# In-line rheology of starch-based mixtures

Polymer Testing World Expo, 29-09-2021

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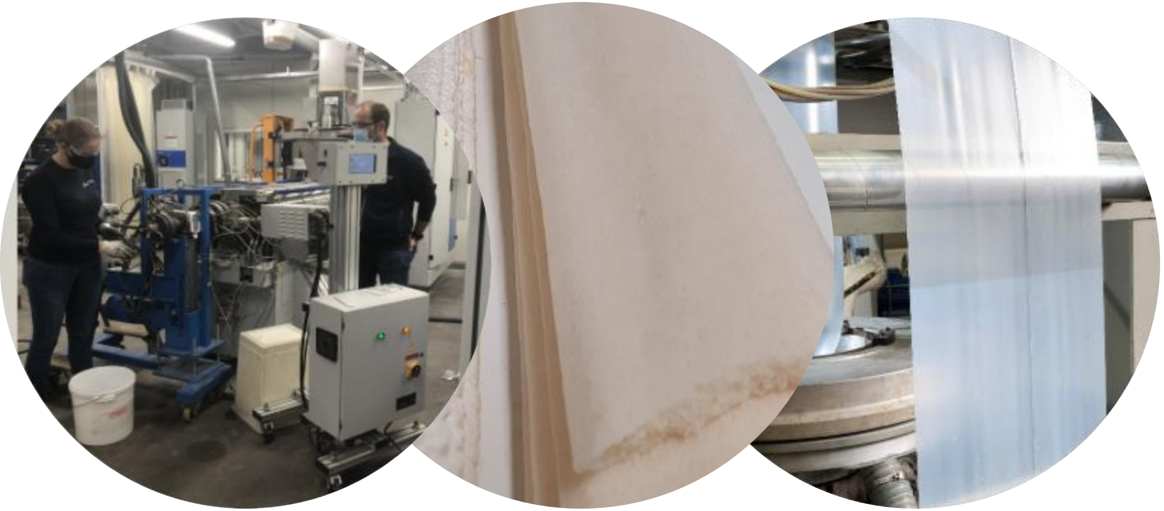

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# Outline

- Introduction Wageningen Research
- Starch and thermoplastic starch (TPS)
- Methods to measure viscosity: offline and in-line
- Examples
- Concluding remarks

# Wageningen University & Research

## Wageningen Food & Biobased Research


To explore the potential of nature to improve the quality of life

# Plastic research at WFBR


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# Facilities for product development

### Facilities

- Polymer synthesis up to 2 kg batch scale.
- Compound production from 0.5 kg to 1000 kg batch scale on 3 modular extruders.
- Supporting infrastructure including dryers, feeders, granulators, pumps.
- Polymer conversion via injection moulding, co-extrusion up to 5 layers in blown film as well as sheets and thermoforming and coating applications, all at pilot scale.

### Analysis

- Extensive options for mechanical, thermal, optical, chemical and rheological analysis specifically suited to support plastic development.

### Sustainability

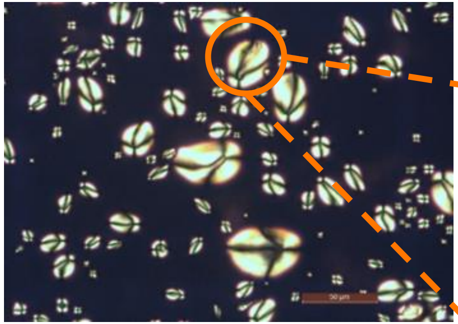
- Facilities to study end-of-life including mechanical recycling of plastic products and biodegradation in different environments.

- Cost effective, modular & flexible
- High quality level
- Offers integrated innovation
- Experienced supporting staff
- Focus on TRL 4-7
- Can be translated to higher TRL

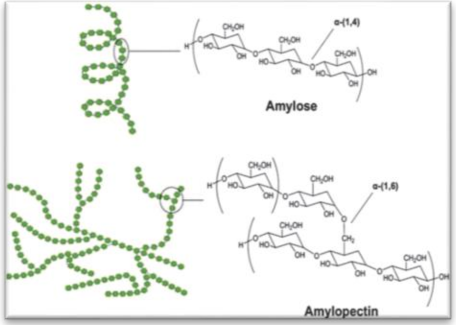
# Biobased materials: Starch

Different sources in nature:
Potato, corn, tapioca, etc
10-20% water content

5-100 µm



- Native is granular
- Different shapes and diameters
- Gelatinization vs melting




Amylose and Amylopectin
High molar mass
Semi crystalline

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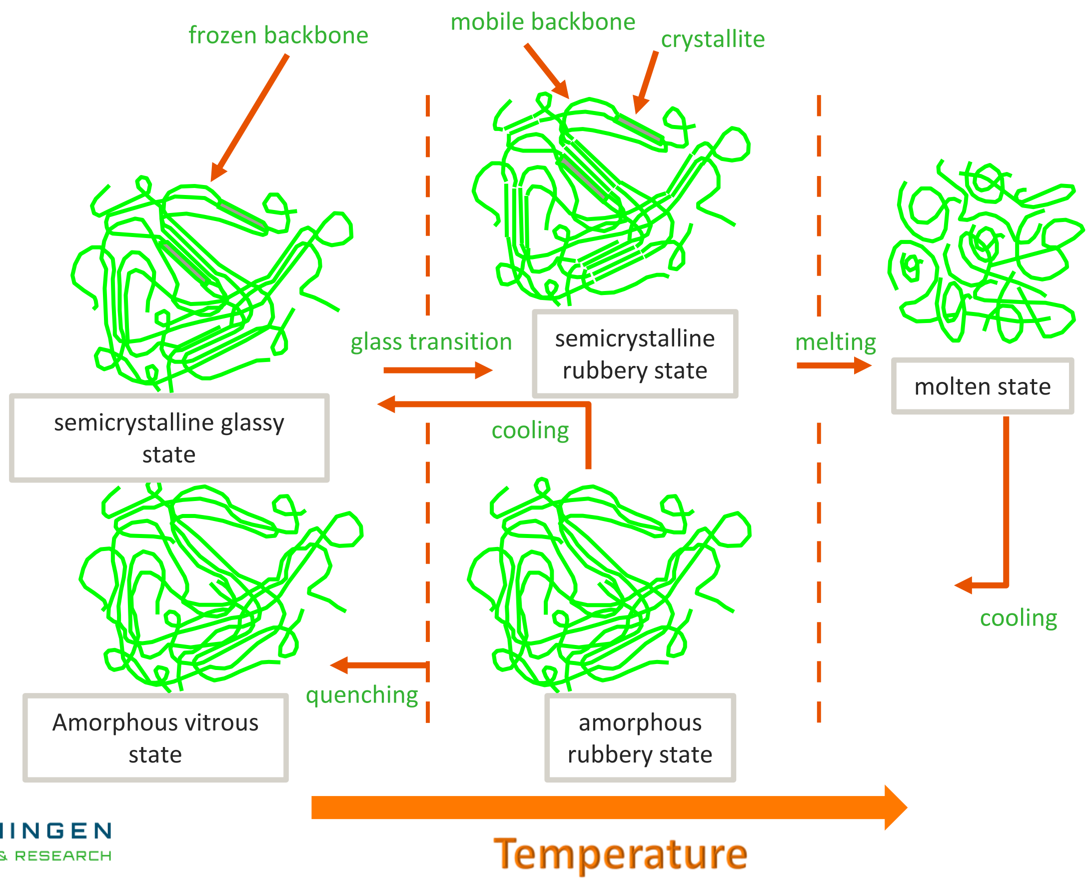
# TPS: structural changes



# From starch to thermoplastic starch (TPS)

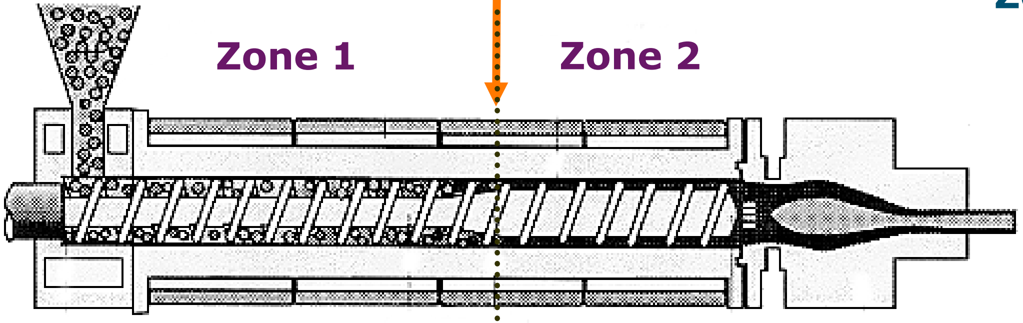
Starch in powder form

Starch, Plasticizers,
Additives, Water

Gas
Additives
Compatibilizer
Second biopolymer

**Zone 1**) Melting or gelatinisation
**Zone 2**) Blending/transport

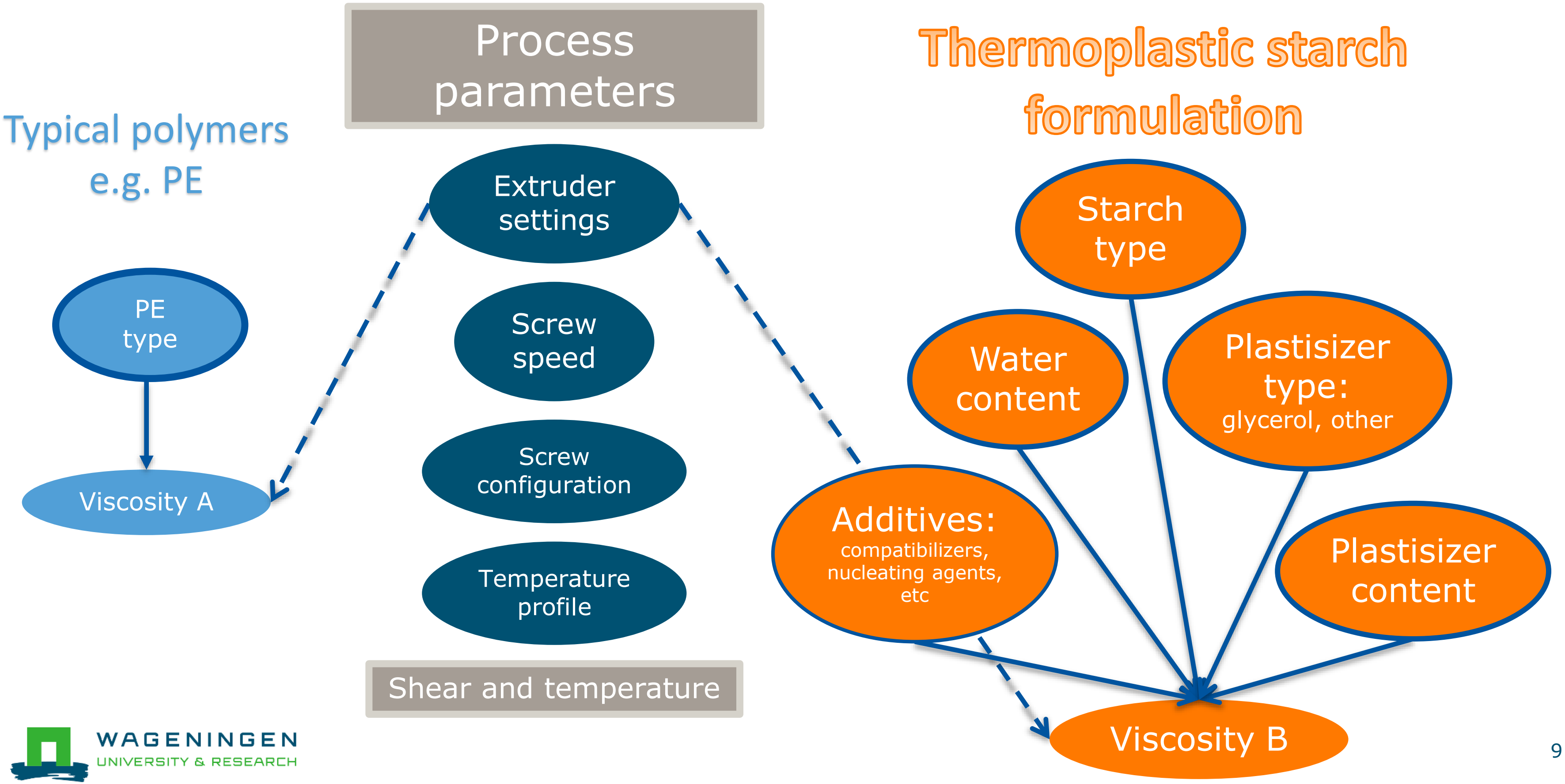
**Zone 1** **Zone 2**



**TPS**

Granulate (or foam)

# What defines viscosity of TPS?

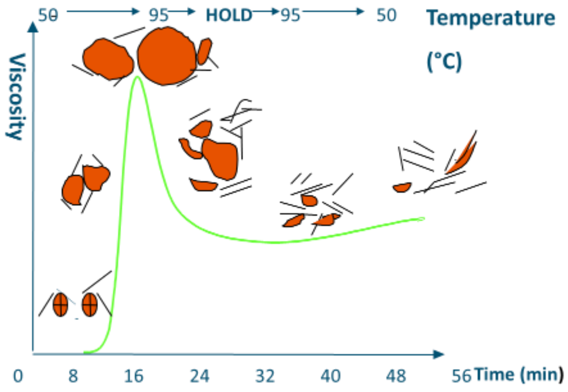


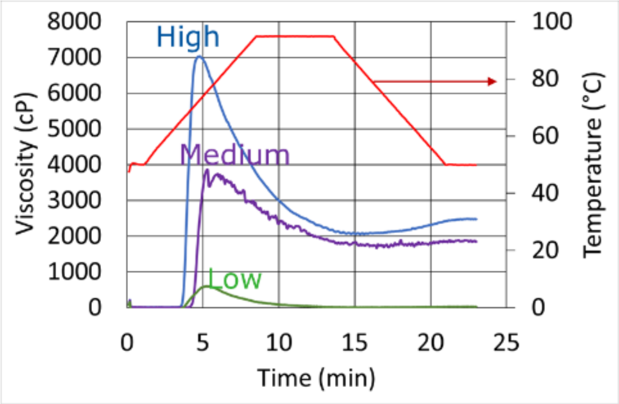
# How to measure starch viscosity? Option 1

**Rapid Visco Analyser (RVA)**

- Typically used for native starch
- Information on gelatinisation peak, end viscosity
- Clear differences of starch types

- Only possible with water soluble materials (like starch!)
- Relatively low temperatures and shear

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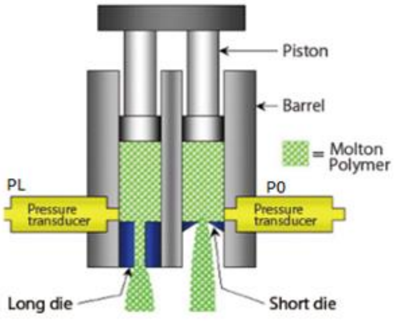
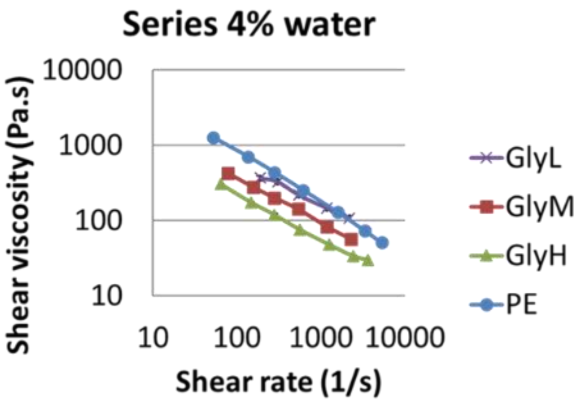
# How to measure starch viscosity? Option 2

**Offline Capillary Rheometer**

- Typically used for polymers
- Closed system
- Measurement in pellets
- Shear rates comparable to extrusion




- Molten material needed!
- Till now not possible to measure TPS under extruder conditions (high water content!)

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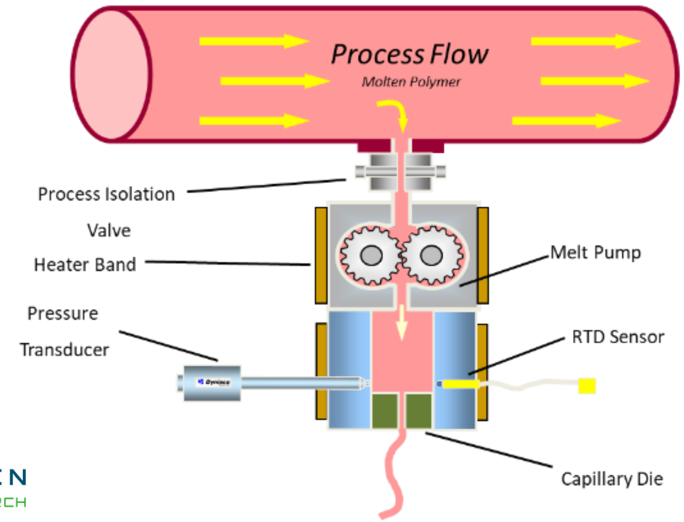
# How to measure starch viscosity? Option 3

## In-line Capillary Rheometer

- Directly connected to extruder
- Possible to measure mixture at high water contents!




Dynisco

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# Project: Carbohydrate-based foam as sustainable thick packaging material

"Development of (a new technology for the production of) thick-walled starch based packaging materials suitable for packaging heavy products"

Topsector Agri& Food

TKI Agri&Food
Postbus 557
6700 AN Wageningen
www.tki-agrifood.nl

PaperFoam®

*Packaging towards a sustainable future*

Project partners:
PaperFoam B.V.
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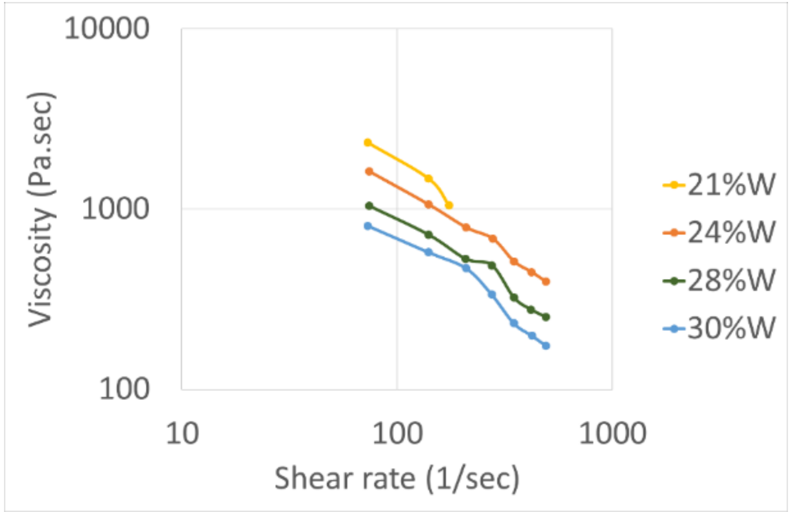
BEWiSynbra Group
WFBR

# Measurements in-line capillary rheometer

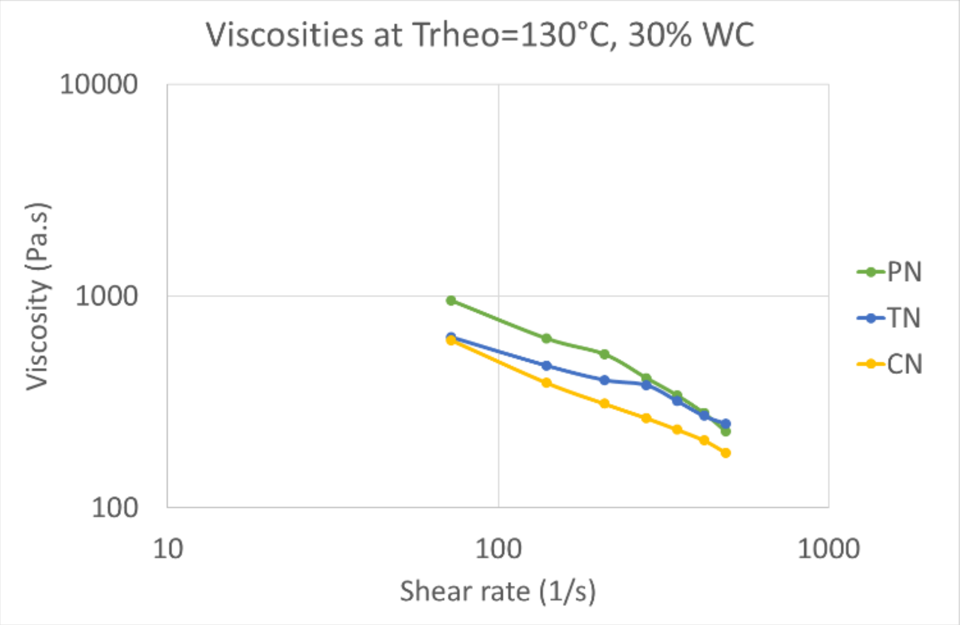
# Effect of water content of starch formulations




Increasing water content
@ $T_{rheo}$ = 140°C.

- It is possible to measure viscosity values in a reproducible way at different water contents under extrusion conditions

# Effect of different starch types




Different starch types result in different viscosity of the formulation!

# Flow modeling for starch-based compounds

**INPUT**

- rheology
- processing conditions (Q, T, WC)
- geometry

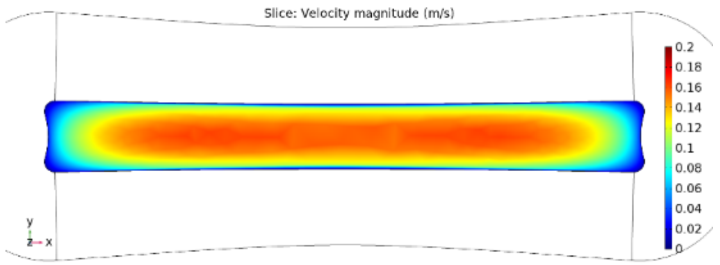
CFD →

**OUTPUT**

- velocity field
- pressure field

Engineering →

Die design




Good match with experiments!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# Conclusions

- Thermoplastic starch is a challenging material to characterize
- Offline rheometers can provide part of the flow information of some TPS systems
- In-line rheometry provides valuable information for starch based mixtures under extrusion conditions!
- Rheological measurements help to improve and understand processing and properties of starch based thermoplastic products

# Questions?

Thanks to colleagues at WFBR, Dynisco, consortium partners of AF-17037 and collaborators from Naples University