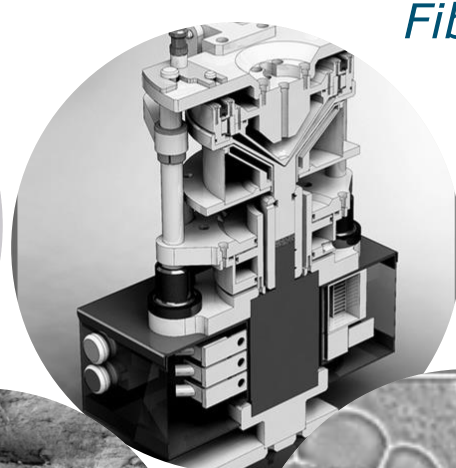
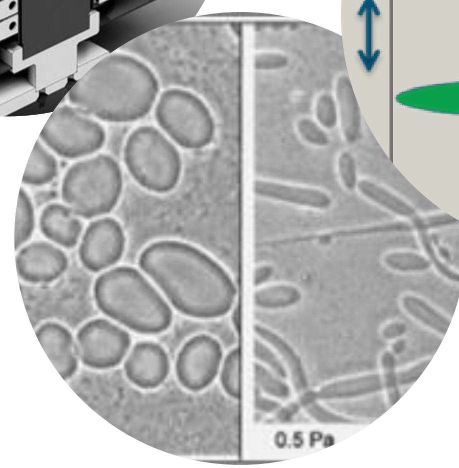
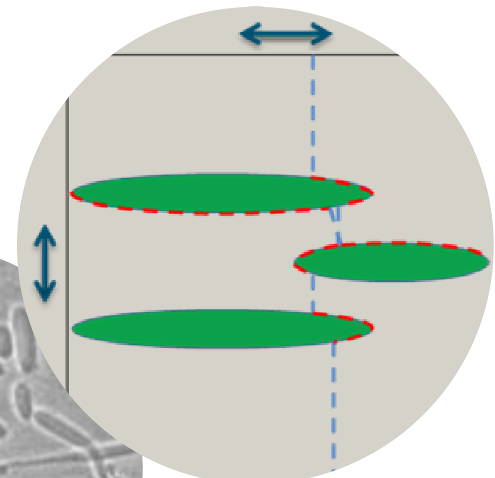
Fibrous structures from a condensed water-in-water emulsion by simple shear flow deformation

Fibrous structures for meat replacers







Birgit Dekkers, Costas Nikiforidis, Remko Boom, Atze Jan van der Goot

Food Process Engineering

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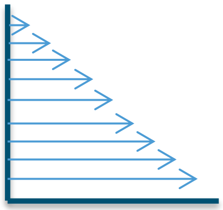
Shear-induced structuring

Fibrous structures

- Fibrous structures - application of meat replacers
- Shear-induced structuring with simple shear flow
- Two phase system is needed

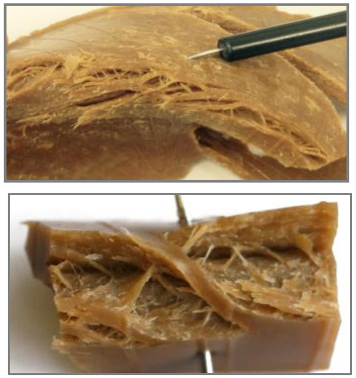


Simple shear flow

Soy Protein Isolate

Soy Protein Concentrate

SPI + Pectin



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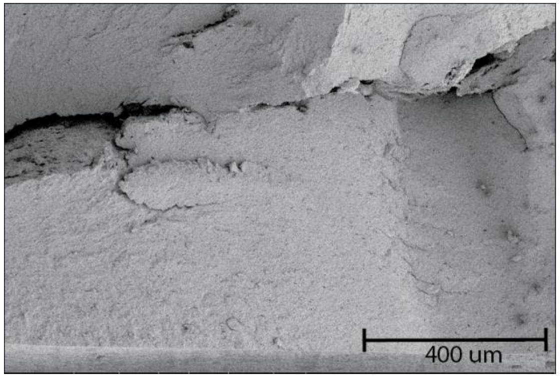
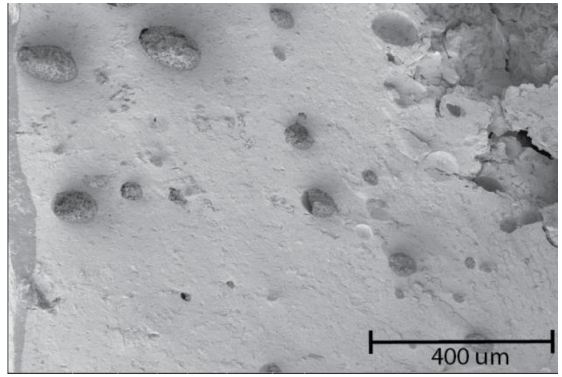
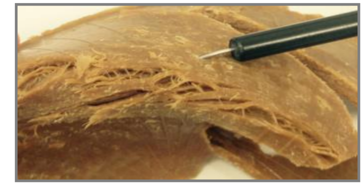
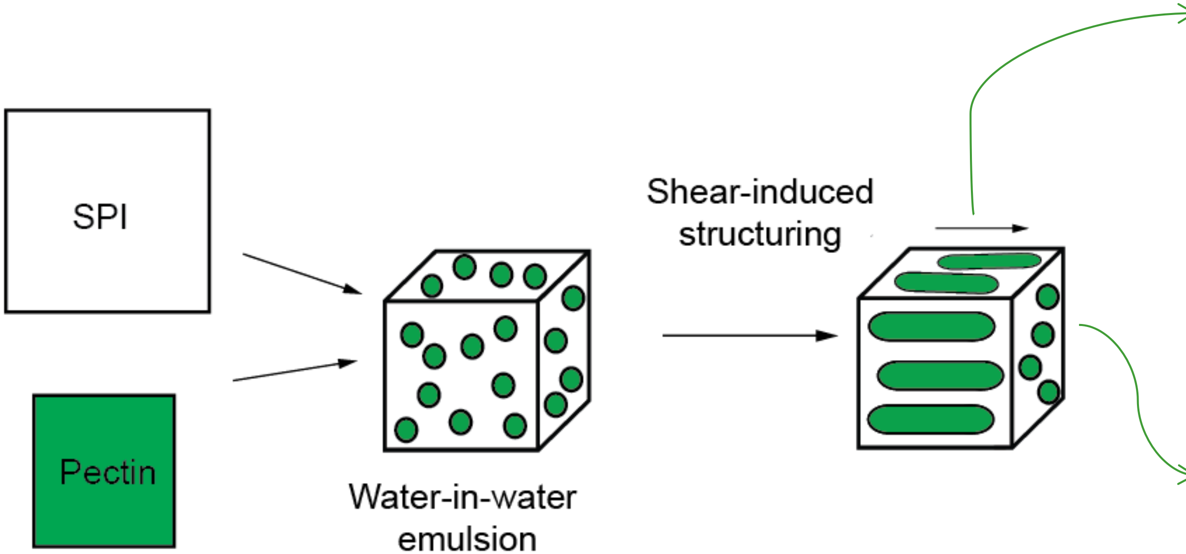
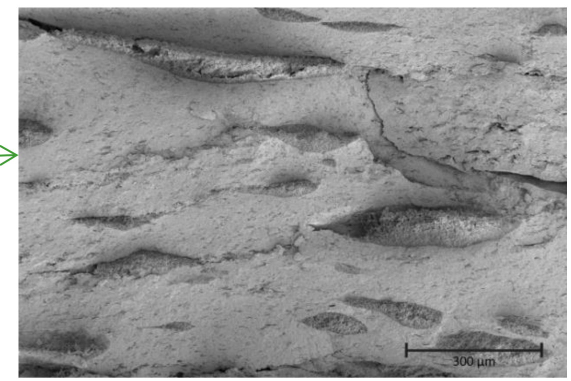
Microstructure SPI + pectin

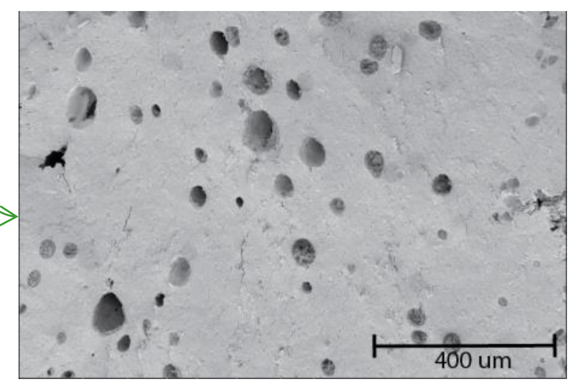




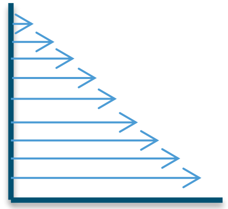






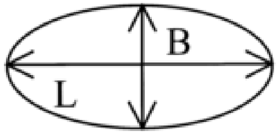


Simple shear flow deformation in model systems



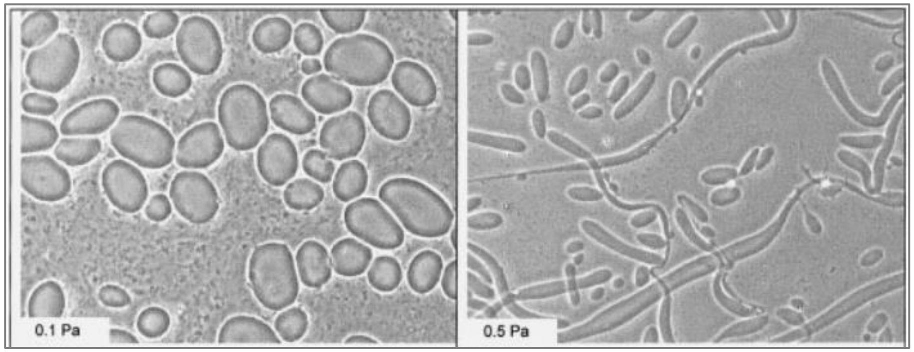
Water-in-water emulsion gellan (2% w/w) & κ-carrageenan (2% w/w)

$$Ca = \frac{\dot{\gamma} \cdot \eta_c \cdot D}{2 \cdot \Gamma}$$



$$D = \frac{L - B}{L + B}$$

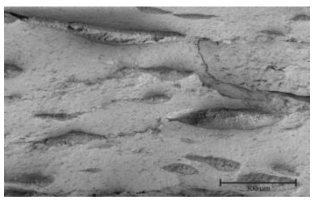
$$Def = Ca \cdot \frac{16 \cdot {}^{\eta_d}/_{\eta_c} + 16}{19 \cdot {}^{\eta_d}/_{\eta_c} + 16}$$

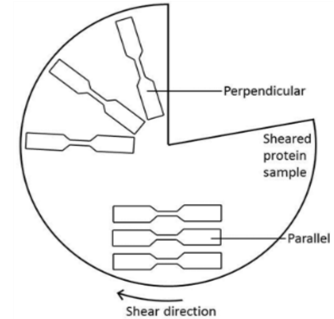


- **Coalescence process** is implied by the observation that the droplet size is increased by application of shear.
- **Viscosity** of blends determines whether high shear stresses result in deformation or break-up of droplets
- Knowledge on **time–temperature dependency** of the relevant material properties

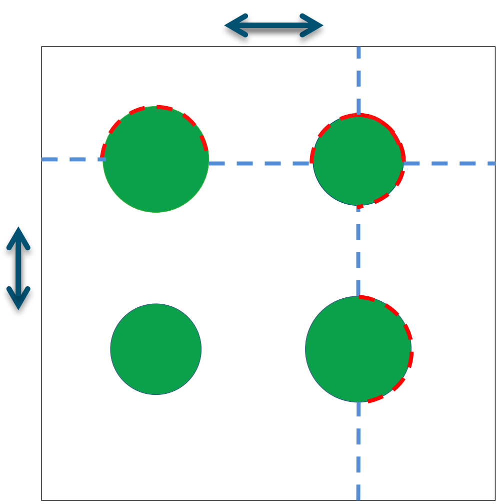
Wolf, B., Scirocco, R., Frith, W. J., & Norton, I. T. (2000). doi:10.1016/S0268-005X(99)00062-4

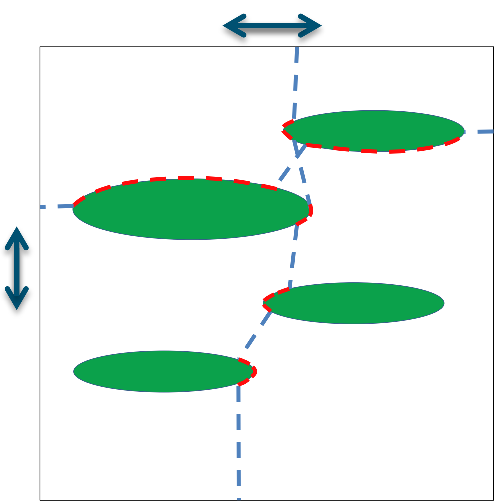
Fracture facilitating area

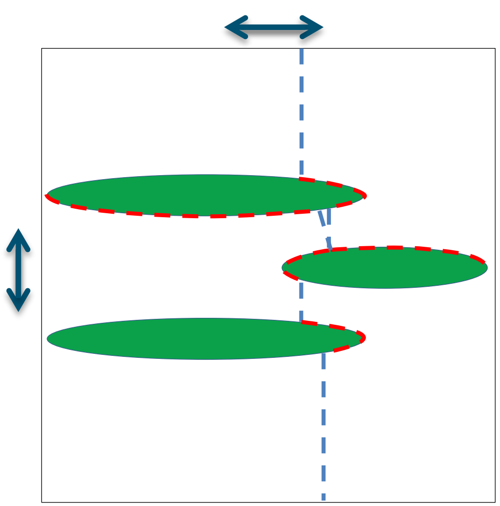




Pectin phase itself is weak, or
weak adhesion between pectin and SPI







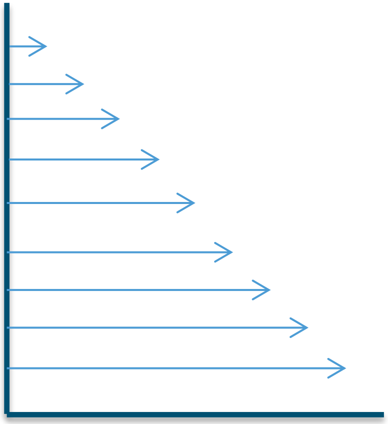
Fibers appear when deforming the product originated from detachment through/along the long side of the pectin filament.

Shear-induced structuring

Important variables for structuring

A. Shear rate
B. Shearing time
C. Temperature
D. Dry matter content (45 wt%)
E. Ratio proteins/polysaccharides

(2.2 wt% pectin / 41.8 wt% SPI)



Simple shear flow

Shear-induced structuring

Important variables for structuring

A. Shear rate

B. Shearing time

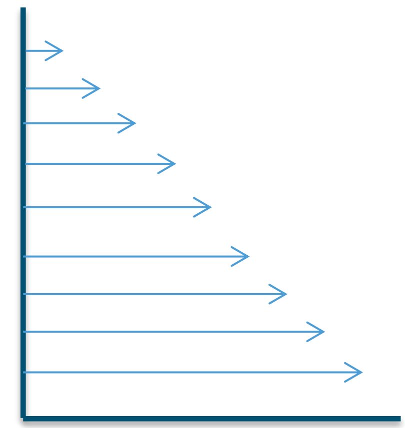
C. Temperature

η_d/η_c

D. Dry matter content (45 wt%)

E. Ratio proteins/polysaccharides

(2.2 wt% pectin / 41.8 wt% SPI)



Simple shear flow

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A. Shear rate

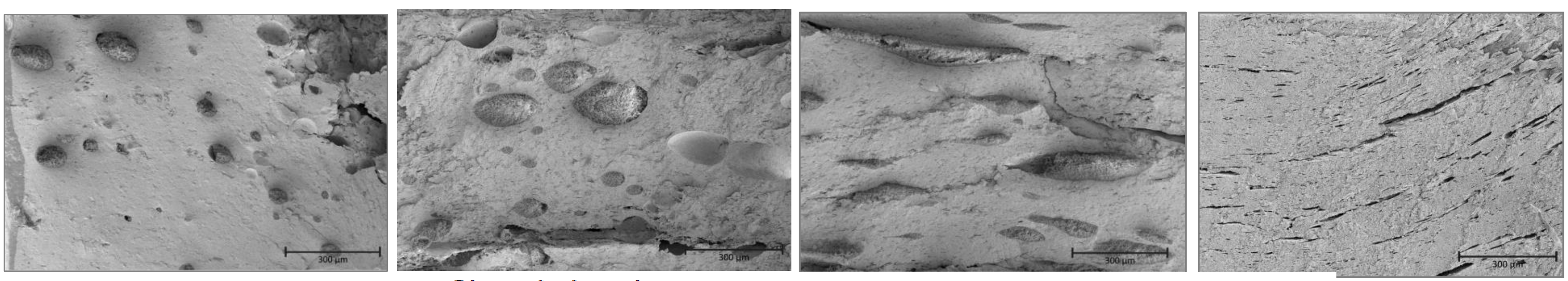
0 s^{-1} | 13 s^{-1} | 39 s^{-1} | 130 s^{-1}

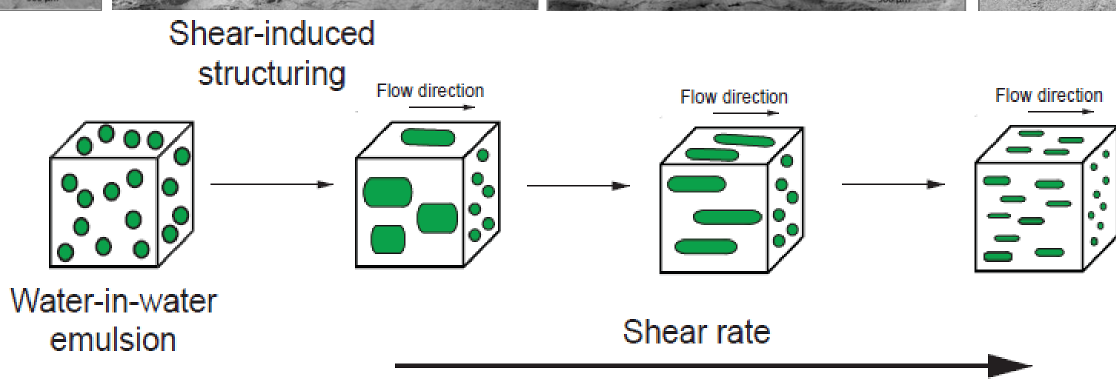
Macrostructure

Shear flow →

Microstructure

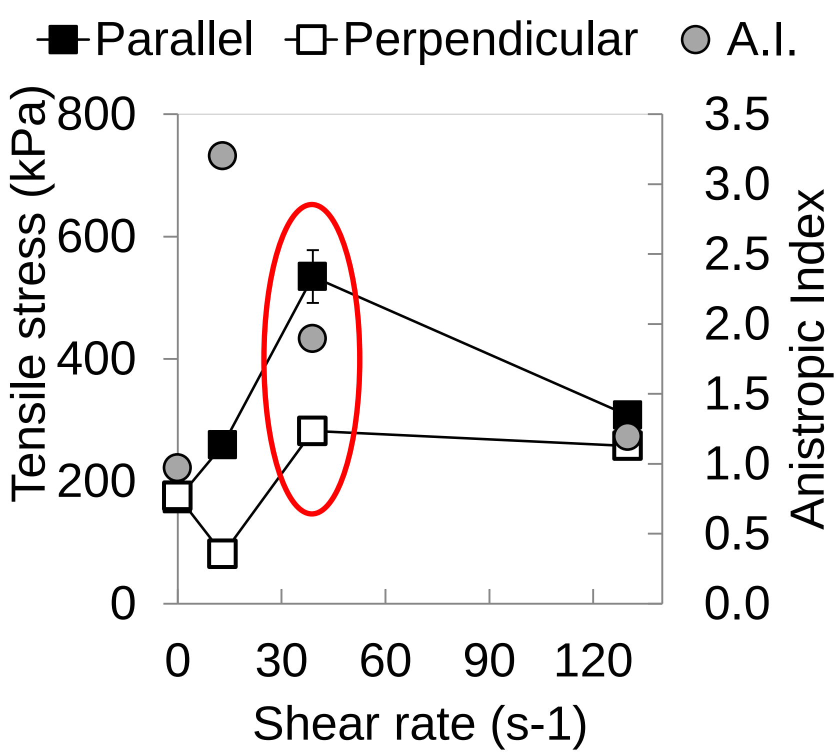
Shear flow →

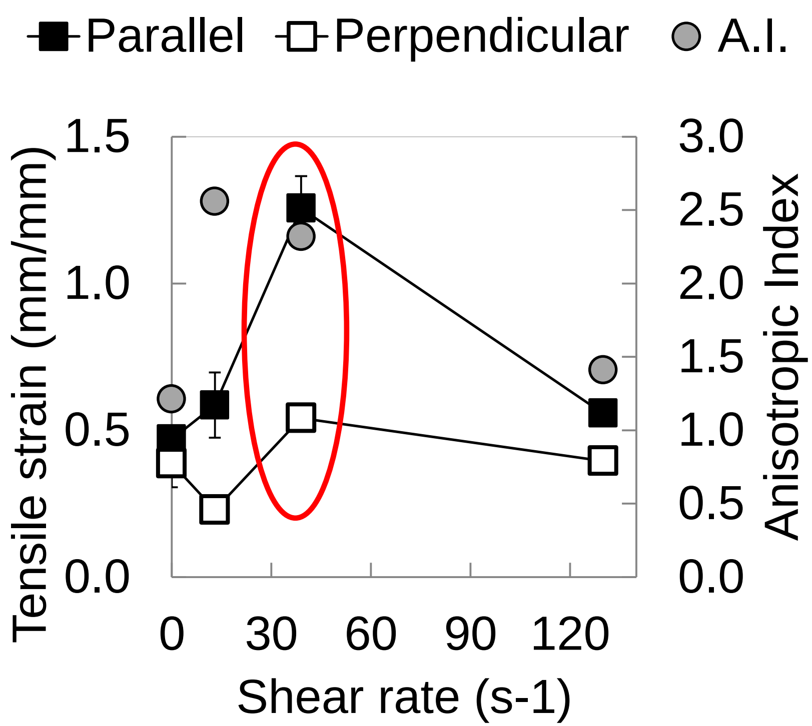




A. Shear rate

Tensile strength analysis





Optimum shear rate (39 s^{-1})
Balance deformation and droplet break-up

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B. Shearing time

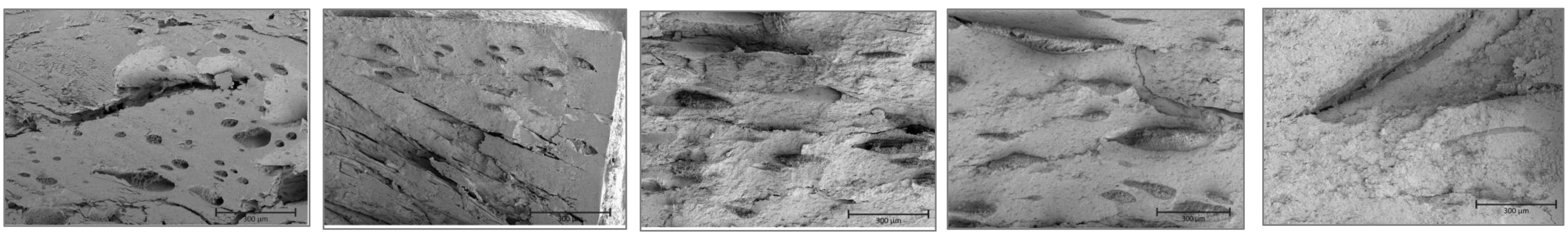
3 5 10 15 30

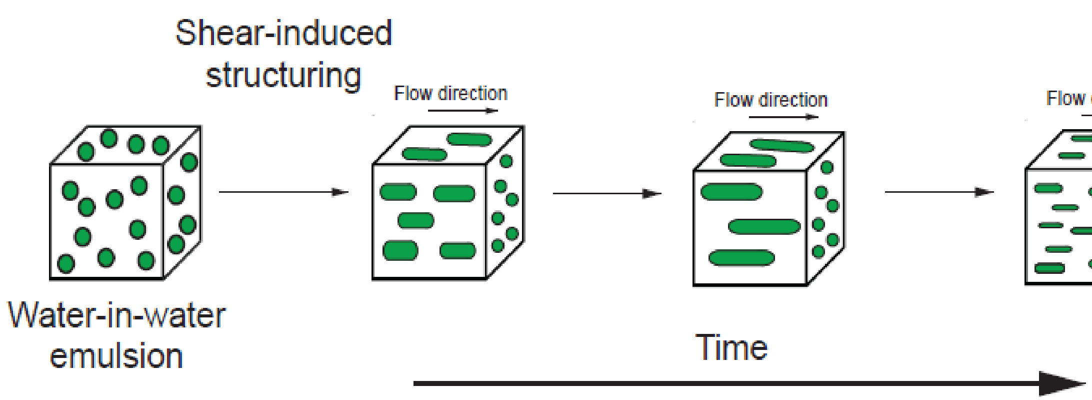
Macrostructure

Shear flow →

Microstructure

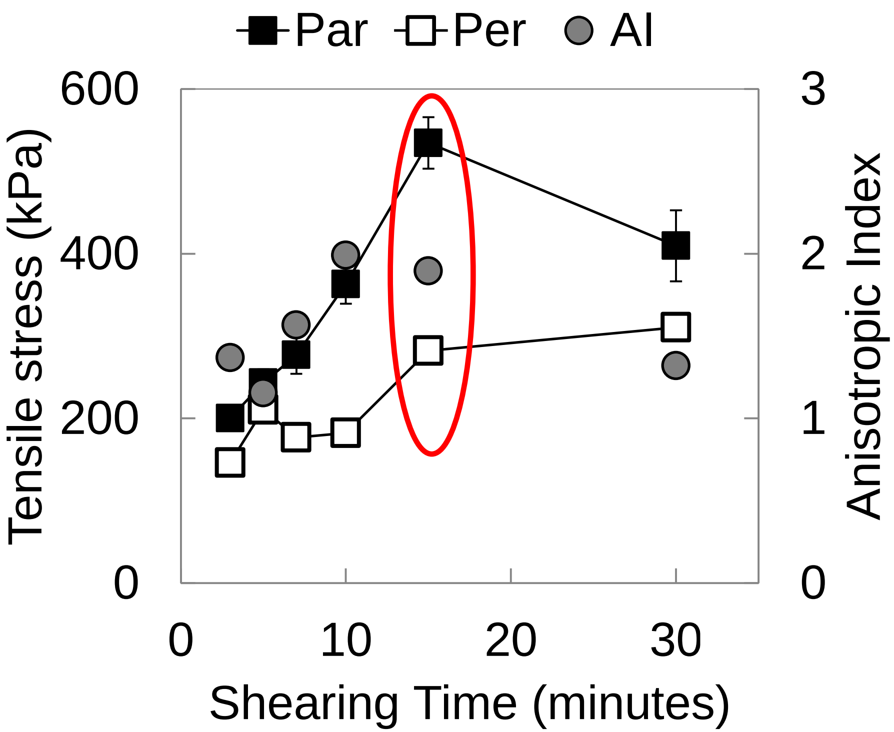
Shear flow →

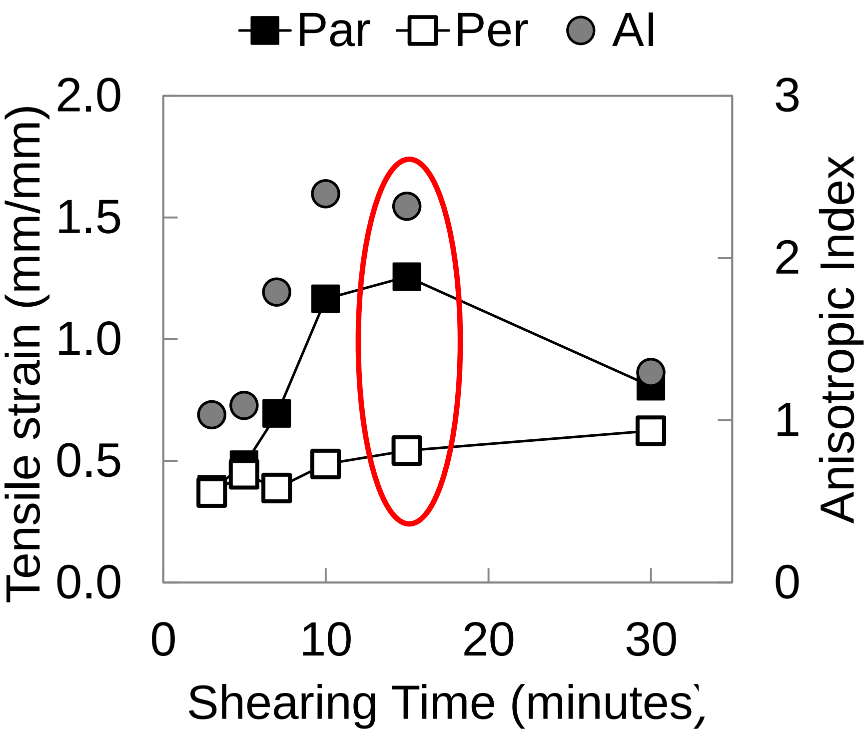




B. Shearing time

Tensile strength analysis





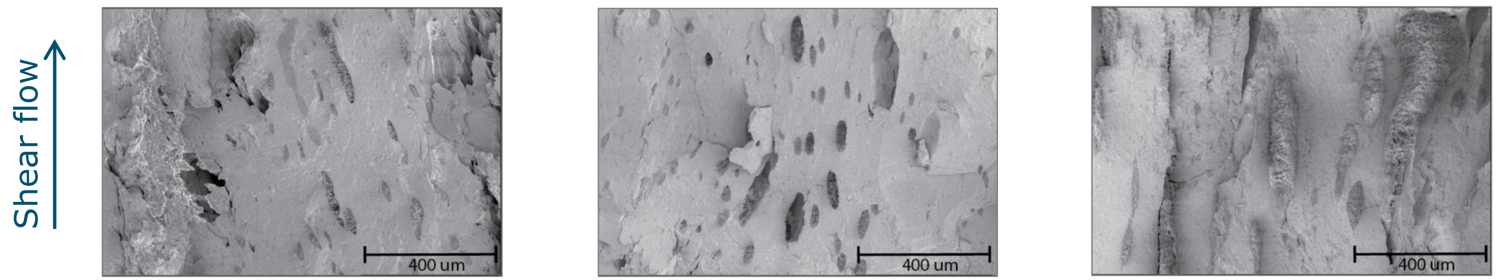
Coalescence process is implied by the observation that the droplet size is increased over **time**.

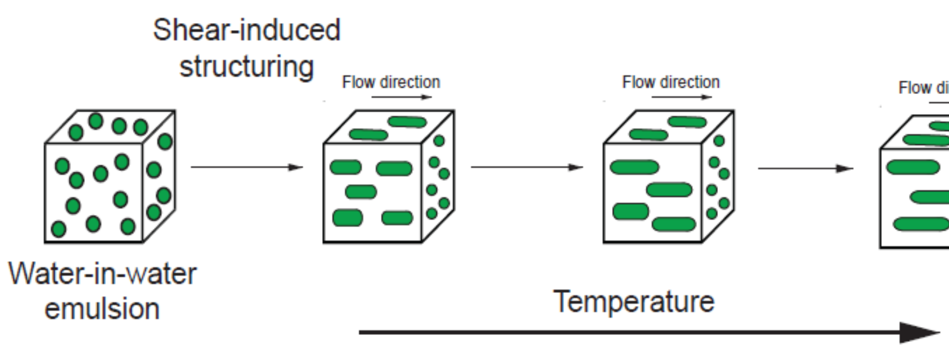
C. Temperature

120 ^oC | 130 ^oC | 140 ^oC

Macrostructure

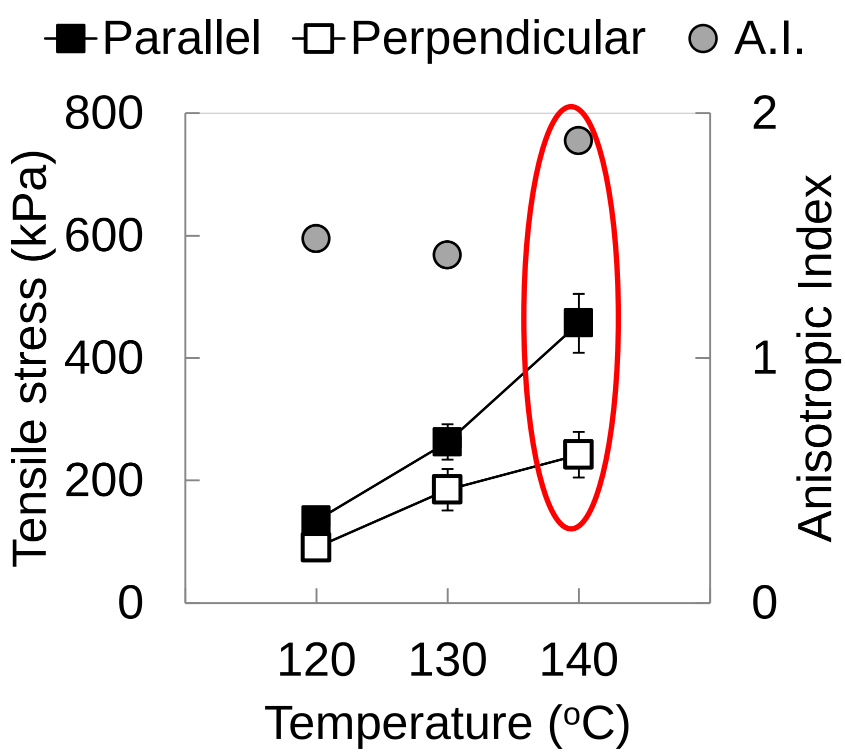
Microstructure

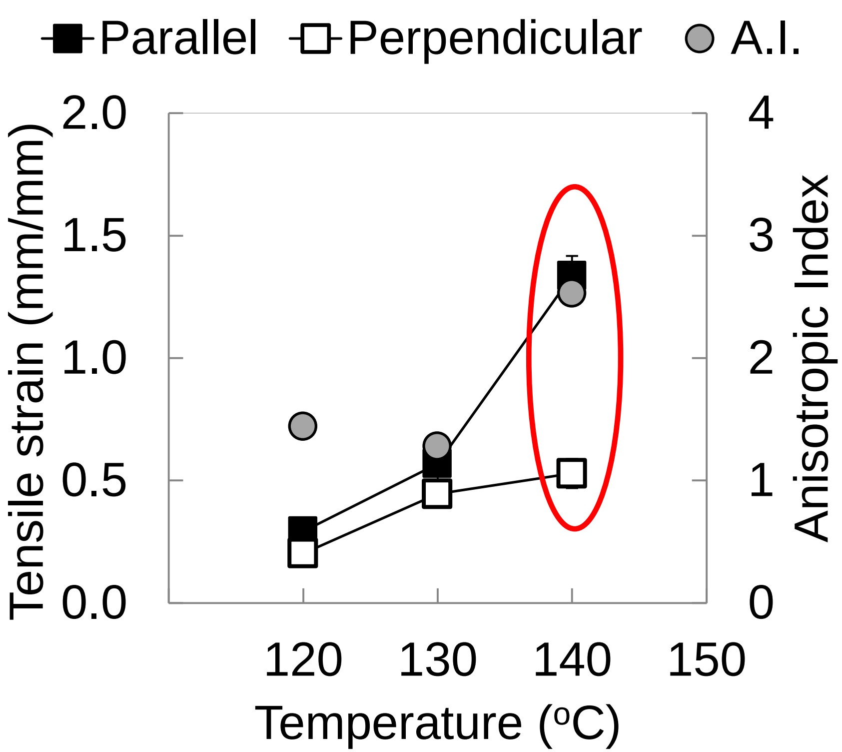




C. Temperature

Tensile strength analysis





A shearing temperature of 140°C is needed for fibrous structure formation

Coalescence process is implied by the observation that the droplet size is increased by application of **shearing temperature**.

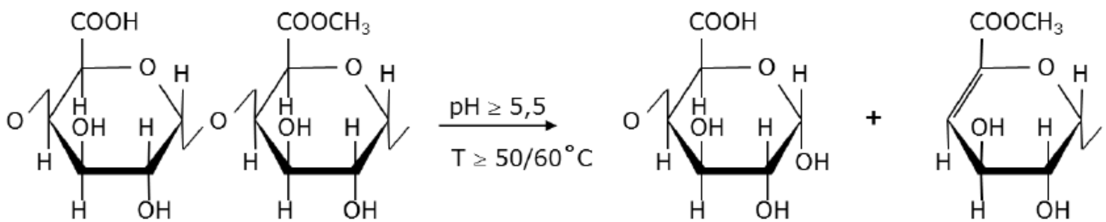
Time-temperature dependency

Changes in pectin phase / interaction
pectin - SPI

- Temperature
- Time

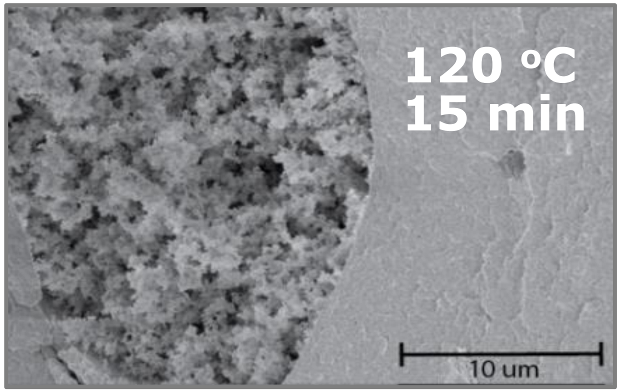
Non enzymatic degradation of pectin

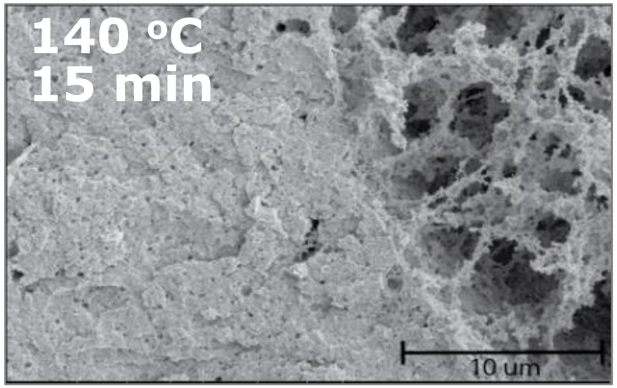
β-Elimination/acid hydrolysis

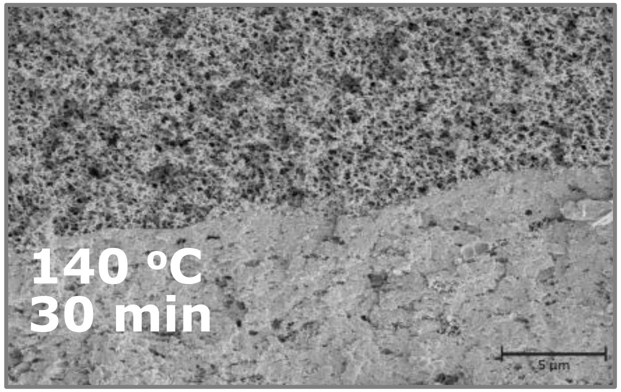


Lower molecular weight → Viscosity (η_d/η_c)

Lower molecular weight → Flexibility

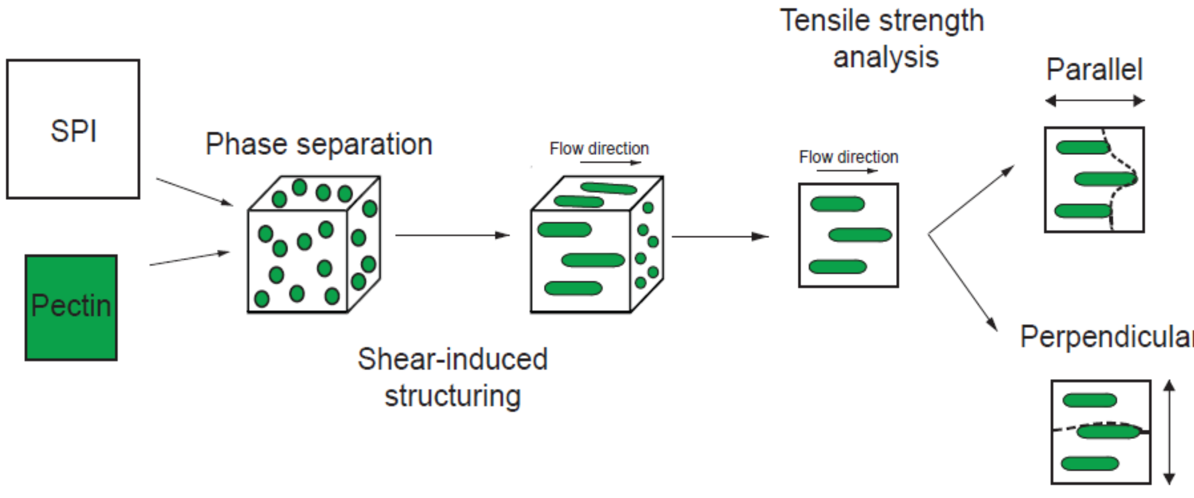






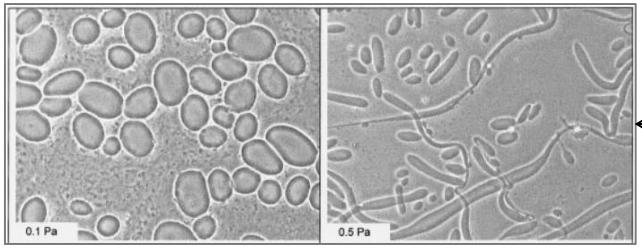
Fibrous structures for meat replacers

- Simple shear flow deformation of pectin/soy blends - fibrous structures
- Pectin is weak dispersed phase or weak adhesion between pectin and SPI→ elongated droplets under simple shear flow
- Fibers appear when deforming the product by tearing originated from detachment through/along the long side of the pectin filament
- Deformation is dependent on shear 1) rate 2) time 3) temperature, hence fibrous structure formation can be tailored with these process parameters

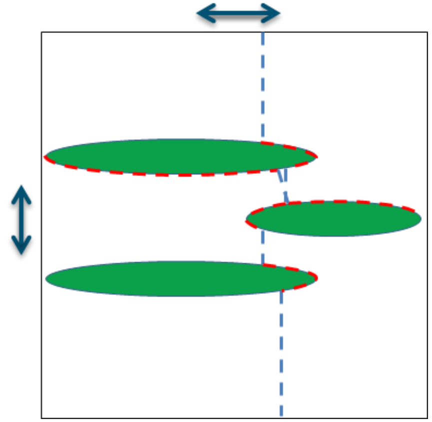


Fibrous structures from a condensed water-in-water emulsion by simple shear flow deformation

Model systems based on (semi)diluted water-in-water emulsions



Fracture facilitating area



Fibrous structures for meat replacers

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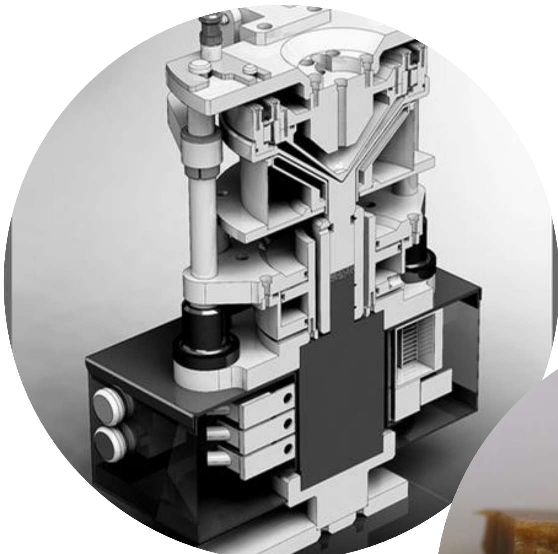
Formation of fibrous protein structures from a condensed water-in-water emulsion by simple shear flow deformation

Fibrous structures for meat replacers



Acknowledgements

Technical workshop

Jarno Gieteling

Tiny Franssen-Verheijen

Luuk Beekmans

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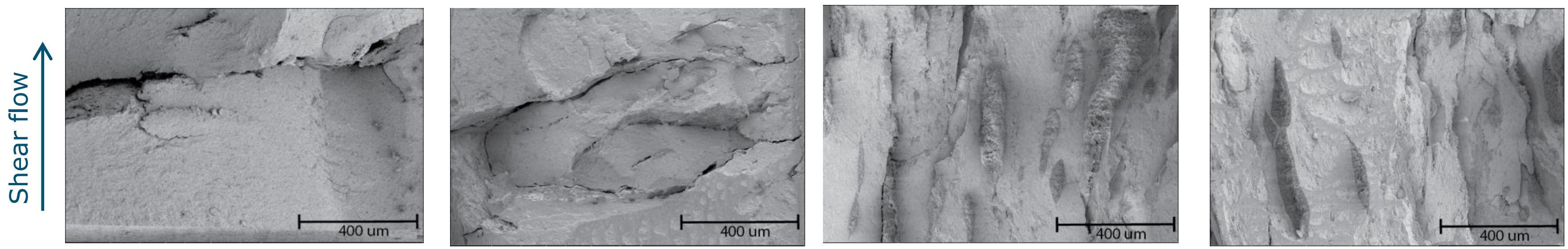
Ratio pectin/SPI

0 wt% | 1.3 wt% | 2.2 wt% | 3.1 wt%

Macrostructure

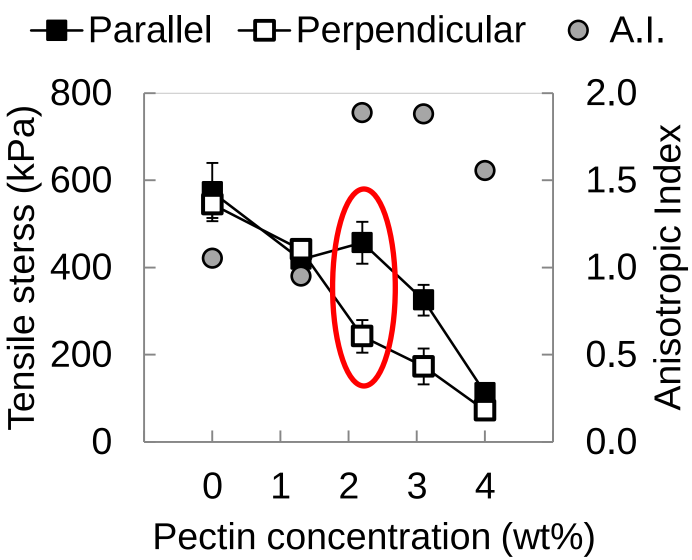
Microstructure

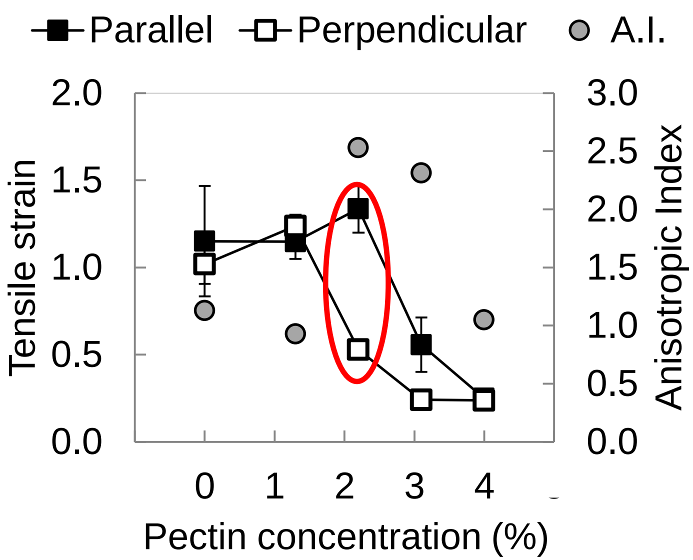


45 wt% dry matter, replace SPI with pectin stepwise

Ratio pectin/SPI

Tensile strength analysis

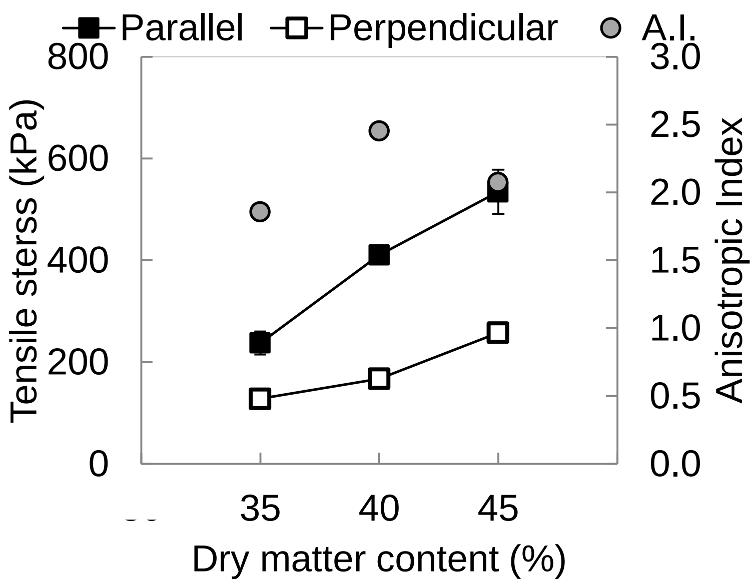


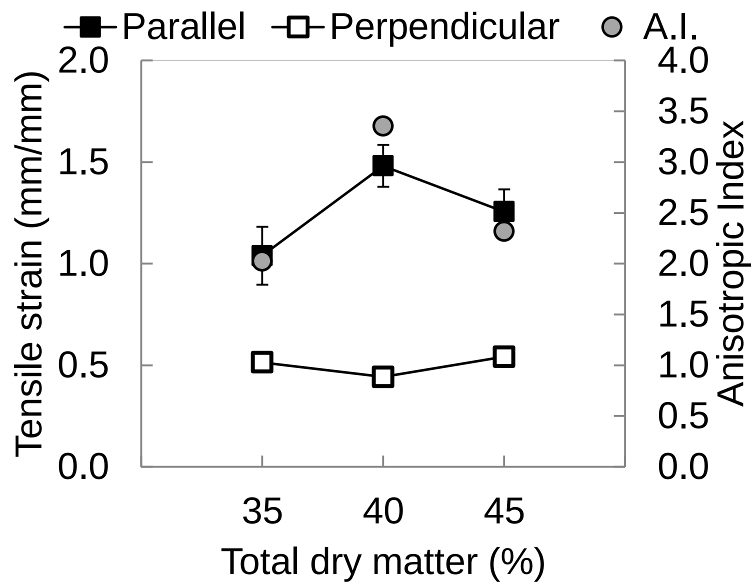


Optimum for the ratio proteins and polysaccharides

(2.2 wt% pectin / 41.8 wt% SPI) for fibrous structure formation

Dry matter





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