Shear cell technology

Towards a next generation of meat analogues

Jacqueline Berghout

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Towards a next generation of meat analogues

- Anisotropic, fibrous structures

Soy protein isolate and wheat gluten
Plant Meat Matters project

Soy protein isolate and pectin
Dekkers *et al.* (2016)

Soy protein concentrate
Grabowska *et al.* (2016)

Soy protein concentrate
Krintiras *et al.* (2016)

Pea protein isolate and wheat gluten
Schreuders *et al.* (2019)

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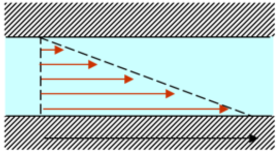
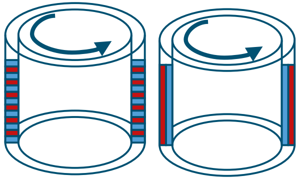
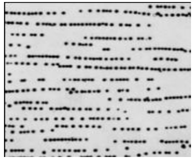
Why shear cell technology

- Shear cell technology to improve scientific understanding of dense polymer blends under flow
    - Decouple mixing and structure formation: simple shear flow to make anisotropic structures





‘Shear banding’ by Vermant – Current opinion in Colloid & Interface Science – 2001



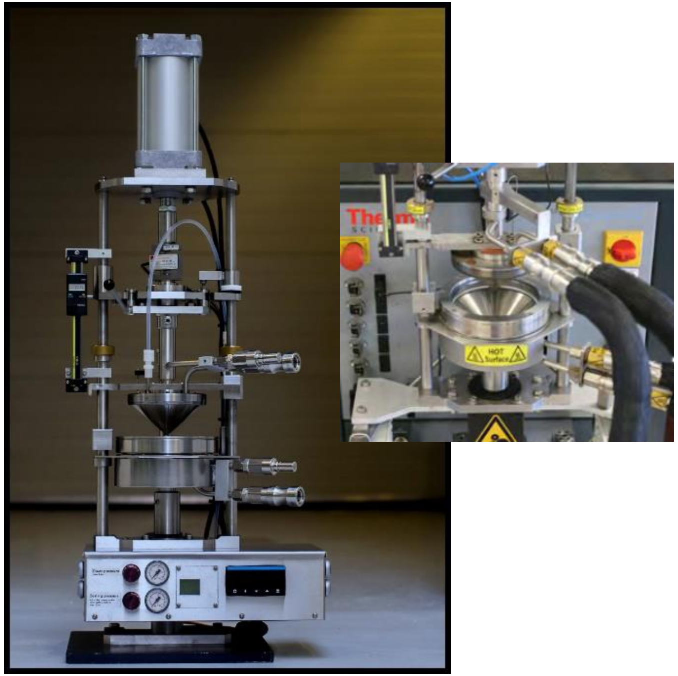
Particle string formation by Won & Kim 2004

- Create large (7 kg) and thick (3 cm) fibrous structures that can be cut and shaped into whole muscle meat fractions

e.g. beef steak

Shear cell technology

Conical shear cell (~100g)



Schematic representation

Conical shear cell

Couette shear cell

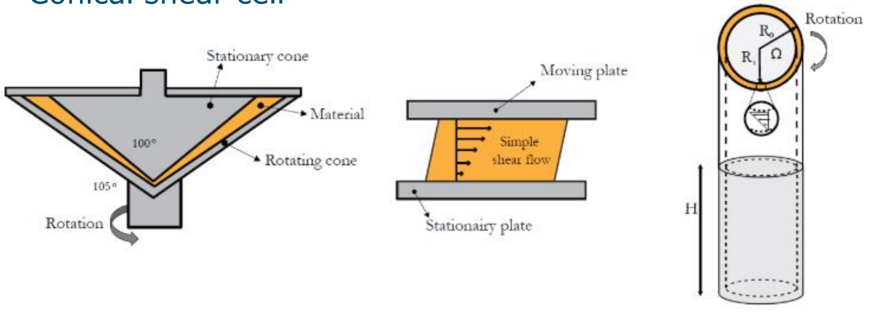


Fig. 1.1 Illustration of cone-in-cone and couette device in which materials can be deformed with simple shear flow

Dekkers – PhD thesis – 2018

Shear cell technology

Krintiras – PhD thesis - 2016

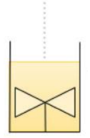
Couette shear cell (7 kg)

Shear cell technology

What is happening in the shear cell?

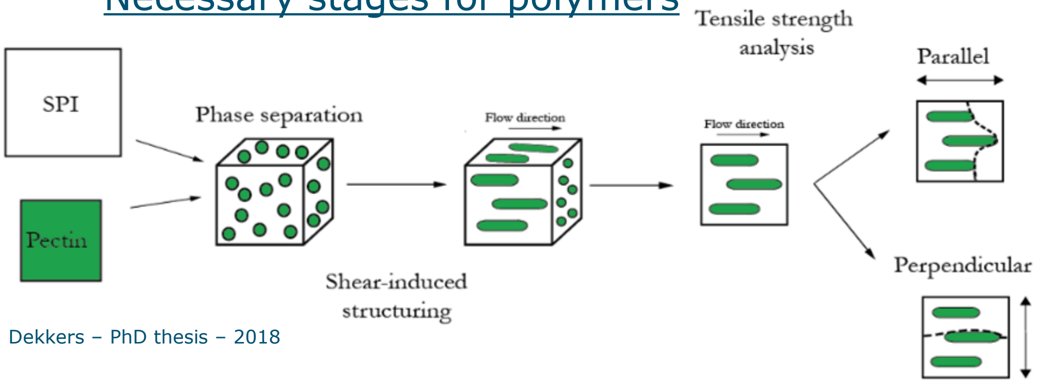
Processing steps

mixing



Cornet et al. - Critical Reviews in Food Science and Nutrition – 2021

Necessary stages for polymers



Dekkers – PhD thesis – 2018

Dense polymer systems

High shear rate may increase T in conical system

Shear (γ)

Proteins: melt - align - fix

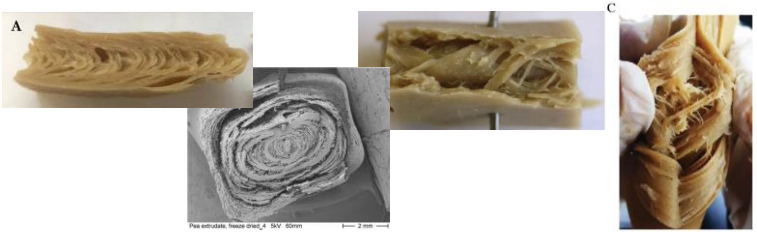
Temperature (T)
time (t)

Tolstoguzov – JAOCS – 1993

High-moisture extrusion and shear cell technology

For meat analogues | similarities

- Anisotropic structures: layered, fibrous

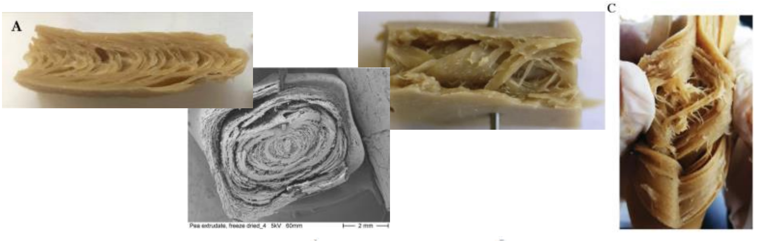


Cornet *et al.* - Critical Reviews in Food Science and Nutrition – 2021
Dekkers et al. – Trends in Food Science & Technology – 2018
Osen – PhD thesis – 2017
Samard – Journal of the Science of Food and Agriculture – 2019
Grabowska – Journal of Food Engineering – 2016

High-moisture extrusion and shear cell technology

For meat analogues | similarities

- Anisotropic structures: layered, fibrous
- Similar formulations, protein isolates and concentrates
  - Leguminous source such as soy or pea
  - Wheat gluten or polysaccharide
  - Water contents ranging from 50 – 70%
- Similar basic steps:
  - Mixing and hydration
  - Thermo-mechanical treatment
  - Cooling



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High-moisture extrusion and shear cell technology

For meat analogues | differences

- Extrusion
  - Continuous process
  - Commercially available
  - Mixing inside the barrel
  - Simple shear flow and elongational flow
  - Temperature range: 100-175°C
  - More intense thermomechanical treatment
  - Residence time: 2-5 min
  - Mostly layered structures
  - Thinner strands of product

- Shear cell
  - Batch process
  - Not commercially available (yet)
  - External mixing
  - Simple shear flow
  - Temperature range: 95-140°C
  - Residence time: at least 20 min (conical shear cell)
  - Mostly fibrous structures
  - Large and relatively thick pieces

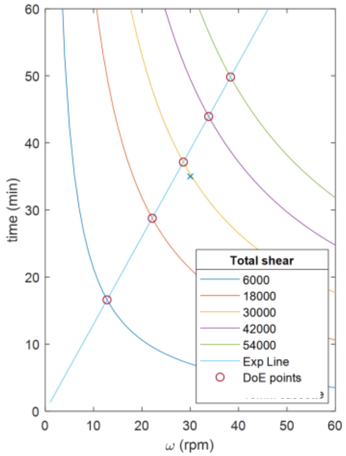
Cornet *et al.* - Critical Reviews in Food Science and Nutrition – 2021
Dekkers *et al.* – Trends in Food Science & Technology – 2018
Dekkers *et al.* – Innovative Food Science and Emerging Technologies – 2016

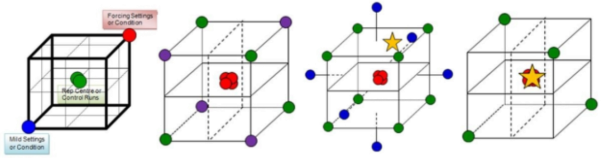
Research within the Plant Meat Matters project

- Create a window of operation for
    - Shear cell technology
    - Using soy protein isolate and wheat gluten
    - By studying the influence of process parameters on structure formation in the shear cell

Window of operation

- 4 variables with 5 levels: $5^4 = 625$ experiments
  - Temperature
  - 'Total shear' = shear rate * time (assumption)
- Design of Experiments (DoE) to reduce # experiments = 31 experiments
- Output
  - Visual observation: with or without fibres
  - Product temperature: T_{core}



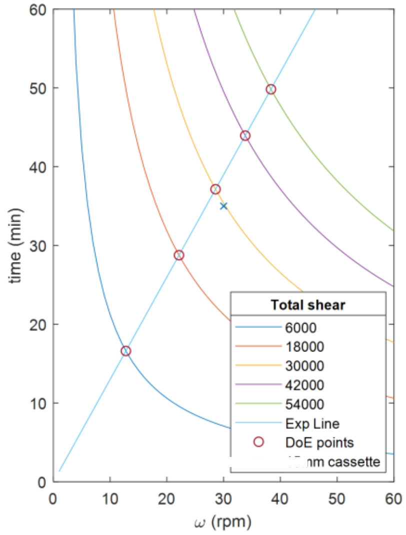


Window of operation

Experimental details

- Recipe: soy protein isolate, wheat gluten, salt (NaCl) and water at 31% dry matter*
- Process parameter settings: 5 levels for each parameter
    - Temperature 1 – 130°C – 190°C
    - Temperature 2 – 70°C – 190°C
    - Total shear 1 – 6000 – 54000
    - Total shear 2 – 500 – 7500

Total shear is a combination of shear rate (rotational speed) and time

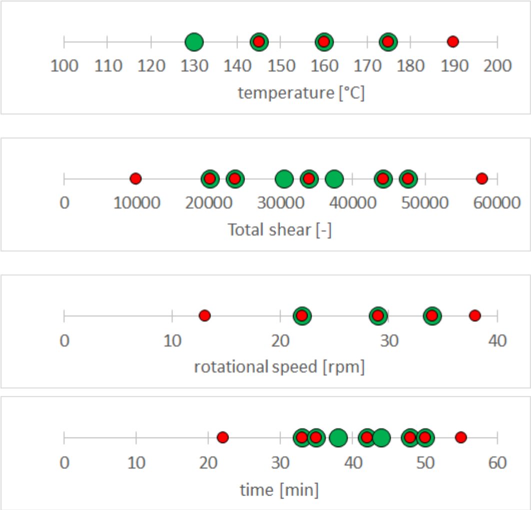


* Dekkers *et al.* – Food Hydrocolloids – 2016 & 2018

Window of operation

Results

- Fibres
- No fibres



- No trend observed for a fibrous structure for the input parameters
- Literature and experience show that T>120°C is important for structure formation of proteins
- There seemed to be a trend for a fibrous structure for the output parameter maximum T_{core} reached and T_{core}

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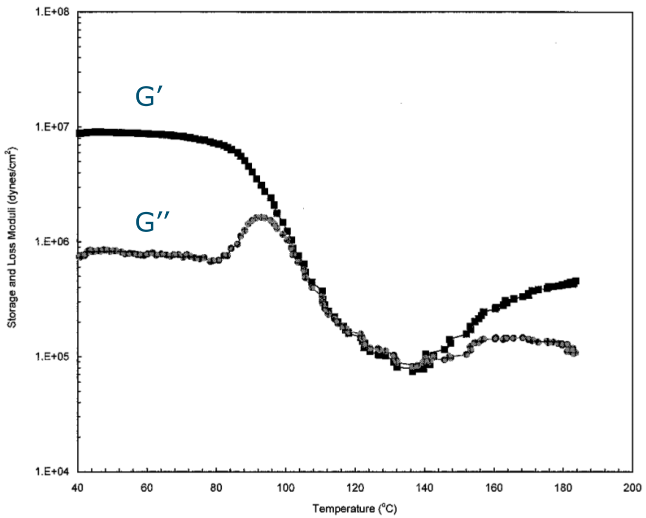
Hypothesis

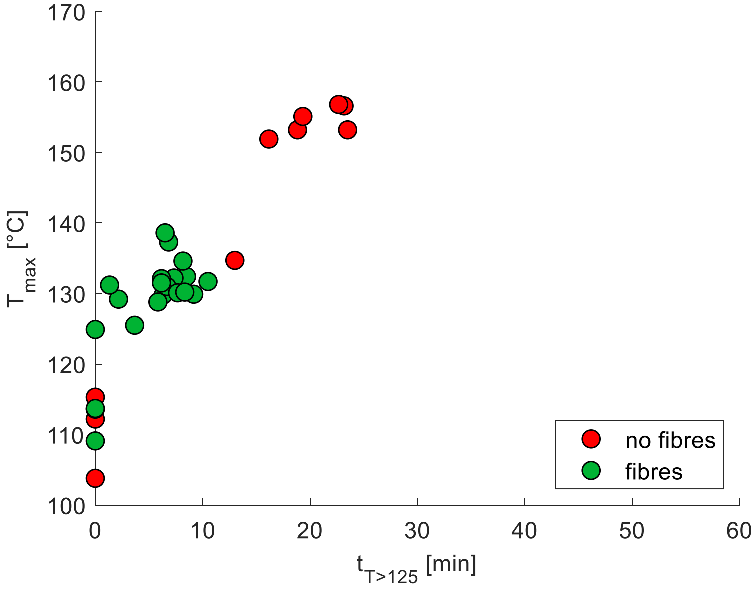
- Proteins 'melt' as a function of temperature and time align and be fixed
- Wheat gluten rheological behaviour



- There is a relation between the presence of fibres, time above T_{core} and max T_{core}

Toufeili *et al.* – Cereal Chemistry – 2002

Relation between time above T_{core} and max T_{core}



- There is a relation
- Clustering of points with fibres and without fibres is preferred
- Search for another reference T_{core} that gives best clustering of data
  - Temperature that is relevant for structure formation
  - Separation of dots on the x-axis

→ Allows to develop empirical model that relates time above T_{core} to process parameters

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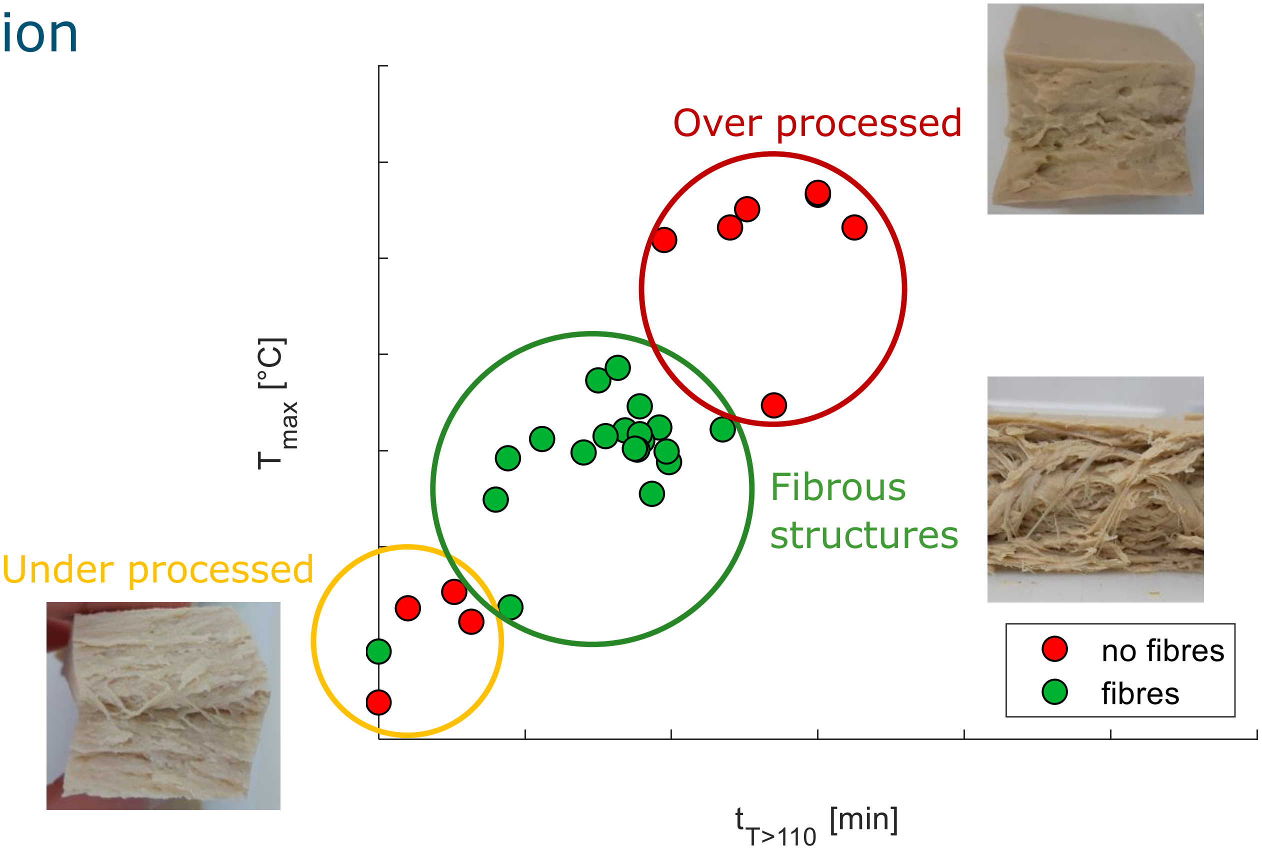
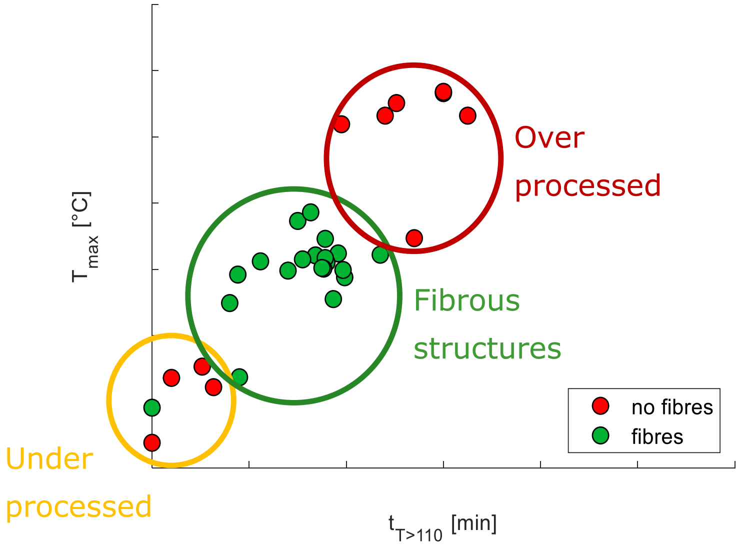
Window of operation



Summary of this research

- A window of operation was created for soy protein isolate and wheat gluten
- Time that T_{core} has been above a certain temperature can be related to fibre formation
- Over-processing should be avoided (max T_{core} and time)



Shear cell technology for meat analogues

- Shear cell technology is very suitable for creating large and thick pieces of fibrous structures that can be cut into whole cut muscle meats

What is next:

- The insights obtained will be combined with our rheological and modelling work to improve the understanding processing conditions required for structuring dense polymer (protein) blends into anisotropic structures

- Follow up research will include different formulations, e.g. moisture content effects, recipes with other plant proteins

Thank you!

Special thanks to the PMM project team

Questions or suggestions

→ during Q&A session ☺

Jacqueline Berghout
jacqueline.berghout@wur.nl