Concentrates
- Flours

WP 3: PRODUCT FORMULATION / PROTOTYPES
- Meat Substitutes
- Spread-like
- Meat-like
- Bakery Products
- Bread
- Biscuits
- Pasta
- Smoothy
- Milk-like
- Powders

WP 4: MARKET ANALYSIS

WP 5: Field Tests: IT -- DK -- NL -- RO

WP 6: Dissemination

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 635727.

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WP 5: SUSTAINABILITY ASSESSMENT

WP 6: Dissemination

Farm2Fork LCA models

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PROTEIN2FOOD: project steps

**WP 1: Agriculture**
- Field Tests: IT -- DK -- NL -- RO
  - White Lupin
  - Quinoa

**WP 2: Processing**
- Dry Fractionation
- Wet Fractionation
  - Wholemeal Flours
  - Isolates

**WP 3: Product Formulation / Prototypes**
- Meat Substitutes
- Meat-like

**WP 4: Market Analysis**

**WP 5: SUSTAINABILITY ASSESSMENT**

**WP 6: Dissemination**

Farm2Fork LCA models
LCA of vegetable meat substitute

Nutrient flow from air (Nitrogen Fixation)

Ressources:
- white lupine
- quinoa

Handling of Multi-output processes
- Processing Crops
- Processing to Food Product
- Vegetable meat substitute

Emissions:
- to Air (e.g. CO₂, CH₄)
- to Water (e.g. NO₃⁻)

Functional unit

System boundary

N-Cycle of legumes

Nutrient flow from air (Nitrogen Fixation)

Ressources:
- e.g. Water
- e.g. Area

Emissions:
- to Air (e.g. CO₂, CH₄)
- to Water (e.g. NO₃⁻)

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LCA of vegetable meat substitute

System boundary

Cultivation
- white lupine
- quinoa

Processing Crops
- lupine protein isolate
- quinoa flour
- water

Processing to Food Product

Vegetable meat substitute

N-Cycle of legumes

Nutrient flow from air (Nitrogen Fixation)

Ressources:
- e.g. Water
- e.g. Area

Emissions:
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- to Water (e.g. NO₃⁻)

LCIA category results

- Climate change
- Ozone depletion
- Particulate matter
- Photochemical ozone formation
- Acidification
- Eutrophication, aquatic
- Eutrophication, terrestrial

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How to implement N-related advantages of legumes?

- N₂-fixation from atmosphere
  178 kg N/ha (lit.: Sulas 2016)

- Indirect N₂O emission to air

- Nitrate (NO₃⁻) leaching to (ground) water

- Harvest

- Net Remaining N in soil pool
  33 kg N/ha (lit.: FIBL)

- Removal from field with lupin seeds

- Credit given: production of 33 kg N/ha Mineral N fertilizer
Handling of multi-output processes

Nutrient flow from air (Nitrogen Fixation)

Ressources: e.g. Water e.g. Area

Emissions: to Air (e.g. $\text{CO}_2$, $\text{CH}_4$) to Water (e.g. $\text{NO}_3^-$)

Handling of Multi-output processes

System boundary

Cultivation

white lupine
quinoa

Processing Crops

lupine protein isolate
quinoaflour
water

Processing to Food Product

Vegetable meat substitute

N-Cycle of legumes

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Example quinoa wet processing

drying electricity
water (washing)
water (extraction)

Quinoa seed → Quinoa wet processing → Saponin

Quinoa wet processing → Fibre/protein 1

Quinoa wet processing → Isolate 2

Quinoa wet processing → Isolate 3

Quinoa wet processing → Starch fraction

Fibre/protein 1 → Classified as “desired product”

Isolate 2 → Classified as “product 2”

Isolate 3 → Classified as “product 3”

Starch fraction → Classified as “by-product”

Value = 0 – 100 % of the desired product
Handling of by-products is important when looking for innovative alternatives.

<table>
<thead>
<tr>
<th>Usage of all ingredients</th>
<th>100%</th>
<th>75%</th>
<th>50%</th>
<th>25%</th>
<th>0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing</td>
<td>3,5</td>
<td>1,5</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>+ Neutralization and Drying</td>
<td>2,5</td>
<td>1,5</td>
<td>1</td>
<td>0,5</td>
<td>0</td>
</tr>
<tr>
<td>+ solvent-based Oil Extraction</td>
<td>0,5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Crop Processing</td>
<td>0,5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cultivation</td>
<td>0,5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Credit: mineral N-fertiliser</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Innovative product: vegetable meat substitute (30 g of protein)
Functional unit

Nutrient flow from air (Nitrogen Fixation)

Ressources:
- e.g. Water
- e.g. Area

Emissions:
- to Air (e.g. CO₂, CH₄)
- to Water (e.g. NO₃⁻)

Handling of Multi-output processes

System boundary

Cultivation
- white lupine
- quinoa

Processing Crops
- lupine protein isolate
- quinoa flour
- water

Processing to Food Product

Vegetable meat substitute

Functional unit results
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### Functional unit: comparison with chicken breast

<table>
<thead>
<tr>
<th>Possible Functional Units</th>
<th>Innovative meat substitute</th>
<th>Traditional: Chicken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on Weight (per 100 g Product)</td>
<td>100 g</td>
<td>100 g</td>
</tr>
</tbody>
</table>

* TPV: textured protein-rich vegetables  
** based on the recommendation of the DGE (0,8 g protein per kg body weight) for a 70 kg weighting person  
*** approximately the amount of calories to achieve the daily protein requirements
Protein content is the appropriate functional unit when assessing protein supply.
To sum up ...

• Cultivation of legumes reduces use of mineral N-fertilizer

• Environment would benefit much more from high-quality usage of all grain ingredients

• Protein content is the appropriate functional unit for assessment of protein-rich food