The protein challenge: Value creation in the protein ingredients market

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World challenge for proteins

Growing demand in protein
- World population expansion and ageing
- More people willing to eat animal protein in developing countries
- Protein ingredient market price is raising (x 3 during the last 15 years)

Durable agriculture
- Compromise between yield and entrants usage
- Land sanitary evolution

Multiple potential sources
- Seeds
- Roots
- Leaves
- Coproducts
- Algae
- Microorganisms
- Insects
- ....

Used as is or after processing
Agricultural resources usages


- Usages dominated by feed
- 50% of the world population is using less than 25 g of animal proteins/day
- 18% of the world population is using more than 60 g of animal proteins per day

Allocation of biomass to production target (main product). Respective amounts include raw materials and by-products, even if their use fall into a different category.
High animal protein diets are only possible in rich countries
European Challenges

World Protein Exchanges

Plant protein production in the world (Fodder excl)
Unit = million tons of proteins

Plant protein usage in the world (Fodder excl)
Unit = million tons of proteins

Europe has favorable soils & pedoclimatic conditions
European challenges

Europe is importing 60% of its protein needs
- Mainly from North & South America
- From soy (seed or meal)

France is importing 40% of its protein needs
- Mainly from North & South America
- The gap is linked to the rape seed cake available after biodiesel production.

Europe is consuming less and less pulses, in France
- 7.4 kg/capita/year beginning of the 20th Century
- 1.7 kg/capita/year now
- 50% are imported

Environmental impact
- Actual protein usage cycles are not sustainable
  - Symbiotic N drop from 100% after World War II down to less than 5%
- In Europe
  - 11.2 Million tons of N are coming from fertilizers
  - 7.1 Million tons are coming from animal farming
  - 5.8 Million tons are coming from “green fertilizers”
  - ONLY 1 Million tons is coming from symbiotic fixing!
European key challenges

- **Rebalance plant vs animal protein in food**
  - In Europe the protein diet is including 65% of animal protein

  ![Conversion yield graph](chart.png)

  ![World growing demand in Proteins](chart2.png)

- With a convention efficiency between 10 to 40% it is key to bypass as much as we can the animal conversion
- Develop new crop rotations
  - Better answer Market & Societal demand for more plant based protein
How do we utilize proteins?

World proteins balance: from 10 billion tons of agro material

56% from soy, 43% from wheat and less than 1% for pea, rice, potatoes, rape seeds, faba beans, lupine, sunflower, algae's, ….

Average conversion ratio = 4.9

- Protein for food: 115 Mt/y
- Animal protein: 89 Mt/y
- Protein for feed: 440 Mt/y
- Protein agro production: 555 Mt/y

Only 2.3 Mt/y are proteins ingredients.

Animal proteins = 89 Mt/y + 28 Mt/y from fish

56% from soy, 43% from wheat and less than 1% for pea, rice, potatoes, rape seeds, faba beans, lupine, sunflower, algae's, ….
Seed diversity

Shape

Composition

Proteins
Starch
Lipids
Ash
Sugars
Other

Raw materials are diverse in shape, composition, texture...

Antinutritional factors are often present (α-galactosides, Phytic acid, Polyphenols, Tannins, Chlorogenic acid, Phytooestrogens, Saponins, Alkaloids, Cyanogénic Heterosides, ...)
Protein extraction strategies

Analysis

Raw materials
- Dehulling
- Fat removal
- Milling

Flour / meal / cake

Concentrate
- Dry fractionation

Concentrate or isolate
- Wet fractionation

[Diagram showing the process flow from raw materials to concentrate and concentrate or isolate through different fractionation methods.]
Dry processes – example of pea

Dry fractionation processes use the structural heterogeneities of the materials to produce specialized products → plant deconstruction.
Transformation process

Harvesting / storage

Dehulling

Fractionation

Cleaning Preparation

Milling

Functionality?

Batches?

Yields?

Protein enrichment?

Starch or fiber enrichment?
Extraction of lipids and micro-constituents using solvents

- Hexane extraction → remove lipids
- Alcohol extraction → phenolics and saponins
- Microwave & ultrasound assisted extraction of oil
- CO$_2$ Supercritical extraction and subcritical Water extraction
- Alternative green solvents
- Alternative ionic liquids
- Physical separation (tricanter, skimming separator…)
- …
Wet fractionation
Solubilisation step

Faba Flour
Maximum of solubility: pH 9 - 10
Minimum of solubility: pH 4

Pin mill powder
Evaluation of the protein solubilizing at pH 9.5
Protein solubility vs. flour’s PSD
Compromise between energetic cost and protein extraction yield
For next step we selected a powder d90 = 166 µm

Graph:
- Protein solubility (%) vs. pH
- Protein solubility (%) vs. Larger particle size d90 (Log scale µm)

Maximum for a d90<300 µm

Yield

Graph:
- Protein solubility (%) vs. pH
- Protein solubility (%) vs. Larger particle size d90 (Log scale µm)
4 complementary ways to characterize protein

Nutritional  Functional

Organoleptic  Marketing
Nutritional properties

Essential AA balance

Unbalanced diet leading to AA oxidation

Well balanced diet leading to an optimal protein anabolism

Protein digestion speed

Protein digestibility: PDCAAS

Leucine is known to stimulate protein anabolism

Arginine is known to reduce blood pressure

AA having messenger function

Leucine is known to stimulate protein anabolism

mg Leu / g protein

Arginine is known to reduce blood pressure

mg Arg / g protein
Proteins functional properties

**FUNCTIONAL ATTRIBUTES**

**WATER & OIL HOLDING CAPACITIES**

![W&O holding capacities chart]

**FOAMABILITY**

- Foamscan
- Mousses, desserts

**GELLING**

- Texture analyser, rheometer
- Gellies, meat replacers

**INSTANT PROPERTIES**

- Wettability test
- Instant drinks

**EMULSIFICATION**

- Mastersizer 3000
- Dairy alternatives, sauces

**SOLUBILITY**

- High protein drinks

**FUNCTIONALITY SCORE**

- Foamability
- Dispersibility
- Gelling
- Solubility at pH7
- Emulsification

- Reference
- Sample 1
- Sample 2

- Comparison of protein sources
- Process optimization
- Scoring and benchmarking
- Animal proteins replacement
Organoleptic properties

• Plant proteins
  – Often associated with off notes
    • Astringency
    • Bitterness
    • Beany, hay, cardboard aroma

– 5 strategies to deal with off-notes
  1. Selecting favorable raw material (variety selection, storage conditions...)
  2. Prevent by processing (dehulling, enzymes deactivation, microbio control ...)
  3. Eliminate by post processing (flash under vacuum,...)
  4. Masking
  5. Formulate

– What is perceived is most of the time a combination of aroma and taste.
# Marketing

<table>
<thead>
<tr>
<th>Items for communication</th>
<th>raw material</th>
<th>process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Allergens (8 in USA, 14 in Europe, 27 in Japan...)</td>
<td>✅</td>
<td>✅</td>
</tr>
<tr>
<td>Anti nutritional factors</td>
<td>✅</td>
<td>✅</td>
</tr>
<tr>
<td>Bio activities (more than 30 linked to peptides)</td>
<td>✅</td>
<td>✅</td>
</tr>
<tr>
<td>Clean label</td>
<td>✅</td>
<td>✅</td>
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<tr>
<td>GMO free</td>
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<tr>
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<tr>
<td>Plant origin</td>
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<td>✅</td>
</tr>
<tr>
<td>Protein purity</td>
<td>✅</td>
<td>✅</td>
</tr>
</tbody>
</table>
Market selection

Properties

- Bioactive
- Functional
- Soluble
- Insoluble

Proteins concentration %

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

Eggs, Gelatin NaCas

Properties

- wheat albumines & globulines
- corn steep liquor
- corn gluten
- vital wheat gluten
- soluble wheat gluten
- functional wheat gluten
- SPC
- whey protein isolate
- whey protein concentrate
- milk isolate

Increasing value
Pick the right scale

- It is key to know which market is targeted in order to define the size of the project.
Successful industrial protein ingredient project

Brilliant brains

Smart ideas

Strong market understanding

Regulatory expertise

Robust hypothesis
IMPROVE is a **protein innovation center**, located in France 1 hour north of Paris.

**Private – public partnerships** between
- **industrials** from the cereals, oilseed and pulses processing sectors
- **Academics** like Amiens University or INRA (French Institute of Agronomy)
- **Financial investors** including various banks and the French government

IMPROVE **started in 2014**, it can offer **22 brains** and **5,5 Million € equipment** to support innovation in the alternative protein world.

IMPROVE can carry out
- **dry or wet processing at pilot scale** on a wide range of raw materials (seeds, roots, leaves, by-products, microorganisms biomass, algae, insects...)
- **Labs characterization** (composition, in vitro digestibility, functional properties...)
- **Intellectual support**: literature review, brainstorming session, plant audit, market survey, consulting...
Get the most out of your Protein R&D budget!