From small-scale insight to design of new dry processes for foods

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wageningen

Wageningen

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Directions

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Quick facts

Wageningen is a municipality and a historic town in the central Netherlands, in the province of Gelderland. It is famous for Wageningen University, which specialises in life sciences. Wikipedia

Province: Gelderland
Area: 32.35 km²
Area code: 0317

Wageningen University and Research Centre

- General University,
  and several Research Centres
- ~ 6 500 researchers
  ~ 10 000 BSc and MSc students
  ~ 2 300 PhD students
- Specialised on food & food production, living environment, Health, lifestyle & livelihood
- In global top 3 in our fields
  NTU globally best Agri university; QS World Univ. ranking Agri&For 2nd
- Strongly growing university, emphasis on PhD-level

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Research Institutes

Plant Sciences

Animal Sciences

Agrotechnology and Food Sciences

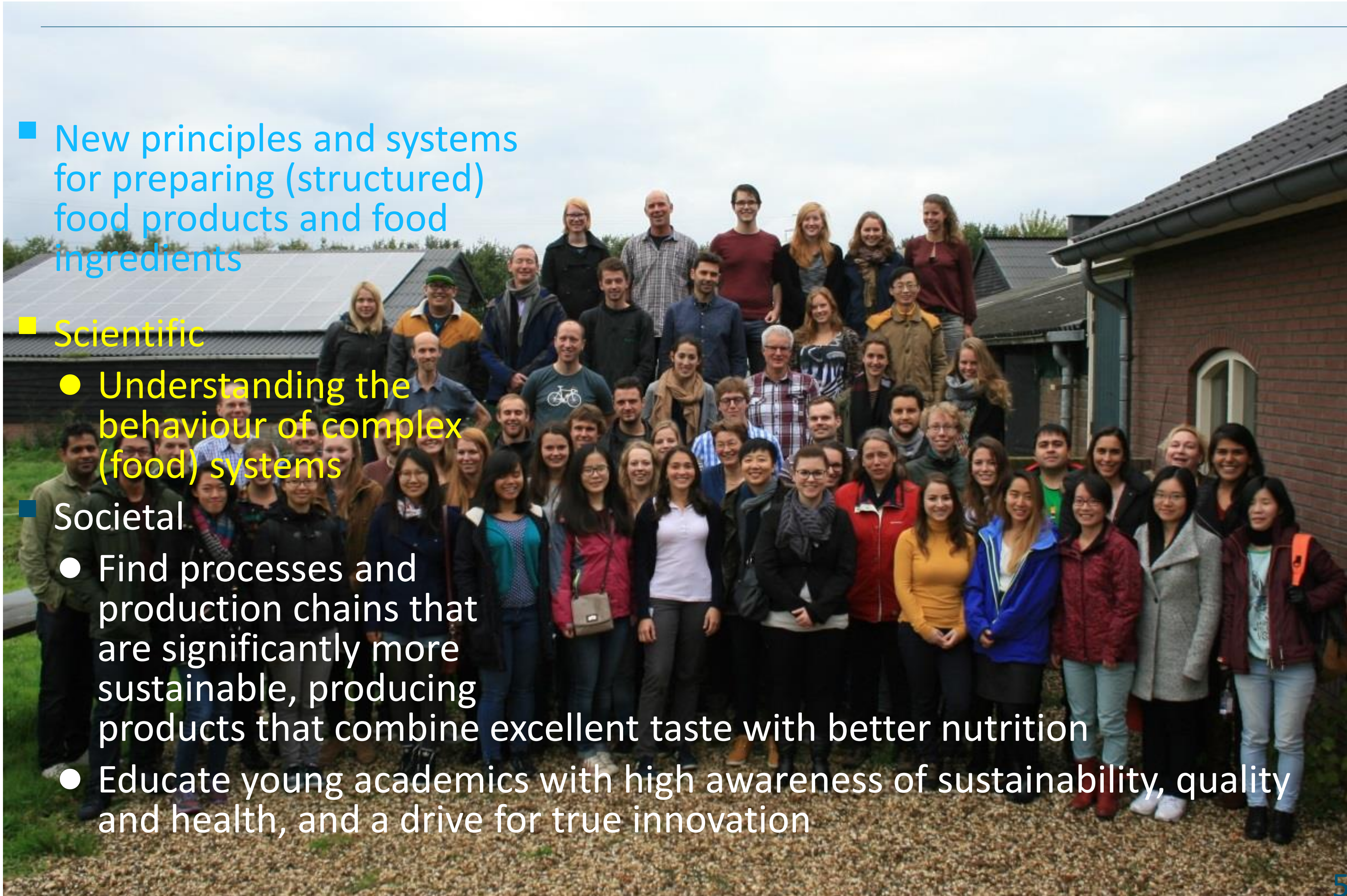
Environmental sciences

Social Sciences

21 chairs in 4 clusters
- Nutrition Sciences
- Food Sciences
- Biobased Sciences
- Biomolecular Sciences

Food and Biobased Research Institute (FBR)
- Food Technology and Packaging
- Biobased Economy

Food Process Engineering Laboratory



- New principles and systems for preparing (structured) food products and food ingredients
- Scientific
  - Understanding the behaviour of complex (food) systems
- Societal
  - Find processes and production chains that are significantly more sustainable, producing products that combine excellent taste with better nutrition
  - Educate young academics with high awareness of sustainability, quality and health, and a drive for true innovation

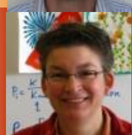
Chair:
Remko Boom

Microtechnology in Food
Karin Schroen

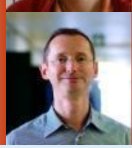
Food Nanotechnology
Claire Berton

Concentrated processing; 'soft solids'
Atze Jan van der Goot

Drying and solids processing
Maarten Schutyser



Digestive kinetics and enzymatic conversion
Anja Janssen



Thermodynamic process system analysis
Remko Boom (new scientist from April)

Ingredient production

Protein Structuring

Typical size of the group:
7 scientific staff, 5 technical staff,
~ 25 PhD students, 3 – 6 postdocs,
10 – 40 BSc or MSc thesis students

Endowed chairs

Albert van der Padt

Remko Boom (acting)

Drying and Solids Processing

Drying

Dry Fractionation

Baking & Frying

The approach

- Study dynamic behaviour of concentrated and dry materials under relevant conditions.

- Unravel mechanisms underlying the relation between processing and product properties.

$$A = A_D exp\left(-\left(\frac{t}{\alpha(T, xw)}\right)^{\beta_T}\right)$$

- Develop new processing principles; more energy efficient and better product quality.

Study:
Drying of a droplet / film
Crust or skin formation
Fragmentation of particles
Agglomeration behaviour

Understand:
Water removal
Inactivation mechanisms
Structure formation
Particle dynamics

Develop:
New operating windows
New processing principles

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The approach

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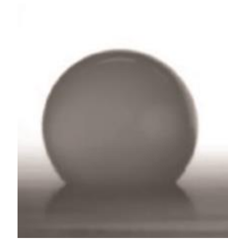
- Unravel mechanisms underlying the relation between processing and product properties.

$$A = A_D exp\left(-\left(\frac{t}{\alpha(T, xw)}\right)^{\beta_T}\right)$$

- Develop new processing principles; more energy efficient and better product quality.

✓ ***Move towards rational design using bottom-up approach***

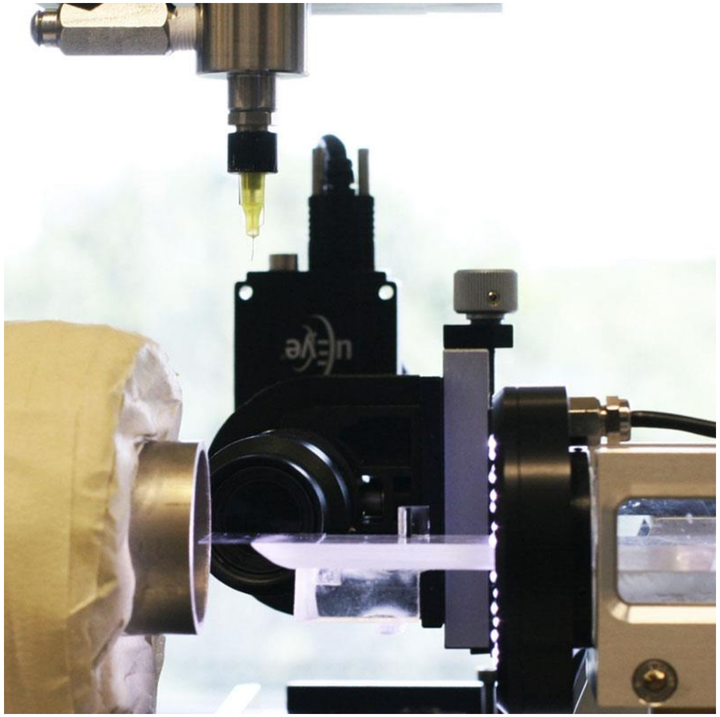
Link to fundamental science groups

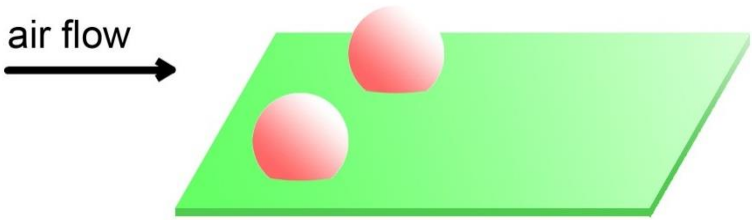


Science for Impact

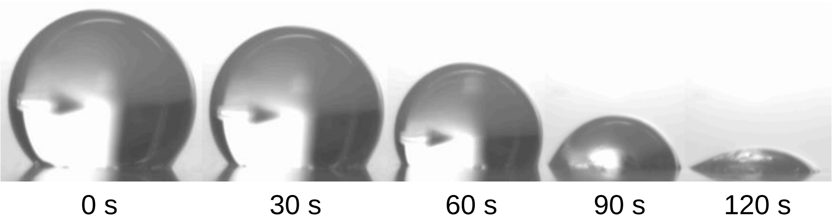
Link to industrial partners

Single droplet drying





- Hydrophobic membrane
- Initial d_p=200 μm
- Heat & mass transfer correlation derived for water droplets



Perdana et al., Chem. Eng. Technol. 2011, 34, No. 7, 1151–1158

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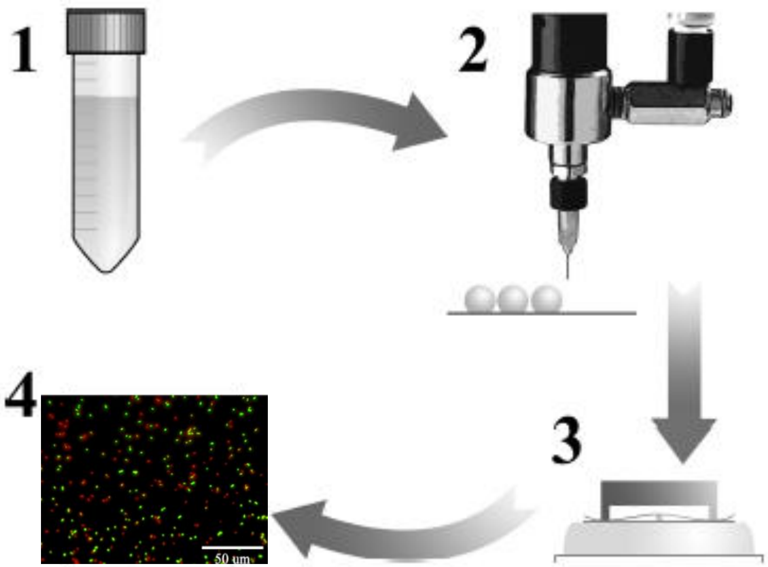
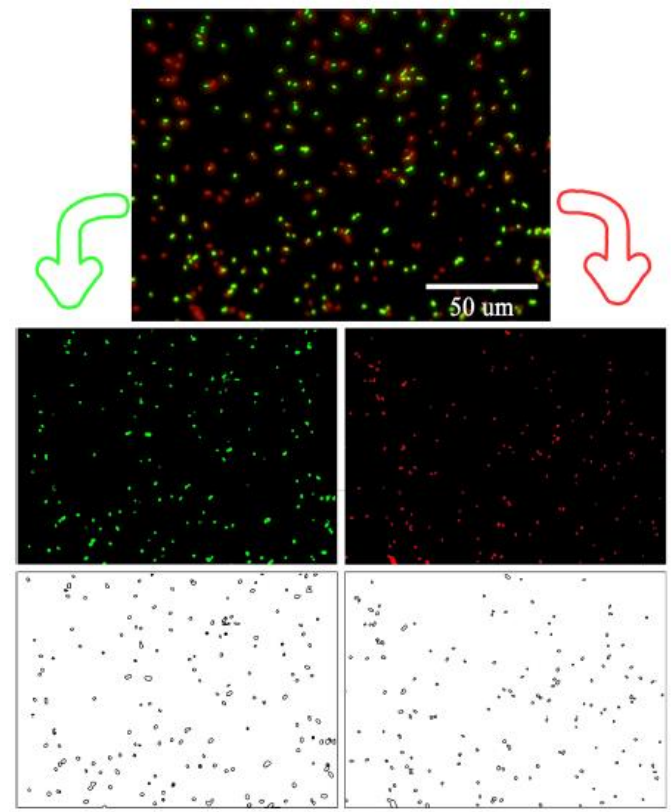
Novel method for enumeration of bacteria





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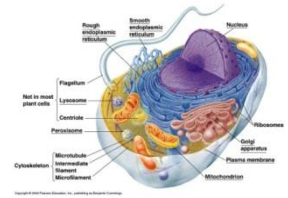
Perdana, J., L. Bereschenko, et al. (2012). "A novel method for viability enumeration for single-droplet drying of Lactobacillus plantarum WCFS1." Applied and Environmental Microbiology 78(22): 6.

Spray drying of probiotics



- Single droplet drying observations
  - T < 45°C: dehydration inactivation
  - T > 45°C: combined thermal-dehydration inactivation
- Modelling of viability loss
  - Models for (i) dehydration and (ii) thermal inactivation
  - Prediction of residual viability after single droplet drying
- Spray drying experiments for validation – lab & pilot
  - Compared to predictions

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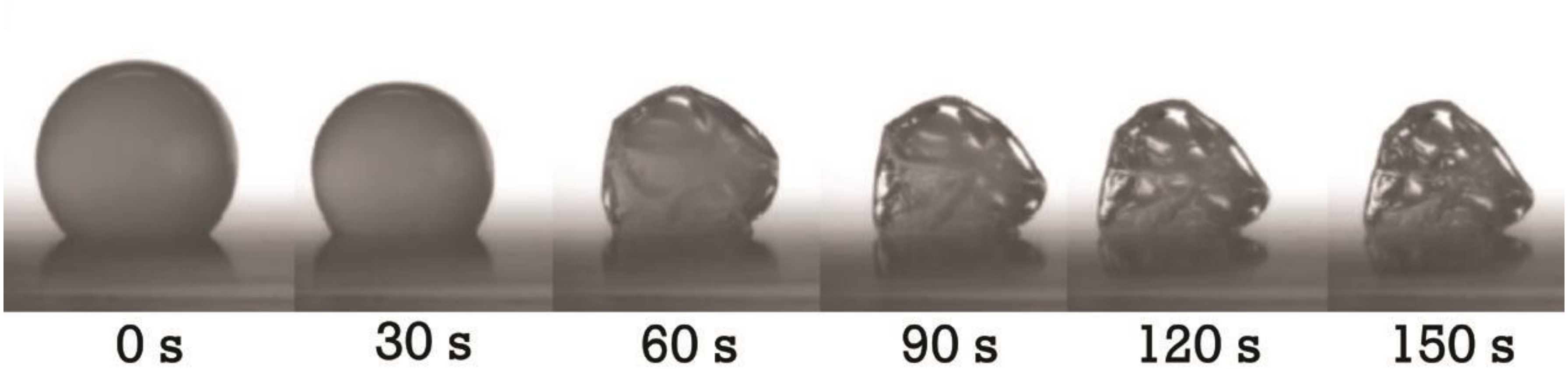
Perdana et al., Dehydration and thermal inactivation of Lactobacillus plantarum WCFS1 in Food Research International 54(2): 1351-1359

Monitoring droplet drying



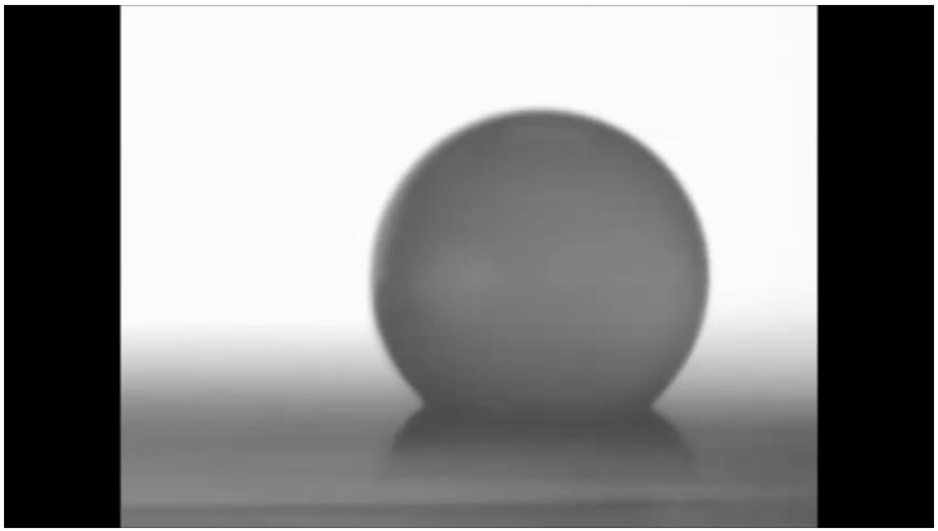
- 20 w/w% maltodextrin suspension
- Initial drying stage: ideal shrinkage
- Second drying stage: formation of wrinkles

Perdana et al., Food Bioprocess Technol (2013)

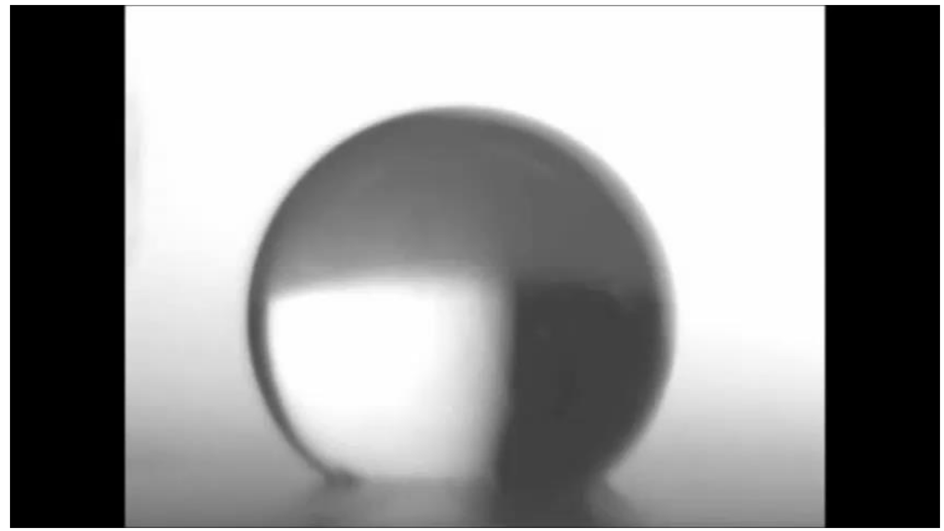
6(4): 964-977

Structure formation

Maltodextrin

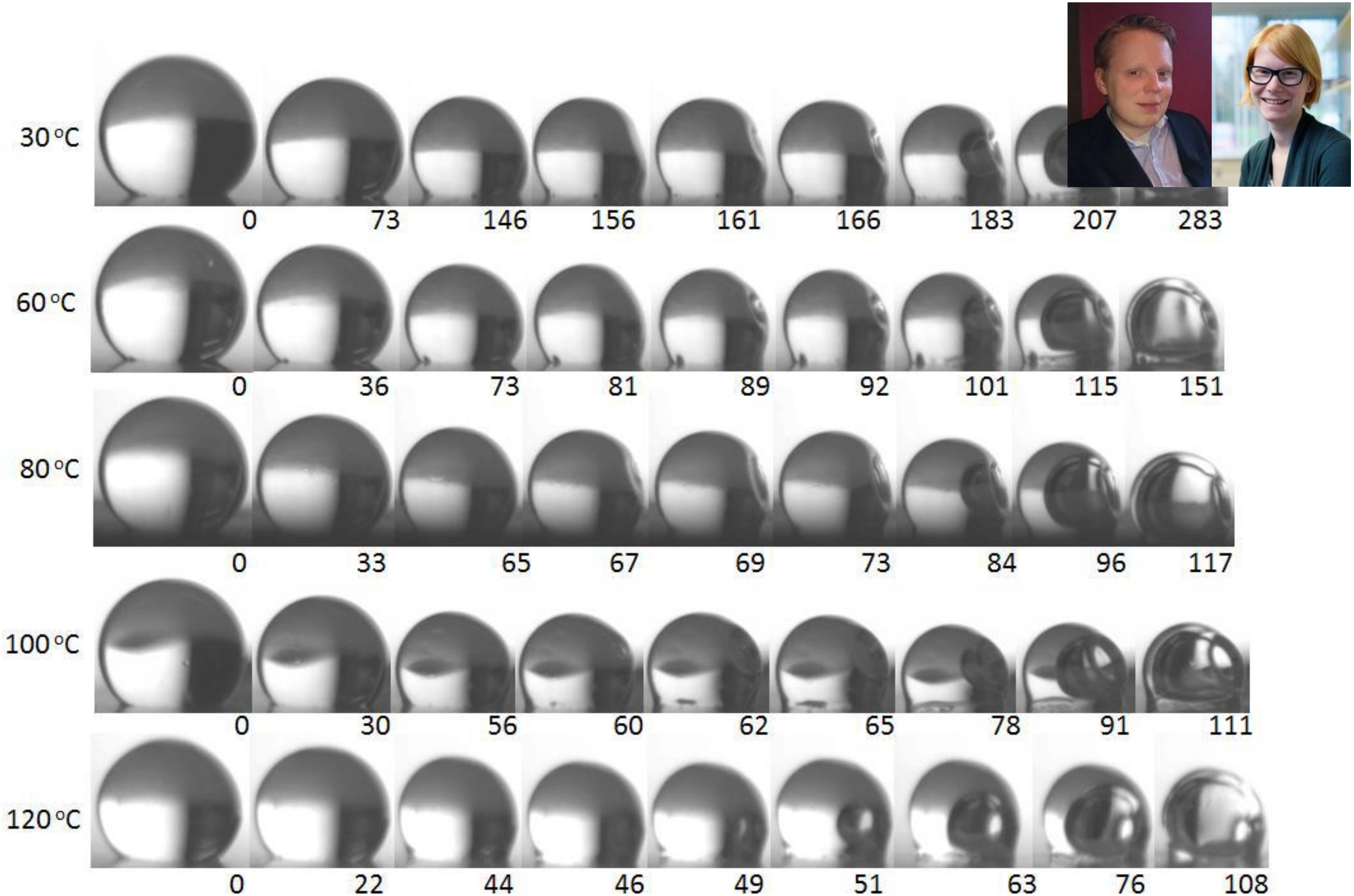


Whey Protein



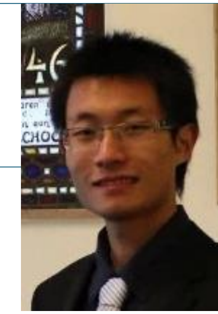
How do we explain this remarkable difference?

Single droplet drying of WPI solutions



Bouman, J. et al., IDS Proceedings 2014

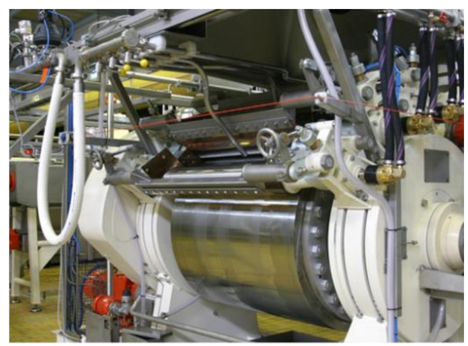
Thin film drying

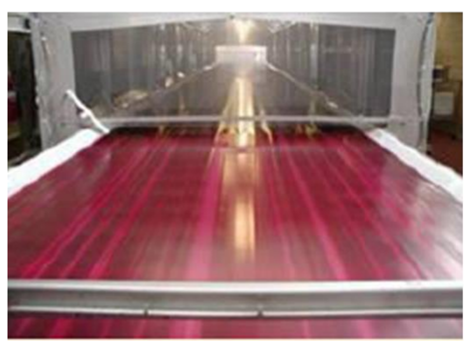


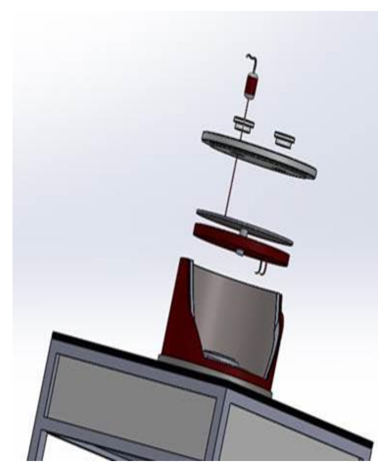
Develop knowledge-based guidelines for conductive mild thin film drying:

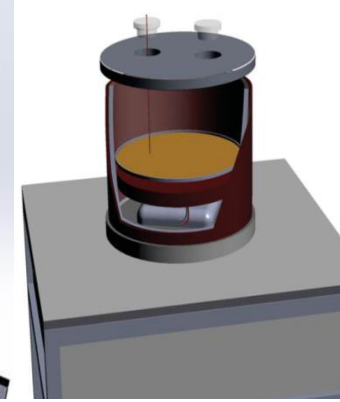
1) Investigate drying at the product scale and develop transient thin film drying models.

2) Comparison of drying technologies (Drum, ATFD & Refractance Window Drying) via pilot scale experimenting & benchmarking.



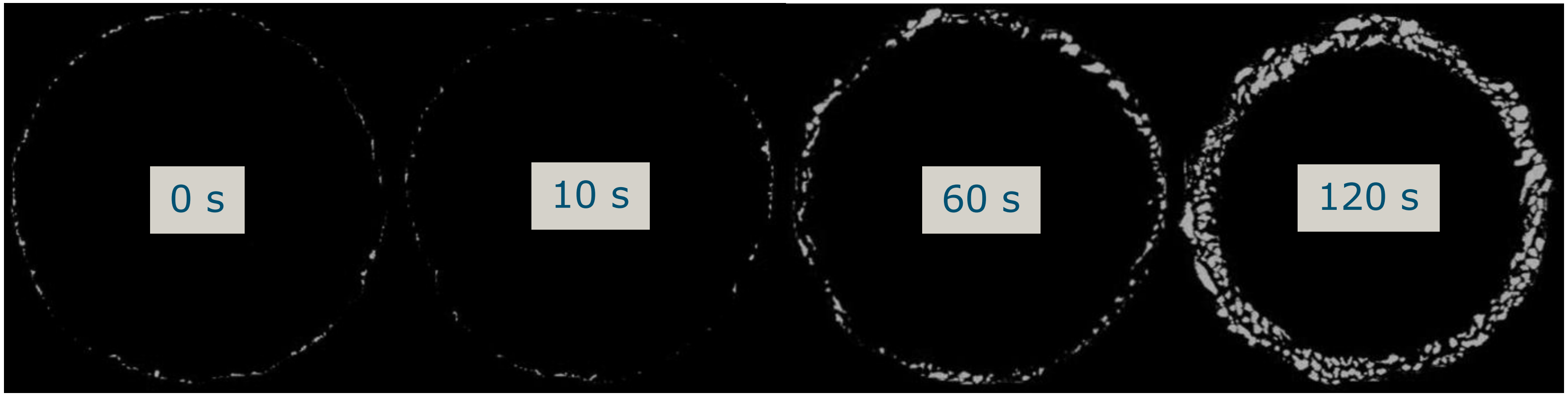




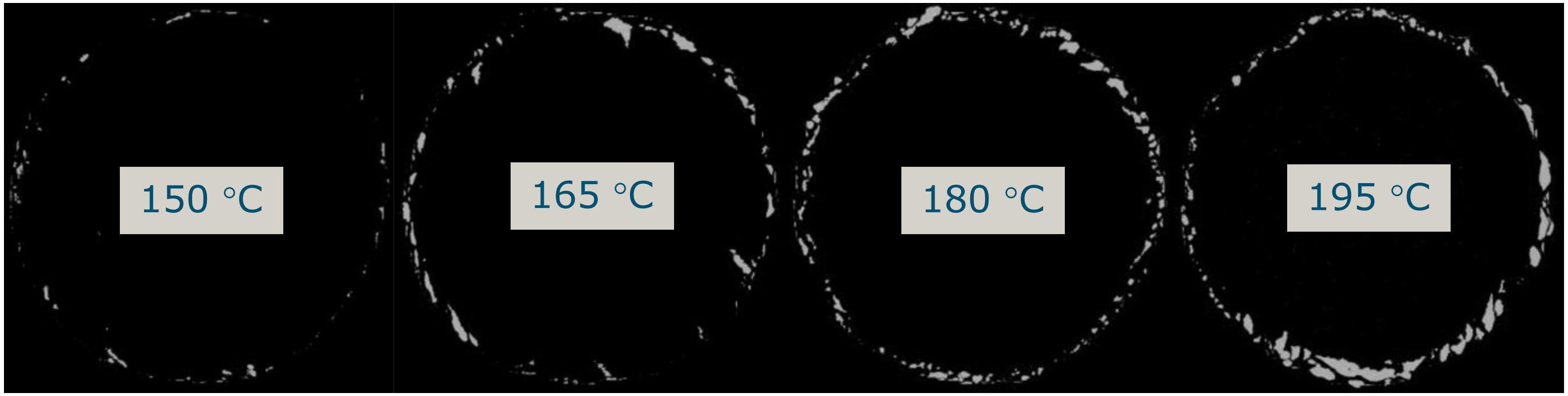


Frying - Crust formation

- Crust increase during frying (180 °C)



- Crust increase with frying temperature (same moisture)



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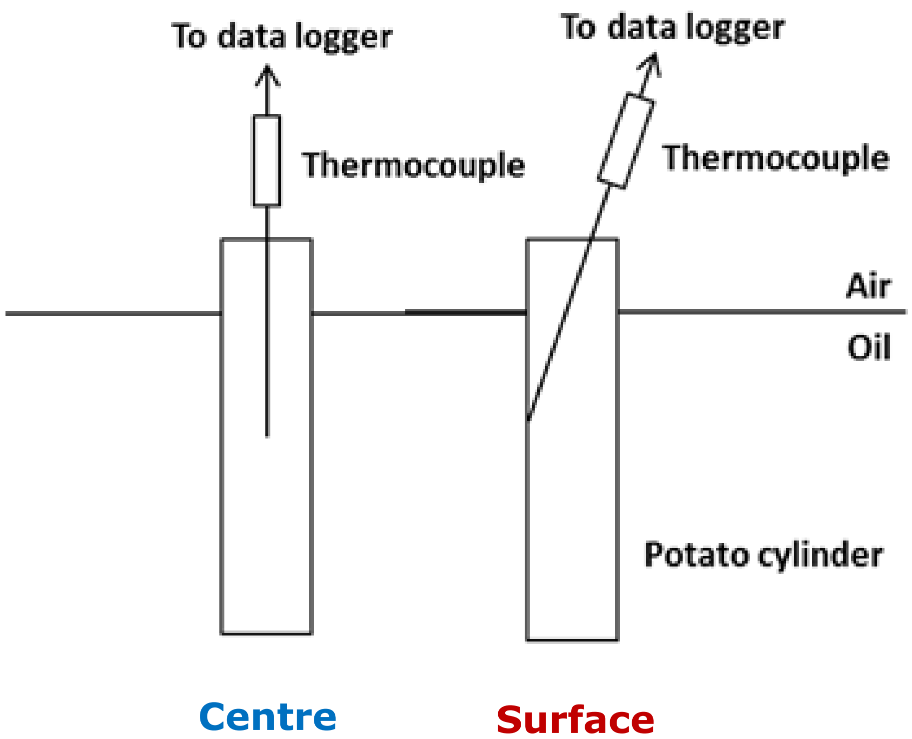
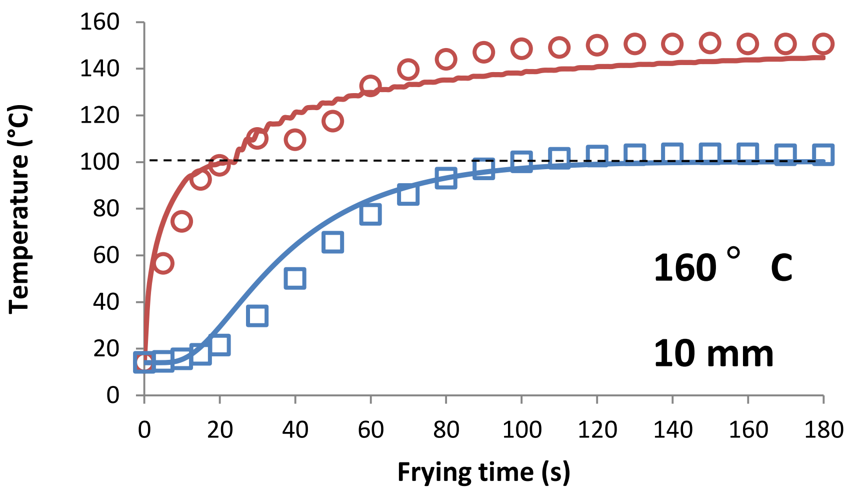
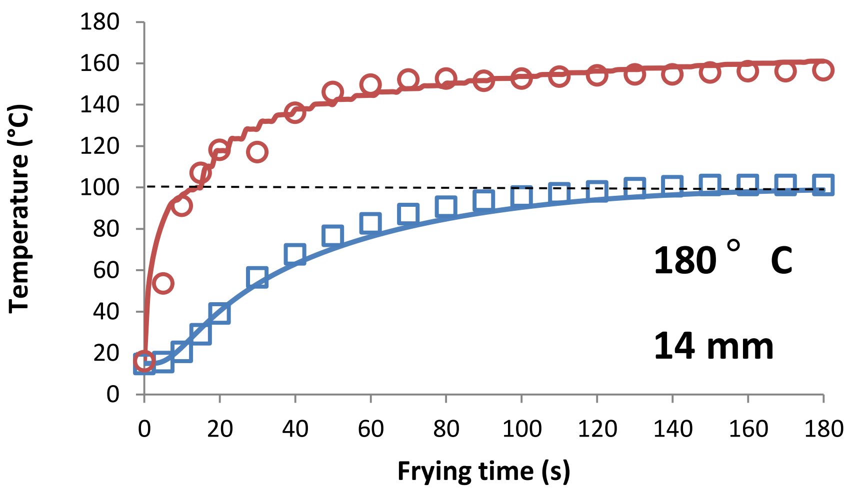
van Koerten, K.N., et al., (2015). Crust morphology and crispness development during deep-fat frying of potato. Food Research International.

Crust-Core model – Temperature validation

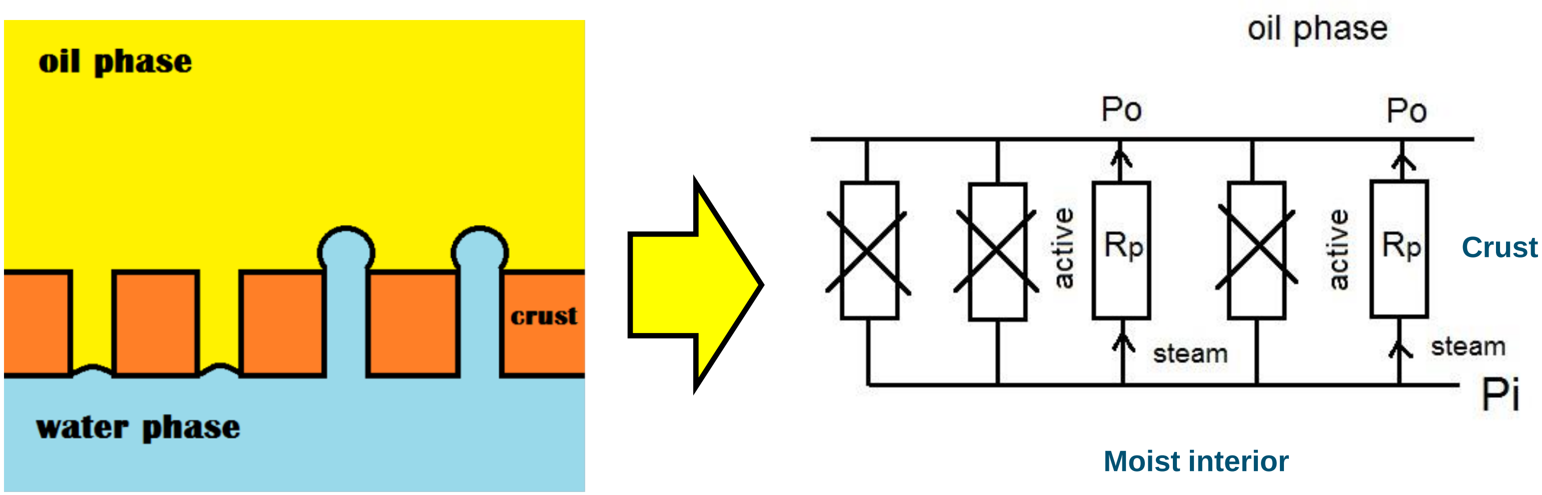






van Koerten, K.N., et al., (2016). Under review.

Oil uptake during frying - modelling



$$S = \frac{M_0 - M}{M_0} \cdot K \cdot \frac{w_{max} - w}{w_{max}} + oil_0$$

$$K = N_T \cdot \rho_{oil} \cdot A \cdot r$$

= fitted parameters

S= oil uptake (g)
M= absolute moisture content (g)
w= evaporation rate (g/s)
oil0= initial oil uptake before wmax (g)
N_T= total amount of pores
ρ_{oil}= density oil (g/m^3)
A= average pore area (m^2)
r= radius of French fry (m)

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van Koerten, K.N. et al, (2015). A pore inactivation model for describing oil uptake of French fries during pre-frying. Journal of Food Engineering 146(0), 92-98.

Miniature bread baking approach and its potential use as functional food

Lu Zhang, Sandwich PhD

Supervisors: Maarten Schutyser & Remko Boom (WUR)

Xiao Dong Chen (Soochow University, China)

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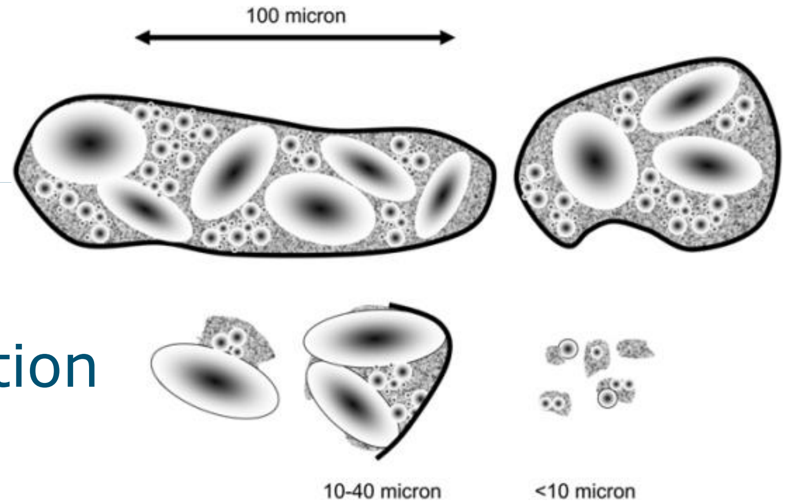
Dry fractionation

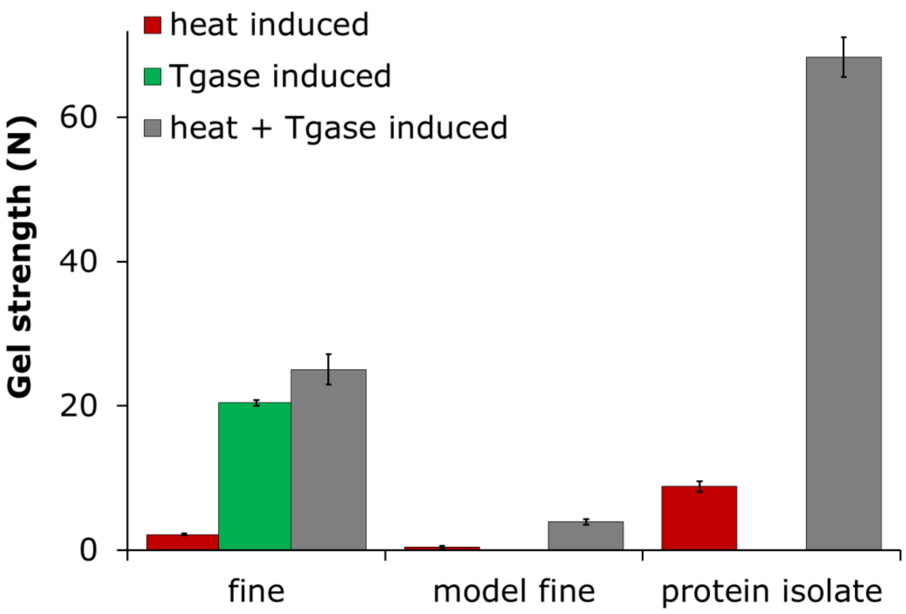


- More sustainable
  - Less or no water consumption
  - Less energy consumption
- More mild
  - Retaining native functional
- But, less pure
  - Functionality is more import
- Conventional dry fractionation
  - Milling & air classification

Schutyser, M.A.I., et al., (2015). Dry fractionation for sustainable production of functional legume protein concentrates. Trends in Food Science & Technology 45(2), 327-3

Pea: Enzymatic gelation

- Enzymatically-induced pea protein gels are stronger than heat-induced protein gels
- Starch and fibre in the fine fraction absorb water, which increases the protein content and the gel strength.



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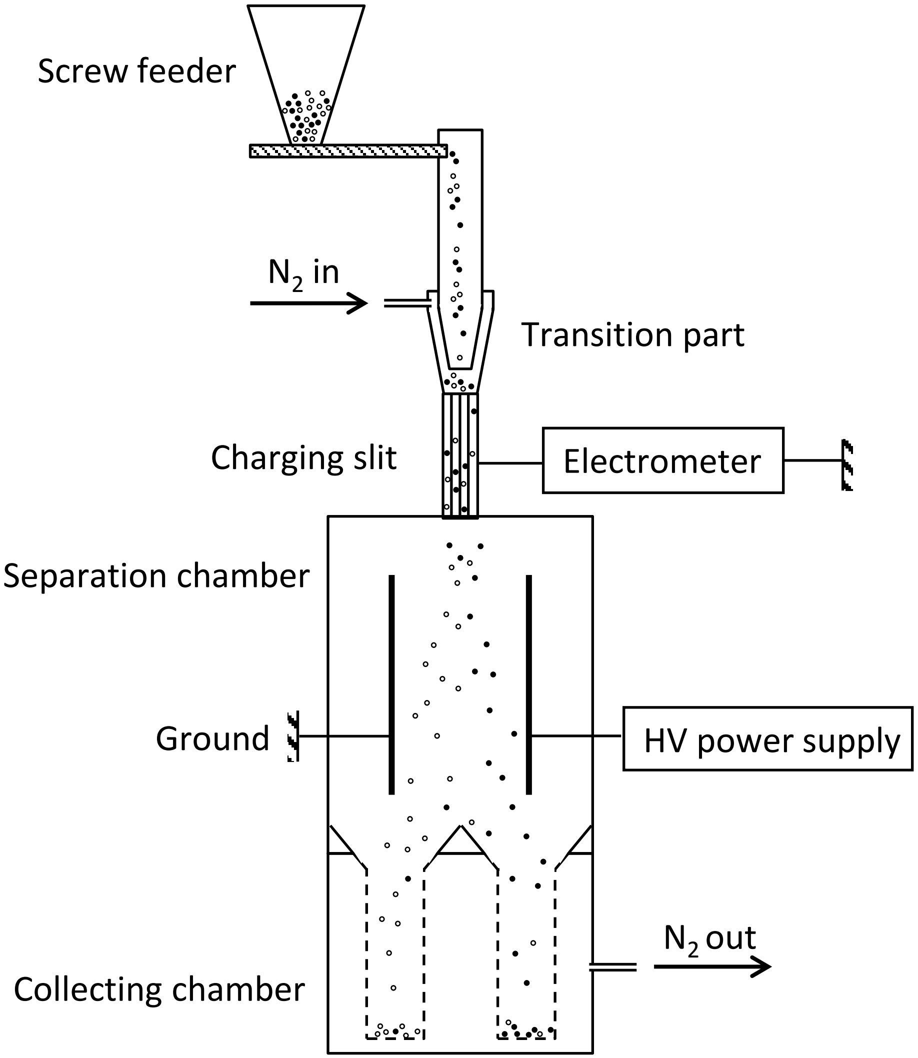
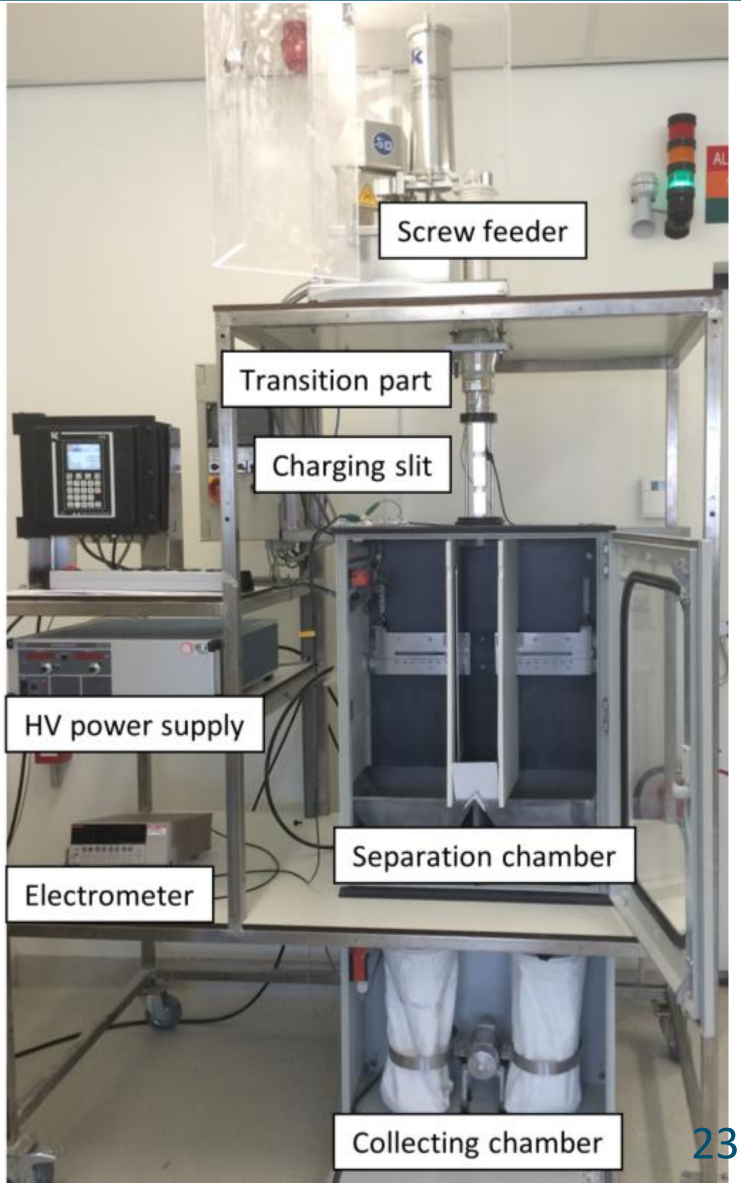
Pelgrom, P. J. M., et al. (2015). Food Hydrocolloids ***44****: 12-22.*

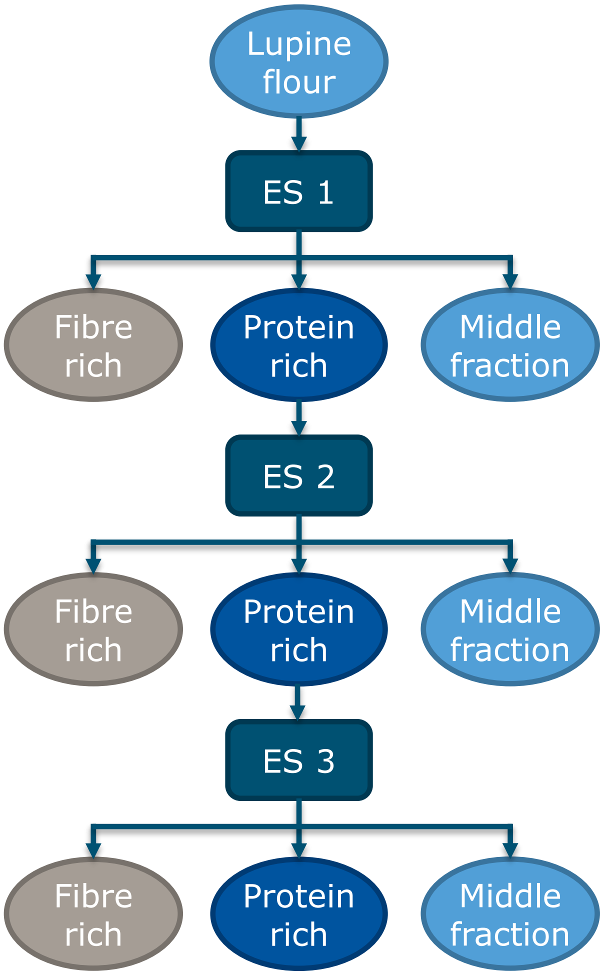
Bench-scale electrostatic separator

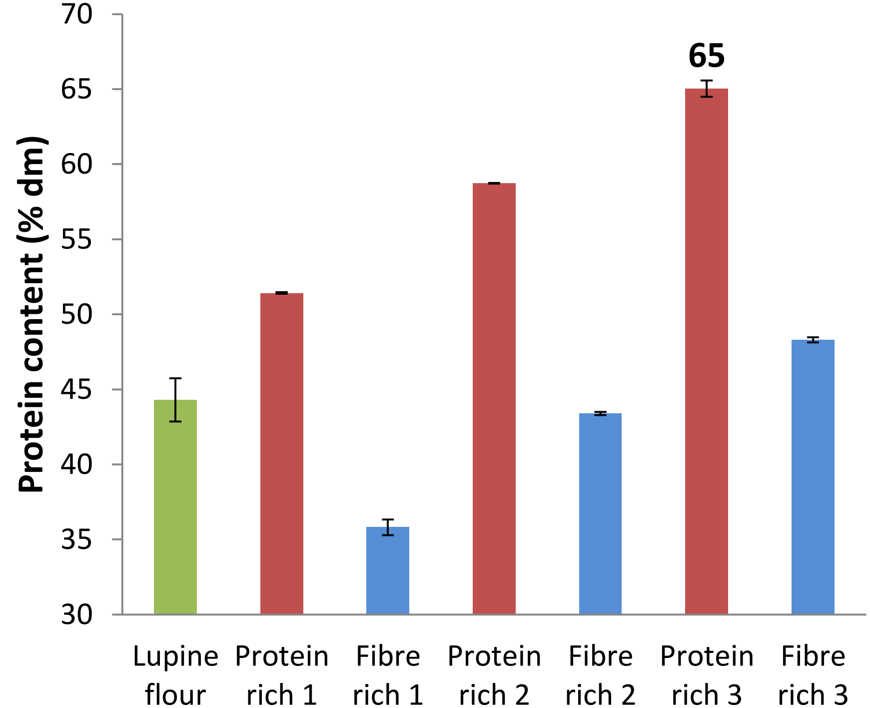


Wang, J., et al.,, (2015). Charging and separation behavior of gluten–starch mixtures assessed with a custom-built electrostatic separator. Separation and Purification Technology 152, 164-171.



Multiple-step ES (MSES) of Lupine





15% more protein enrichment than by air classification (~59% dm)

Wang, J. et al, (2016). Lupine protein enrichment by milling and electrostatic separation. Innovative Food Science & Emerging Technologies.

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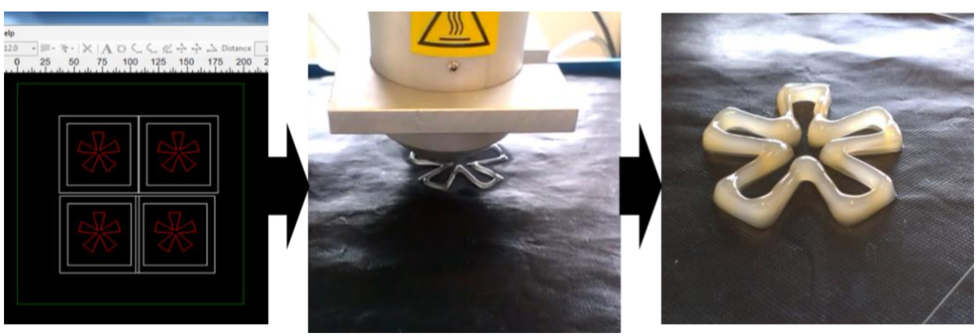
3D Food Printing

Fused deposition modelling of chocolate (paste)



- Food production will be more tailored to individual needs & preferences
    - Health, Age, Lifestyle
- Decentralized production
- Prototyping tool
- Fused deposition modelling
- ***Enable development of 3D printed protein foods***

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Schutyser et al., (2016) Submitted

FDM of caseinate 40% w/w

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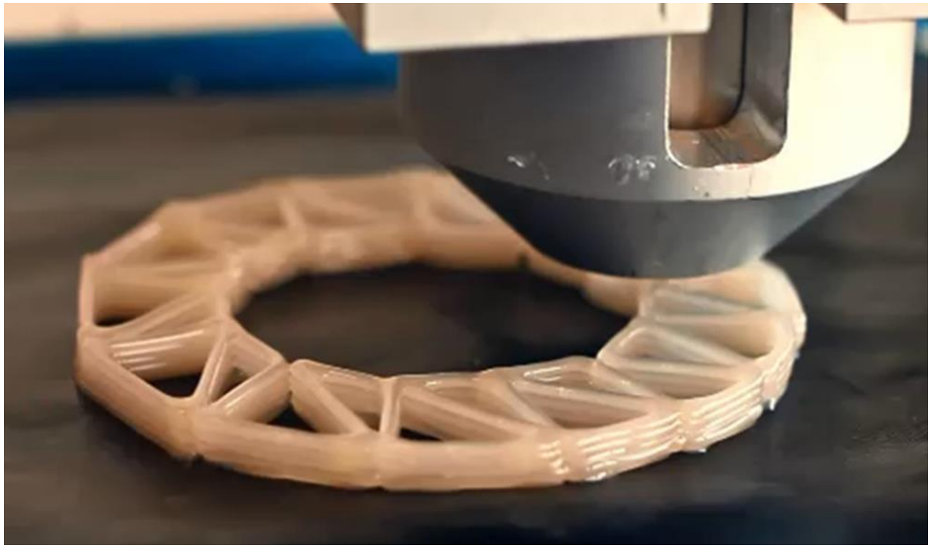
Filled protein-rich structures

- Niche application
    - Healthy
- Spatial design
- Modulate sensory perception.
- *"Shown that the spatial distribution of fat provided similar perceived creaminess in layered gels with lower amount of fat"**

*Mosca, Rocha, Sala, van de Velde, Stieger, 2012

Conclusions

- *From small scale insight to design of new processes*
- Drying & solids processing
  - Spray drying & thin film drying
  - Dry fractionation
  - Baking & Frying
  - 3D Food Printing



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Jue Wang
Lu Zhang

And many others!

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