Unfractionated vegetal shells: it foams !

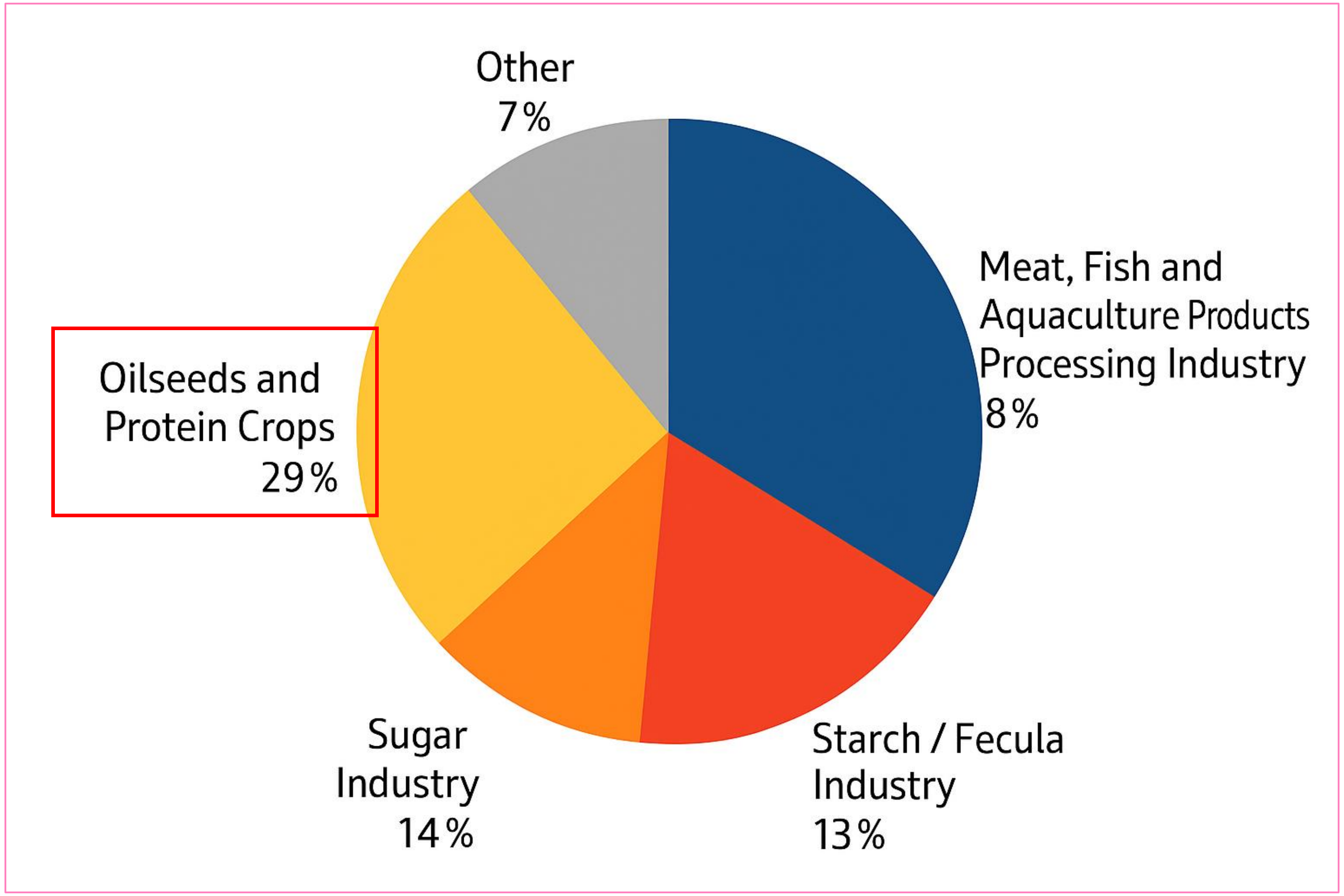
Agathe Tanchoux, Hervé This, Delphine Huc-Mathis

Growing interest in food waste revalorisation

Agri-food waste are rich in valuable compounds[2]

1. Hannah Ritchie, 2020; 2. Socas-Rodríguez *et al.*, 2021

Large volumes of vegetal shells are wasted

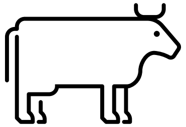


Breakdown of byproduct volume by sector in France[3]

3. Reseda Study, 2017

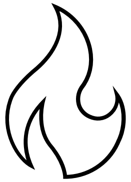
Numerous by-products revalorisation methods

Animal feed



Ex : oil cakes

Methanisation & burning



Materials

- Hard matter
  - Ex : insulation
- Soft matter
  - Ex : emulsion, foam, suspension

Dispersed system with many applications : foam

Foam of yellow pea shell powder

- Widely used in different fields[4] such as:
  - Firefighting
  - Pharmaceutic industry
  - Food industry
- Significant challenge associated = ensuring foam stability
- Often made from petro-sourced compounds
- Consumer demand for natural and clean-label products[5]

4. Xiangfang Hu *et al.*, 2023; 5. Chen *et al.*, 2022

Subjects of study

Food waste

Valuable compounds

Valorisation of by-products

Unfractionated vegetal shells and their foaming properties

Challenge of stability

Foam

Clean label

Three by-product flours

Pistachio shells
Pistachia vera L.

Green pea hulls
Pisum Sativum L.

Yellow pea shells
Pisum Sativum L.

What are the characteristics of these foams ? Which flour foams best ?

Methods

Sparging tests

- Adaptation of the Bikerman's[6] method
- 0.5 mL sample, 5% w. suspension
- Airflow of 50 mL/s during 20s

Foaming test[7]

- Rotor stator
- 100 mL sample, 5% w. suspension
- 10,000 rpm for 3 min

Foam stability & density

6mL syringe

Microscopy

- Optical microscope
- Sample of foam on a slide without coverslip

Granulometry[8]

Laser diffraction particle size analyser

Dry matter[9]

- IR Moisture analyser
- 2g sample

NMR analysis[10]

- 0.7mg sample
- Analysis of the supernatants
- ISQ RMN, 300 MHz
- Number of scan : 2048
- Capillary tube : D_20 + TSP
- Zg 90

pH

6. Bikerman, 1973; 7. Kroezen and Wassink, 1986; 8. Gee and Bauder, 1986; 9. Janas and Kowalska, 2023; 10. This *et al.*, 2021

Methods

Sparging tests

- Adaptation of the Bikerman's[6] method
- 0.5 mL sample, 5% w. suspension
- Airflow of 50 mL/s during 20s

Foaming test[7]

- Rotor stator
- 100 mL sample, 5% w. suspension
- 10,000 rpm for 3 min

Foam stability & density

6mL syringe

Microscopy

- Optical microscope
- Sample of foam on a slide without coverslip

Granulometry[8]

Laser diffraction particle size analyser

Dry matter[9]

- IR Moisture analyser
- 2g sample

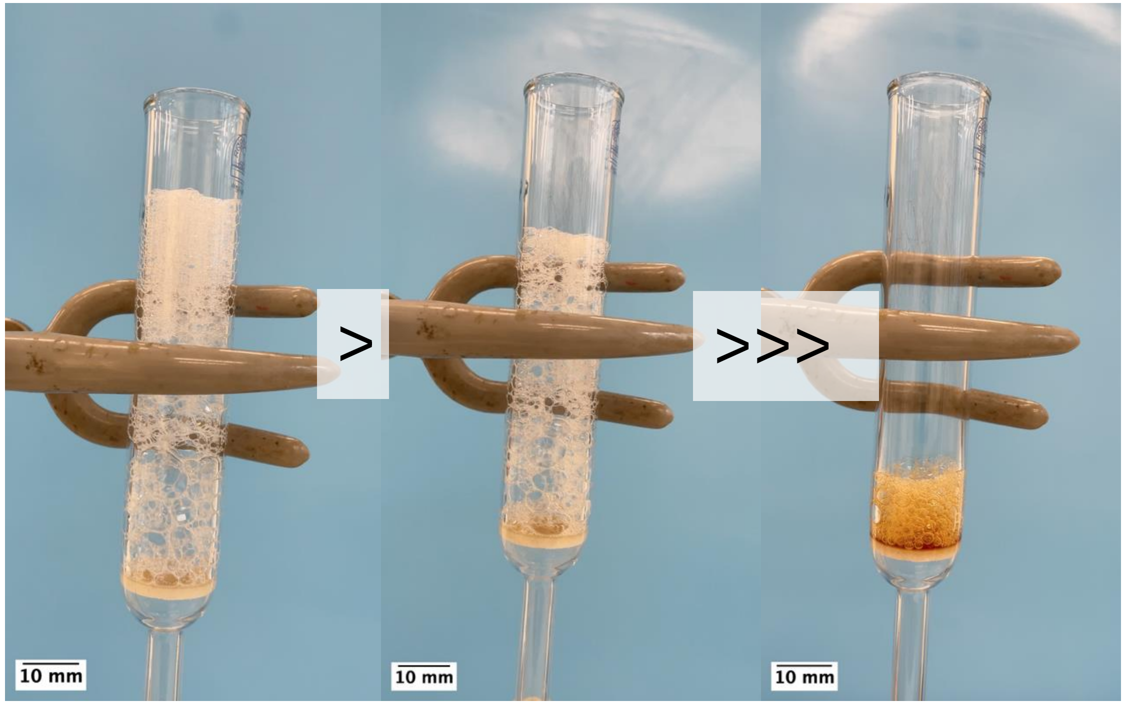
NMR analysis[10]

- 0.7mg sample
- Analysis of the supernatants
- ISQ RMN, 300 MHz
- Number of scan : 2048
- Capillary tube : D_20 + TSP
- Zg 90

pH

6. Bikerman, 1973; 7. Kroezen and Wassink, 1986; 8. Gee and Bauder, 1986; 9. Janas and Kowalska, 2023; 10. This *et al.*, 2021

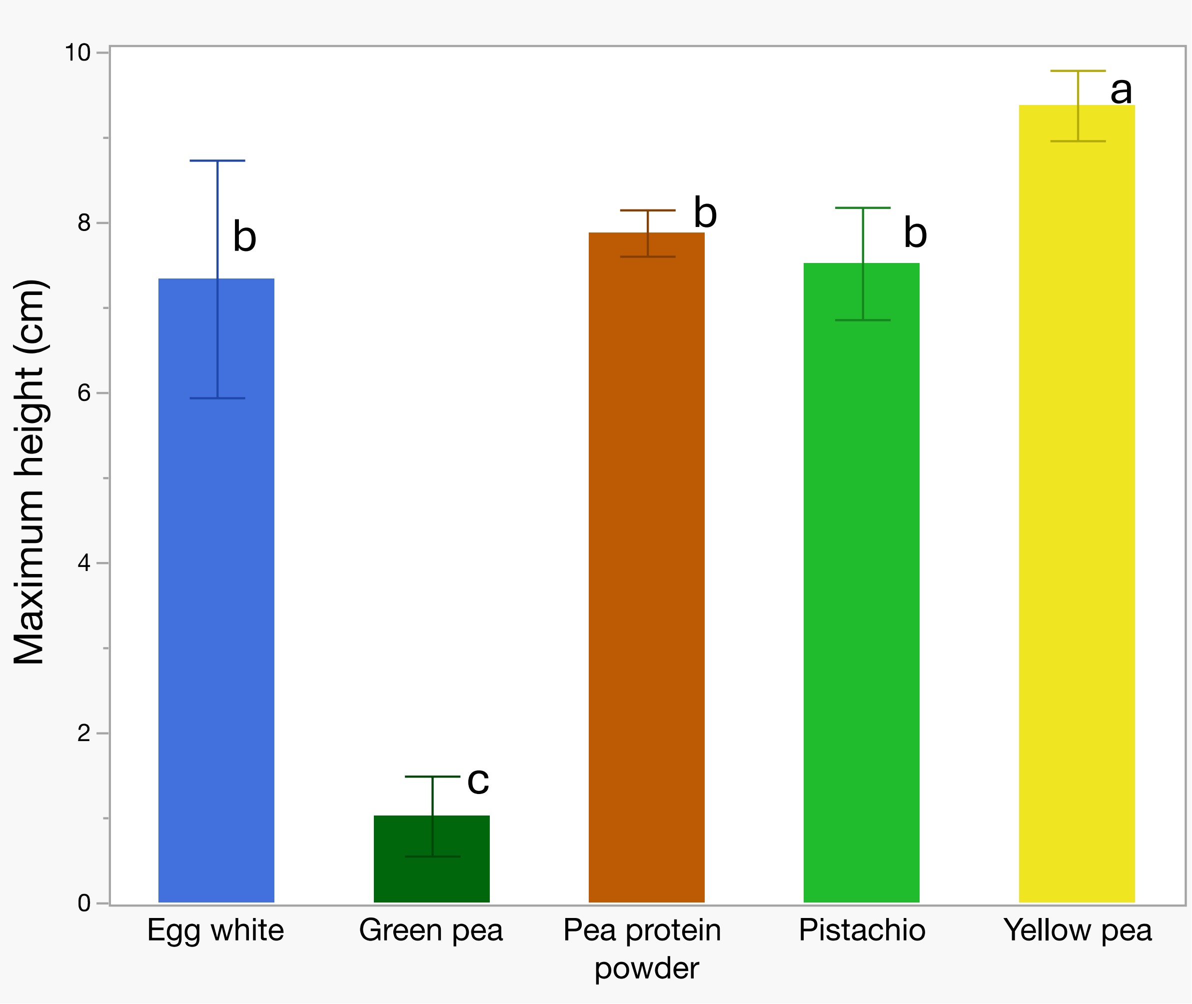
Results ½ : maximal height of foams



Yellow pea

Pistachio

Green pea



Sparging tests

Foaming properties of flours as good as those of benchmarks

Methods

Sparging tests

- Adaptation of the Bikerman's[6] method
- 0.5 mL sample, 5% w. suspension
- Airflow of 50 mL/s during 20s

Foaming test[7]

- Rotor stator
- 100 mL sample, 5% w. suspension
- 10,000 rpm for 3 min

Foam stability & density

6mL syringe

Microscopy

- Optical microscope
- Sample of foam on a slide without coverslip

Granulometry[8]

Laser diffraction particle size analyser

Dry matter[9]

- IR Moisture analyser
- 2g sample

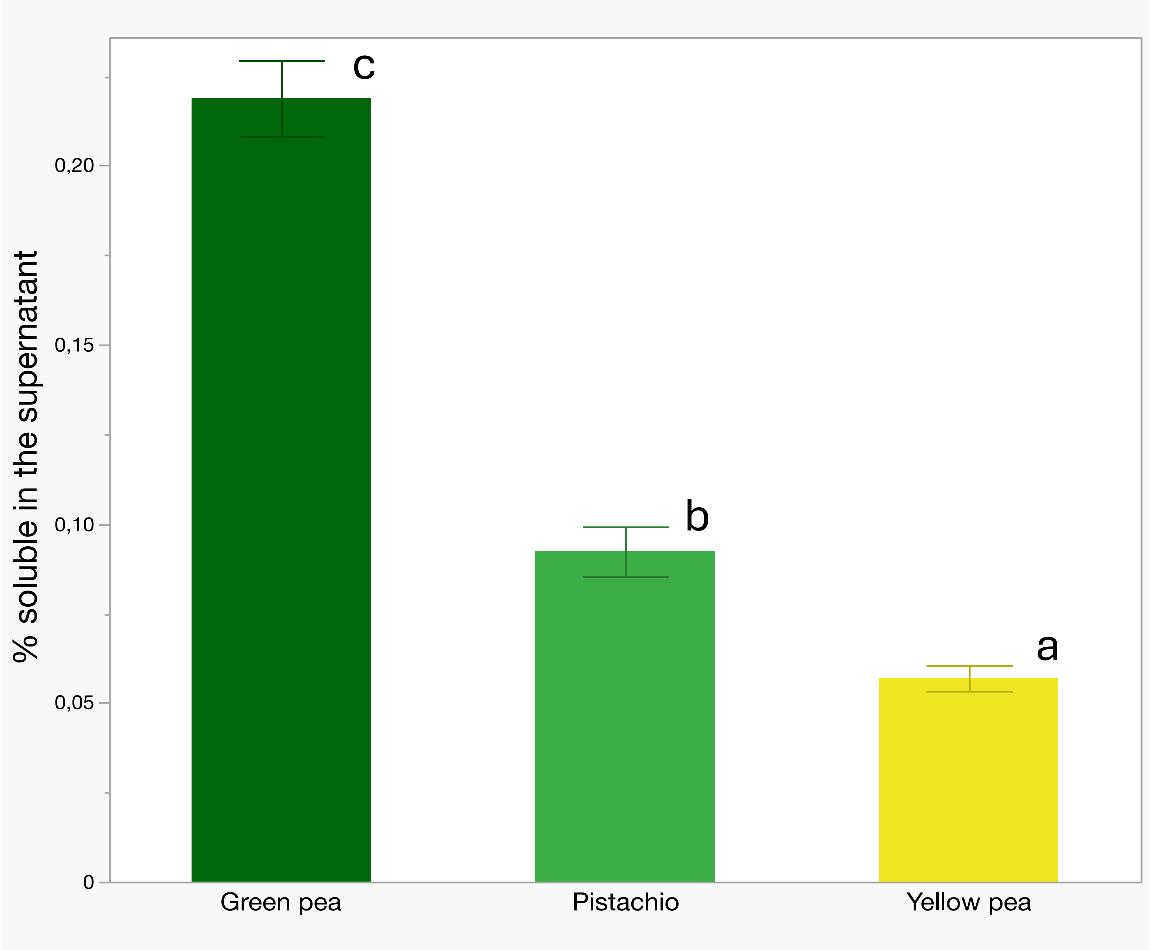
NMR analysis[10]

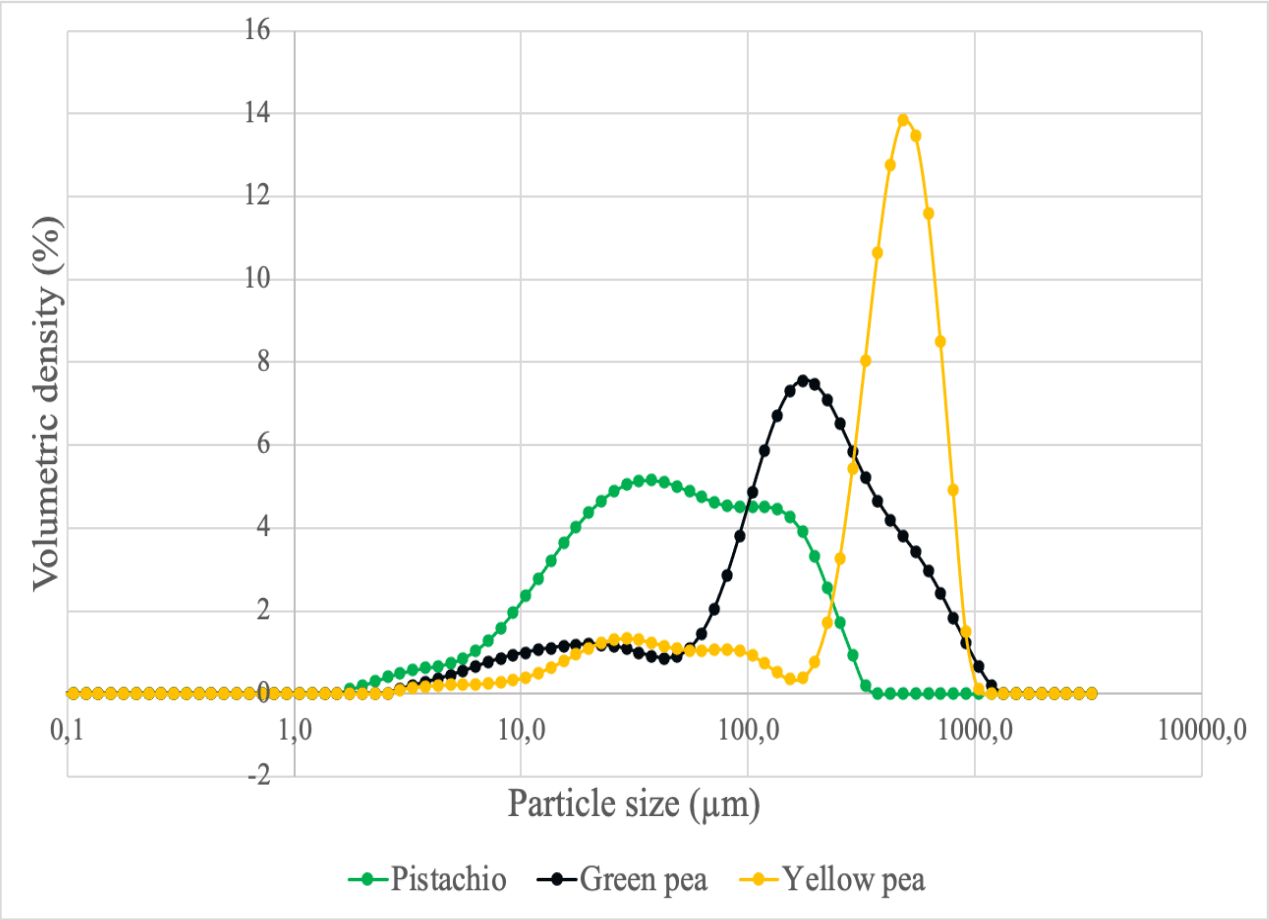
- 0.7mg sample
- Analysis of the supernatants
- ISQ RMN, 300 MHz
- Number of scan : 2048
- Capillary tube : D_20 + TSP
- Zg 90

pH

6. Bikerman, 1973; 7. Kroezen and Wassink, 1986; 8. Gee and Bauder, 1986; 9. Janas and Kowalska, 2023; 10. This *et al.*, 2021

Results 2/2 : characterisation of flours





Solubility of flours

Various particle size

Conclusion and perspectives

- Measure the protein contents of flours
- Pursue NMR analysis to identify foaming agents : phosphatidylcholine ?
- Investigate interfacial properties of flours
- What role do particules play at the interfaces ? Is the Pickering mechanism involved ?

References

[1] H. Ritchie, ‘Food waste is responsible for 6% of global greenhouse gas emissions’, *Our World Data*, Mar. 2020, Accessed: Apr. 26, 2025. [Online]. Available: https://ourworldindata.org/food-waste-emissions

[2] B. Socas-Rodríguez, G. Álvarez-Rivera, A. Valdés, E. Ibáñez, and A. Cifuentes, ‘Food by-products and food wastes: are they safe enough for their valorization?’, *Trends Food Sci. Technol.*, vol. 114, pp. 133–147, Aug. 2021, doi: 10.1016/j.tifs.2021.05.002.

[3] ‘Reseda_rapport_complet_gisements_coproduits.pdf’. Accessed: May 10, 2025. [Online]. Available: https://idele.fr/fileadmin/medias/Documents/Reseda_rapport_complet_gisements_coproduits.pdf

[4] X. Hu and Z. Meng, ‘An overview of edible foams in food and modern cuisine: Destabilization and stabilization mechanisms and applications’, *Compr. Rev. Food Sci. Food Saf.*, vol. 23, no. 1, p. e13284, 2024, doi: 10.1111/1541-4337.13284.

[5] A. Chen, N. Kayrala, M. Trapeau, M. Aoun, and N. Bordenave, ‘The clean label trend: An ineffective heuristic that disserves both consumers and the food industry?’, *Compr. Rev. Food Sci. Food Saf.*, vol. 21, no. 6, pp. 4921–4938, 2022, doi: 10.1111/1541-4337.13031.

[6] J. J. Bikerman, *Foams*. Springer Science & Business Media, 2013.

[7] A. B. J. Kroezen and J. G. Wassink, ‘Foam Generation in Rotor-Stator Mixers’, *J. Soc. Dye. Colour.*, vol. 102, no. 12, pp. 397–402, 1986, doi: 10.1111/j.1478-4408.1986.tb01053.x.

[8] G. W. Gee and J. W. Bauder, ‘Particle-size Analysis’, in *Methods of Soil Analysis*, John Wiley & Sons, Ltd, 1986, pp. 383–411. doi: 10.2136/sssabookser5.1.2ed.c15.

[9] S. Janas and M. Kowalska, ‘Accuracy of drying selected products using a moisture analyzer method based on infrared radiation’, *Metrol. Meas. Syst.*, pp. 305–321, Feb. 2023, doi: 10.24425/mms.2023.144873.

[10] H. This, M. Bria, and L. Febvay, ‘L’intégration des signaux (incluant des résonances) dans les spectres unidimensionnels obtenus par spectroscopie de résonance magnétique quantitative in situ’, 2021.