The future of proteins in industrial food production
what will be the part of lupin in this competition?

Market opportunities and challenges
Challenges of the future

Population growth

Climate change

Much more people have to be fed on less arable land!
## Current situation: Top 10. energy containing products in worldwide harvests (FAO 2016)

<table>
<thead>
<tr>
<th>Product**</th>
<th>Amount t/a</th>
<th>Digestable Energy kcal/a</th>
<th>Energy per person kcal/d*)</th>
<th>Protein per person g/d*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Maize</td>
<td>1,060,107,470</td>
<td>3.7*10^15</td>
<td>1355</td>
<td>34</td>
</tr>
<tr>
<td>2. Rice</td>
<td>740,961,445</td>
<td>2.6*10^15</td>
<td>947</td>
<td>18</td>
</tr>
<tr>
<td>3. Wheat</td>
<td>749,460,077</td>
<td>2.5*10^15</td>
<td>925</td>
<td>33</td>
</tr>
<tr>
<td>4. Soybeans</td>
<td>334,894,085</td>
<td>1.5*10^15</td>
<td>546</td>
<td>44</td>
</tr>
<tr>
<td>5. Sugar cane</td>
<td>1,890,661,751</td>
<td>7.6*10^14</td>
<td>276</td>
<td>-</td>
</tr>
<tr>
<td>6. Palm oil</td>
<td>63,931,710</td>
<td>5.8*10^14</td>
<td>210</td>
<td>-</td>
</tr>
<tr>
<td>7. Barley</td>
<td>141,277,993</td>
<td>4.9*10^14</td>
<td>181</td>
<td>6</td>
</tr>
<tr>
<td>8. Rapeseed</td>
<td>68,855,446</td>
<td>3.4*10^14</td>
<td>126</td>
<td>6</td>
</tr>
<tr>
<td>9. Potatoes</td>
<td>376,826,967</td>
<td>2.9*10^14</td>
<td>106</td>
<td>3</td>
</tr>
<tr>
<td>10. Sorghum</td>
<td>63,930,558</td>
<td>2.2*10^14</td>
<td>82</td>
<td>2</td>
</tr>
</tbody>
</table>

TOTAL (141 Products): 1.47*10^{16} kcal/a: ~ 5,460 kcal/human and day

*) based on 7.5 bn people

Source: **) FAO-STAT, Data from 2016
Already now:
food for more than 17 billion (vegan living) people
But: shortage in resources and instable and high food prices

- Food- and agricultural waste
  - >100 Mio. Tons in the EU**)
  - 33% worldwide along all value added chains**)

- Production of animals
  (Ressource-Factor~1:5)
  - Meat*: 334 Mio. t/a
  - Milk*: 827 Mio. t/a
  - Eggs*: 87 Mio. t/a
  - Fish from Aquaculture*: 80 Mio. t/a

- Use of agricultural goods for energy production

Sources:
  *) FAO-STAT, Data from 2017 / for Fish from 2016
  **) European Commission, 2014
Worldwide use of agricultural raw materials

- **Food**: 32%
- **Animal feed**: 60%
- **Biomass for technical use**: 4%
- **Biomass for energy use**: 4%

Source: (UBA 2014, Thrän 2015)
Our approach: Integrated use of plant seeds...

Vegetable raw materials
Protein- and Oilseeds

Production
Purifying

High valuable food/feed ingredients
Technical raw materials
Clean bio-energy

Lupin, sunflower, soy, rapeseed, pea, linseed, cereals and by-products from food industry

Proteins, fibers, lipids, secondary plant metabolites, residues for energy use
… and: development of tasty foods from plant proteins

Substitution of animal proteins (milk, egg, meat)

Impact in the food market can only be achieved through high consumer acceptance

-> High requirements in functional and sensorial properties!
“healthy tasting vegan food” was yesterday
- indulgence is the new vegan approach
Ongoing discussion about alternative protein sources

- in-vitro-meat
- Insects
- Microalgae
- Seaweeds
- New Ingredients from 
  Lupins, other Pulses, Oilseeds and Cereals
So what’s with lupin?
Example in Germany: Sweet Lupins (*L. angustifolius*)

- Valuable legume with a high content of functional protein fractions
- Produced in Germany – no long transport distances
- No GMO varieties
- Increase of soil quality

But:
Lupin is on the allergen list in the EU and Lupin meals are astringent, have a bitter taste and a beany and green flavor.
Scientific and technical approach for lupin ingredients

- Selection of suitable Lupin-species and varieties concerning functionality and sensorial properties
- Identification of relevant flavor- and taste-active components
- Elucidation of the generation of off-flavors
- Development of a strategy for selective separation of unwanted flavors and components
- Realization in technical scale
Identification of flavors

Aroma-Extract

Seeds

Flakes or meal
### Evaluation and extraction of flavors

<table>
<thead>
<tr>
<th>No.</th>
<th>Geruchsstoff</th>
<th>Beschreibendes Geruchattribut</th>
<th>FD-Faktor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-Octen-3-one</td>
<td>nach Pilz</td>
<td>32</td>
</tr>
<tr>
<td>2</td>
<td>2-Acetyl-1-pyrroline</td>
<td>nach Popcorn</td>
<td>32</td>
</tr>
<tr>
<td>3</td>
<td>(Z)-1,5-Octadien-3-one</td>
<td>nach Geranien, metallisch</td>
<td>128</td>
</tr>
<tr>
<td>4</td>
<td>3-Isopropyl-2-methoxypyrazin</td>
<td>nach Erbse, nach grüner Paprika</td>
<td>256</td>
</tr>
<tr>
<td>5</td>
<td>Essigsäure</td>
<td>nach Essig</td>
<td>32</td>
</tr>
<tr>
<td>6</td>
<td>Unbekannt</td>
<td>nach Erde</td>
<td>32</td>
</tr>
<tr>
<td>7</td>
<td>(Z)-2-Nonenal</td>
<td>nach Karton</td>
<td>32</td>
</tr>
<tr>
<td>8</td>
<td>3-Isobutyl-2-methoxypyrazin</td>
<td>nach grüner Paprika, nach Erde</td>
<td>32</td>
</tr>
<tr>
<td>9</td>
<td>(E)-2-Nonenal</td>
<td>nach Karton, fettig, grün</td>
<td>256</td>
</tr>
<tr>
<td>10</td>
<td>(E,Z)-2,6-Nonadienal</td>
<td>nach Gurke, grün</td>
<td>256</td>
</tr>
<tr>
<td>11</td>
<td>2-Methylbuttersäure/3-Methylbuttersäure</td>
<td>schweißig, fruchtig, nach Käse</td>
<td>2048</td>
</tr>
<tr>
<td>12</td>
<td>Unbekannt</td>
<td>nach Kunststoff</td>
<td>256</td>
</tr>
<tr>
<td>13</td>
<td>Pentansäure</td>
<td>nach Käse, schweißig, fruchtig</td>
<td>32</td>
</tr>
<tr>
<td>14</td>
<td>(E,E,Z)-2,4,6-Nonatrienal</td>
<td>nussig, nach Haferflocken</td>
<td>256</td>
</tr>
<tr>
<td>15</td>
<td>γ-Octalacton</td>
<td>nach Kokos, süßlich</td>
<td>64</td>
</tr>
<tr>
<td>16</td>
<td>4-(2,6,6-trimethyl-1-cyclohexenyl)-3-buten-2-on (β-Ionon)</td>
<td>nach Veilchen, blumig</td>
<td>512</td>
</tr>
<tr>
<td>17</td>
<td>3-Hydroxy-2-methyl-pyran-4-on (Maltol)</td>
<td>nach Karamell</td>
<td>256</td>
</tr>
<tr>
<td>18</td>
<td>trans-4,5-Epoxy-(E)-2-decenal</td>
<td>Metallisch</td>
<td>1024</td>
</tr>
<tr>
<td>19</td>
<td>γ-Decalacton</td>
<td>nach Kokos, süßlich</td>
<td>256</td>
</tr>
<tr>
<td>20</td>
<td>Unbekannt</td>
<td>muffig, feucht</td>
<td>256</td>
</tr>
<tr>
<td>21</td>
<td>γ-Decalacton</td>
<td>nach Pfirsich, fruchtig</td>
<td>32</td>
</tr>
<tr>
<td>22</td>
<td>Unbekannt</td>
<td>phenolisch, würzig</td>
<td>64</td>
</tr>
<tr>
<td>23</td>
<td>3-Hydroxy-4,5-dimethyl-2(5H)-furanon (sotolon)</td>
<td>würzig, nach Suppe</td>
<td>256</td>
</tr>
<tr>
<td>24</td>
<td>Vanillin</td>
<td>nach Vanille, süßlich</td>
<td>1024</td>
</tr>
<tr>
<td>25</td>
<td>Phenylessigsäure</td>
<td>nach Bienenwachs, nach Honig</td>
<td>256</td>
</tr>
</tbody>
</table>

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**Beliebtheit des Proteins nach Lösemittelbehandlung**

![Beliebtheit des Proteins](image_url)
Technical Realization

Seeds → De-hulling → Breaking the cells → Solvent-Treatment → Aqueous Extraction

Hulls

Oil

Protein Isolate

Off-Flavors
Stations of Implementation

- 1989: first scientific work with lupins
- 2009: several trials of exploitation without success
- 2010: Founding of Prolupin GmbH out of Fraunhofer IVV
- 2011: Market launch of first product (lupin-ice-cream)
- 2013: Installation of industrial production in Grimmen
- 2014: Development of new products such as milk, yoghurt, pudding, cheese, mayonnaise, dressings
- 2015: Start of marketing the new products via retail
Various applications for lupin protein

the best protein evaluated by industry: great taste, smell and functionality
Lupin-Products – from our lab into the market

But: the protein isolate is too expensive for reaching a mass market today
What to do for a positive future of lupins as ingredients?

- lower the costs of the process: higher protein yield, lower de-oiling costs, larger plant throughputs
- using all by-products (proteins, fibers, oil, SPM)
- look for new applications with high profit range or higher throughputs
- development of new cheaper protein ingredients, by
  - optimization of flavor and taste in meals and concentrates
  - extrusion or ethanol treatment of meals
- work on the allergen image
Lupin-Research at Fraunhofer IVV: functional ingredients from by-products such as nutritional fibers

- Research in optimization of nutritional added value of fibers and other fractions

- For bile acids relevant binding mechanisms of all fractions are under investigation

- Fibers show mechanisms to reduce mass transfer by effects of their viscosity

- Phenolic components seem to be responsible for binding effects of secondary bile acids

- Potential as a healthy ingredient
Lupin-Research at Fraunhofer: new applications

- Further optimization of food products
  - Choice of suitable starter cultures e.g. *Lactobacillus plantarum* and *Pediococcus pentosaceus*
  - Choice of suitable lupin species: species with high conglutin *α* content like *Lupinus angustifolius* seem beneficial for yogurt
  - Processing: intense heat treatment of lupin milk is beneficial regarding the texture of lupin yogurts
  - Further fermented products such as cheese and others
Lupin-Research at Fraunhofer IVV: Allergenicity

- Intensive research in modification of protein isolates
  - Identification of process conditions leading to partly destruction of protein structure
  - Keeping in mind not to reduce the sensory properties of lupin protein preparations and trying to optimize flavor and taste
  - Defining process conditions for increasing the functional properties such as foaming and emulsifying for tailored applications
  - Testing the allergenicity reduction and creating evidence for declaration of “allergen reduced lupin proteins”
Lupin-research-summary: what might be the future?

- Realize a high valuable use of all by-products such as fibers, hulls, oligosaccharides, oil and all protein fractions -> reducing the price

- Using lupin protein in blended food protein combinations for optimized functionality, nutritional quality, flavor and taste

- For this approach: creating more simple and functional ingredients by integrated processes from kernels and de-oiled meal -> reducing the costs

- Further reduction of allergenicity to change the allergen declaration and image

- Testing more new species and varieties for new future markets -> collaboration
The future is healthy, the future is tasty...

The future is Lupin!
Thank you very much for your attention!

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Deputy Director

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