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INTERNATIONAL CONFERENCE ON SUSTAINABLE FOODS

Achieving the Sustainable Development Goals

July 24 25 2024

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ADVANCING THE UTILIZATION OF PLANT-PROTEIN-RICH INGREDIENTS FOR A SUSTAINABLE FOOD SUPPLY

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INNOGRAIN Lab

PROBLEM: NECESSARY SHIFT IN THE DIET

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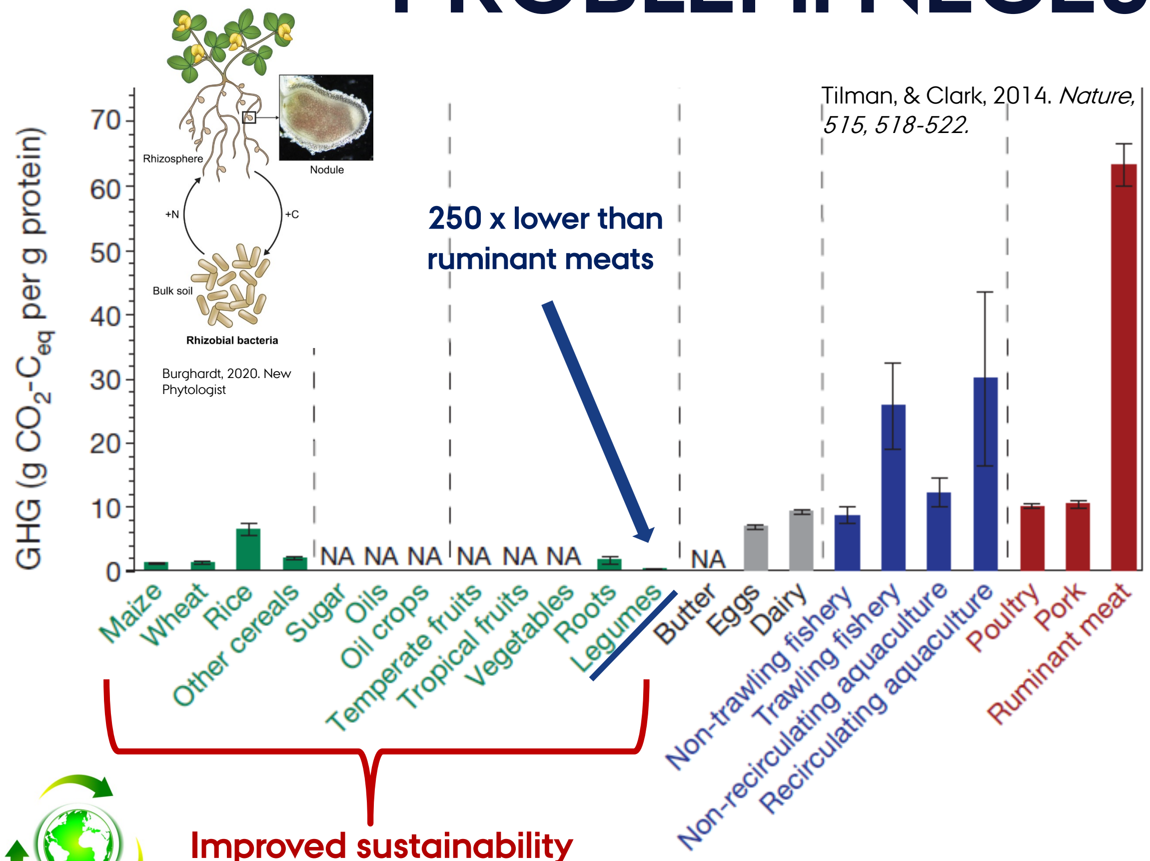
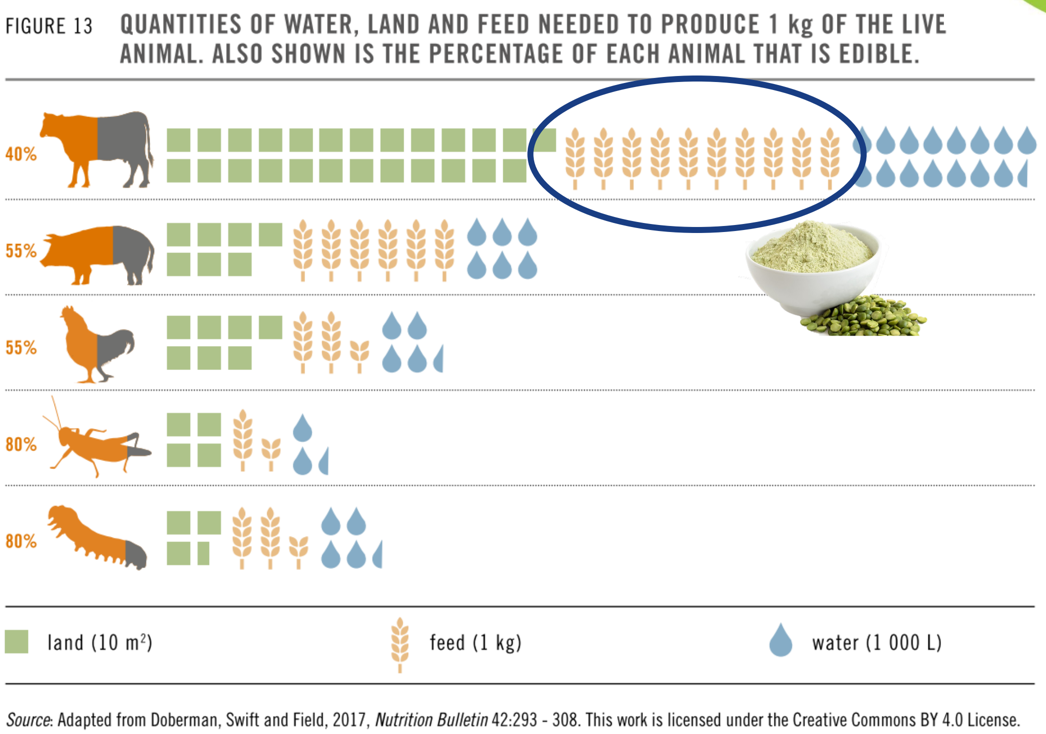


Improved sustainability through alternative proteins

More **sustainable** sources of **plant proteins** can be introduced to the **food market**



CHALLENGE: INTEGRATE PLANT PROTEIN INGREDIENTS INTO FOODS

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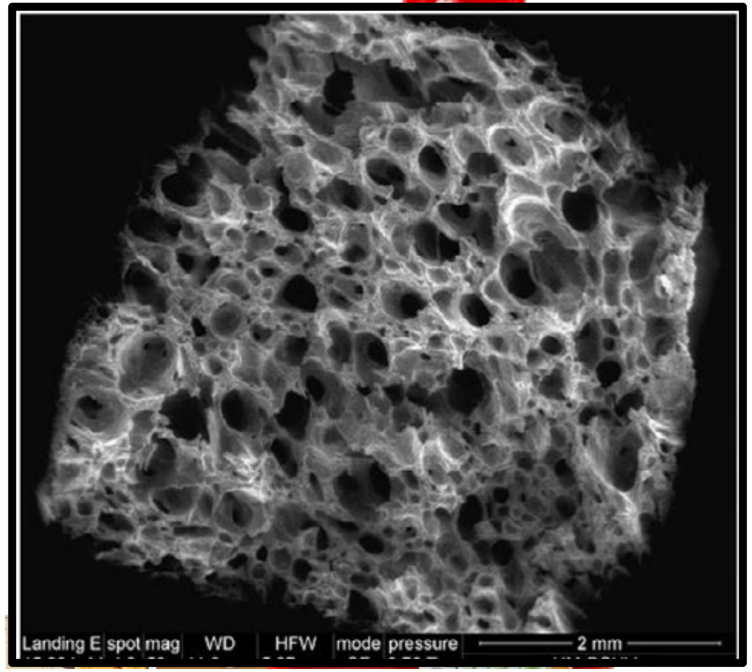
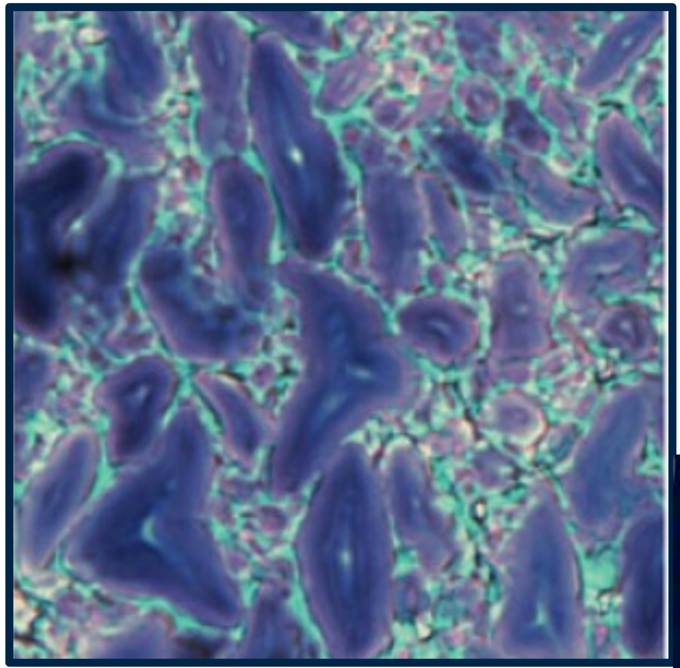
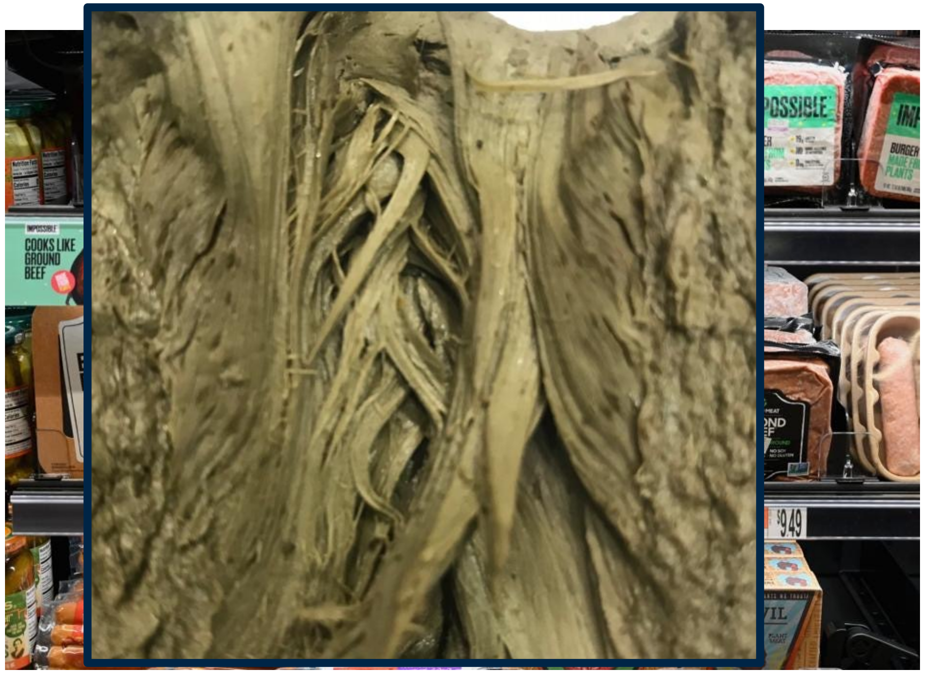
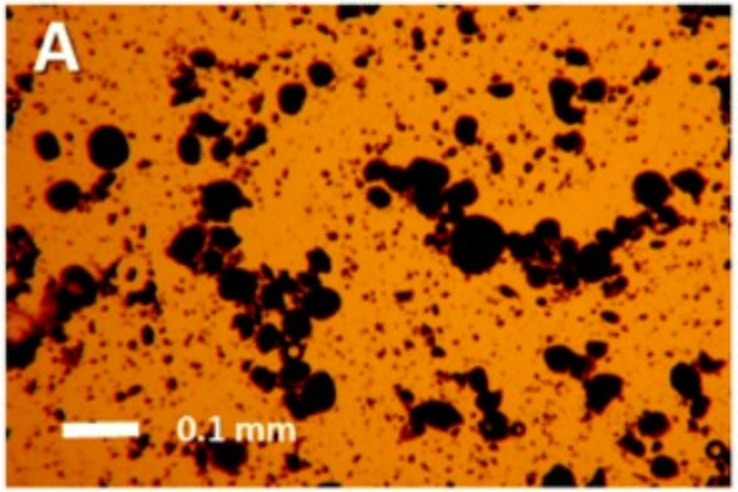
Need to understand the functionality in the complexity of a food matrix

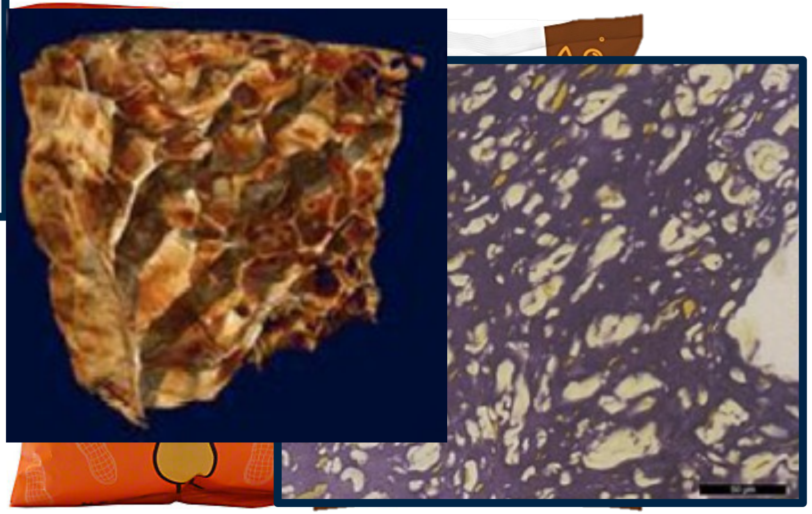




Laleg et al. Food Funct., 2016, **7**, 1196-1207







Schuchardt et al. Food Funct., 2016, **7**, 464-474

CHALLENGE: INTEGRATE PLANT PROTEIN INGREDIENTS INTO FOODS

How can we deliver sustainable plant-based food with optimal functionality and minimal waste?

Delving into the Complexity of Protein Ingredients from Less Refined Plant Biomass

Sustainable & Tailored Processing of Plant Tissues, including valorization of side-streams

Optimal Breeding of High Protein and More Resilient Crops

LESS REFINEMENT, MORE SUSTAINABLE

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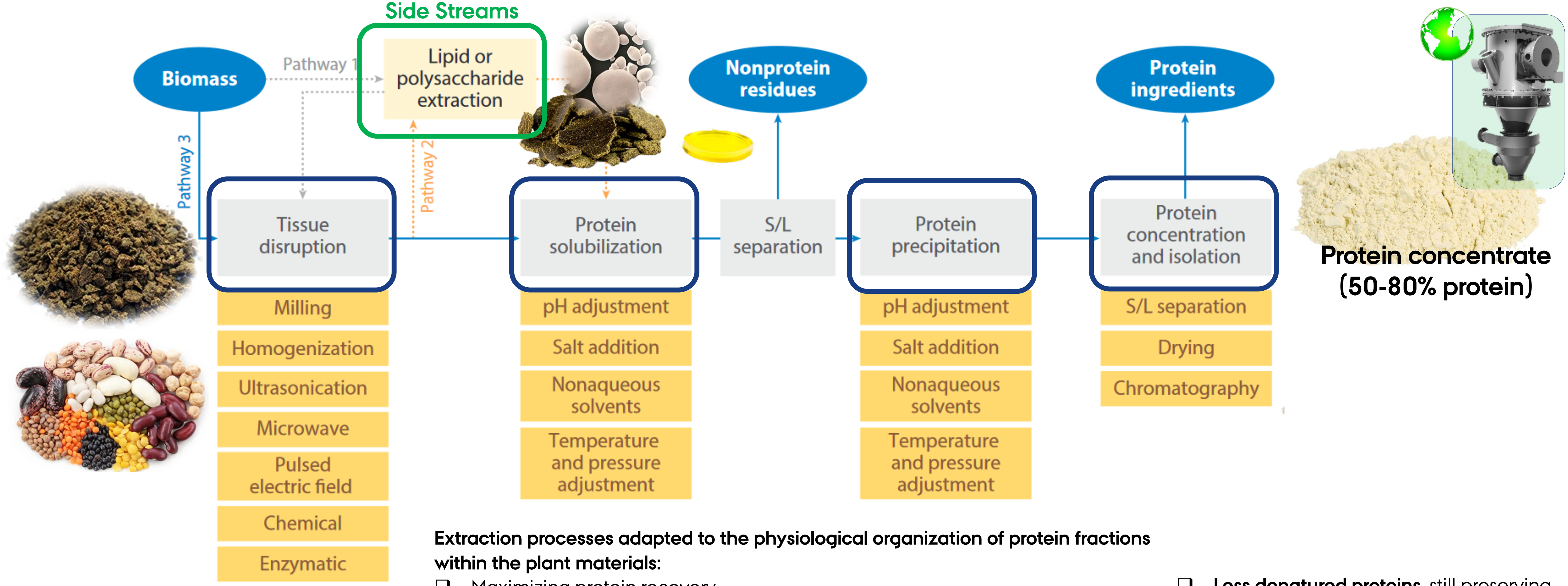
General design of protein extraction to obtain plant-protein concentrates and isolates



Grossmann & Weiss (2021). Annu. Rev. Food Sci. Technol., 12:93-117.

Extraction processes adapted to the physiological organization of protein fractions within the plant materials:

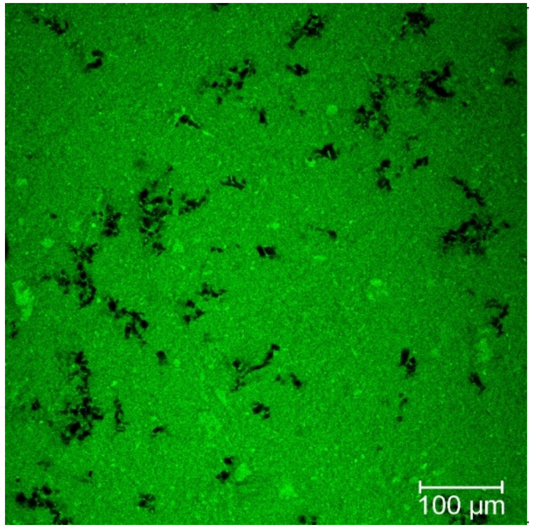
- ❑ Maximizing protein recovery
- ❑ Preserving their native structure
- ❑ Wheat gluten → washing starch out of a wheat dough
- ❑ Oilseed proteins → tandem alkaline extraction-isoelectric precipitation
- ❑ **Legume proteins → air classification**

- ❑ **Less denatured proteins**, still preserving their native oligomeric state
- ❑ Less side-streams
- ❑ **Non-proteinaceous components** (including anti-nutritional factors)

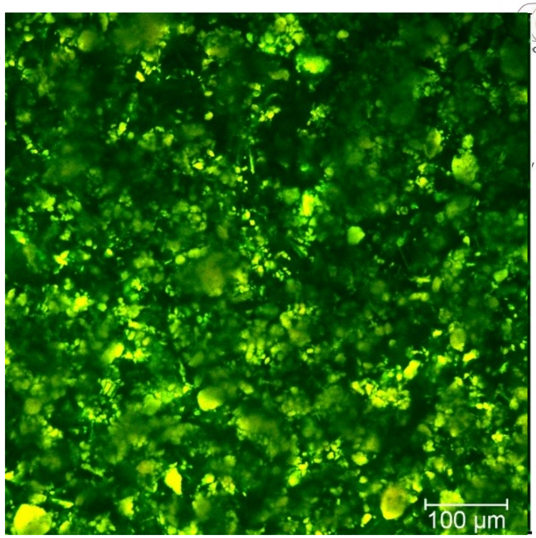
PROTEIN CONCENTRATES VS. ISOLATES

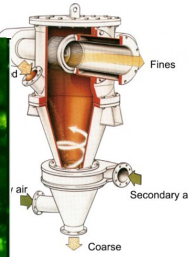
AE-IP

PPI1

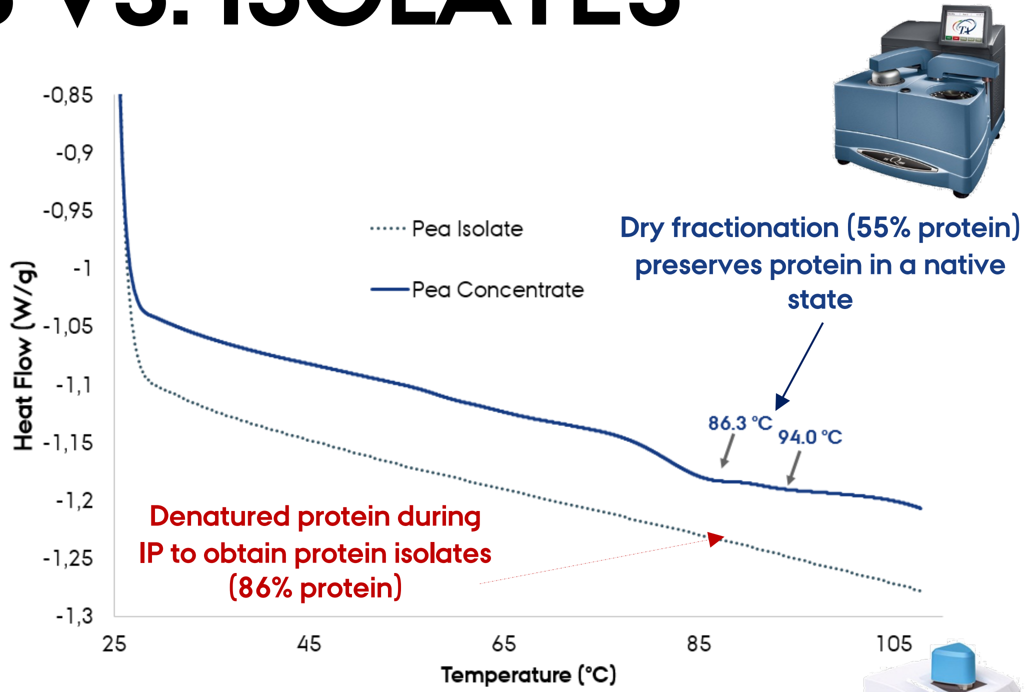


PPC



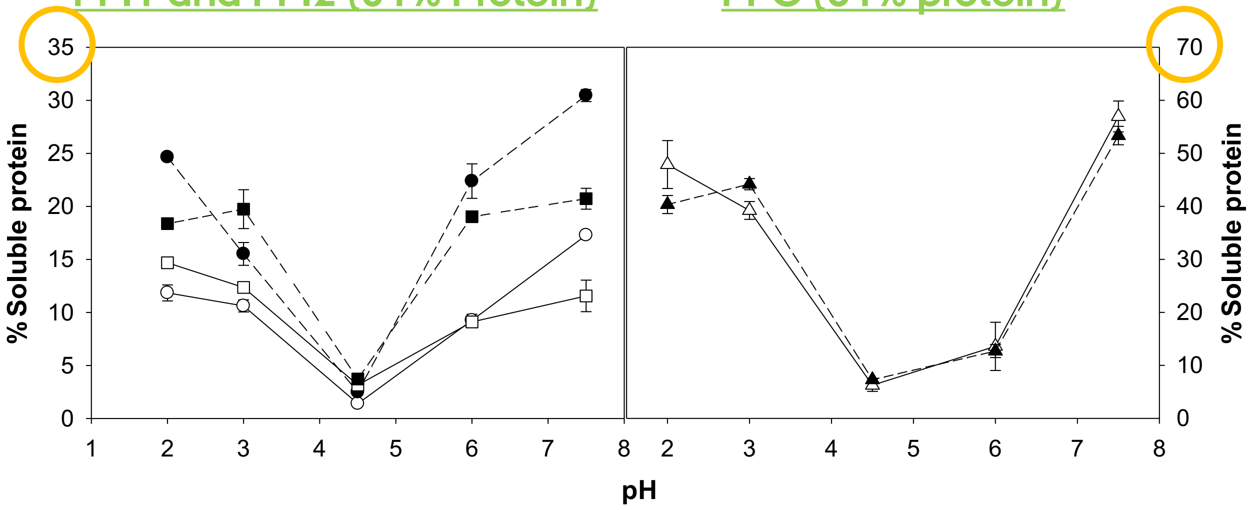


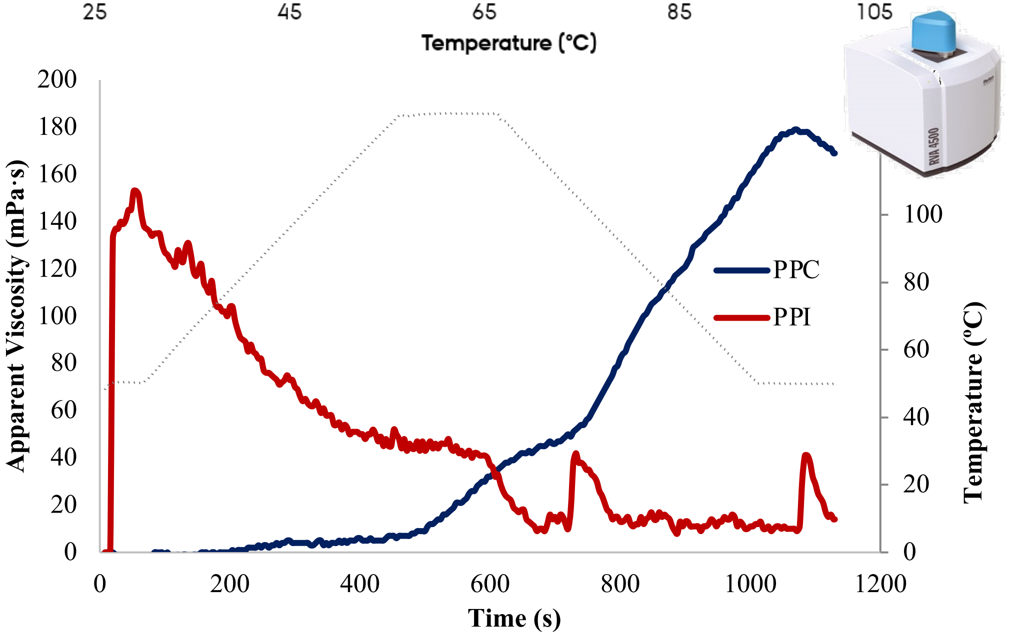
AirF



PPI1 and PPI2 (81% Protein)

PPC (51% protein)

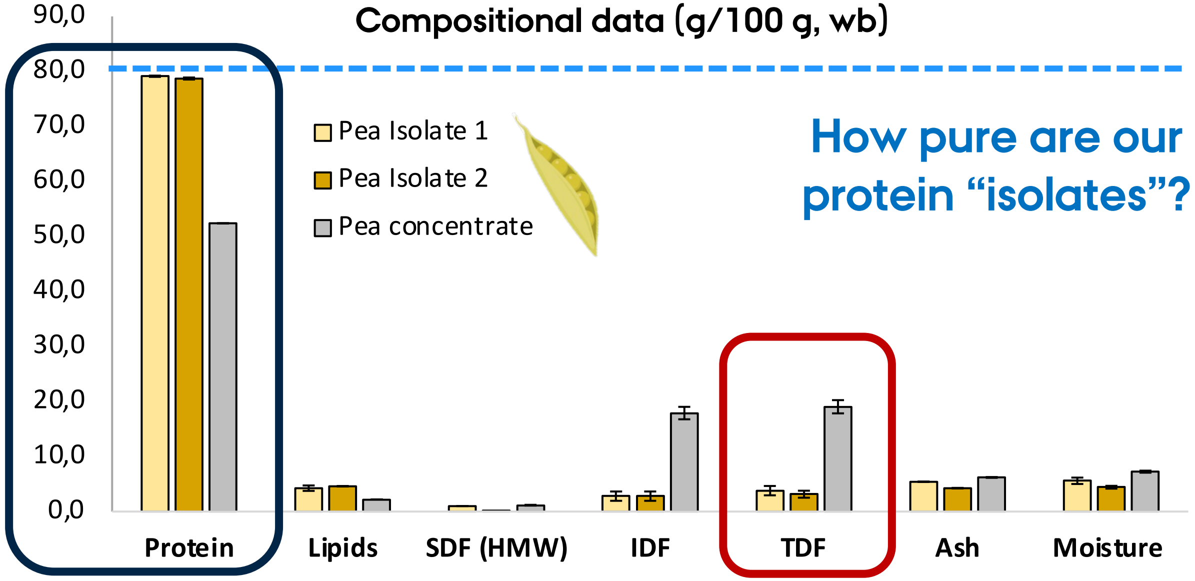


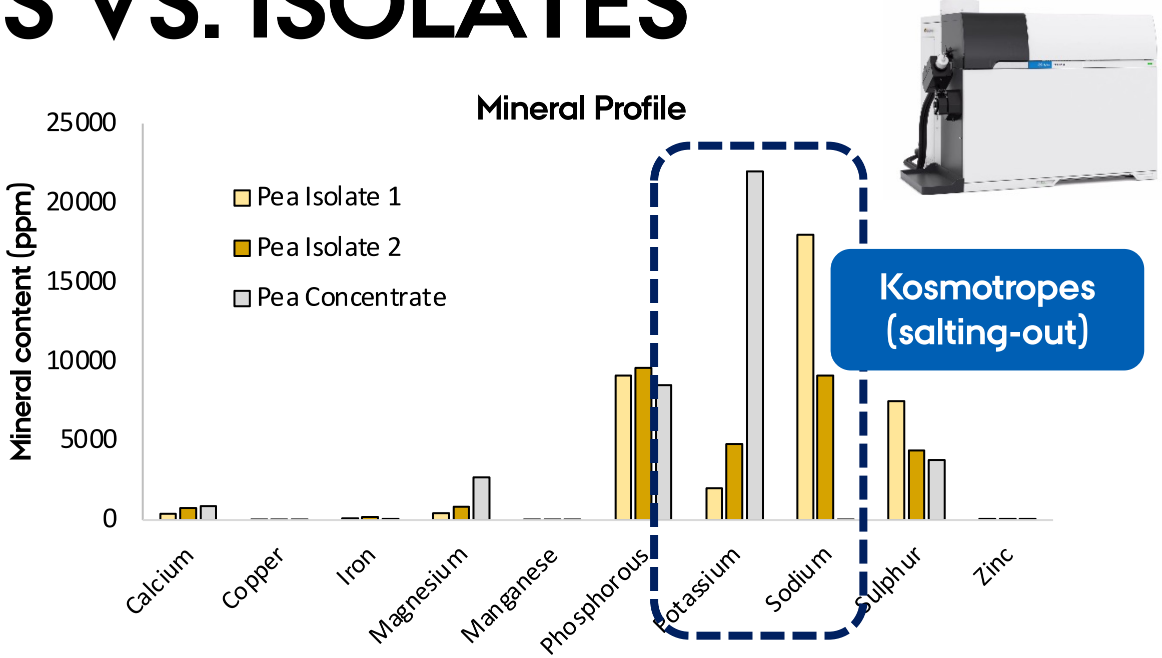


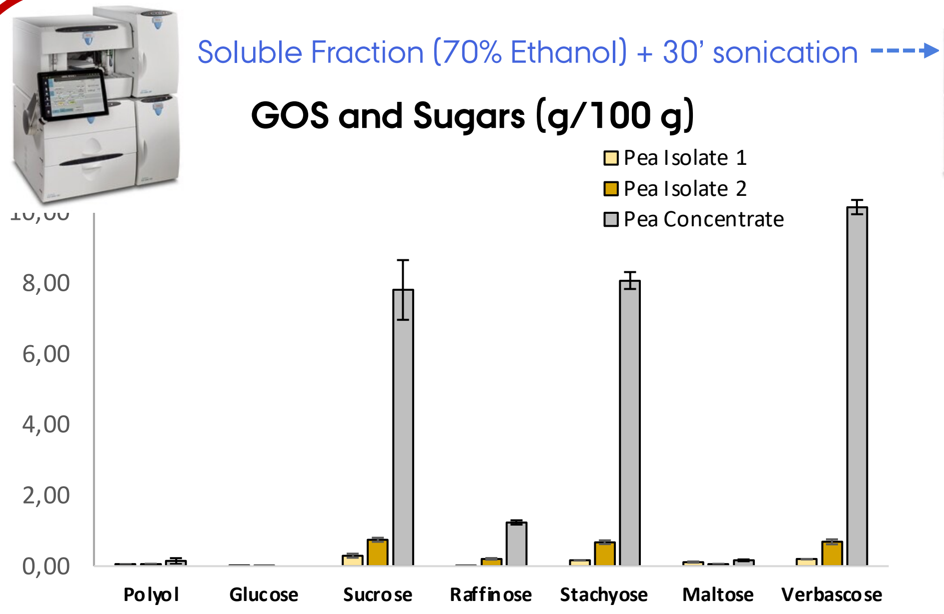
Jiménez-Munoz, Nielsen, Roman, & Corredig. 2023. *Food Chemistry, 401*, 134178.

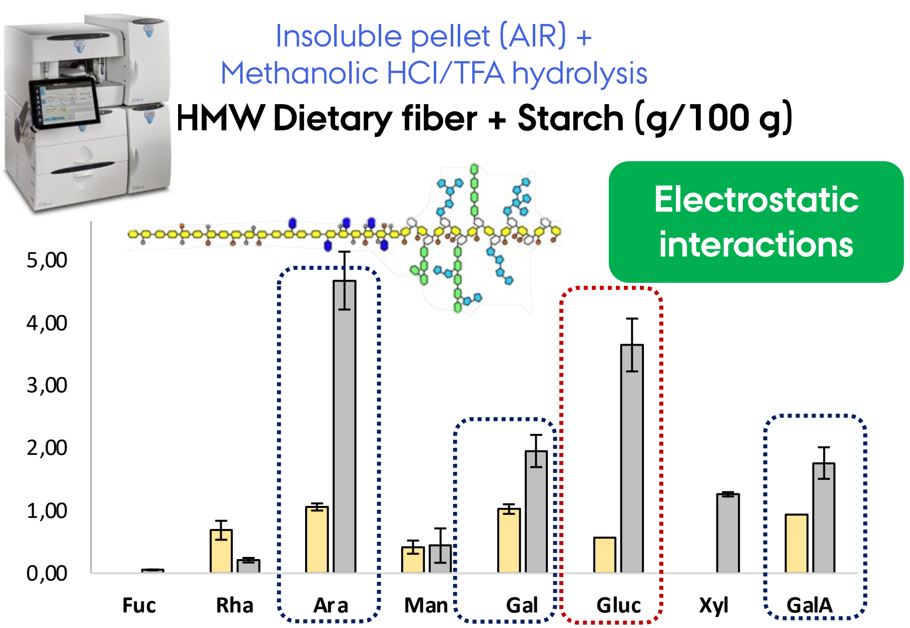
Roman, Jiménez-Munoz, & Corredig. 2023 (to be submitted)

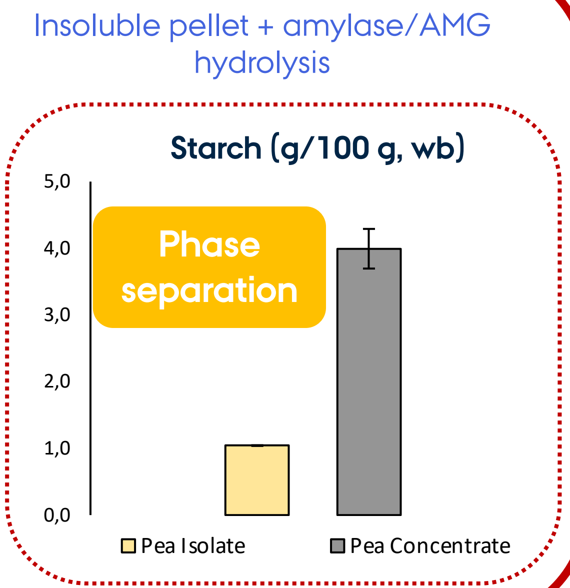
PROTEIN CONCENTRATES VS. ISOLATES











THE COMPLEXITY OF FIBER FRACTION IN LEGUMES

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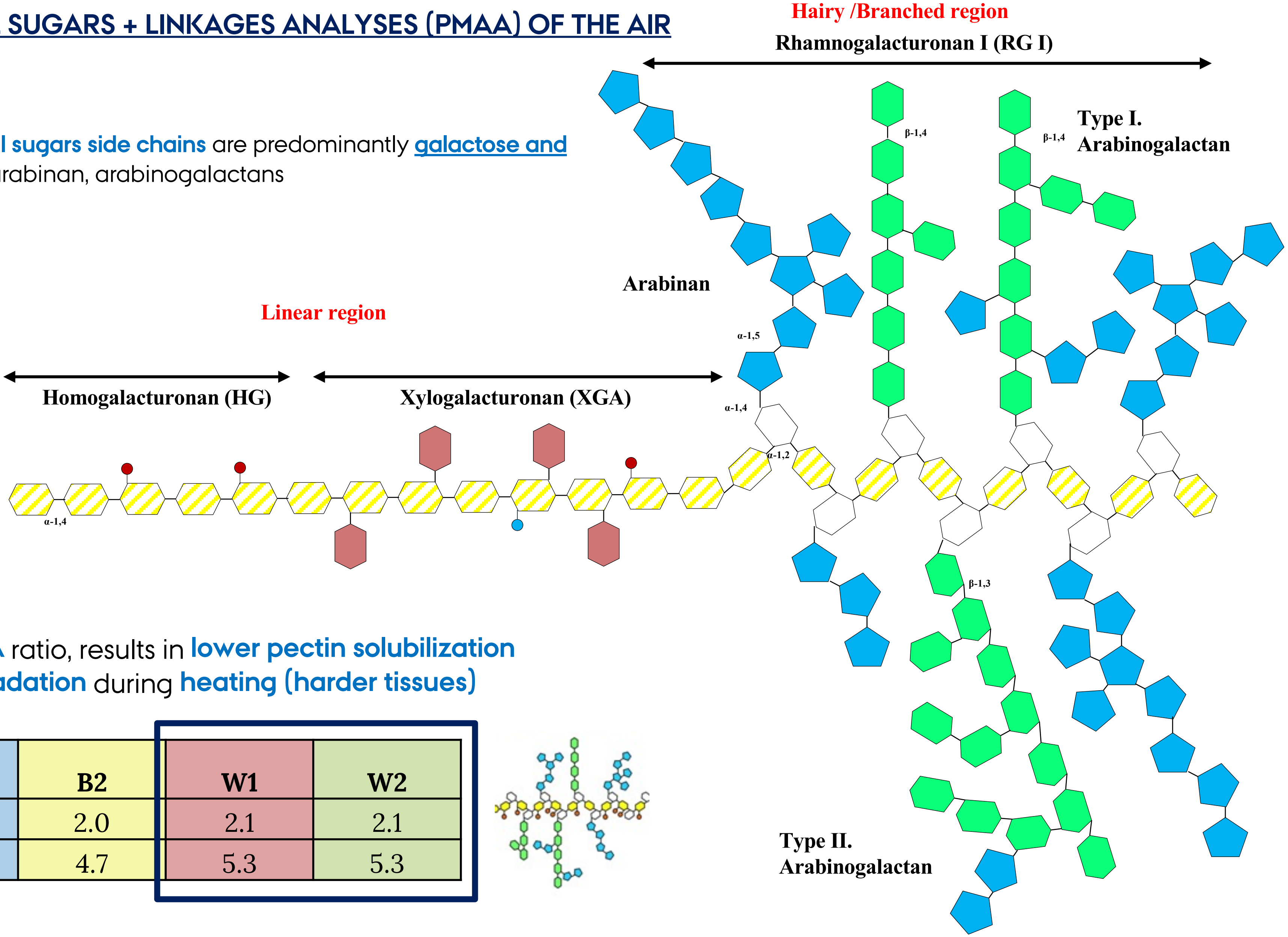
Pettolino et al., 2012

ACIDIC (UA) AND NEUTRAL SUGARS + LINKAGES ANALYSES (PMAA) OF THE AIR

RGI- rich pectin, whose neutral sugars side chains are predominantly galactose and arabinose, forming galactan, arabinan, arabinogalactans



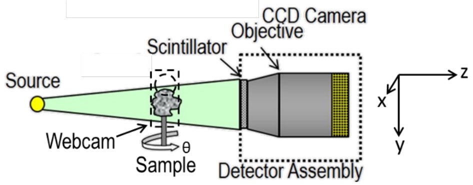
Importance of Protein-Carbohydrates Interplay during cooking

Higher Ara/UA and NS/UA ratio, results in lower pectin solubilization and galacturonan degradation during heating (harder tissues)

	B1	B2	W1	W2
Ara/UA	2.0	2.0	2.1	2.1
NS/UA	4.9	4.7	5.3	5.3

STARCH-PROTEIN INTERPLAY IN FOOD MATRICES

X-RAY COMPUTED TOMOGRAPHY

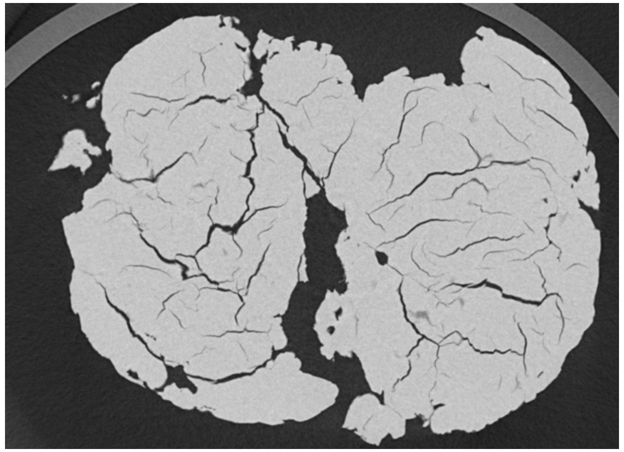


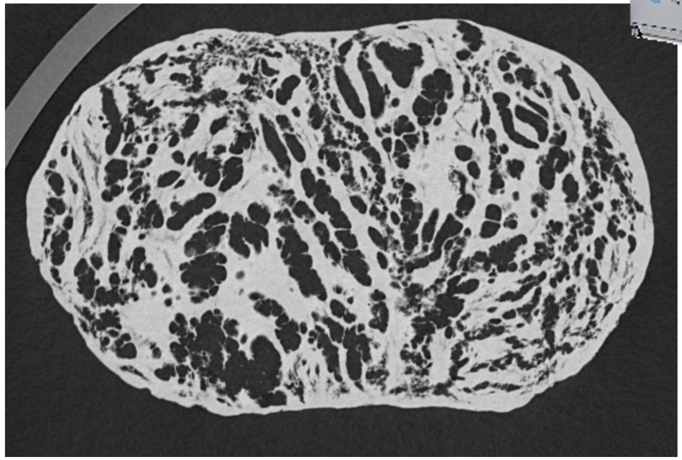
Increased air gaps and fiber formation → Improved fibrousness & softness of the matrix

Low Moisture Processing (30%)

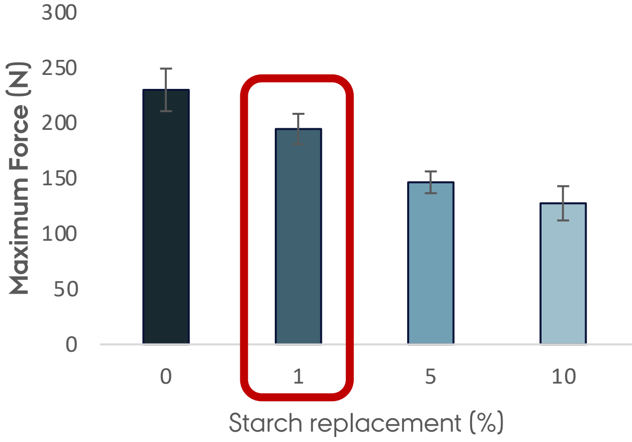
High Moisture Processing (60%)

Protein Matrix

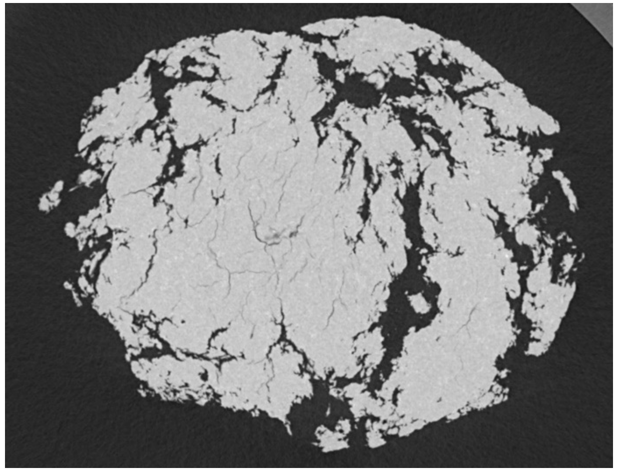


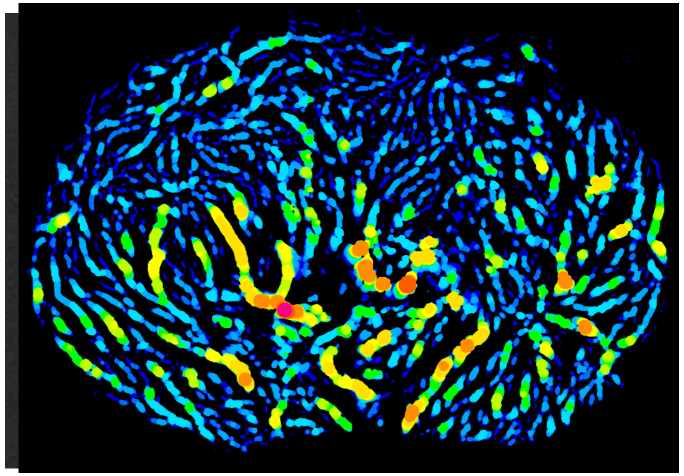


PI-Starch – 30% Moisture

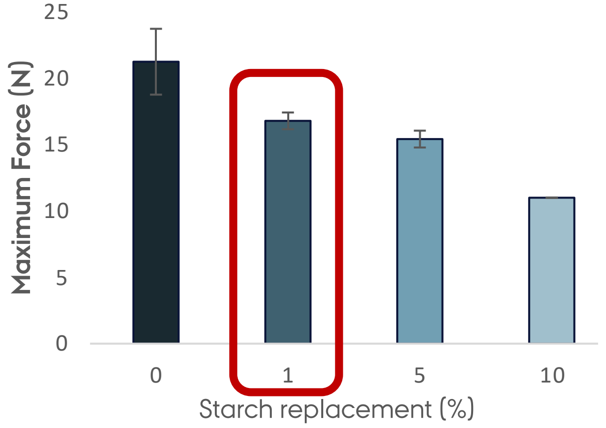


Protein- Starch Matrix



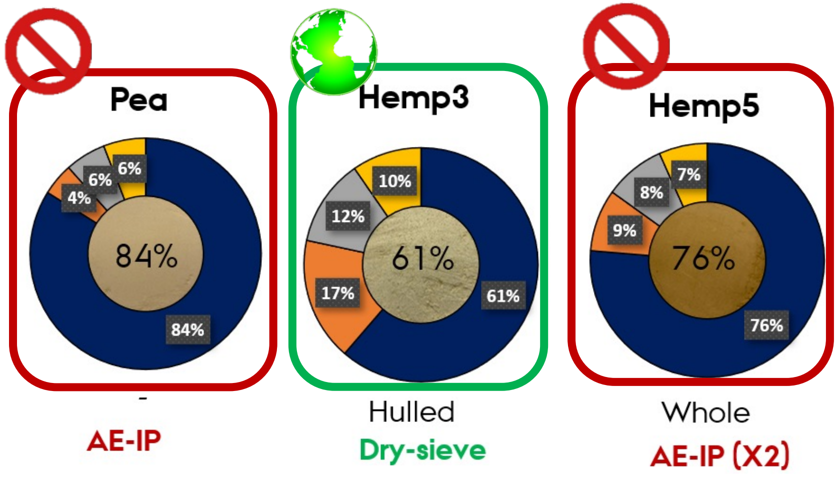


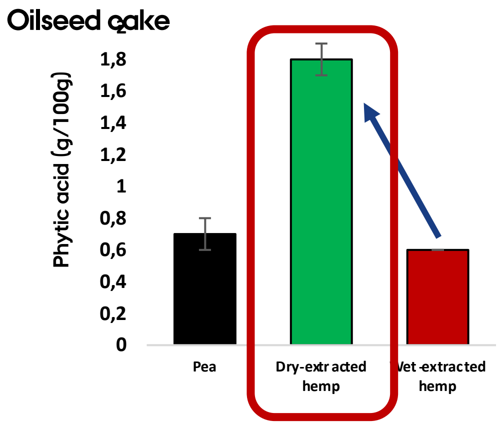
PI-Starch – 60% Moisture

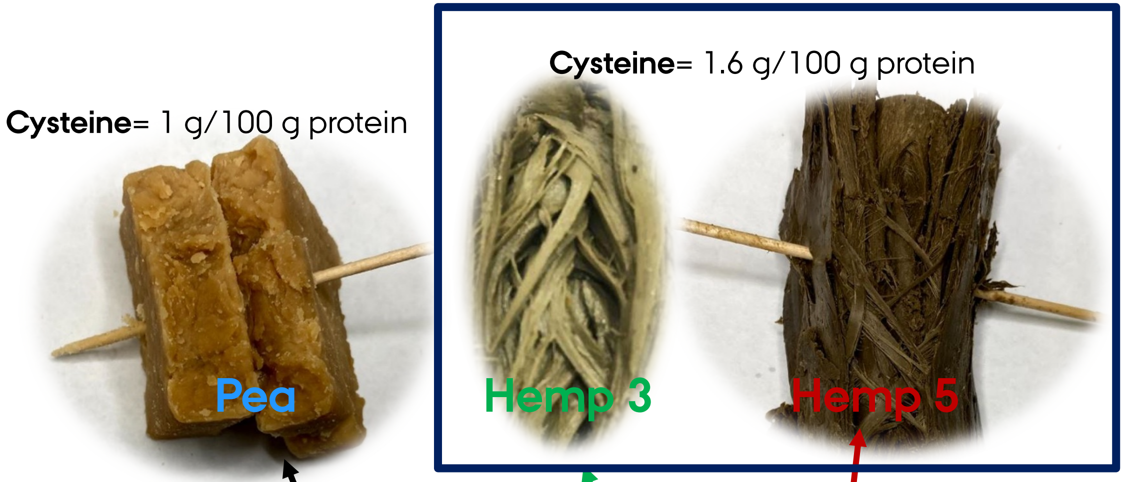


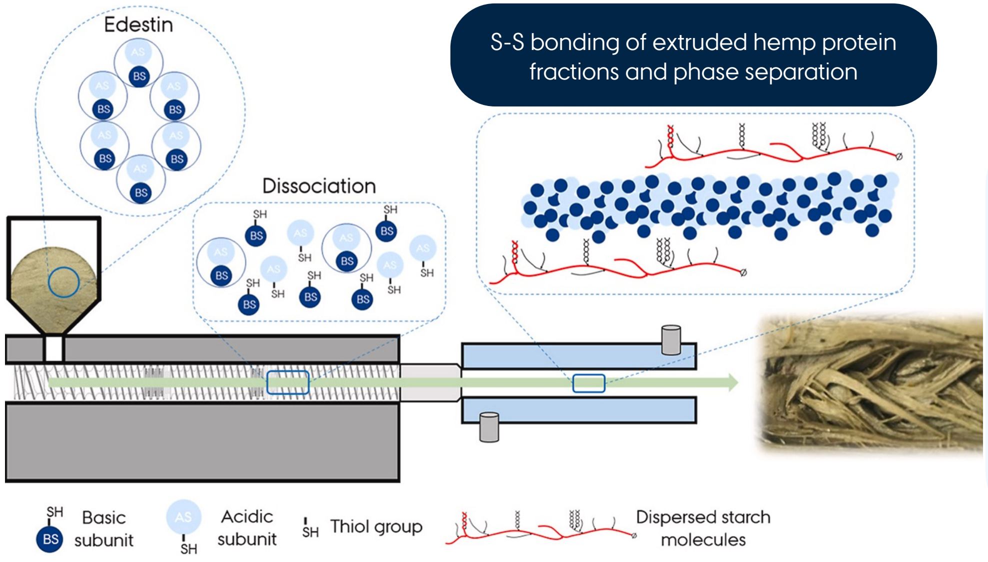
Roman, Hugues, Hall, & Corredig (unpublished)

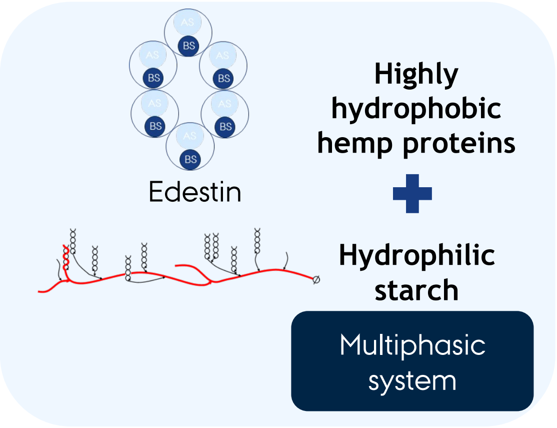
SUSTAINABLE PROCESS OF LESS REFINED SIDE STREAMS

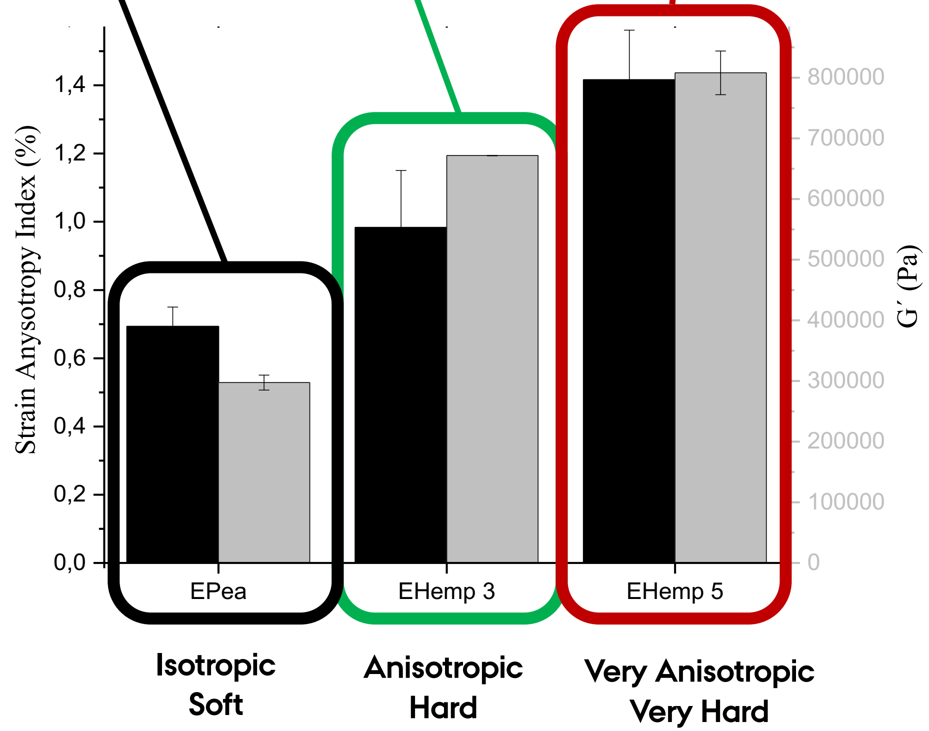












Nasrollahzadeh,[1] Roman,[1] et al. 2022. Food Hydrocolloids. 131, 107755.
[1] *Equal contribution*

LUPIN: PROTEIN-RICH CROP ALTERNATIVE

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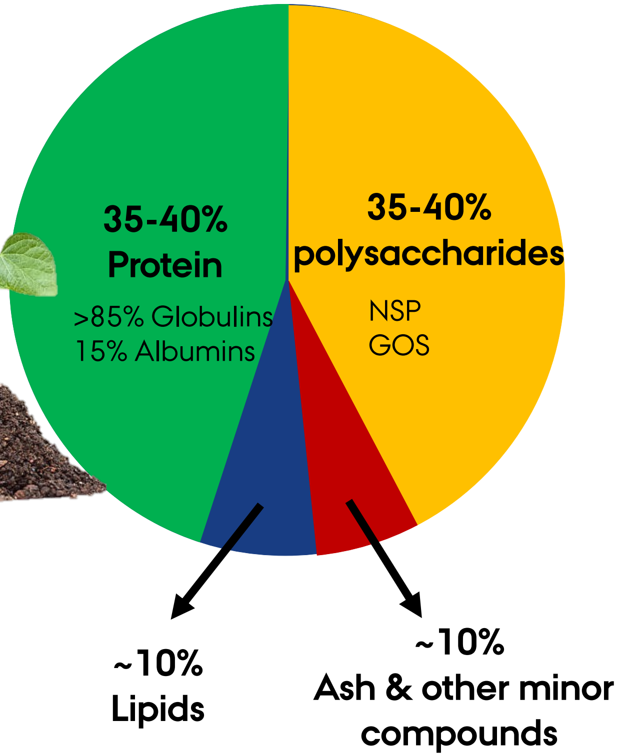
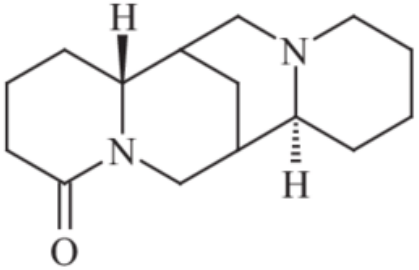
Lupinus spp.

Blue lupin *(Lupinus angustifolius)*



- ↑↑N_2 fixation and ↓↓ GHG emissions
- Can grow in acidic and sandy soil, erosion control crop
- Higher seed-yield & more freeze-tolerance
- Short cycle and wide adaptation potential

Quinolizidine Alkaloids (QAs)



Toxic secondary metabolites of Lupinus plants

(arrhythmia, vomiting, convulsions...)

- ✓ ↑↑Protein
- ✓ ↓↓QAs
- ✓ ↑↑ Climate robustness

The presence of QAs, prevents the direct consumption of lupins as ingredients or foods → Eliminate by post-harvest processing or seed crossbreeding selection

BREEDING OF PROTEIN RICH CROPS: LUPINS

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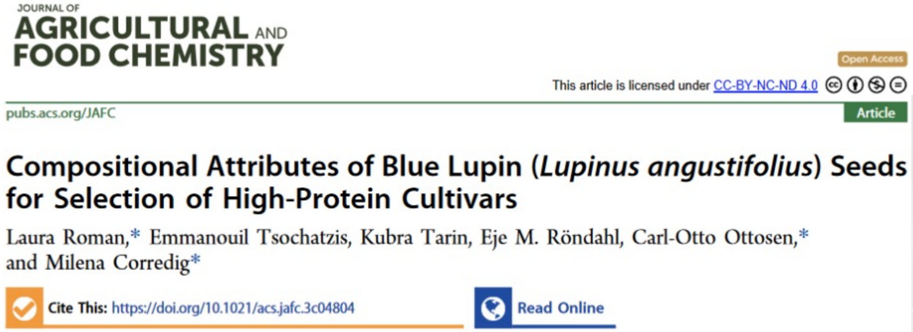
- **22 blue lupin seed varieties and crossbreedings → grown in AFP greenhouse under the same controlled environment**
- Seeds were let dry in the pods and the pods carrying the seeds were harvested for analyses

Nordic Seed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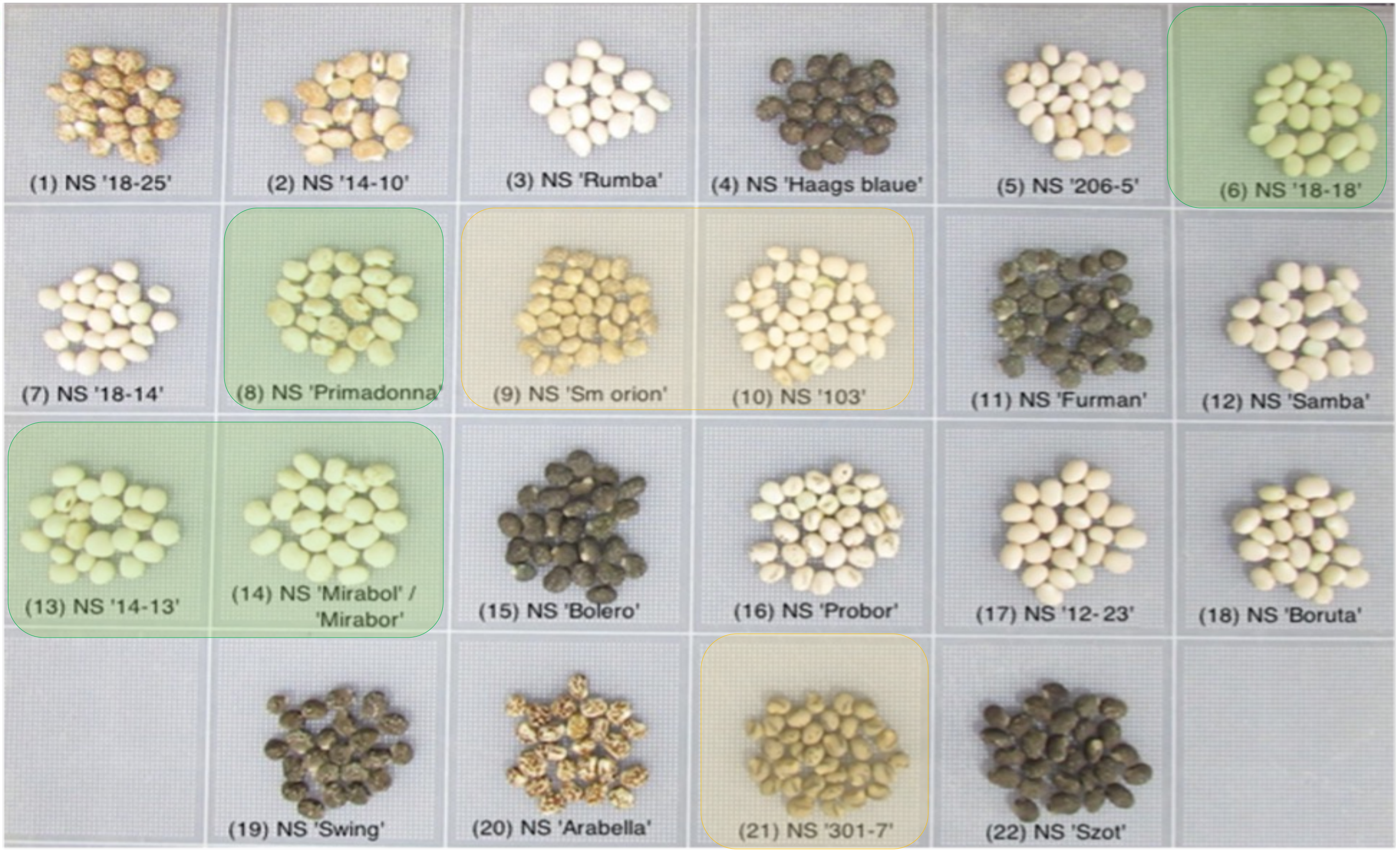
Compositional Attributes of Blue Lupin (*Lupinus angustifolius*) Seeds for Selection of High-Protein Cultivars

Laura Roman,* Emmanouil Tsochatzis, Kubra Tarin, Eje M. Röndahl, Carl-Otto Ottosen,* and Milena Corredig*

Cite This: https://doi.org/10.1021/acs.jafc.3c04804 Read Online

High Grain Yield Low Grain Yield



Roman, Tsochatzis, Tarin, Röndahl, Ottosen, & Corredig. (2023).

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YIELD OF LUPIN PROTEIN ISOLATES (AE-IP)

Milled whole flour

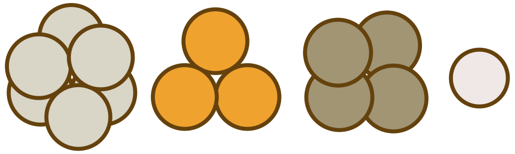
Tissue solubillization under stirring

Alkaline extraction (pH: 9)

Isoelectric precipitation (pH: 4.5)

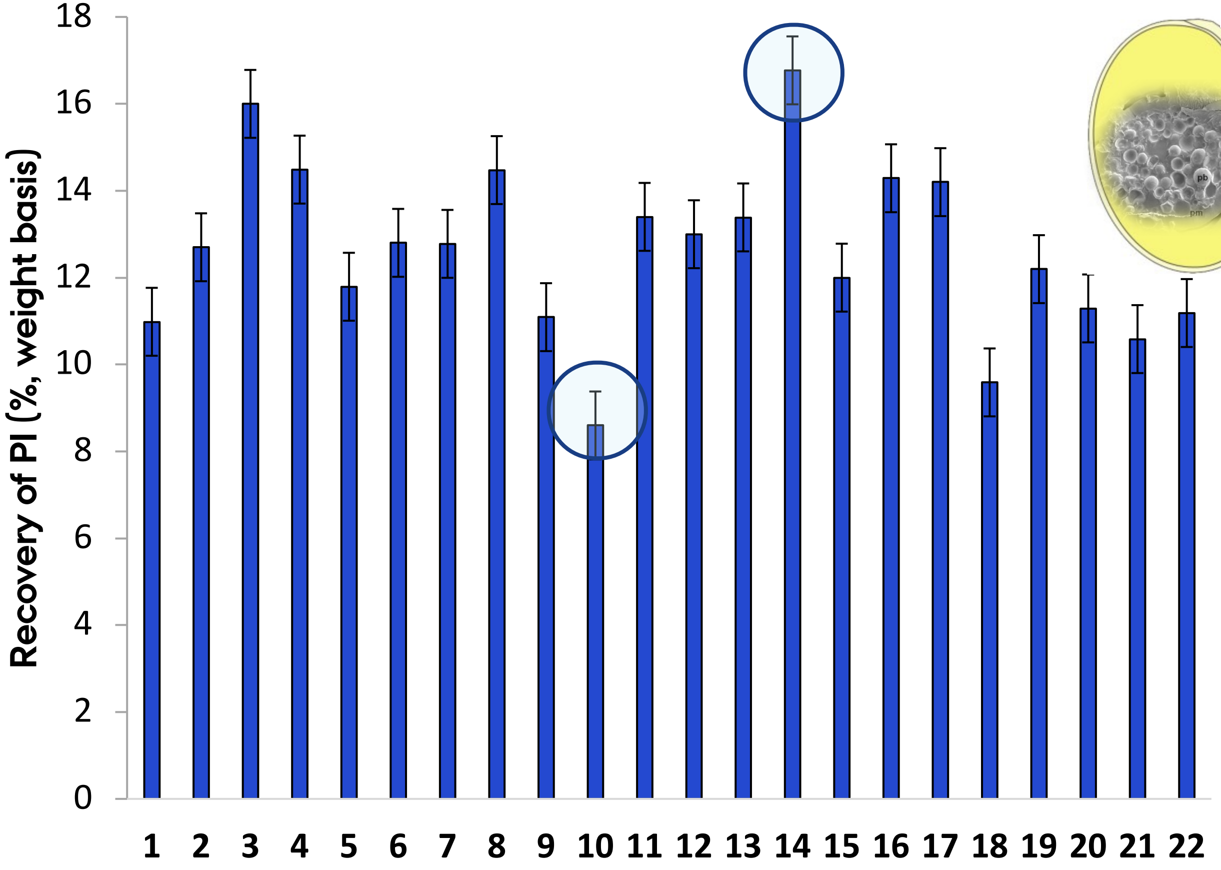
Protein resuspension, neutralization and freeze-drying

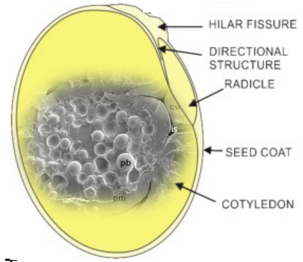
Protein isolate



Recovery of PI (%) = (weight recovered PI)/ (weight initial flour)*100

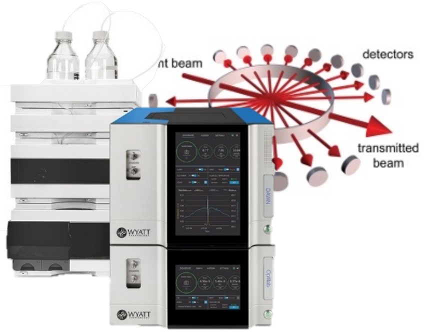
Recovery ranged between 8.6% and 16.8%





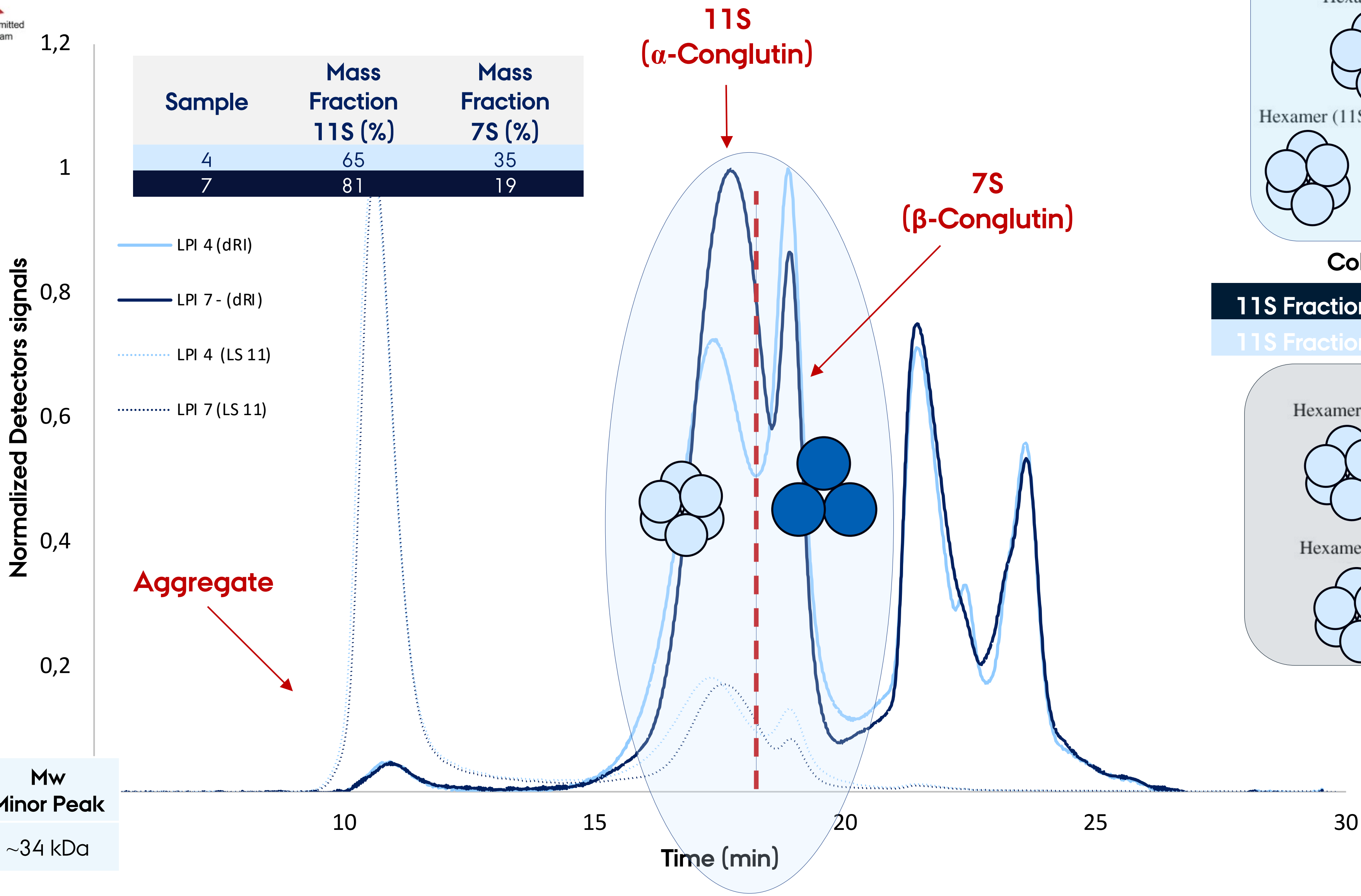
- ❑ Protein purity in Protein isolate: 70-92 % (g/100 g, wb)
- ❑ Correlation with protein, seed weight & mineral composition (K^+ and Ca^{2+})

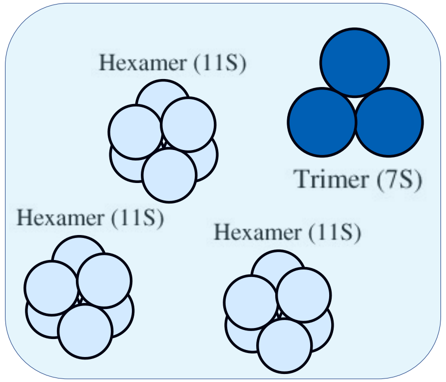
PROTEIN COMPOSITION OF BLUE LUPINS



Identification of lupin varieties richer in 11S

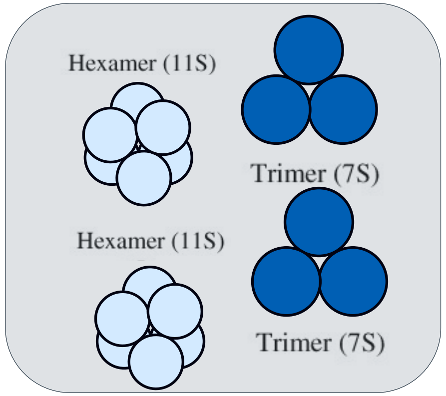
Sample	Mass Fraction 11S (%)	Mass Fraction 7S (%)
4	65	35
7	81	19





Color legend

11S Fraction:	70-80%
11S Fraction:	< 70%



Mw 11S	Mw 7S	Mw Minor Peak
~333 kDa	~193 kDa	~34 kDa

ANTINUTRIENTS: ALKALOIDS IN LUPINS

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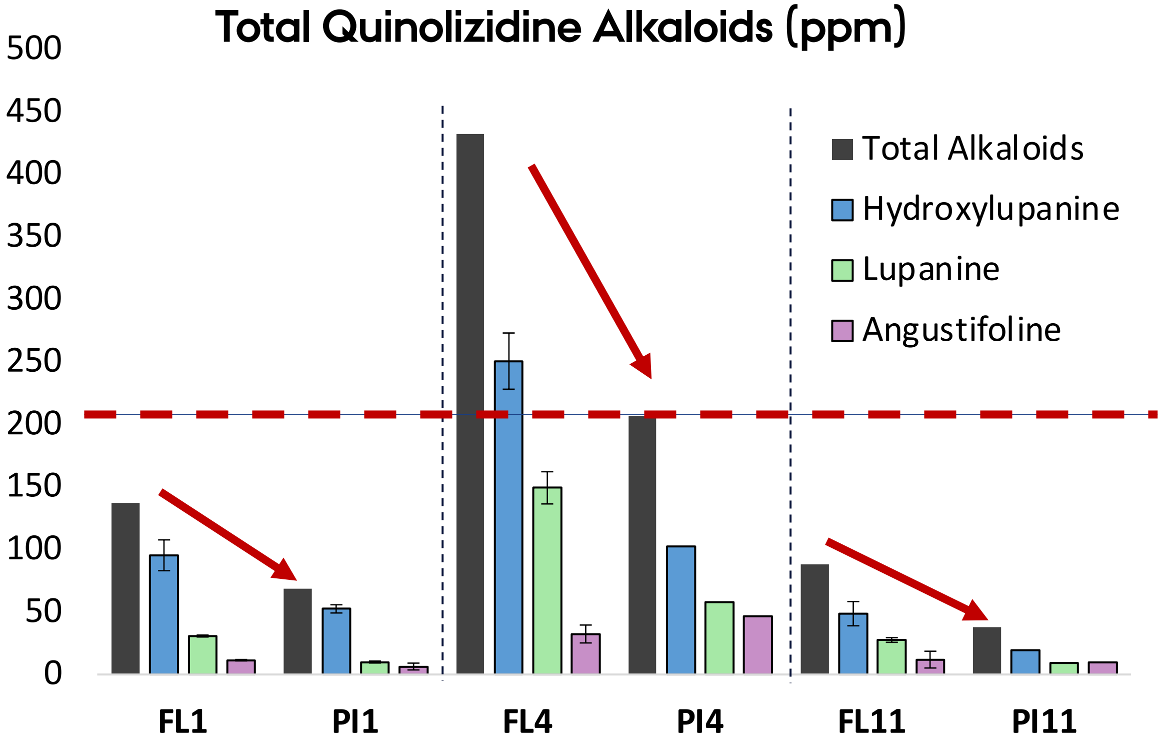
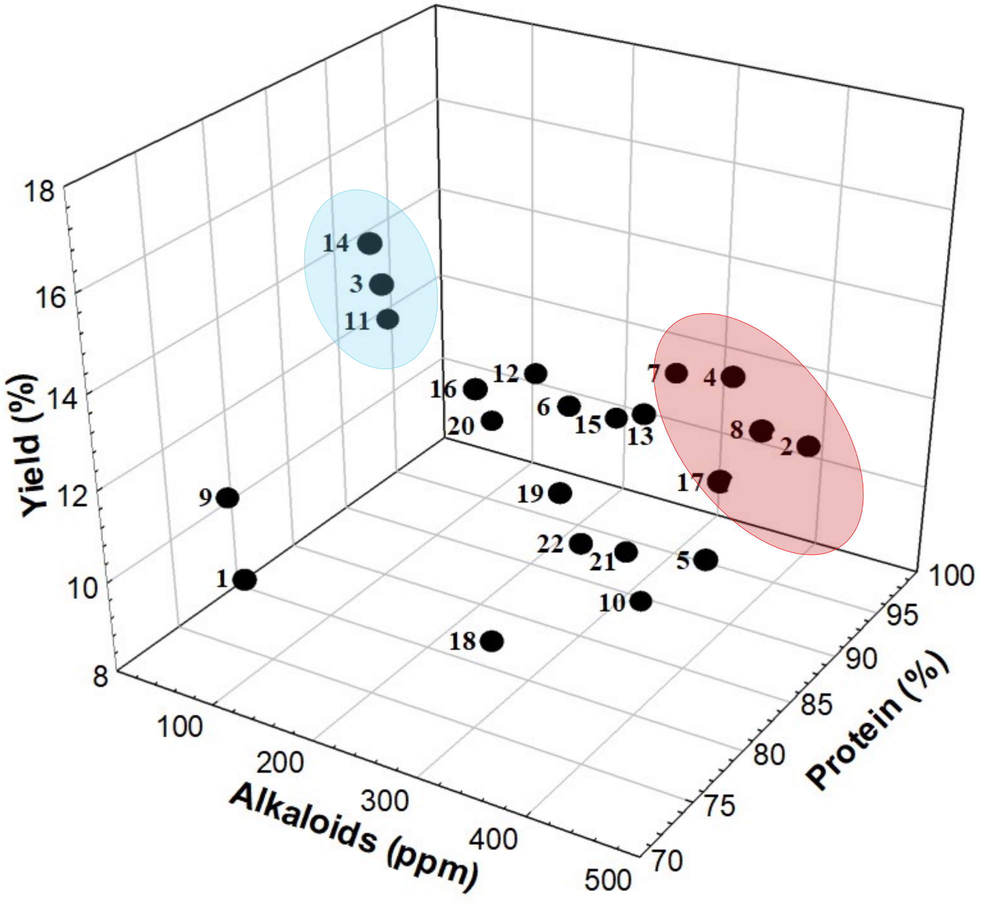
Some regulations impose that lupin products **< 200 ppm of alkaloids**



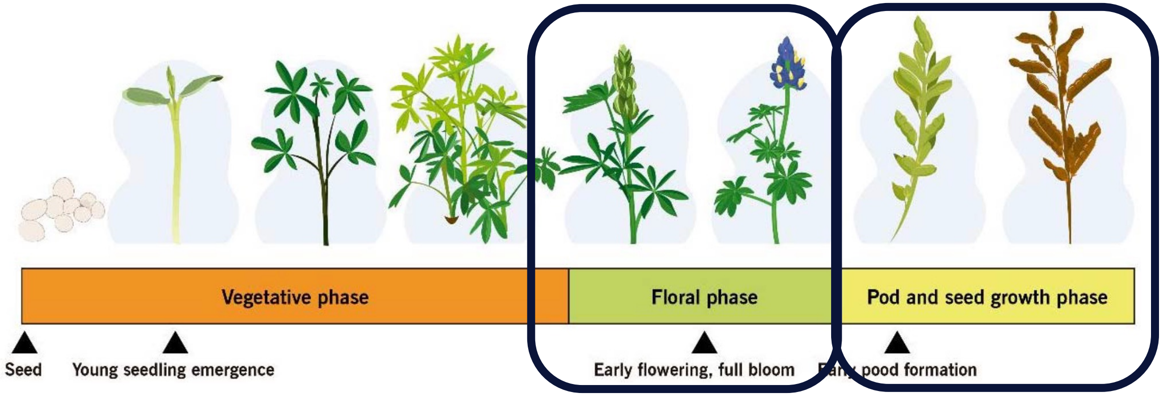
Selection of high-performing breeding lines



Varieties with high yield, high protein and low alkaloids content

SEEDS GROWTH UNDER STRESS CONDTIONS

Roman, Johansson Sjödin, Tsochatzis, Jimenez-Munoz, Ottosen, & Corredig (*to be submitted*)

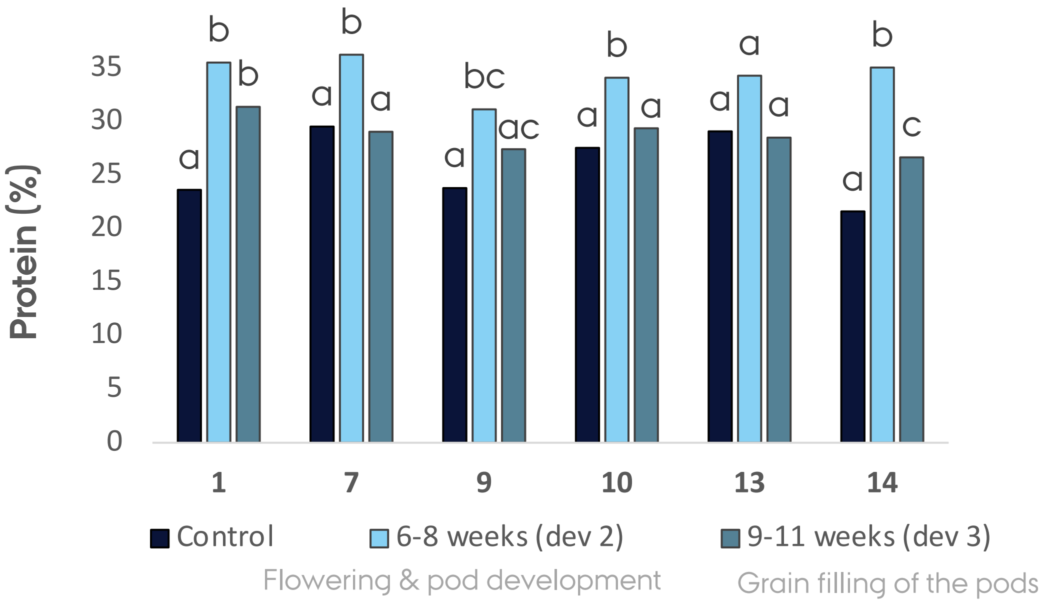


Falconí, C. E., & Yánez-Mendizábal, V. (2022). *Plants*, *11*, 654.

EFFECT OF HEAT STRESS

Heat stress (35/25°C) for 14 days at ≠ growth stages

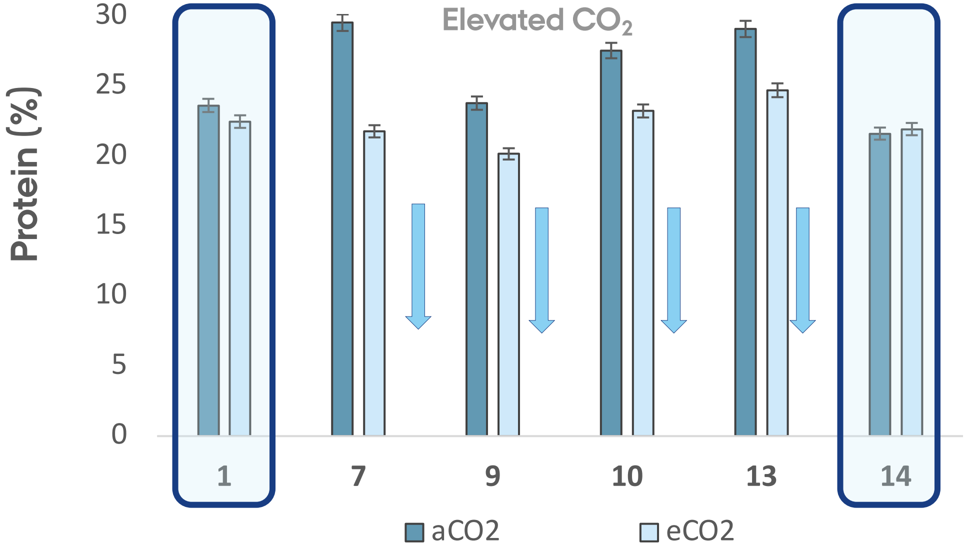
Protein (%) in diff. Heat Stress conditions for aCO2



EFFECT OF CO_2 LEVEL

aCO2 = 420 ppm → eCO2 = 750 ppm

Protein (%) in aCO2 & eCO2 - control treatment



eCO2 conditions also resulted in fewer alkaloids

↓↓ Reduced grain yield

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CONCLUSIONS

- **Breeding strategies:** Select **underutilized lupin crops** to **produce protein-rich ingredients** based on their **protein, grain yield**, **antinutritionals** and plant **resilience,** as optimal starting material **to reduce food waste generation**.

- **Less refined protein ingredients** are **complex systems** whose **non-protein components** can be benefitial to **tailor plant-protein rich matrices** with desired **technological properties**, **minimizing the generation of side steams**.

- Understand how **differences in protein composition** and **processing** can affect the technological **functionality** of the protein ingredients, to **design optimal, sustainable and oriented food applications.**

✓ Learn utilize **plant materials** at their **full potential,** using more **sustainable processing practices** and **reduce the environmental footprint of our food-systems**.

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July 24 25 2024

2 ZERO HUNGER

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

13 CLIMATE ACTION

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July 24 25 2024

Thank you!
¡Obrigada!

INNOGRAIN Lab

Prof. Milena Corredig

Assoc. Prof. Mario Martínez

- Prof. Carl-Otto Ottosen
- Dr. Stephen Hall
- Dr. Emmanuel Tsochatzis
- Dr. Luis Jimenez-Muñoz

- Dr. Louise M.A. Jakobsen
- Dr. Natalia Prieto-Vidal
- Dr. Farzaneh Nasrollahzadeh
- Eje Mattis Röndahl

- Kasper Skov
- Gabriel Hugues
- Lovisa Johansson Sjödin
- Kubra Tarin

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2 ZERO HUNGER

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

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TAKE HOME MESSAGE

We can deliver sustainable plant-based food with optimal functionality and minimal waste:

- Delving into the Complexity of Protein Ingredients from Less Refined Plant Biomass
- Sustainable & Tailored Processing of Plant Tissues, including side-streams
- Optimal Breeding of High Protein and Resilient Crops

Learn utilize **plant materials** at their **full potential,** using more **sustainable processing practices** and **reduce the environmental footprint of our food-systems**.