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

Market opportunities and challenges

XV International Lupin Conference

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Challenges of the future

Population growth

Climate change

Much more people have to be fed on less arable land!

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Current situation: Top 10. energy containing products in worldwide harvests (FAO 2016)

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

*) based on 7.5 bn people

4,754 $\frac{kcal}{person\ day}$

146 $\frac{g\ Protein}{person\ day}$

Source: **) FAO-STAT, Data from 2016

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

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Already now:
food for more than 17 billion (vegan living) people

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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

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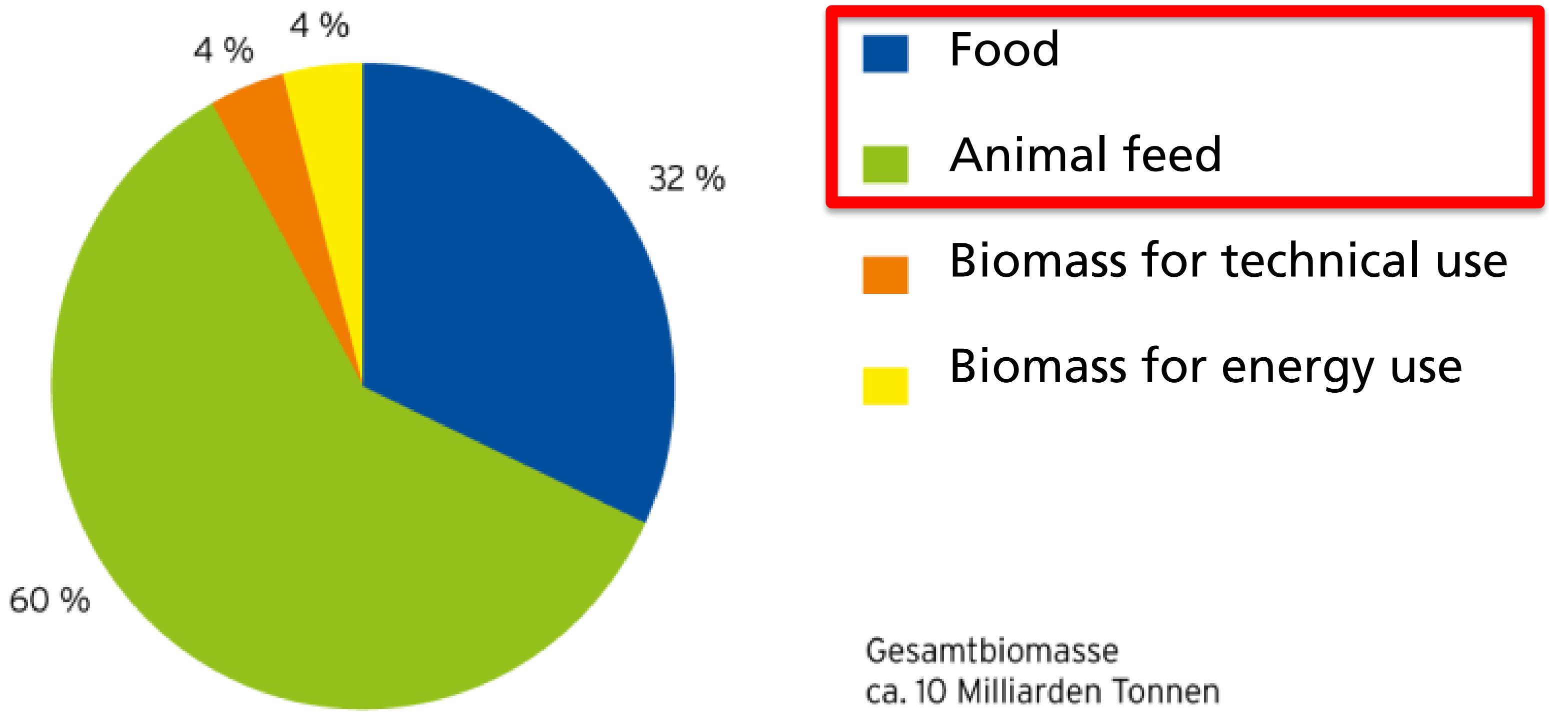
Worldwide use of agricultural raw materials



Source: (UBA 2014, Thrän 2015)

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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

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… and: development of tasty foods from plant proteins

Substitution of animal proteins (milk, egg, meat)

Mayonnaise
without egg

Vegan Drink
without Casein

„vegan sausages “
and
„vegan meat“

Impact in the food market can only be achieved through
high consumer acceptance
-> High requirements in functional and sensorial properties!

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"healthy tasting vegan food" was yesterday

- indulgence is the new vegan approach

IMPOSSIBLE™

Wheat
Potato
Soy

Pea

Lupin: Lupinus angustifolius

Pea
Oat

amidori

PROLupin

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Ongoing discussion about alternative protein sources

- in-vitro-meat
- Insects
- Microalgae
- Seaweeds
- New Ingredients from
  Lupins, other Pulses, Oilseeds and Cereals

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So what's with lupin?

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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

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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

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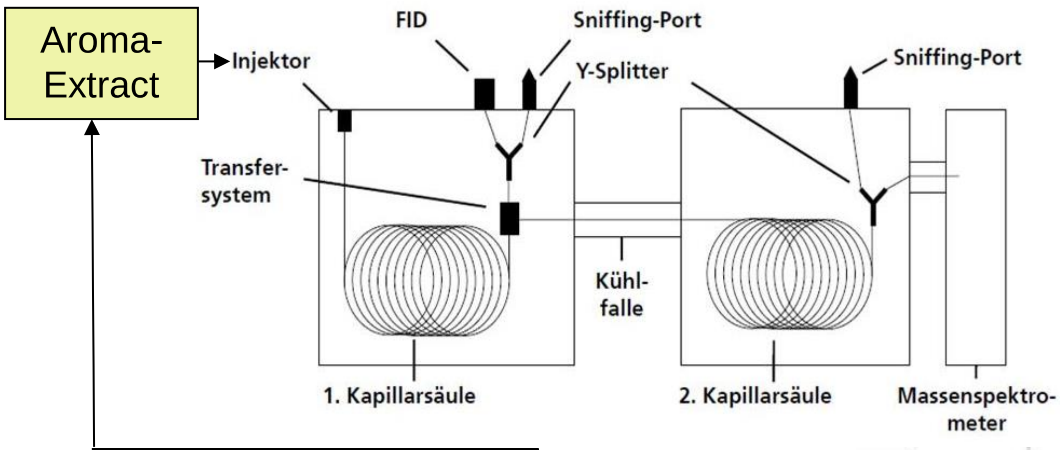
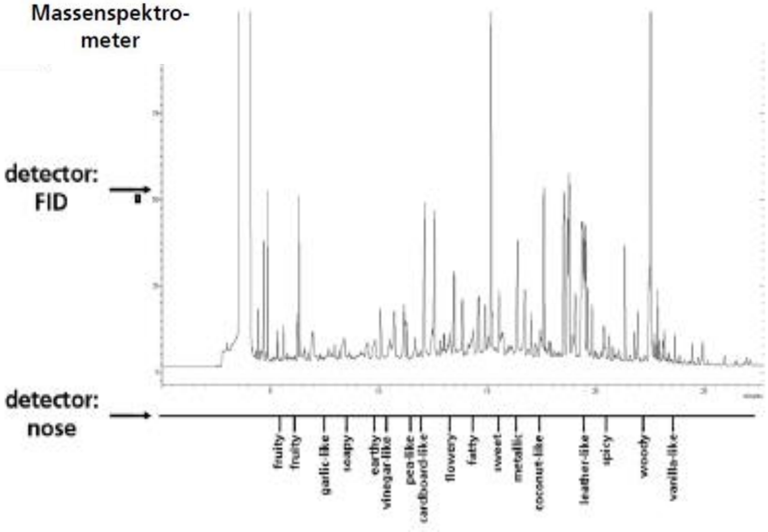
Identification of flavors



Seeds

Flakes or meal



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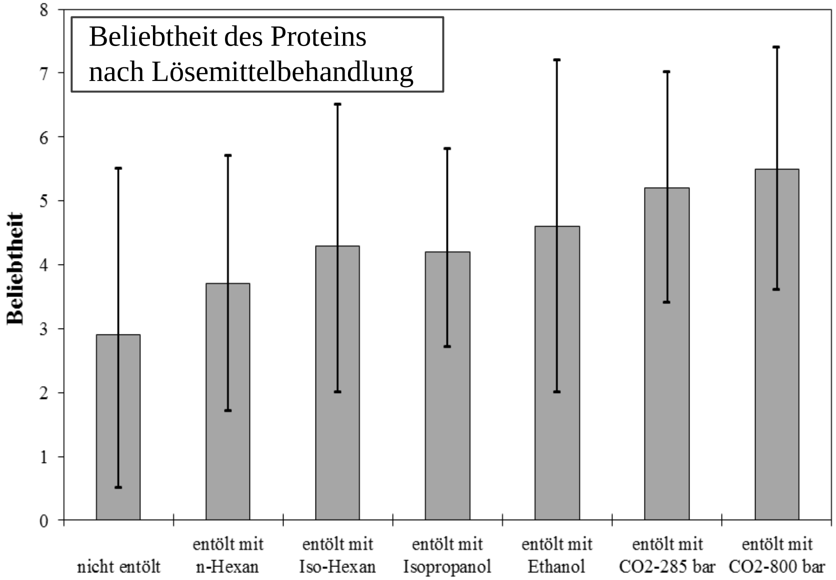
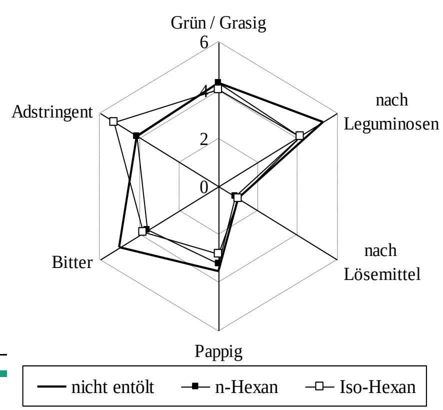
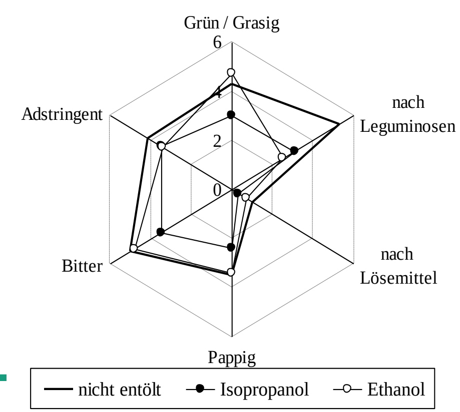
Evaluation and extraction of flavors

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







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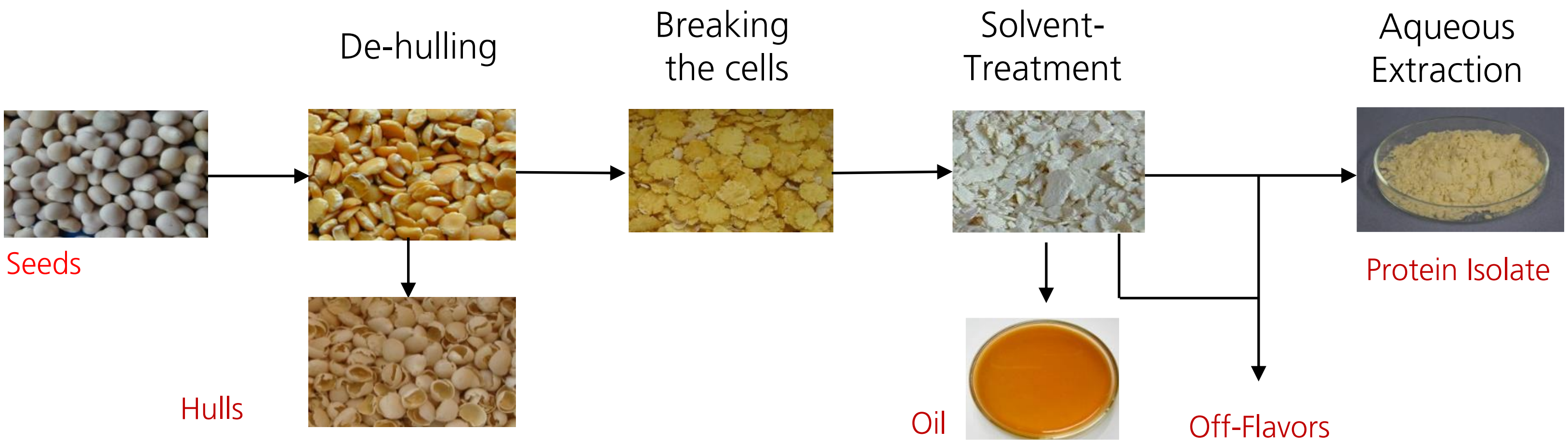
Technical Realization



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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

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Various applications for lupin protein

Vegan Milk

Vegan Pudding

the best protein evaluated by industry: great taste, smell and functionality

Ice Cream

Vegan Mayonnaise

Dips / Dressings

Spreads

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Lupin-Products – from our lab into the market

But: the protein isolate is too expensive for reaching a mass market today

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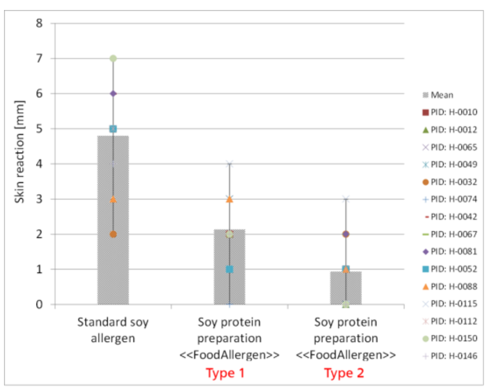
What to do for a positive future of lupins as ingredients?

- 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



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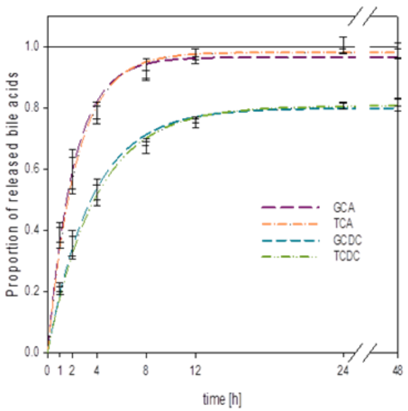
Lupin-Research at Fraunhofer IVV: functional ingredients from by-products such as nutritional fibers



- 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

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Lupin-Research at Fraunhofer: new applications

L. angustifolius

L. albus

L. mutabilis

- 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

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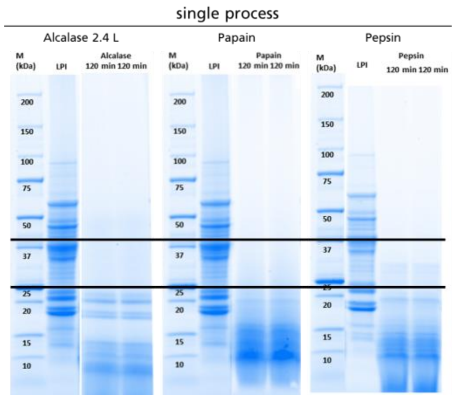
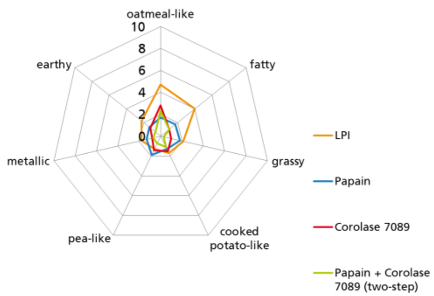
Lupin-Research at Fraunhofer IVV: Allergenicity





- 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**"

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Lupin-research-summary: what might be the future?

new.food.systems

FOOD
ALLERGEN

Food
Ingredients

- 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**

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The future is healthy, the future is tasty…

The future is Lupin !

Thank you very much for your attention!

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