Legume biorefineries – processing options for diversification of functional ingredients

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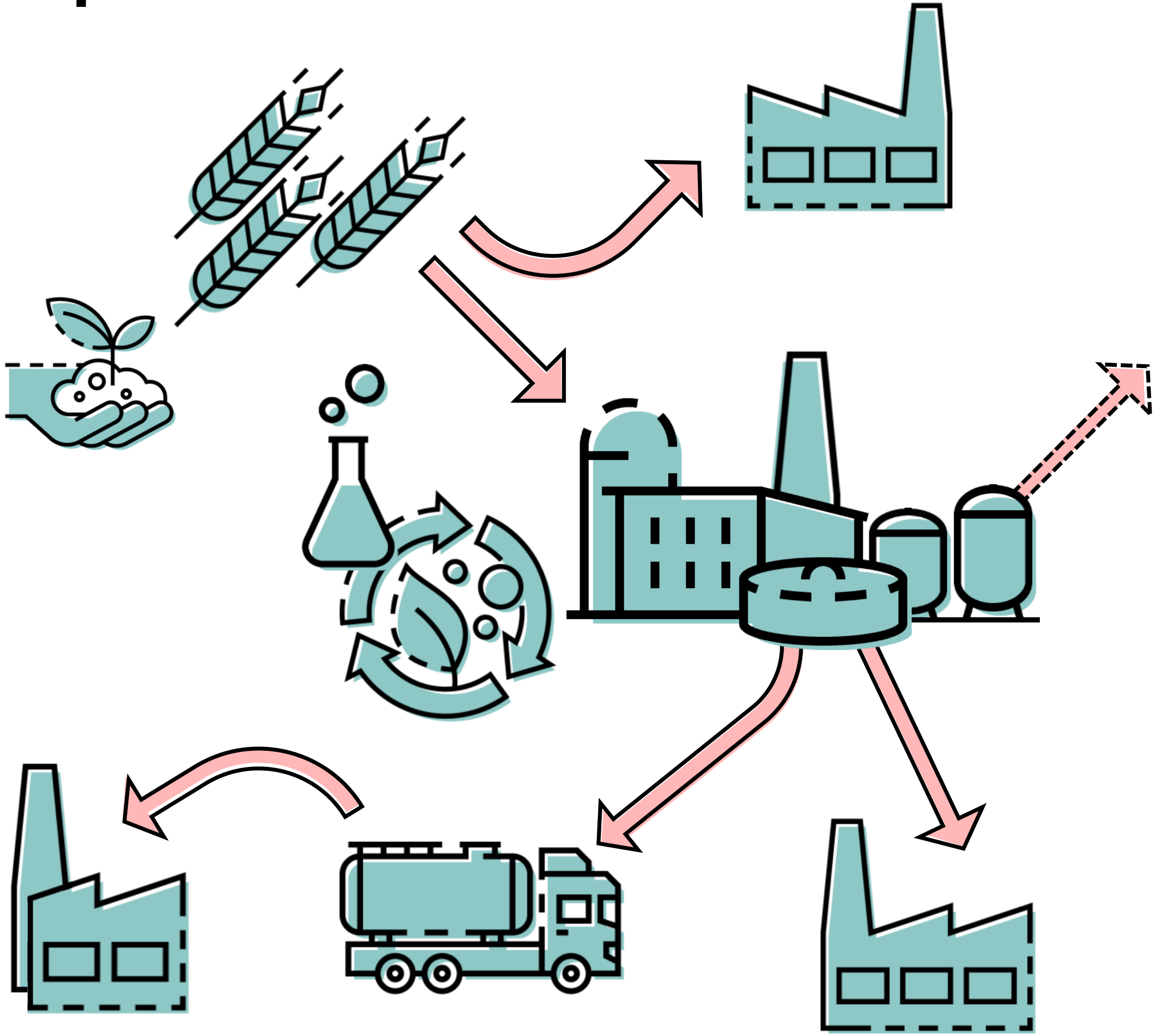
Biorefineries

Sugarcane
Corn
Soy
Wheat

Legumes

Platforms for the transformation of organic raw materials to a range of bio-based products.



Bioenergy
Materials
Food
Feed
Gases
...

Legume biorefineries

Yellow peas (*Pisum sativum*), Faba beans (*Vicia faba*), Lentils (*Lens culinarias*), Chickpeas (*Cicer arietinum* L.), etc.

Protein production

Wet processing → Protein isolates, >80% DM

Dry processing → Protein concentrates, <65% DM

Starch & Fiber by-products

Two Cases on yellow peas:

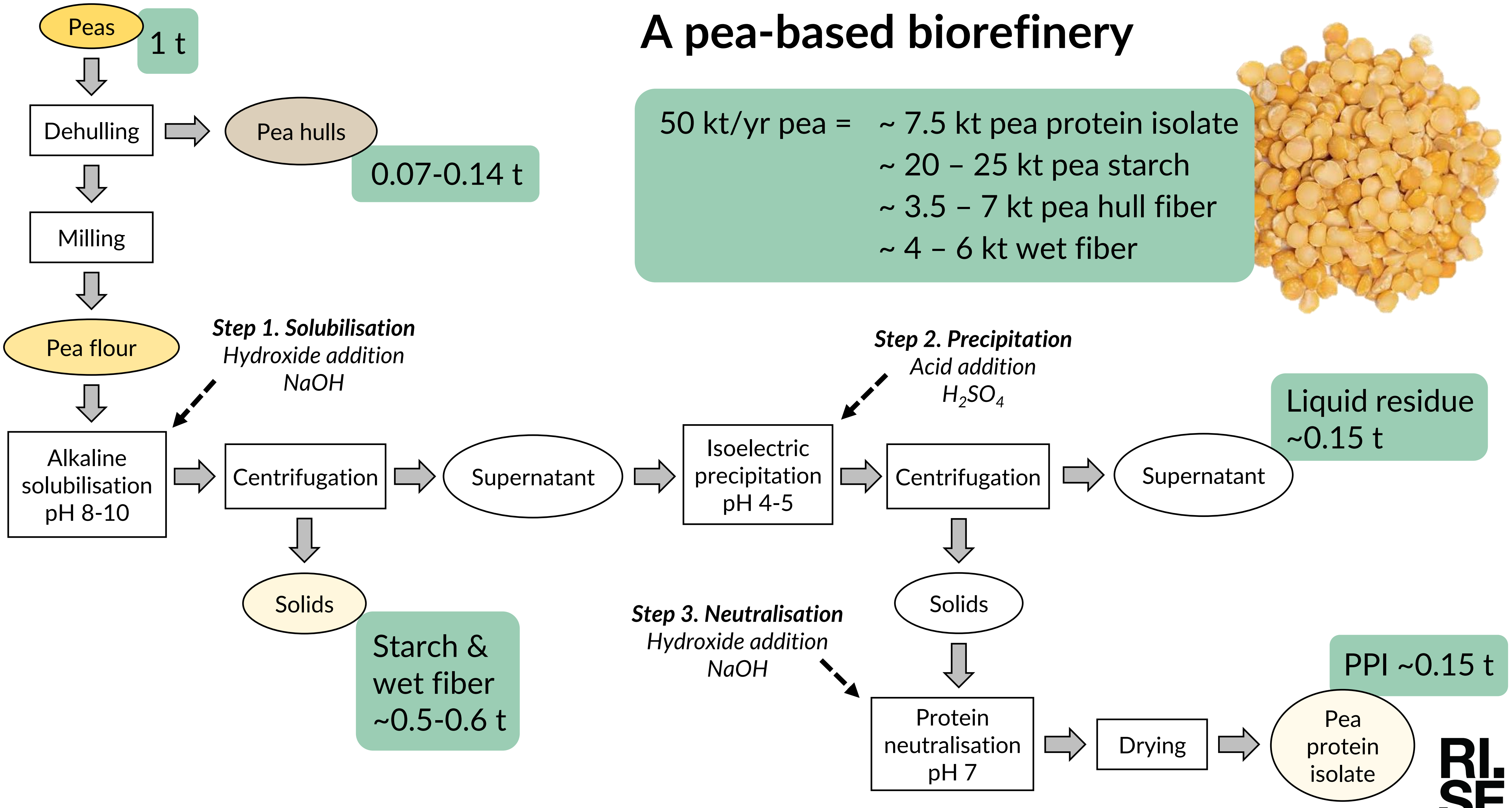
- Sodium reduction
- Phytate reduction

  +

- Side-product utilization

A pea-based biorefinery

50 kt/yr pea =
- ~ 7.5 kt pea protein isolate
- ~ 20 – 25 kt pea starch
- ~ 3.5 – 7 kt pea hull fiber
- ~ 4 – 6 kt wet fiber



Healthier plant-based ingredients and meals

High salt content

- Swedish Na intake high, 2-3x recommended level (target = <2 g Na/day, Sweden = ~6 g Na/day, EU range = 3-5 g Na/day)
- Plant-based meat alternatives typically quite high in salt. PPIs >1% sodium.

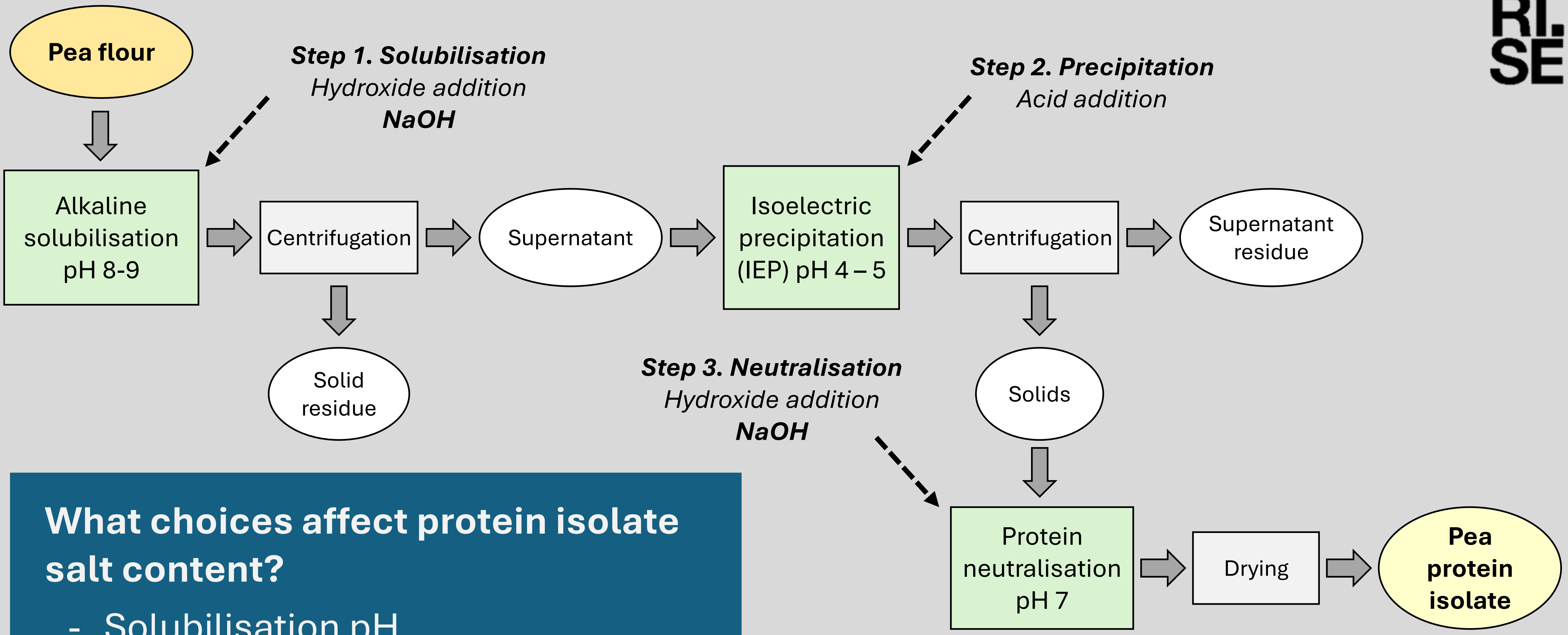
Phytate (anti-nutrient)

- Limits mineral bioavailability, esp. iron, zinc, calcium.
- Decreases protein digestibility.

Questions

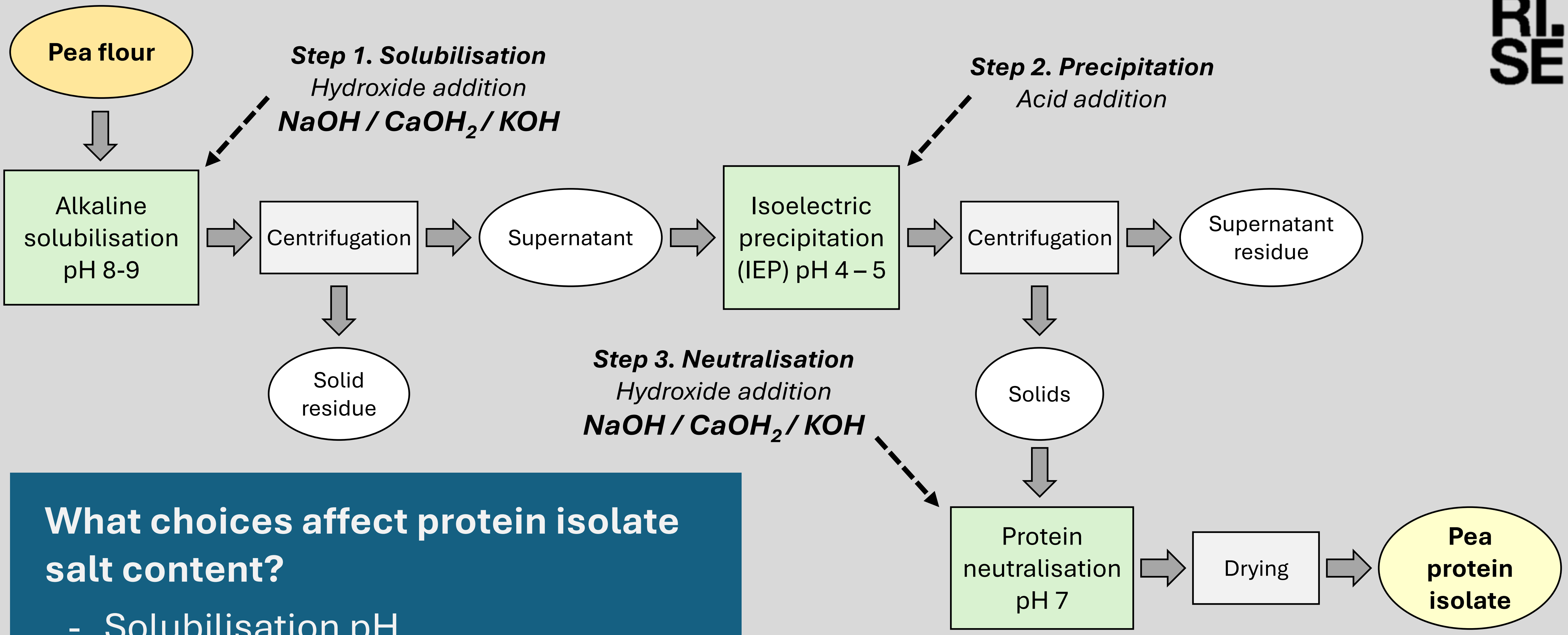
- Can we develop an ingredient that meets these requirements?
- Is it tasty? Does salt reduction make it less palatable with consumers?
- Is the process sustainable on a life-cycle basis?
- What are the wider health implications of a plant-based diet with lower Na intake?

Alessandrini, et al., 2021. https://doi.org/10.3390/nu13124225; Bryngelsson, et al., 2022. https://doi.org/10.1080/09637486.2022.2078286; Mayer-Labba, et al., 2022. https://doi.org/10.3390/nu14193903; Grea at al., 2023. https://doi.org/10.3390/nu15183864



What choices affect protein isolate salt content?

- Solubilisation pH
- **Base choice** ⇦
- Isoelectric precipitation (IEP) pH
- IEP or filtration
- Neutralisation pH



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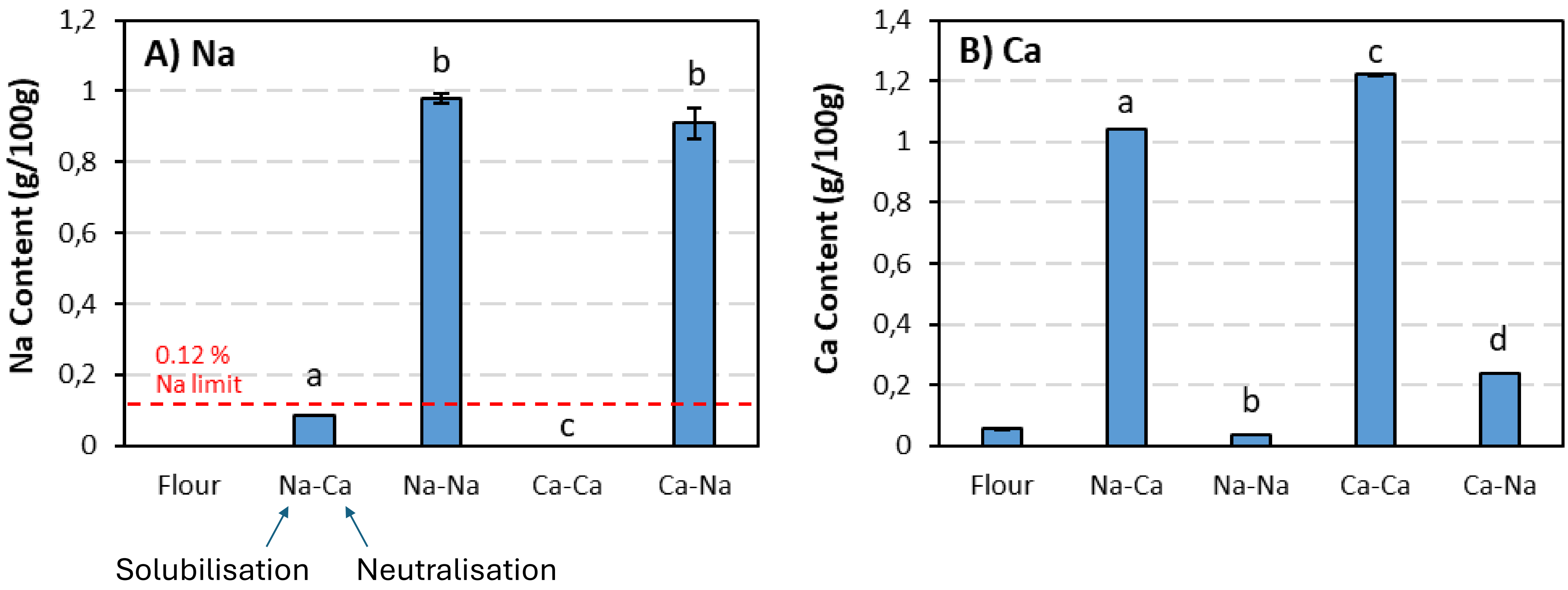
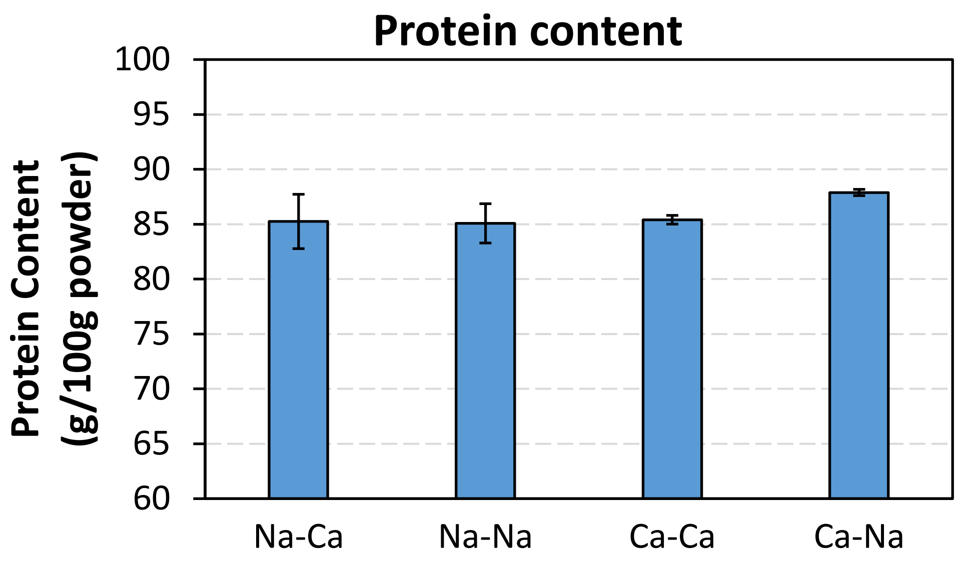
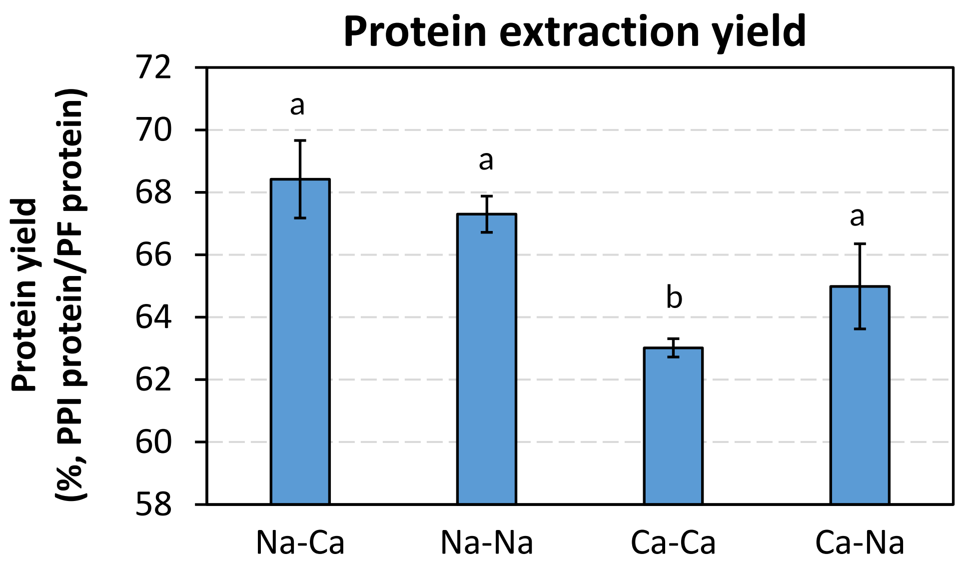
Swapping NaOH for $CaOH_2$ for solubilisation and/or neutralisation

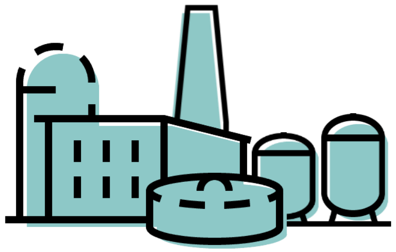
Still possible for low sodium and high yields



Influence of base choice: Purity & yields







- Same protein content.
- Lower protein extraction yield for $CaOH_2$ extraction

5% yield drop = 500 t decrease in protein extracted per year for a 50 kt refinery

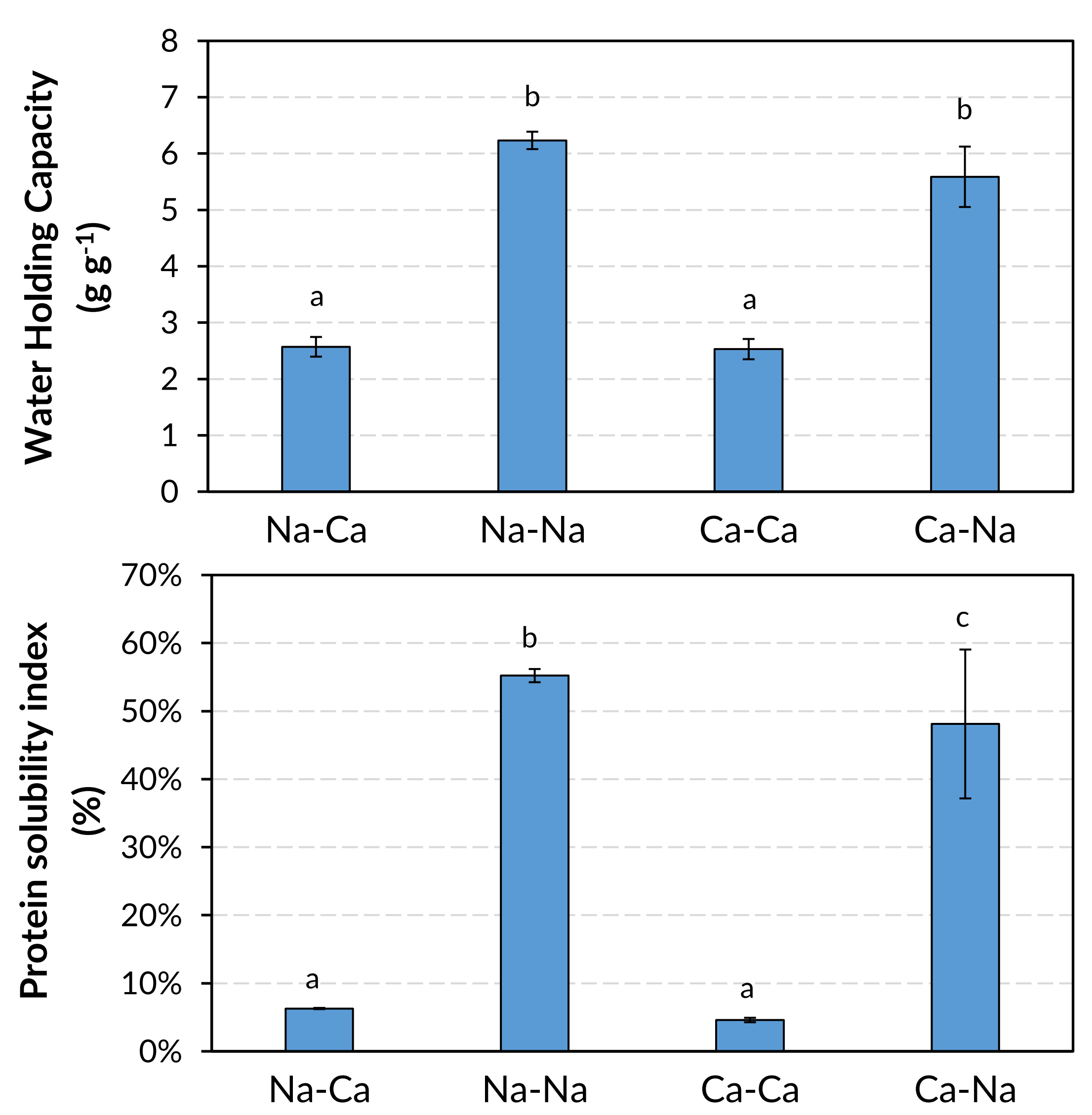
Small difference but a large impact at scale!

Swapping NaOH for $CaOH_2$
for solubilisation and/or neutralisation

Functionality?

High Ca-neutralisation significantly decreases WHC and solubility versus Na.

High WHC is desirable for extrusion of texturized vegetable protein (TVP).



Not for dissemination. Mayers et al. *In prep*

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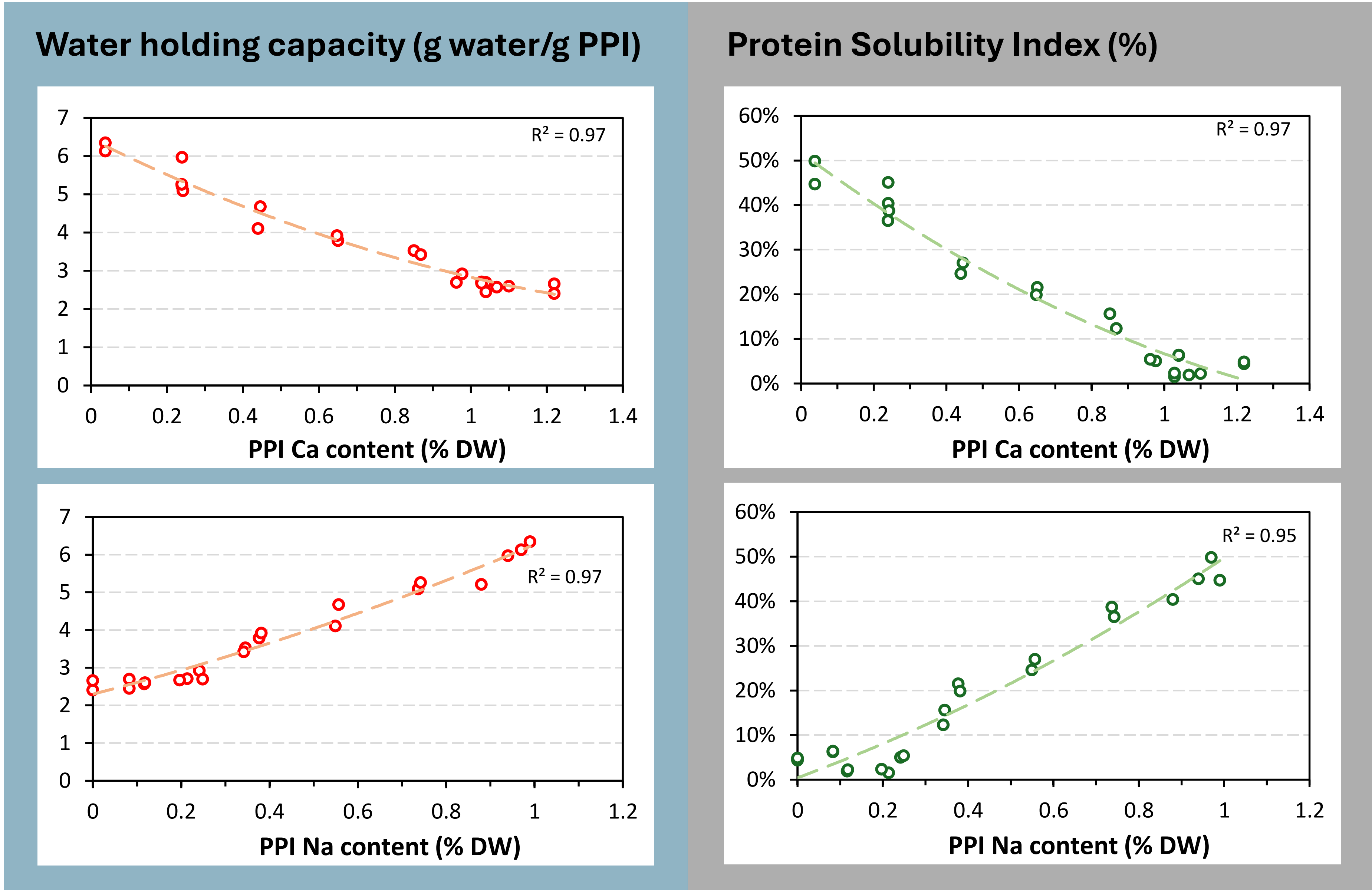
Can we modulate functionality by controlling the mineral profile, i.e. Na and Ca content?

Blends of $CaOH_2$ and NaOH used during neutralisation.

Ca^{2+} inversely proportional to WHC and PSI.

High WHC is desirable for extrusion of texturized vegetable protein (TVP).



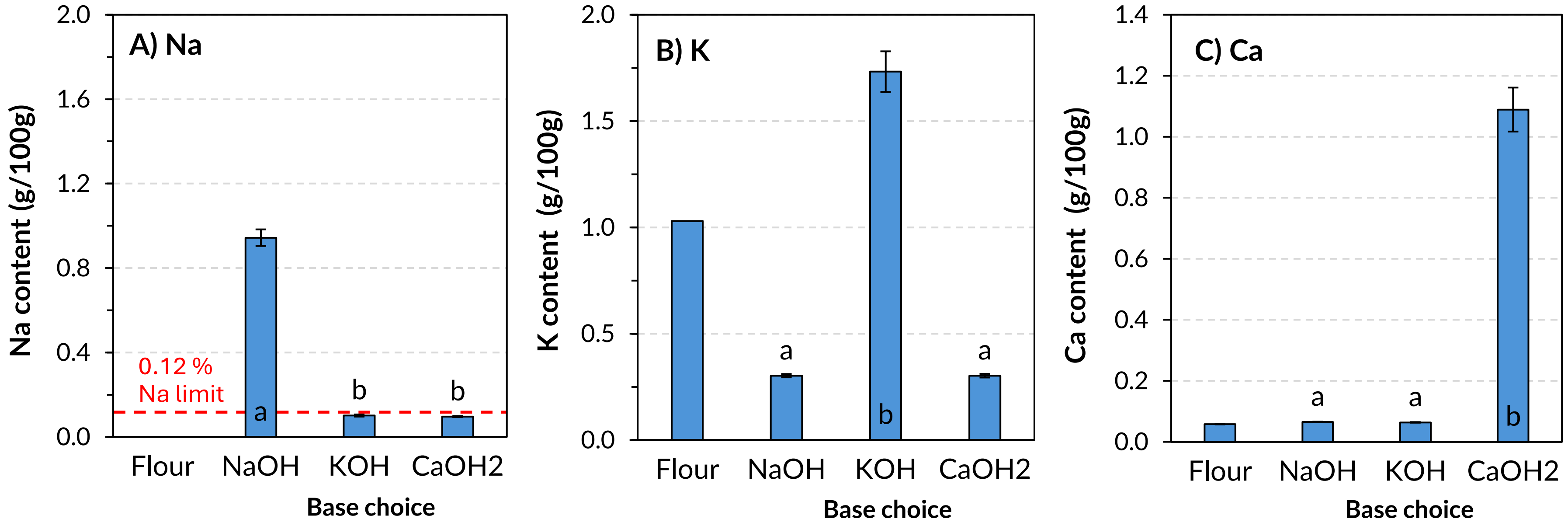
Ahlinder et al. *In prep*

Case 2 – KOH for neutralisation

Protein content + Protein extraction yield = same for NaOH and KOH

Neutralisation base has no influence extraction parameters

Low sodium with no impact on functionality!



Potassium salts known to have a bitter and salty taste.
Sensory evaluation up-coming on PPI with NaOH, KOH and $CaOH_2$!

[EFSA recommends 3.5 g K per day – K not typically lacking in vegetarian diet]

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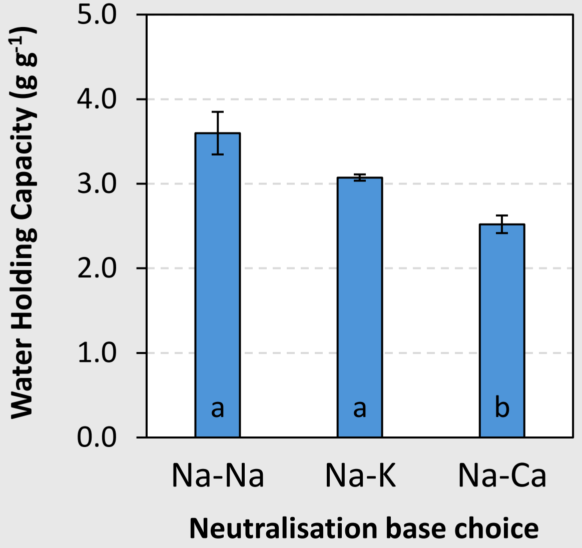
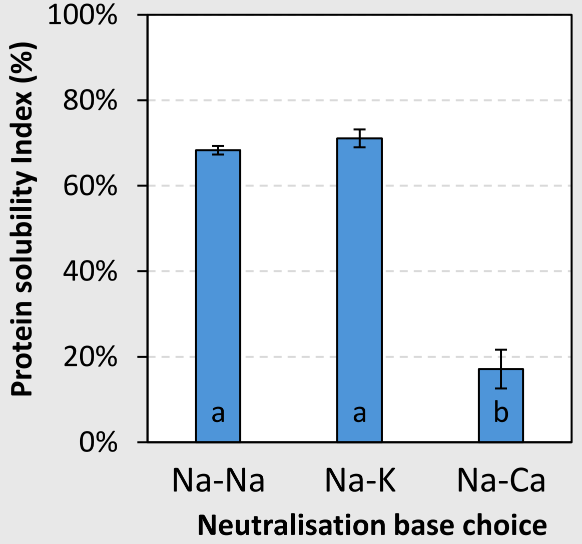
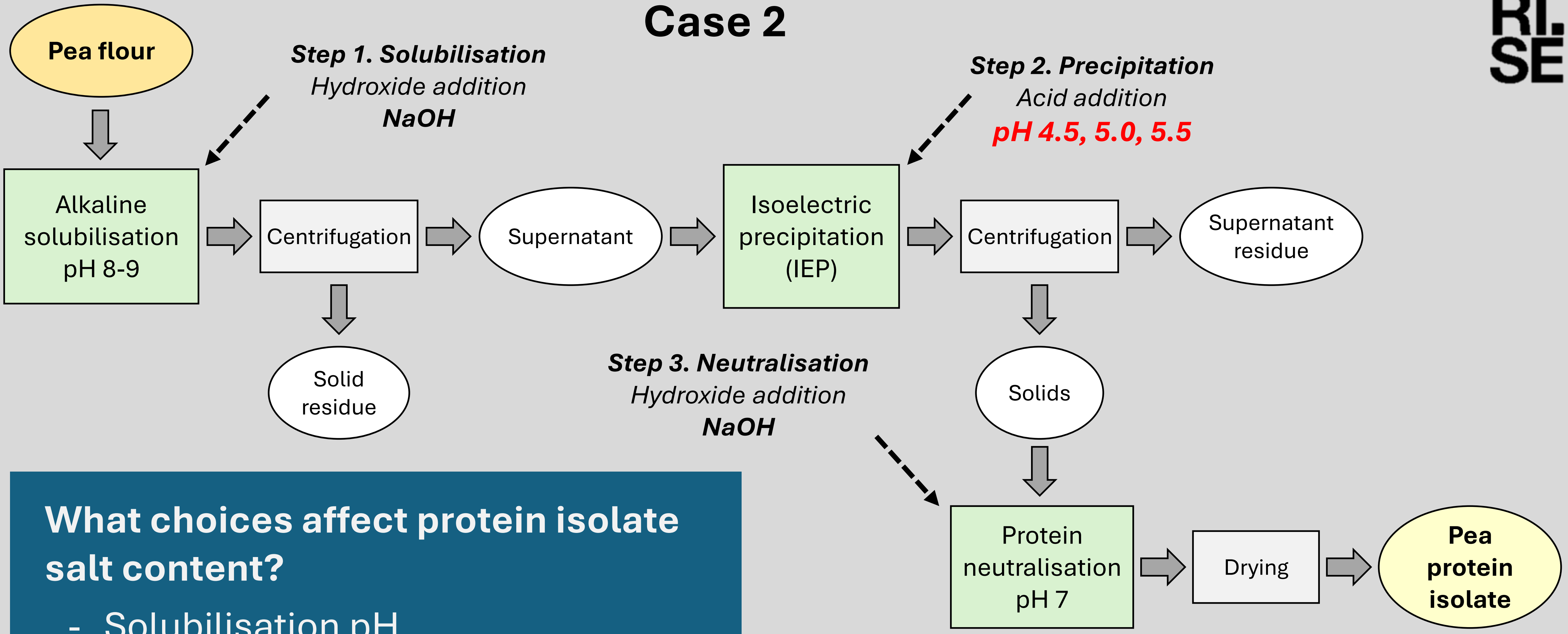
Water holding capacity



Protein solubility index



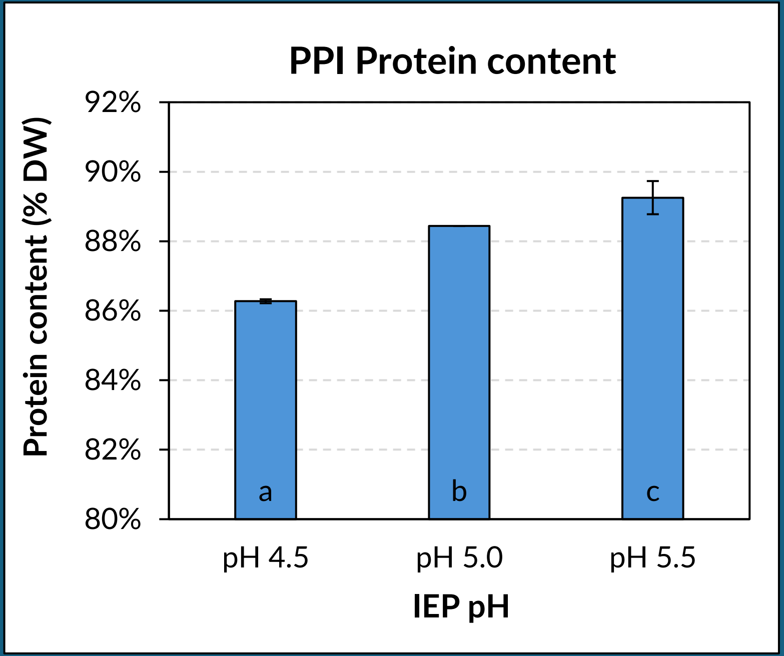
Case 2



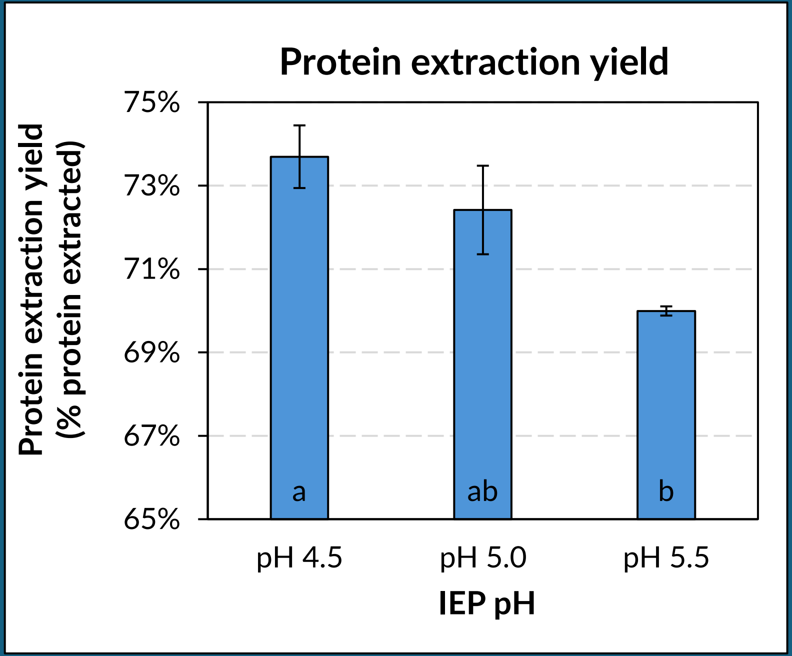
What choices affect protein isolate salt content?

- Solubilisation pH
- Base choice
- **Isoelectric precipitation (IEP) pH**
- IEP or filtration
- Neutralisation pH

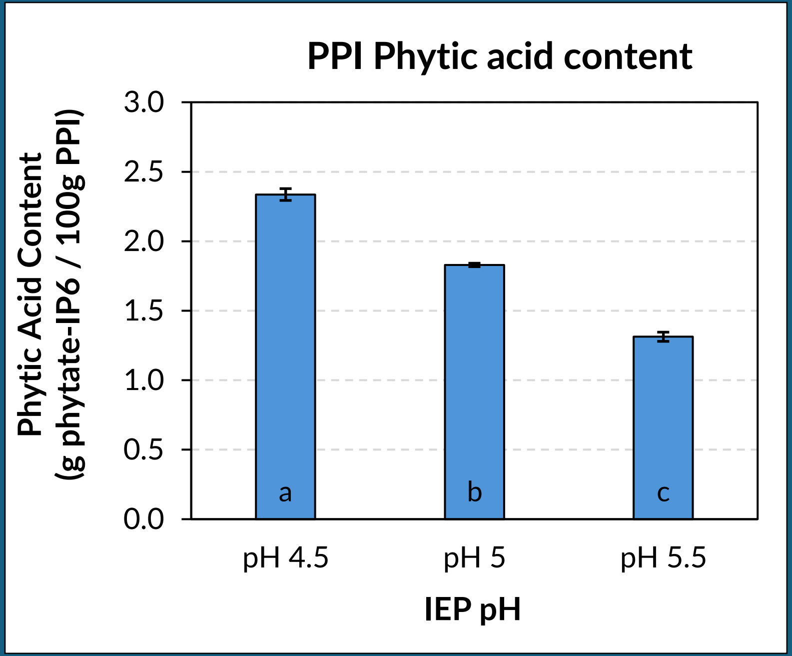
Case 2 – Impact of IEP – Extraction performance



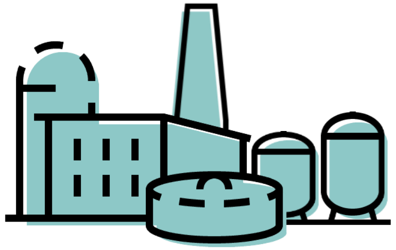
Higher protein content at higher IEP pH



Higher protein yield at lower IEP pH



45% phytate decrease from pH 4.5 → 5.5



Likely optimal pH for protein content is the IEP of 4.6.
Demonstrated the same functionality.

Yield decrease equal to 350 t PPI yr^{-1} production loss

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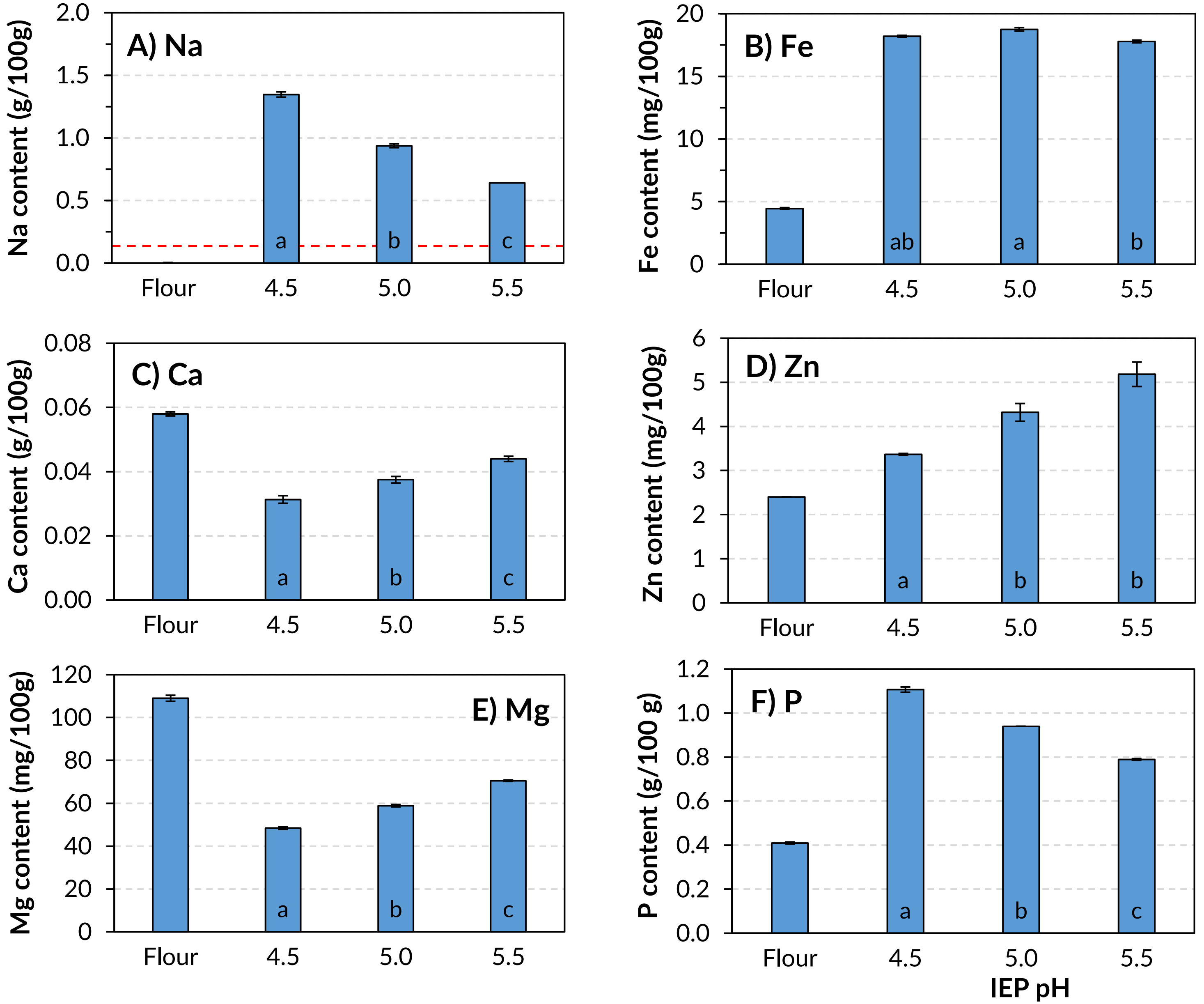
Case 2 – Influence of isoelectric precipitation pH – PPI Mineral content



Precipitation pH affects final PPI mineral content.

Higher Na content at low IEP pH → higher NaOH.

Fe not significantly impacted.

Ca and Mg lost during processing.

P decreases due to higher phytic acid solubility at higher pH.

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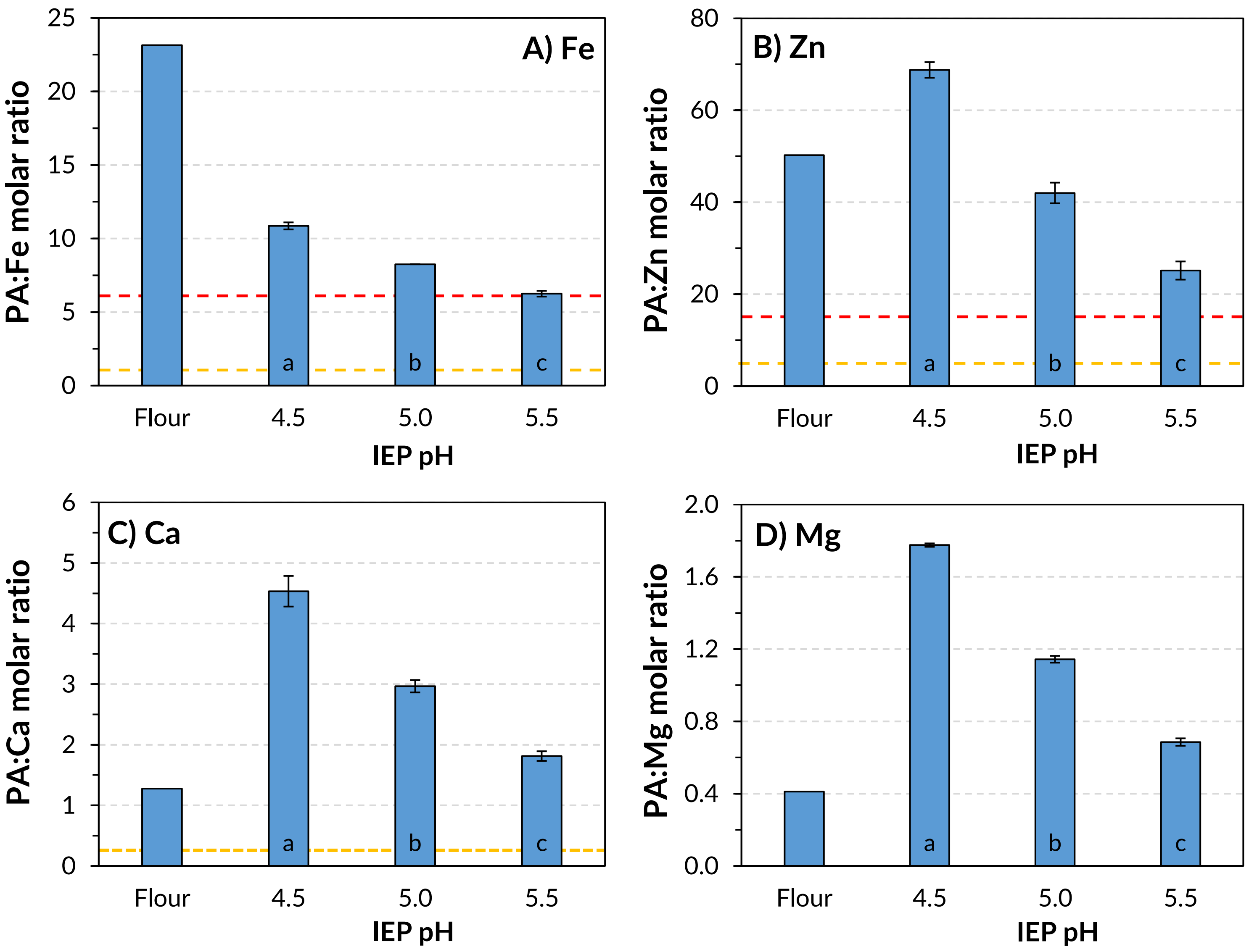
Case 2 – Influence of isoelectric precipitation pH – Phytic acid:mineral molar ratios



Precipitation pH affects final PPI mineral content and PA:mineral ratios.

PA:Fe >6 very poor bioavailability. <1 is preferred[1].

PA:Zn >15 very poor bioavailability. <5 is preferred[2].

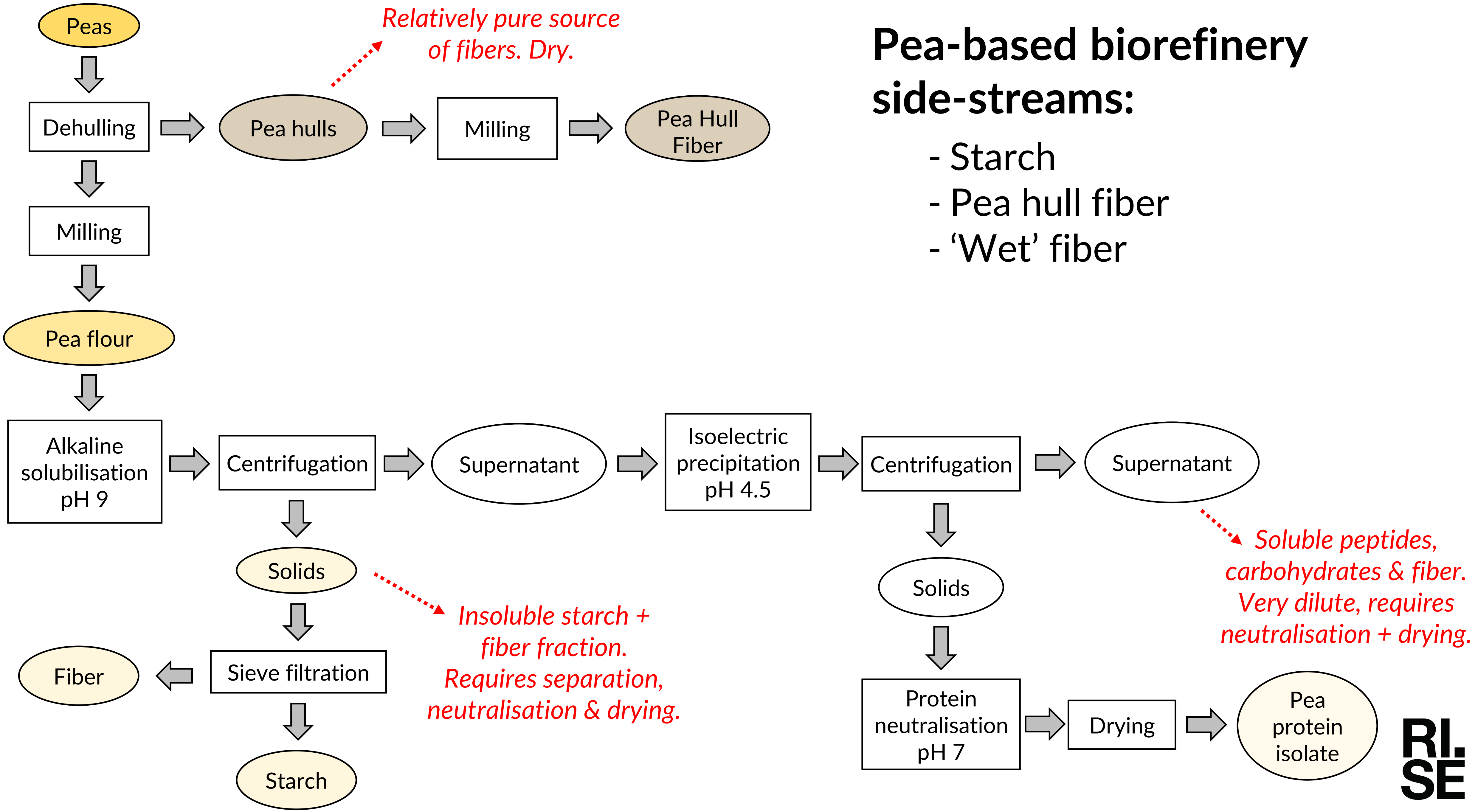
Combination of reduced PA and higher Zn, Ca and Mg.

1) Hurrell, R.F. and Egli, I., 2010. *Am. J. Clin. Nutr.*, 91(5):1461-1467

2) International Zinc Nutrition Consultative Group (IZiNCG); *Food Nutr. Bull.*, 2004 Mar;25(1 Suppl 2):S99-203. PMID: 18046856.

Pea-based biorefinery side-streams:

- Starch
- Pea hull fiber
- ‘Wet’ fiber



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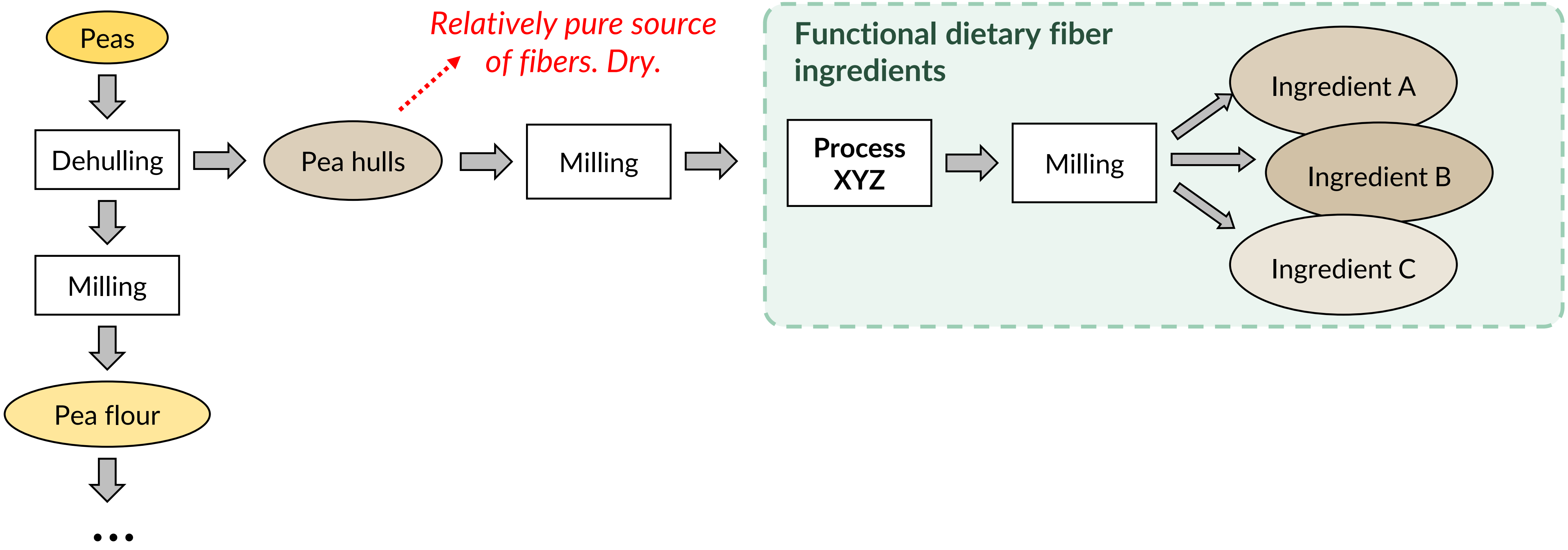
Utilising pea hull fiber

- 7-14% of pea mass depending on feedstock and dehulling efficiency
- Pea hull fiber (PHF) typically contains >75% DM dietary fiber, high in arabinoxylans.
- Neutral flavour and light in colour
- Promising in baking, snack and PMBA/meat-based applications for increasing fiber content
- EC high fiber nutritional claim requires >6 g fiber/100 g (3 g / 100 kcal)

Valdivieso Ramirez, et al., 2021. Production of pea hull soluble fiber-derived oligosaccharides using subcritical water with carboxylic acids.
Jakob, et al., 2024. Effect of heating of pea fibres on their swelling, rheological properties and in vitro colon fermentation.

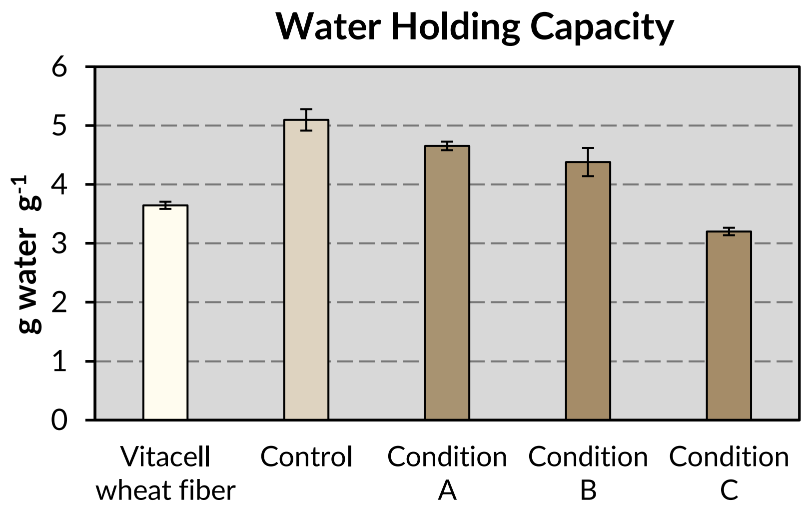
Linking process conditions to ingredient properties for optimised process control and ingredient design.

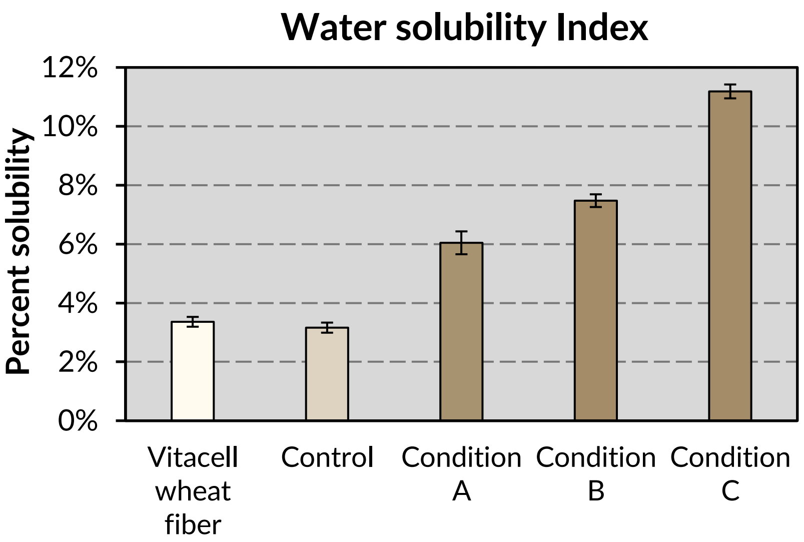
Aim: Multiple ingredients with functionalities optimised for specific applications.

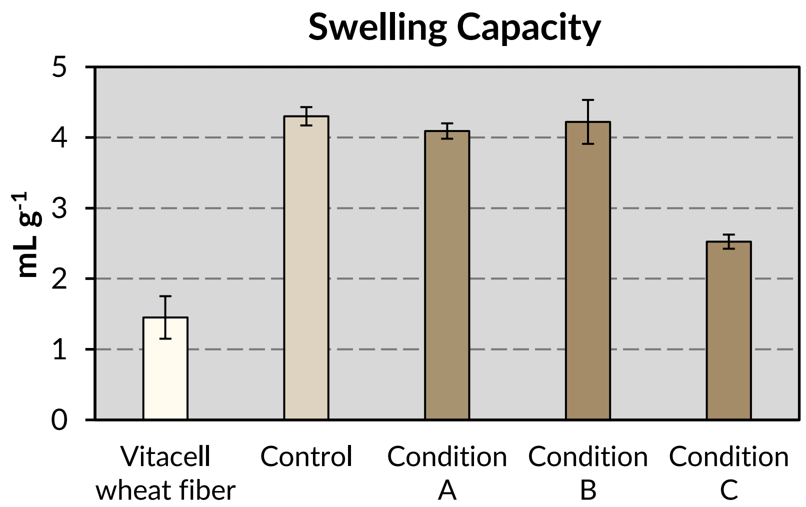


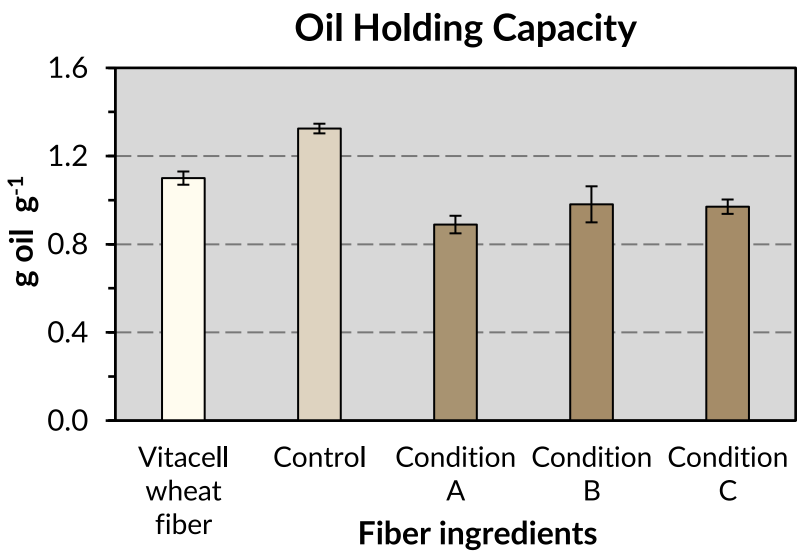
Pea Hull Fiber modification for food applications

HULFiE









Can modify properties to give different functionalities.

Increased soluble dietary fiber.

PHF comparable to Vitacell wheat fiber.

Further optimisation to come…

5% inclusion in white breads show no differences and increased fiber content

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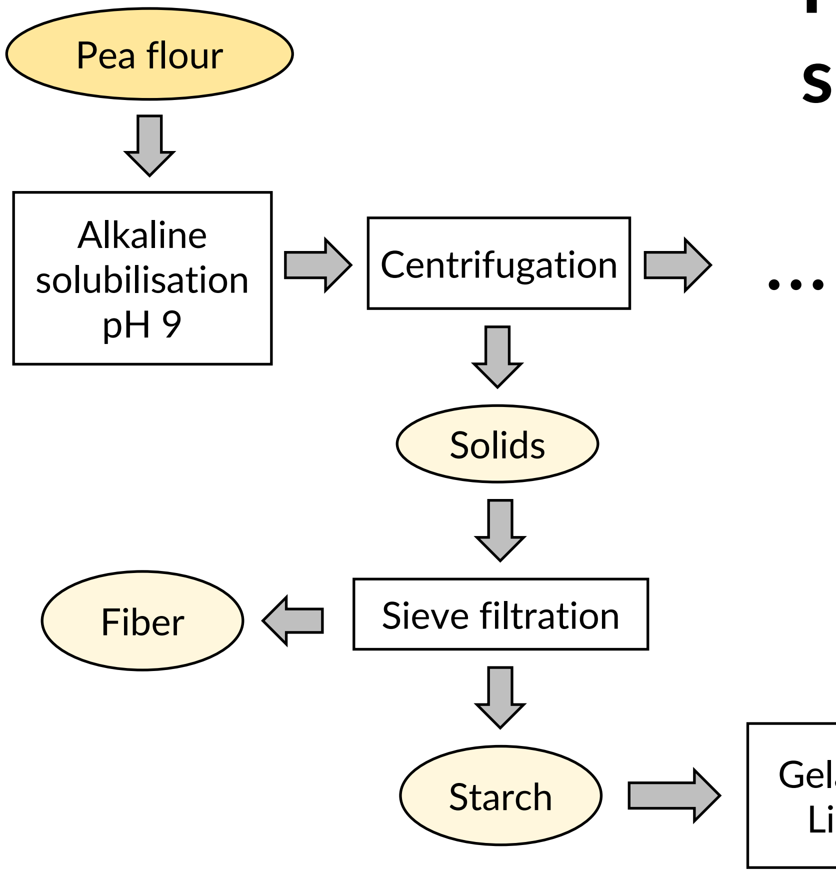
Pea-based biorefinery side streams:

PLANTOMYC

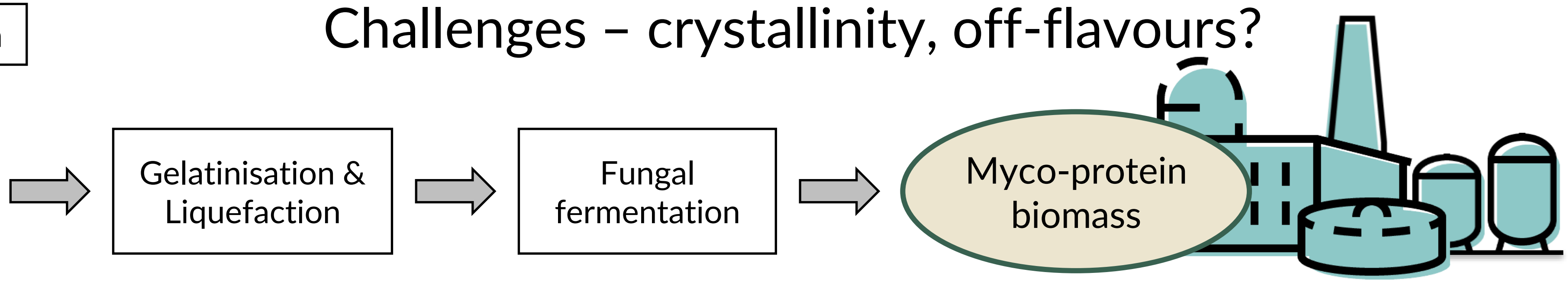
Funded by Horizon Europe



- **Starch**

  Legume starch becoming very abundant – Possible competitive replacement of corn, sugar beet, wheat starches in Europe for fermentation?

  Challenges – crystallinity, off-flavours?



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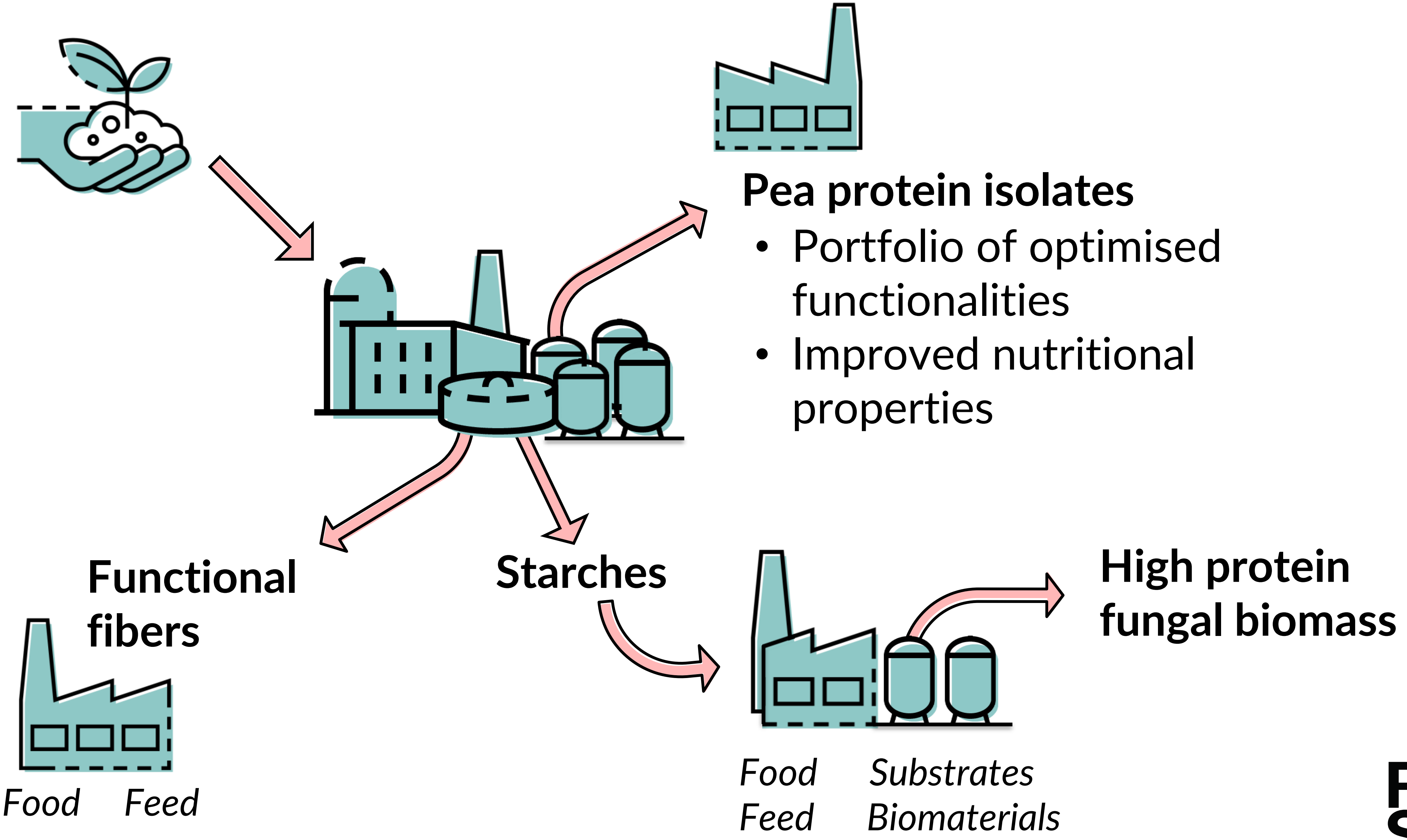
Legumes-based biorefineries



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PILSNER
For healthier pea ingredients

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PLANTOMYC

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