Introduction de protéines végétales dans les laits infantiles : opportunités et verrous fonctionnels et nutritionnels

Amélie Deglaire, Francoise Nau, Linda Le Roux, Raphaël Chacon, Romain Jeantet

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Linda LE ROUX – Raphaël CHACON

Romain JEANTET

Colloque GPN (Groupe Protéines et Nutrition) – 31 mai 2022

INFANT AND FOLLOW-ON FORMULAS

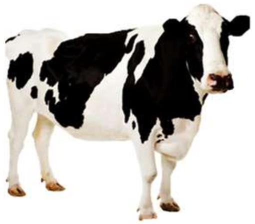
Protein composition

	 Cow milk	 Human milk
Protein (g/100 ml)	**3.3**	**0.9-1.7**
Caseins (%)	*80*	*32-42*
Whey proteins (%)	*20*	*53-66*

Infant formula

=

50 %



Cow milk proteins

+

50 %

Whey proteins

≈

Human milk

Ratio caseins/whey proteins ≈ 40/60

(Chatterton et al. 2013; Le Hërou-Luron et al. 2018)

Cow milk

33 % protein

ALTERNATIVE PROTEIN SOURCES

Algea

50-70% protein

Legume

20-40 % protein

Oilseed

13-35 % protein

Cereal

7-15 % protein

Tuber

1-3 % protein

- Valuable nutritional properties
- Interesting functional properties

- Limiting in one or more EAA
- Digestibility lowered by antinutritional compounds
- Source of food allergens
- Off-flavors, color defaults

OBJECTIVE

<u>Research question:</u>

How do alternative protein sources influence the functional properties and the digestibility of infant formulas ?

50 %

+

50 %

~~**Whe teins**~~

Alternative protein sources

=

New infant formula

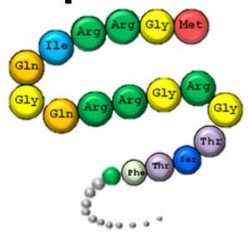
✓ **MANUFACTURING**

✓ **NUTRITION**

✓ **(REGULATION)**

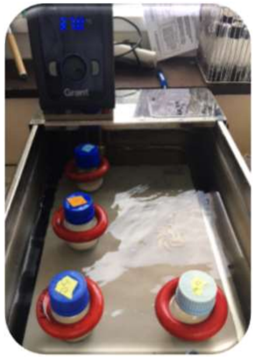
STRATEGY

Alternative protein selection

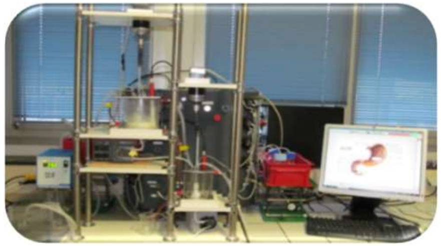


Essential amino acid profile

Infant formula Digestion



In vitro static digestion



In vitro dynamic digestion

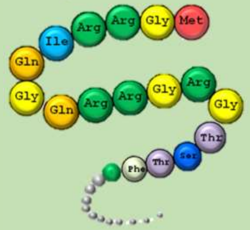
Infant formula Manufacturing

Pilot scale

Semi-industrial scale

STRATEGY

Alternative protein selection



Essential amino acid profile

Which <u>protein sources</u> would be suitable to replace whey proteins in infant formulas ?

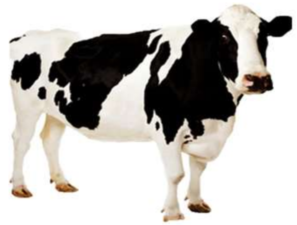
Nutrition

SELECTION OF PROTEINS

New Infant formula

=

50 %



Cow milk proteins

+

50 %

~~Wh… …eins~~

Alternative protein sources

(50 % x Cow milk proteins) + (50 % x Alternative protein)

$$\textbf{PDCAAS-like score } (\%) = \frac{\text{limiting EAA of (}\textbf{New infant formula}\text{)}}{\text{limiting EAA of the }\textbf{Reference}} \times \textbf{Protein digestibility} \times 100$$

Cow milk infant formula

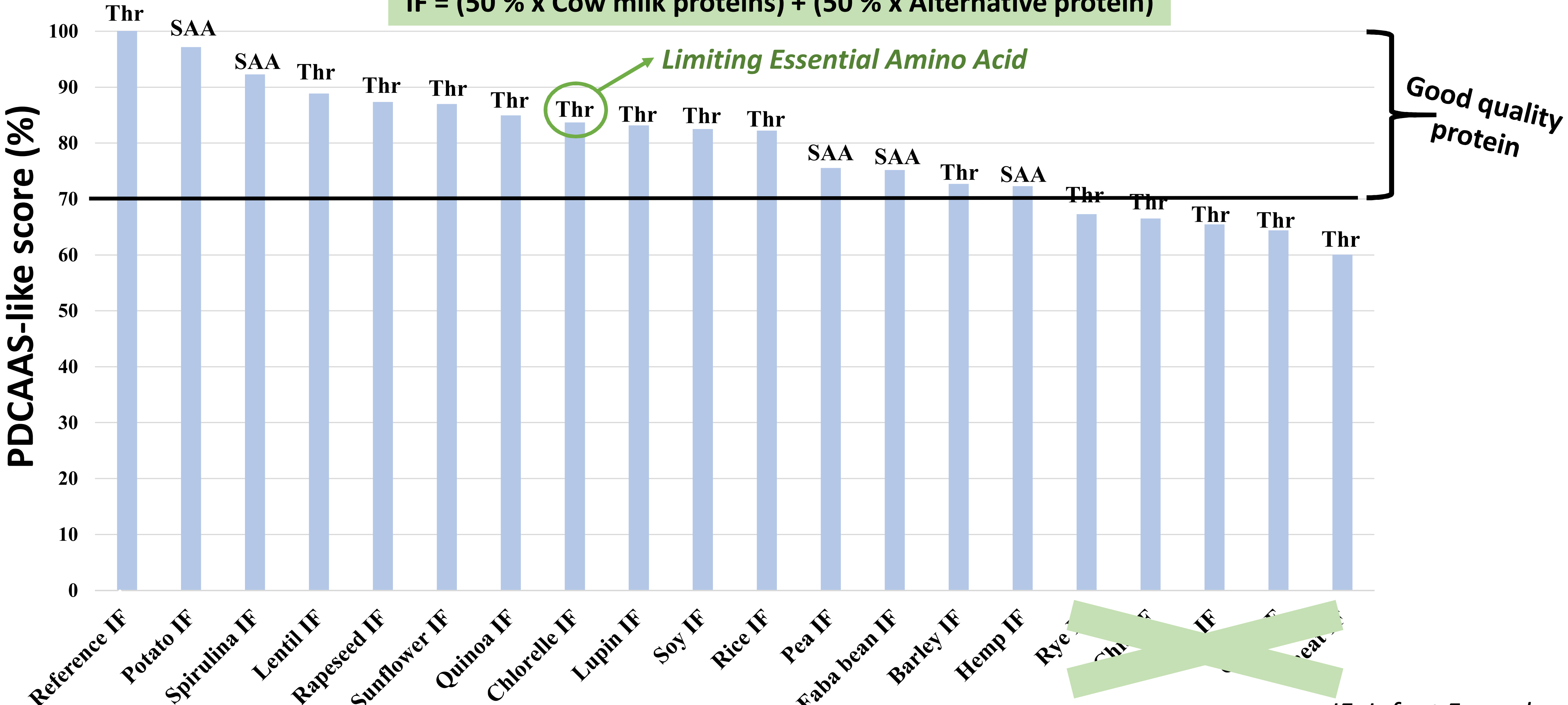
From literature data (*in vivo, in vitro*…)

EAA: essential amino acid

Nutrition

SELECTION OF PROTEINS

IF = (50 % x Cow milk proteins) + (50 % x Alternative protein)



IF: Infant Formula

SELECTION OF PLANT PROTEINS

Protein sources nutritionally adapted to the infant needs — 14 sources / 19 sources

Barley, Rice, Quinoa, Rapeseed, Sunflower, Faba bean, Lentil, Lupin,
Pea, Soya bean, Potato, Chlorella, Spirulina, Hemp

Without allergens — 11 sources

~~Barley~~, Rice, Quinoa, Rapeseed, Sunflower, Faba bean, Lentil, ~~Lupin~~,
Pea, ~~Soya bean~~, Potato, Chlorella, Spirulina, Hemp

Without organoleptic defaults — 9 sources

Rice, Quinoa, Rapeseed, Sunflower, Faba bean, Lentil,
Pea, Potato, Chlorella, ~~Spirulina, Hemp~~

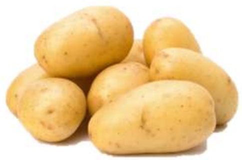
Available in purified form — 4 plant proteins

Pea

Faba bean

Rice

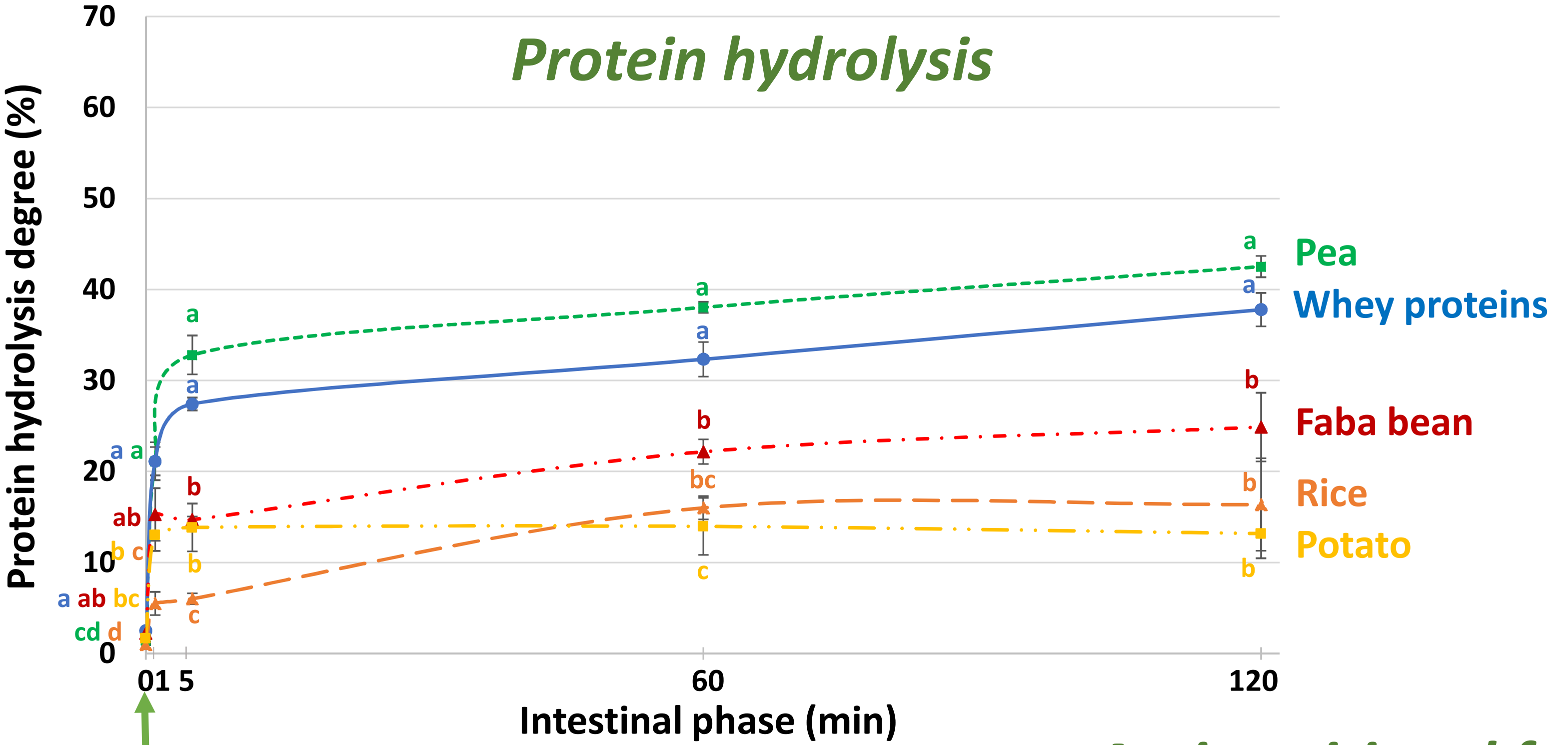
Potato



vs Whey proteins

Digestion

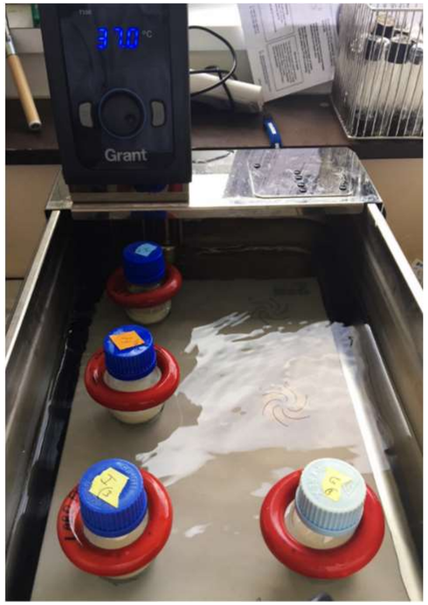
SELECTION OF PROTEINS



End of gastric phase proteolysis < 3%

***In vitro* static digestion infant conditions**

(Ménard et al. 2018)



Antinutritional factor

	Control	Reference	Pea	Faba bean	Rice	Potato
Trypsin activity (U/mg)	105.1 ± 5.0 [a]	108.5 ± 0.9 [a]	108.6 ± 0.5 [a]	109.2 ± 3.4 [a]	107.4 ± 1.1 [a]	**24.1 ± 2.8 [b]**

HIGHLIGHTS

Alternative protein selection

- *In vitro* digestion → Pea close to the Reference but Potato poorly digested due to ANF

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In vitro static digestion reveals how plant proteins modulate model infant formula digestibility

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[b] STLO, INRA, AGROCAMPUS OUEST, 35042 Rennes, France

STRATEGY

How do protein sources affect the <u>manufacturing and the functional properties</u> of infant formulas?

Infant formula Manufacturing

Pilot scale

Semi-industrial scale

MANUFACTURING

Pilot scale

Evaporation capacity
3-5 kg/h

Concentration
70 kg/h

Homogenization
Low pressure

Spray-drying
High temperature

Scale-up

Ingredients
(Powders)
↓
Solution
↓
Solution pasteurized
↓
Concentrate
↓
Concentrate homogenized
↓
Infant formula Powder

Semi-industrial scale

Concentration
280 kg/h

Homogenization
Low pressure | *High pressure*

Spray-drying
High temperature | *Low temperature*

Evaporation capacity
90 kg/h

MANUFACTURING

Pilot scale

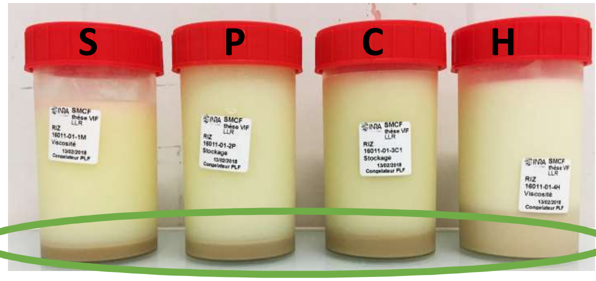
SOLUBILIZATION (S)
↓
PASTEURIZATION (P)
↓
CONCENTRATION (C)
↓
HOMOGENEIZATION (H)
↓
SPRAY DRYING
↓
INFANT FORMULA

Viscosity limits

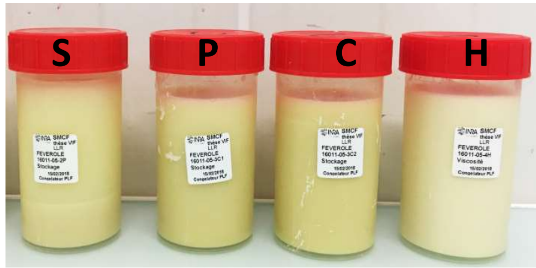
Potato infant formula

Solubility limits

Rice infant formula



Faba bean infant formula



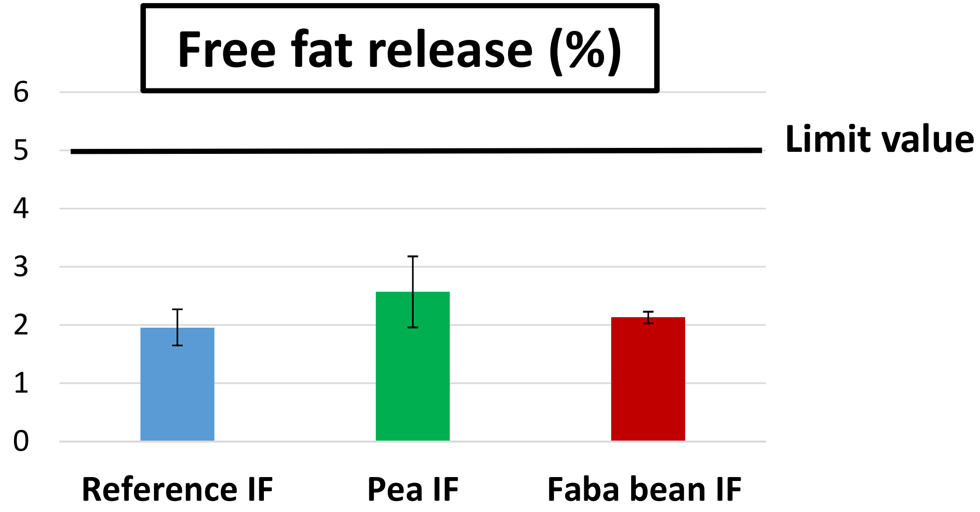
MANUFACTURING

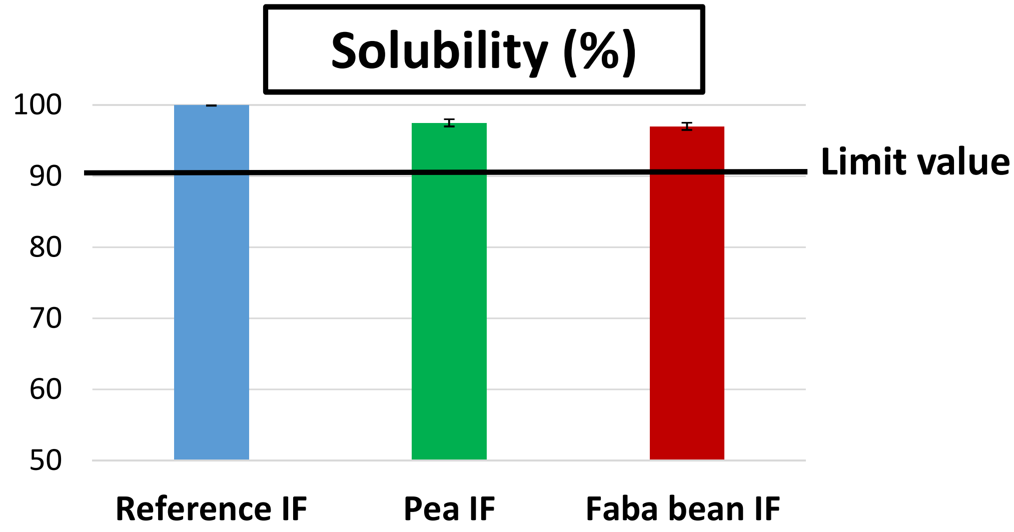
SCALE-UP

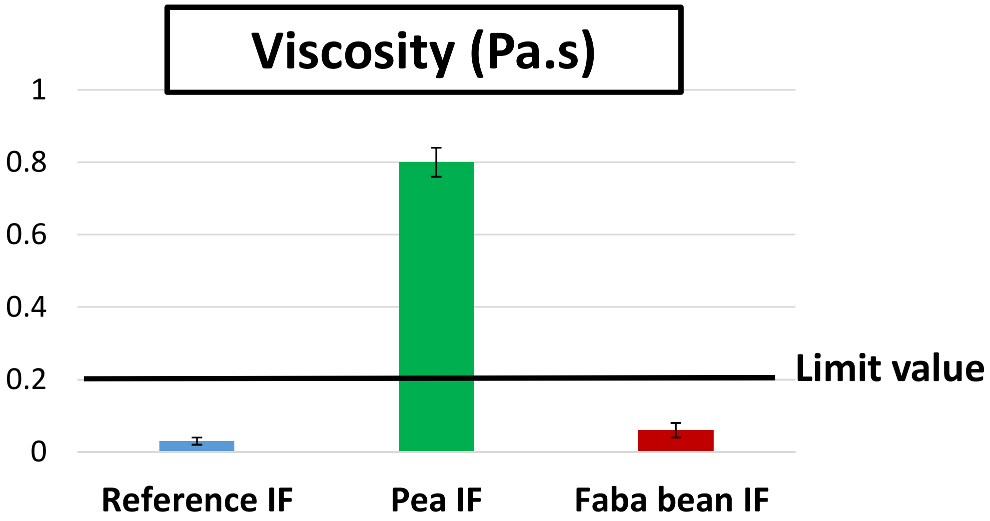
Reference IF | Pea IF | Faba bean IF

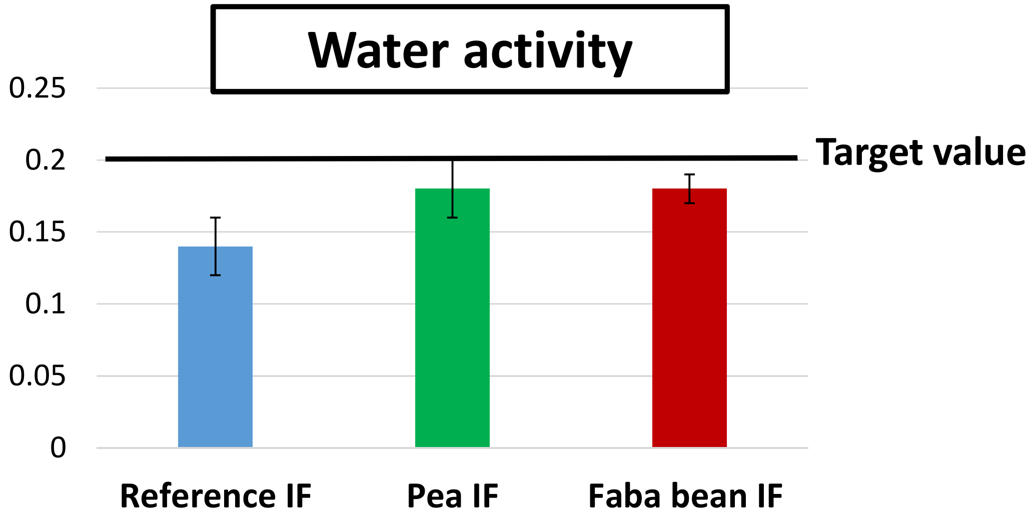
Functionalities

MANUFACTURING









HIGHLIGHTS

LWT - Food Science and Technology 120 (2020) 108891

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LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

ELSEVIER

Plant proteins partially replacing dairy proteins greatly influence infant formula functionalities

Linda Le Roux[a,b], Serge Mejean[b], Raphaël Chacon[a], Christelle Lopez[b], Didier Dupont[b], Amélie Deglaire[b], Françoise Nau[b], Romain Jeantet[b,*]

[a] Sill Dairy International, Raden, 29860, Plouvien, France
[b] STLO, INRA, AGROCAMPUS OUEST, 35042, Rennes, France

Infant formula Manufacturing

Solubility and Viscosity limits

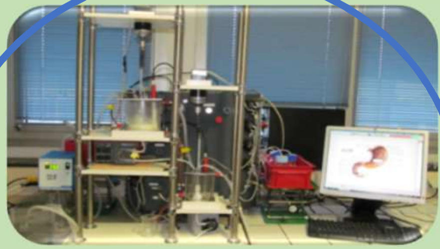
Protein aggregates in Pea IF and Faba bean IF compared to the Reference IF

STRATEGY

How do protein sources affect the digestibility of infant formulas?

Infant formula Digestion

In vitro static digestion



In vitro dynamic digestion

DIGESTION

Reference IF | Pea IF | Faba bean IF

x3

Infant formula
at 1.3 g/100 mL proteins

Gastric compartment

$t_{1/2}$ = 78 min ; β=1.2
pH = -0.0155 x time + pH(IF)
+ Pepsin (no gastric lipase)

Intestinal compartment

$t_{1/2}$ = 200 min ; β = 2.2
pH = 6.2
+ Bile + Pancreatin

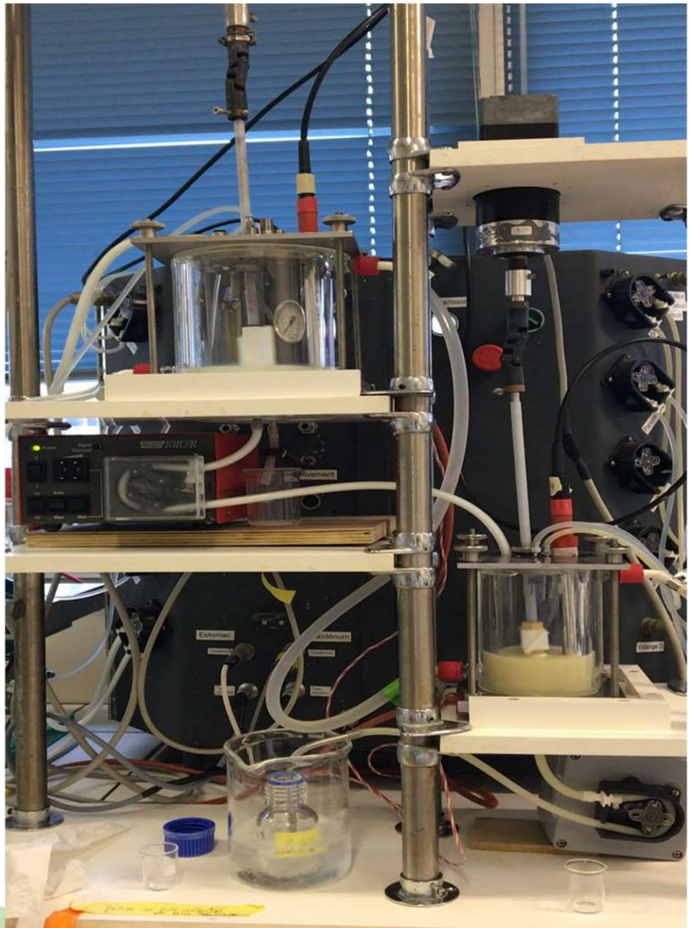
37°C during 180 min

Sample collection over time

- **Free amino acids**
- **Microstructure analysis**
- **Protein digestibility**

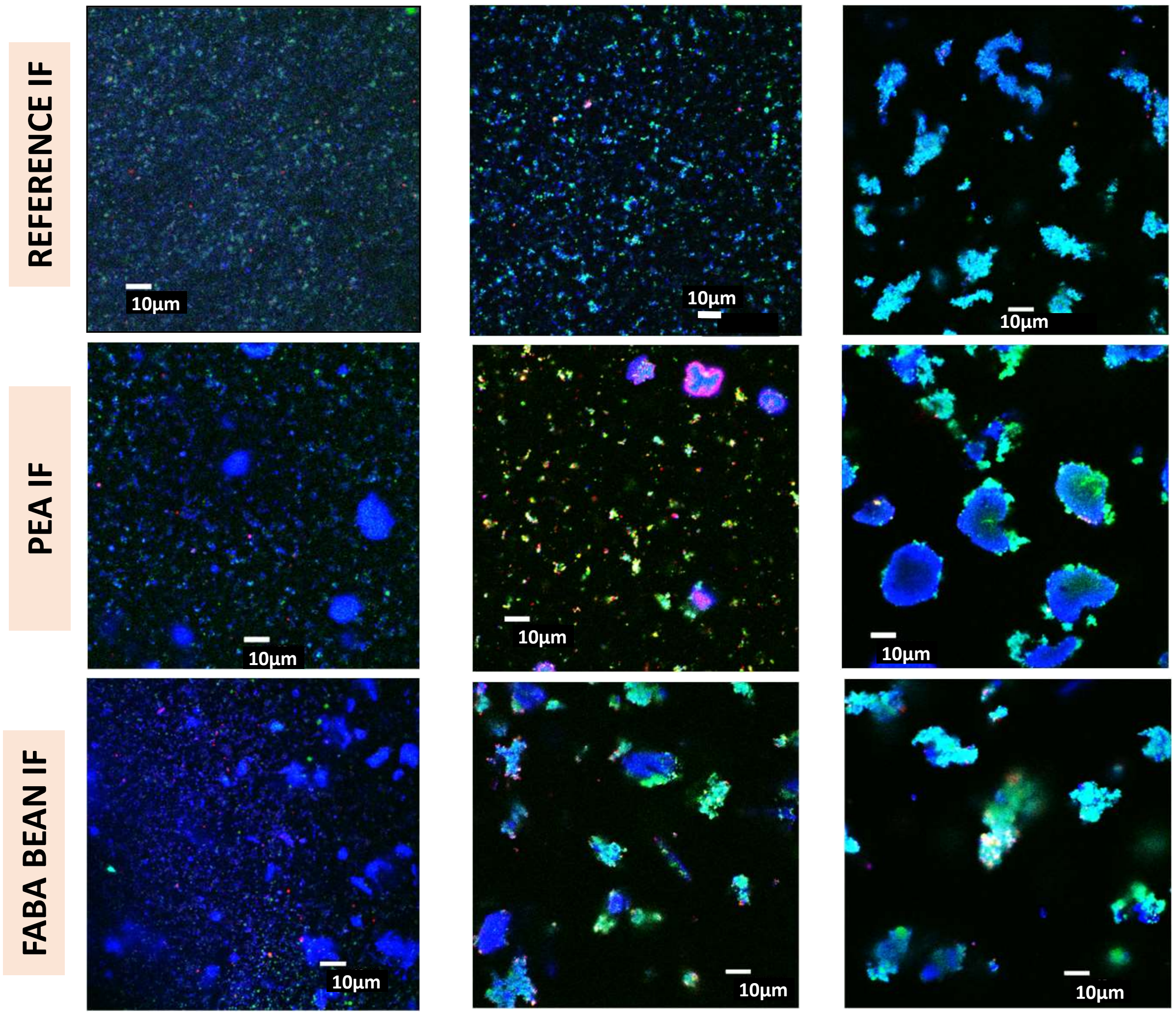
In vitro dynamic digestion DIDGI®

Validated from _in vivo_ studies for infant protein digestion
(Ménard et al. 2014)

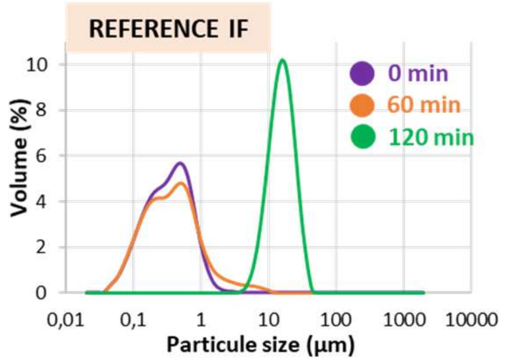


Structure **DIGESTION**

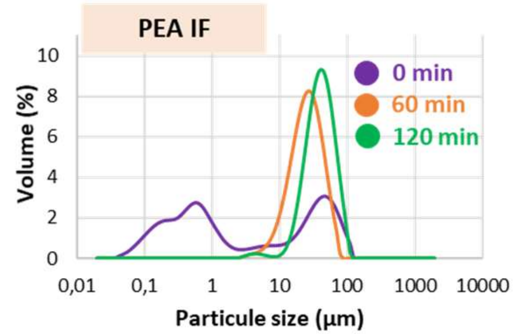
0 min pH=6.8 ± 0.1 | 60 min pH=5.9 ± 0.1 | 120 min pH=4.9 ± 0.1



Gastric Compartment

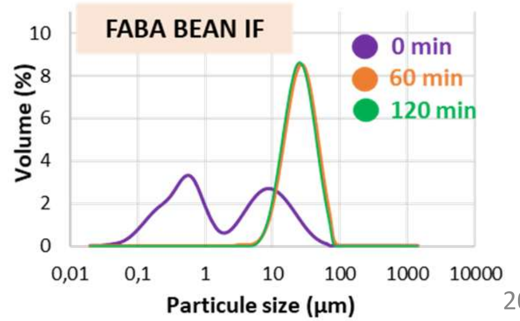


Protein	pI
Whey	5.2
Pea	6.1
Faba bean	5.8



Confocal microscopy
- Proteins
- Lipids
- Amphiphilic

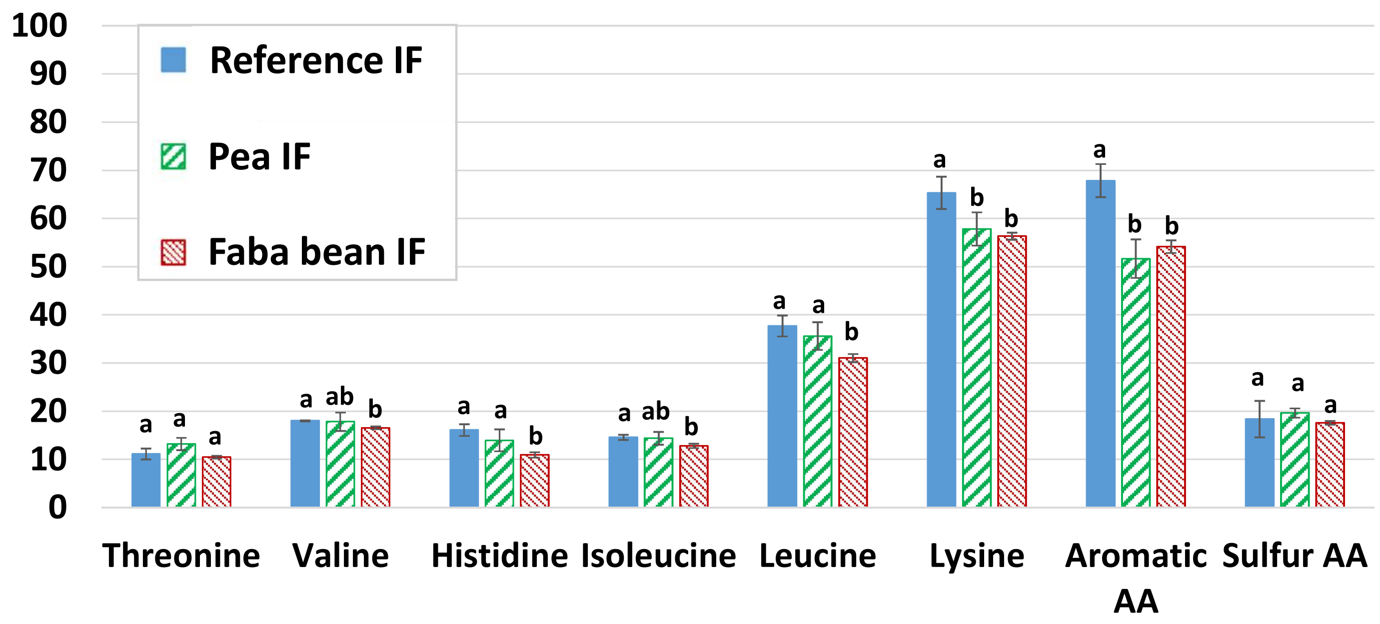
IF: infant formula



Bioaccessibility

DIGESTION

Free essential amino acids (%) at the end of the digestion



Bioaccessibility is slightly higher for the Reference IF compared to Pea IF and Faba bean IF for some amino acids

Context | Objective | 1. Selection | 2. Manufacturing | 3. Digestion | Conclusion | Perspectives

Digestibility

DIGESTION

PDCAAS-like score (%) = $\frac{\text{limiting EAA of (Infant Formula)}}{\text{limiting EAA of the Reference}}$ x ***In vitro*** **protein digestibility** x 100

$$\frac{\Sigma\, N < 10\ \mathrm{kDa}\ (\text{end of the digestion}) = \text{N absorbable}}{\text{N ingested}}$$

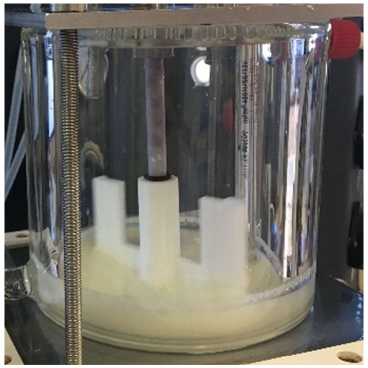
(Cave 1988; Huang et al. 2000; Moughan 1999)

(FAO, 2013)

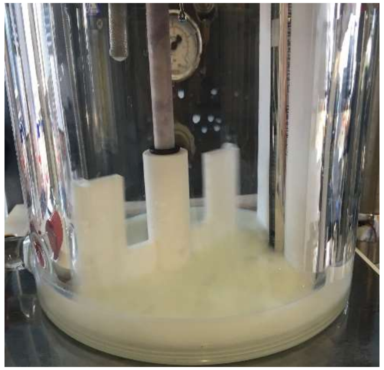
Age Group	His	Ile	Leu	Lys	SAA	AAA	Thr	Trp	Val
	scoring pattern mg/g protein requirement								
Infant (birth to 6 months)[1]	21	55	96	69	33	94	44	17	55
Child (6 months to 3 year)[2]	20	32	66	57	27	52	31	8.5	43
Older child, adolescent, adult[3]	16	30	61	48	23	41	25	6.6	40

	Limiting EAA	*in vitro* Digestibility (%)	PDCAAS-like score (%)
Reference IF	AAA	89.2 ± 3.9 [a]	76.1 ± 3.3 [a]
Pea IF	**Ile**	**74.9 ± 6.7 [b]**	**67.5 ± 6.0 [b]**
Faba bean IF	Ile	91.1 ± 3.1 [a]	75.4 ± 2.5 [ab]

Solubility limits during *in vitro* digestion



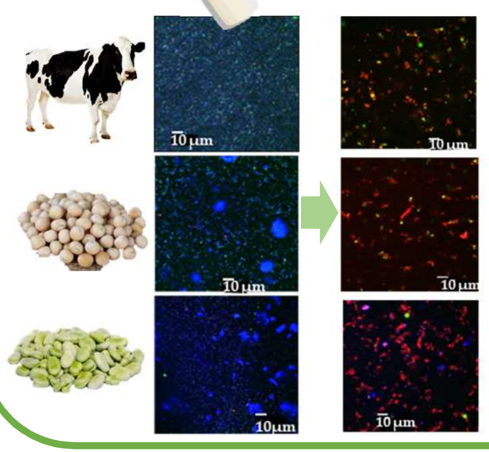
Pea IF



Reference IF

HIGHLIGHTS

Infant formula Digestion



Similar microstructure at the end of digestion

***in vitro* protein digestibility:**

Faba bean IF = Reference IF > Pea IF

foods
MDPI
Article

Are Faba Bean and Pea Proteins Potential Whey Protein Substitutes in Infant Formulas? An In Vitro Dynamic Digestion Approach

Linda Le Roux [1,2], Olivia Ménard [2], Raphaël Chacon [1], Didier Dupont [2], Romain Jeantet [2], Amélie Deglaire [2] and Françoise Nau [2,*]

[1] Sill Dairy International, Raden, 29860 Plouvien, France; linda.leroux@sill.fr (L.L.R.); raphael.chacon@sill.fr (R.C.)

[2] STLO, INRAE, AGROCAMPUS OUEST, 35042 Rennes, France; olivia.menard@inrae.fr (O.M.); didier.dupont@inrae.fr (D.D.); romain.jeantet@agrocampus-ouest.fr (R.J.); amelie.deglaire@agrocampus-ouest.fr (A.D.)

CONCLUSION

14 protein sources

Nutritionally adapted

9 protein sources

Without allergens and organoleptic defaults

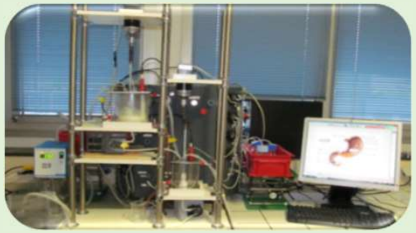
vs **Whey proteins**

Available in purified form

Potato: antinutritional factors

Potato IF: viscosity limits

Rice IF : solubility limits



Poor solubility of p[illegible]F and faba bean IF

Lower digestibility

Good digestibility

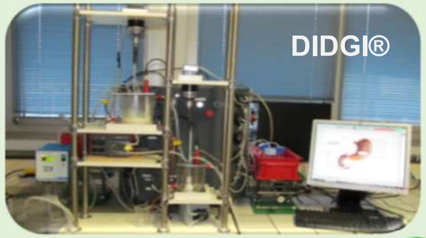
Faba bean good candidate to replace whey protein in infant formulas

PERSPECTIVES

- *In vivo* studies → Allergenicity, microbiota, protein biodisponibility, favisme

In vitro static

IN VITRO

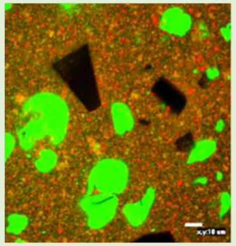


In vitro dynamic

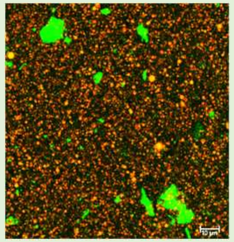
IN VIVO

Piglets

- Functional improvement → Better solubility of plant proteins

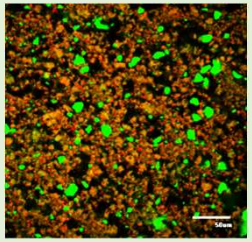


Pea IF

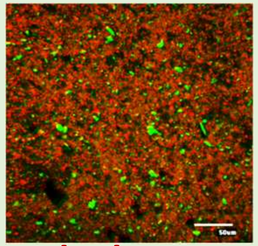


Faba bean IF

Additional homogenization step



Pea IF



Faba bean IF

- Evidence of conformity regarding the European regulation for infant formulas

New protein sources

REGULATION

Better suited for follow-on formula ?

Thank you
for your attention