Disintegration of agglomerates in liquid

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Introduction

Instant powders

Wetting behaviour

Dispersing behaviour

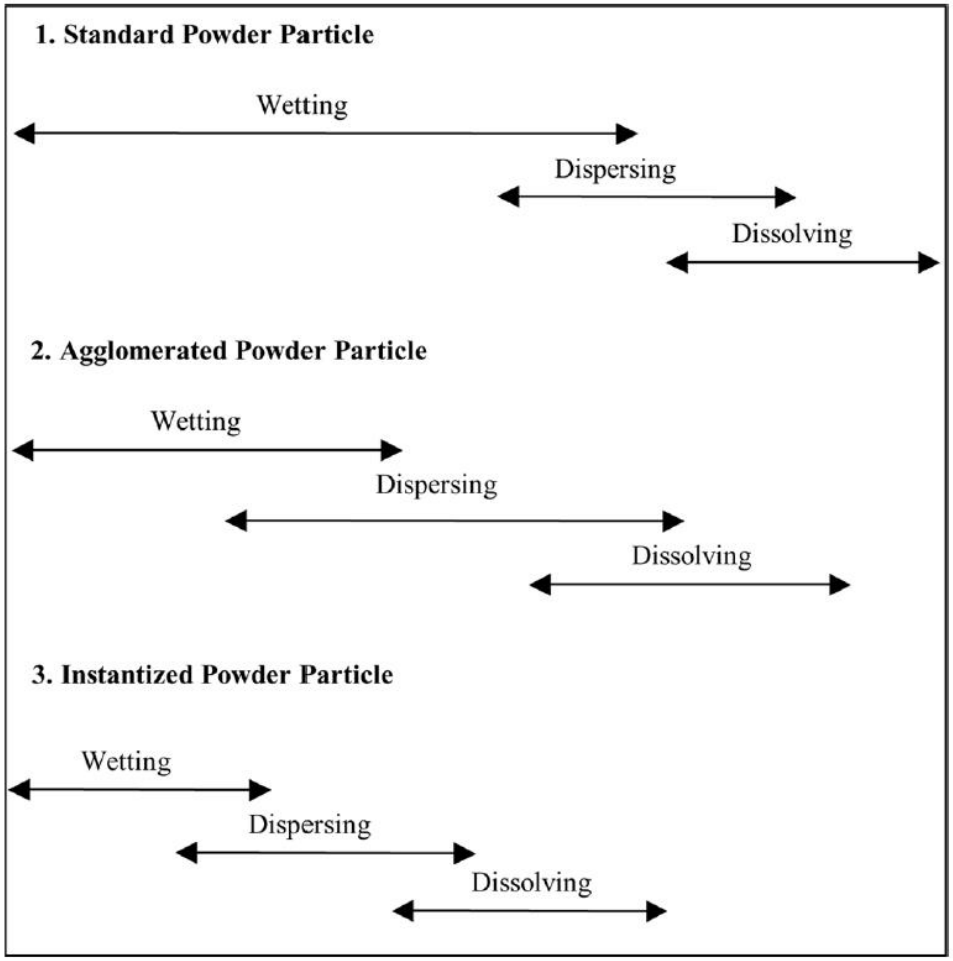
AIM:

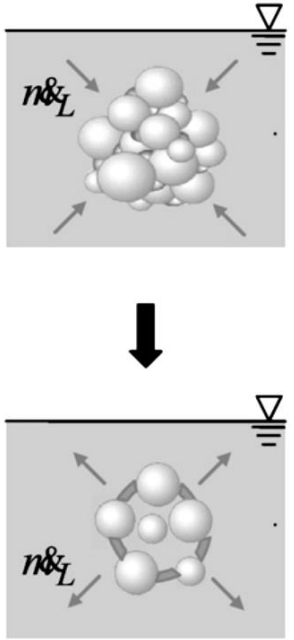
- Good instant properties
- Rapid and complete reconstitution
- No lump formation

Reducing the reconstitution time

- Understanding the rehydration behaviour
- What is the rate limiting step

Powder rehydration





(Fang, Selomulya et al. 2007)

Wetting of powders

Experimental

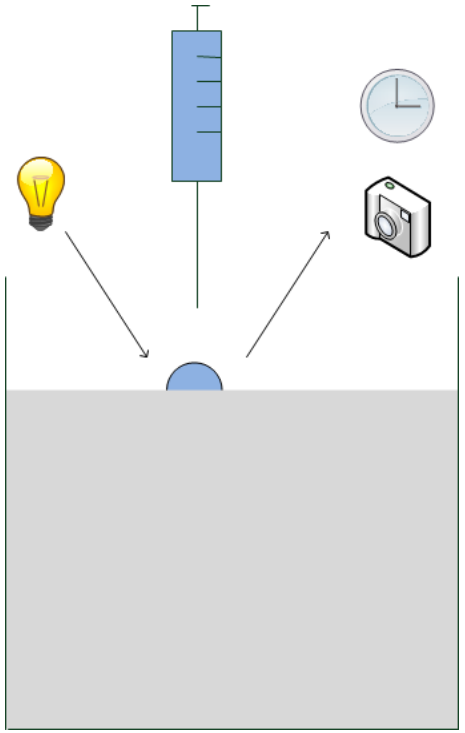
Drop penetration time method

Prepare powder beds by sieving & pressing

Determine the bulk density

Place droplet on powder bed

Record time required to sink in

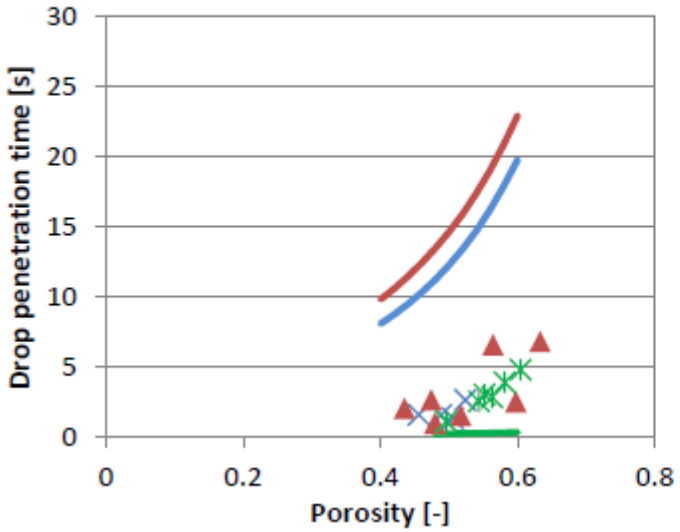


Results

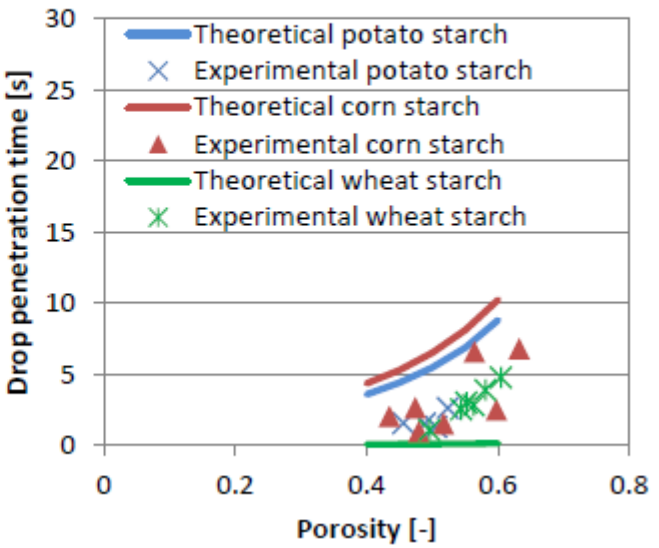
Model adaption – penetration area

- Current model assumes Drawing Area (DA) = Penetration Area (PA)

Original model

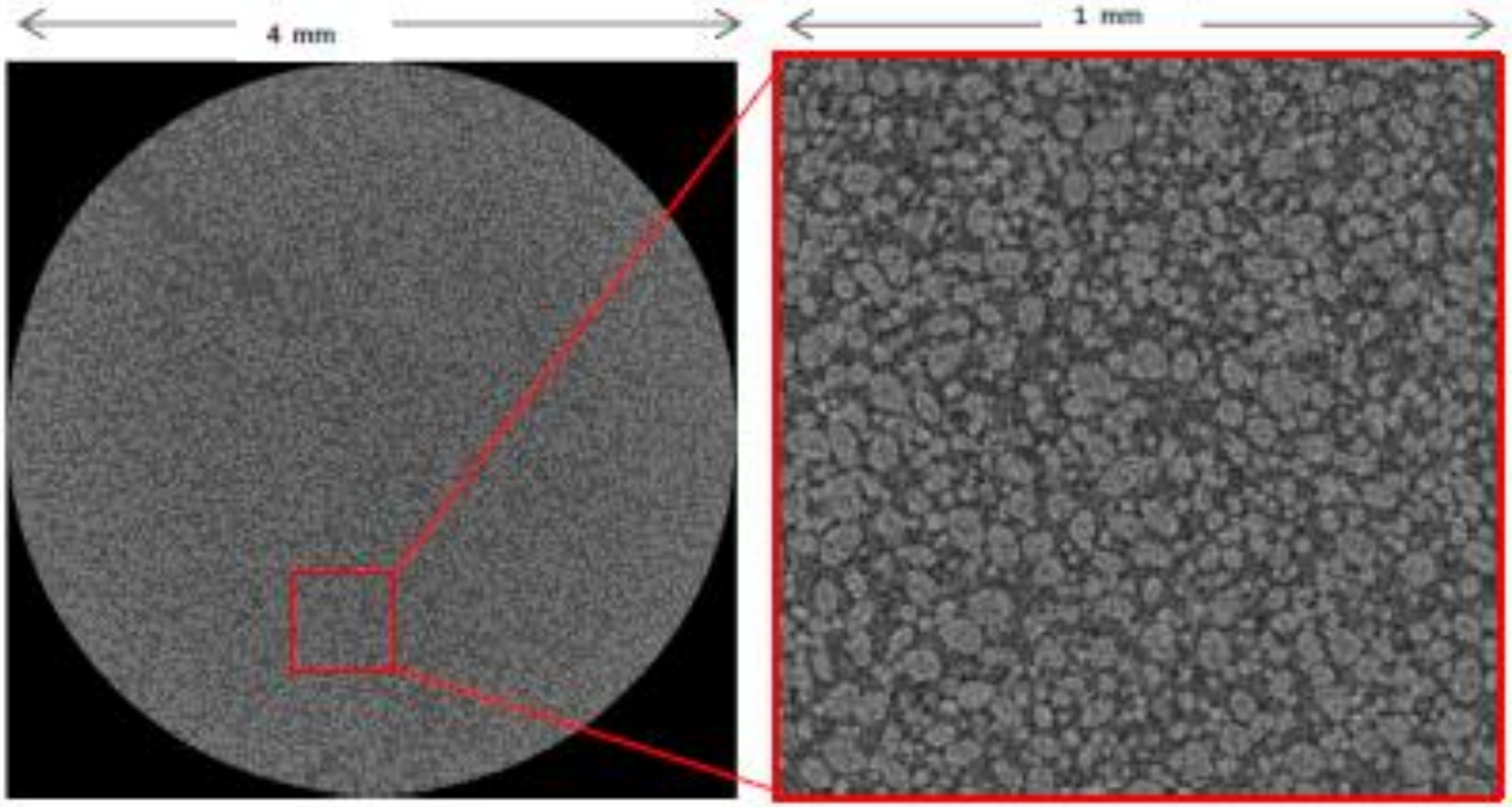


Adapted model I



→ Adaption I decreases difference theory / experiments by factor 2.3
→ (Kozeny Carman)

Micro Computed Tomography



Potato starch ε=075

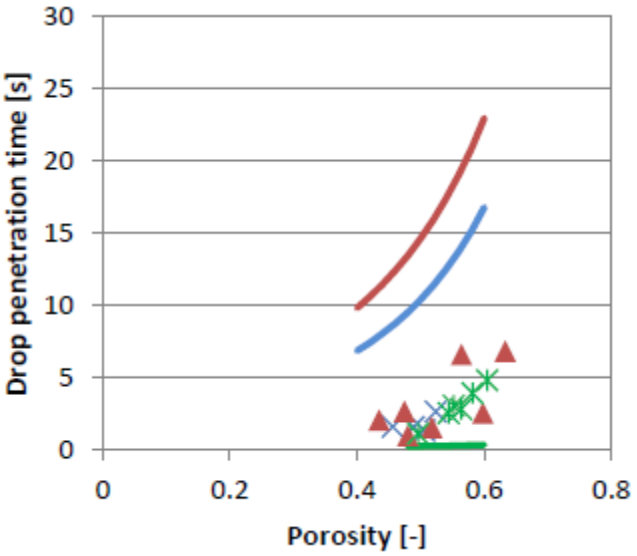
Results

Model adaption – pore size

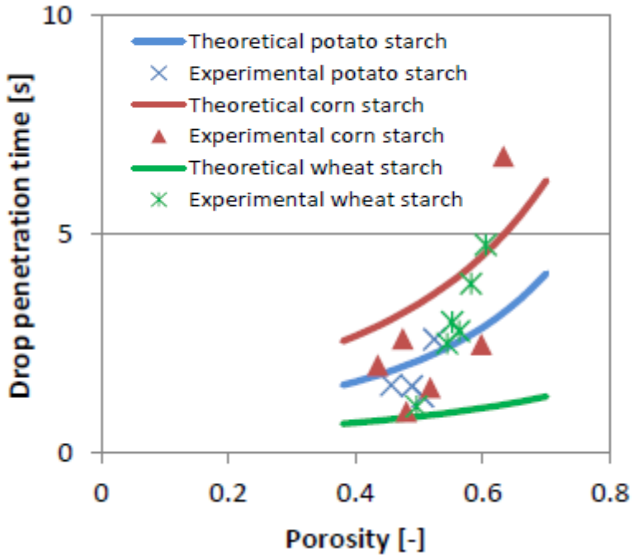
$$R_{eff} = \frac{\phi d}{3} \frac{\varepsilon_{eff}}{(1-\varepsilon_{eff})}$$

- Current model estimates pore size ~ 10^{-7} m
- Experimental pore size (micro CT) ~ 10^{-6} m

Original model



Adapted model II

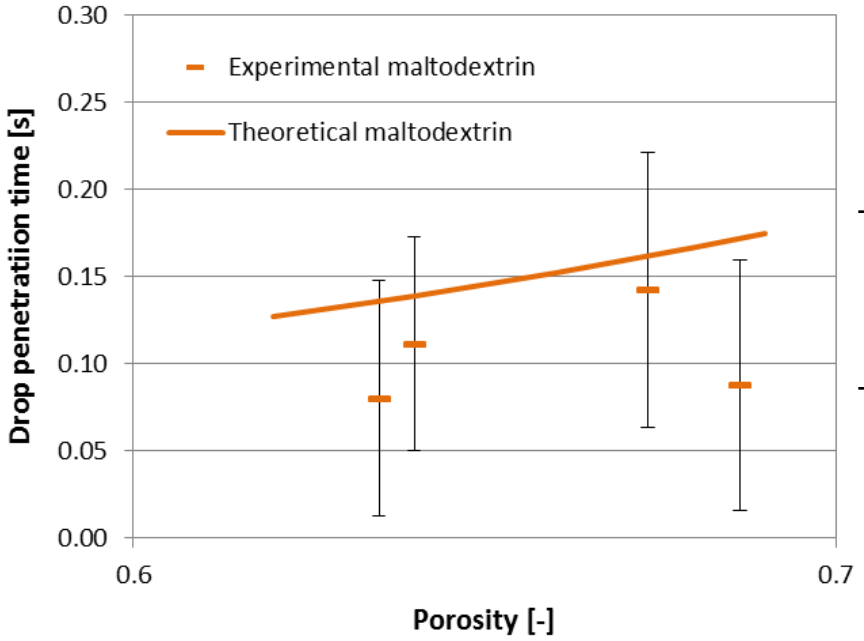


→ Adaption II decreases difference theory / experiments by factor 4.2

→ **(Washburn)**

Results (Maltodextrine & Instant starch)

- Corresponds well to model predictions
- Instant starch behaviour dominated by maltodextrin

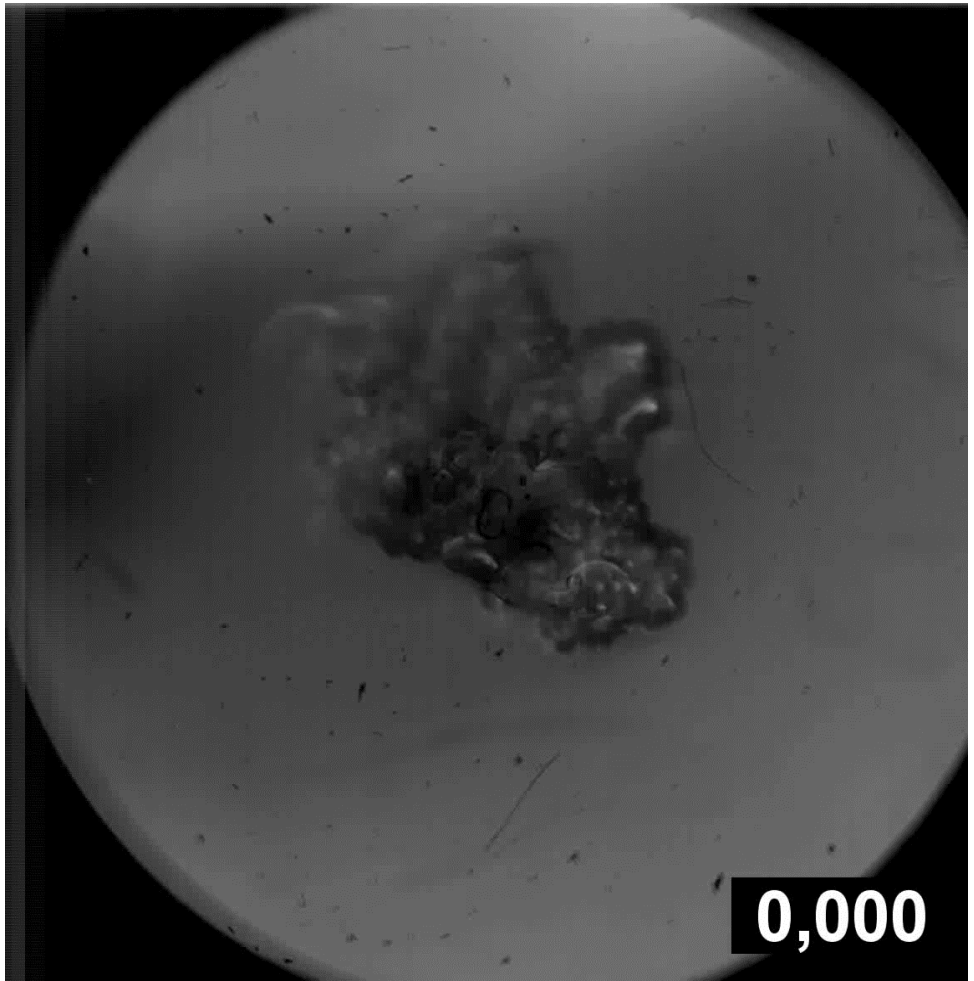


	Drop penetration time [s]		
Weights [#]	Corn starch	Maltodextrin	Instant starch
1	2.0	0.14	0.14
3	1.5	0.11	0.13
12	2.3	0.09	0.10

Disintegration of powders

Disintegration

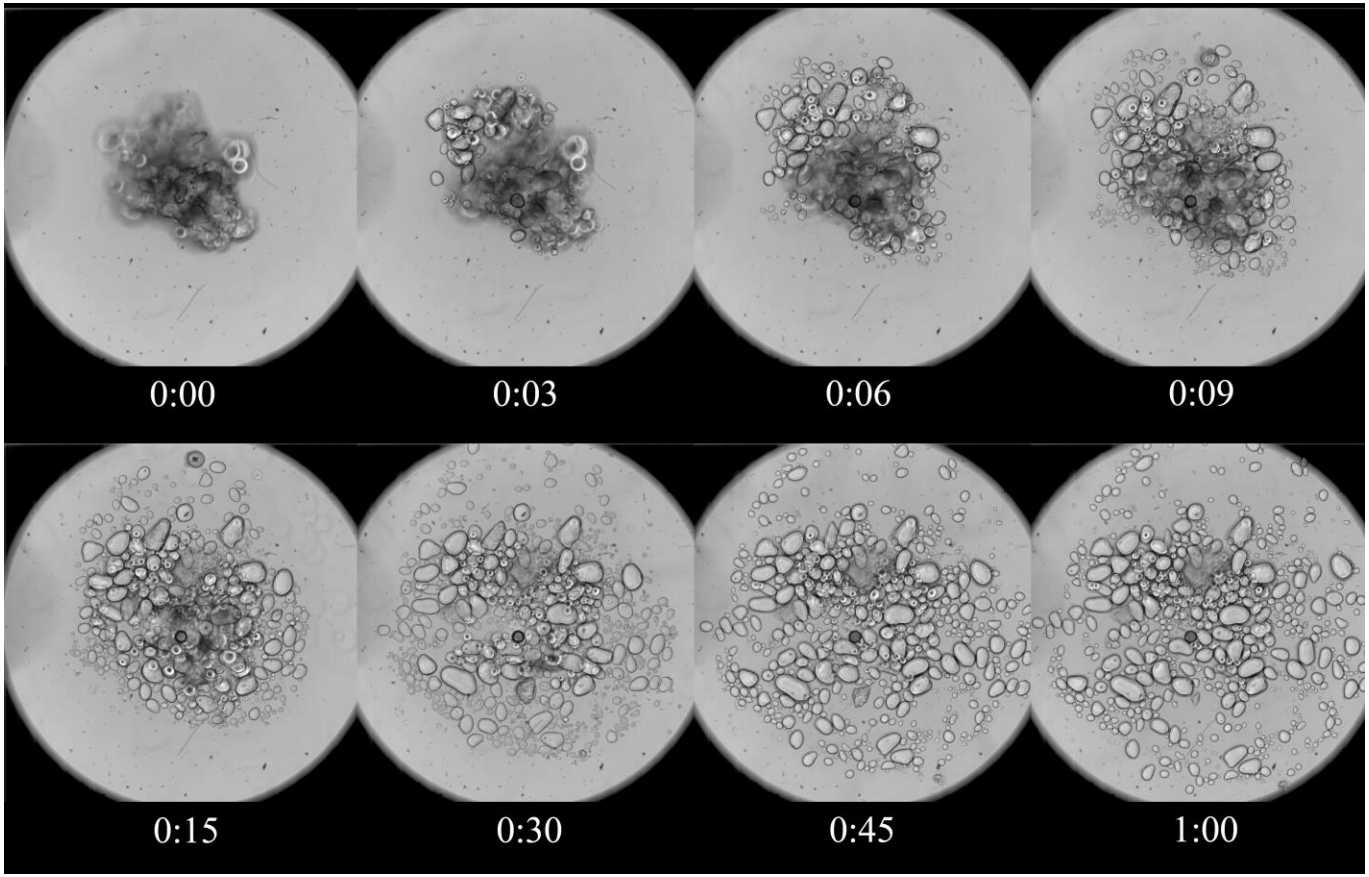
Rehydration of formulated potato starch



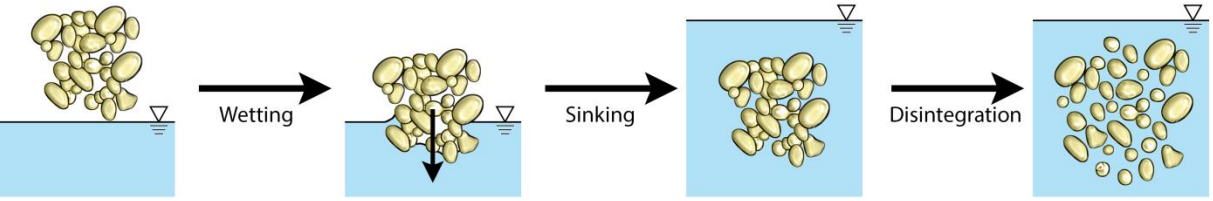
Disintegration

Static version

Rehydration of formulated potato starch



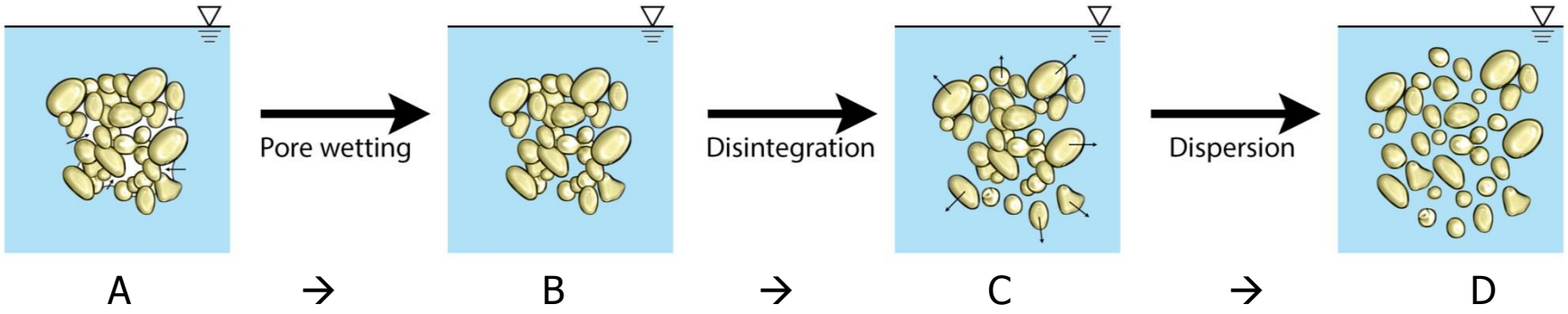
Disintegration



Disintegration

"*The dissolution of the solid bridges between the primary particles followed by dispersion of the primary particles within the liquid volume*"

(Richard, Toubal et al. 2012)



Modelling the data

Various researchers have modelled dispersion as a first order process existing of either a single or multiple exponential terms [1]

$$y = A(1 - \exp(-k_A * t)) + B(1 - \exp(-k_B * t))$$

These researchers measured a property which is linked to disintegration, like the change in:

- Viscosity
- Conductivity
- Light back scattering

[1] To, Mitchell, Hill, Bardon and Matthews - 1994
Kravtchenko, Renoir, Parker, Brigand – 1999
Larsen, Gåserød and Smidsrød – 2003
Galet, Vu, Oulahna and Fages - 2004

Questions to answer

- How can we quantify the disintegration time?
- Can the existing models be used for consumer product?
- What dependency exist for the rate constant?

Experimental setup

Two measurements methods are used during this project to describe disintegration

- Laser light diffraction
  - Measure the particle size distribution and follow this over time
  - Changes in the D90 reflect how the particles get smaller
  - Applicable to powders with good wetting properties

- Spectrophotometer
  - Measure the change in optical density over time
  - Other reconstitution effects are also measured

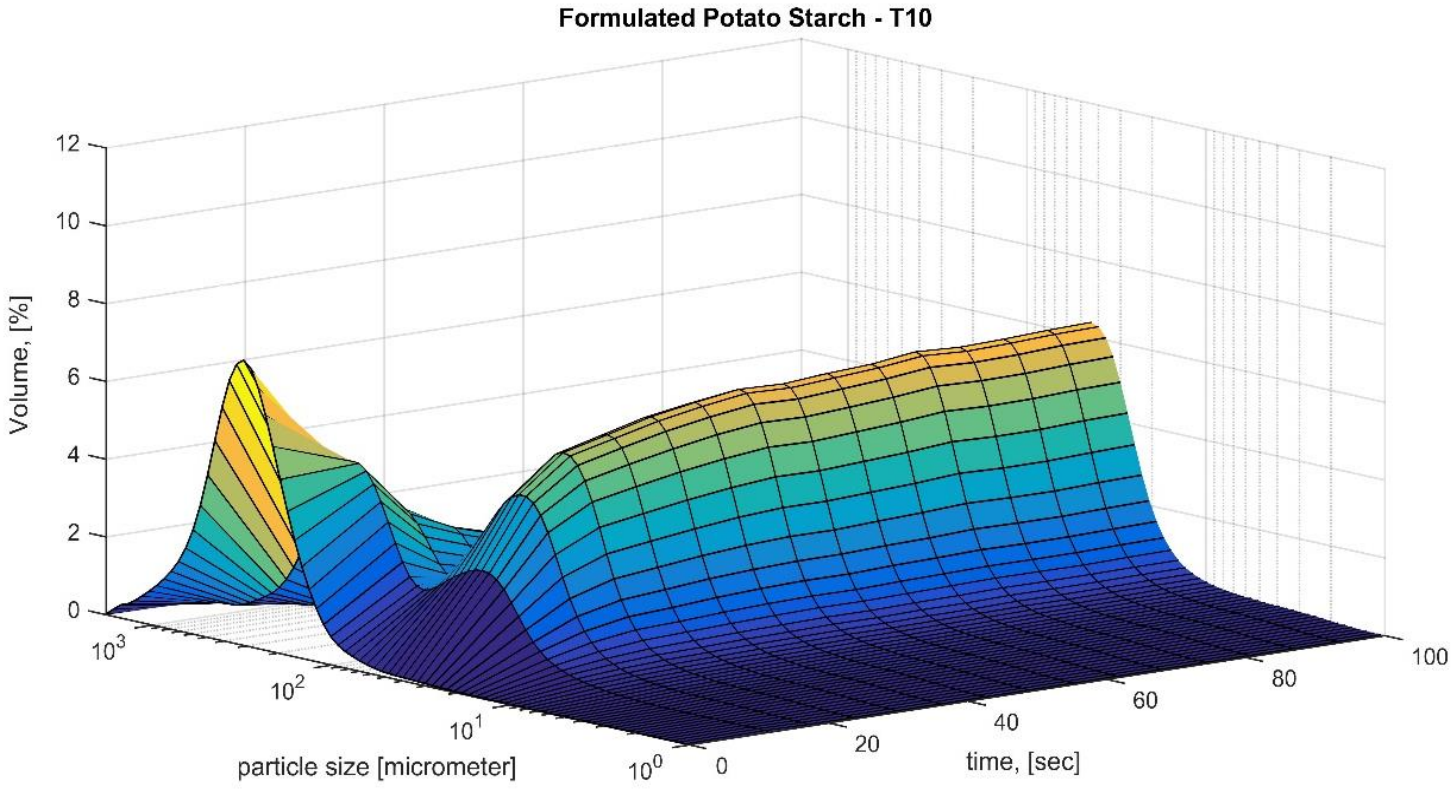
Laser diffraction

Introduction

- Reservoir is filled with water
- Powder is added to the top
- Powder is pumped around to the laser
- The laser light is scattered by the particles
- A particle size distribution (PSD) is sought that best fits the scatter pattern

Laser diffraction
PSD

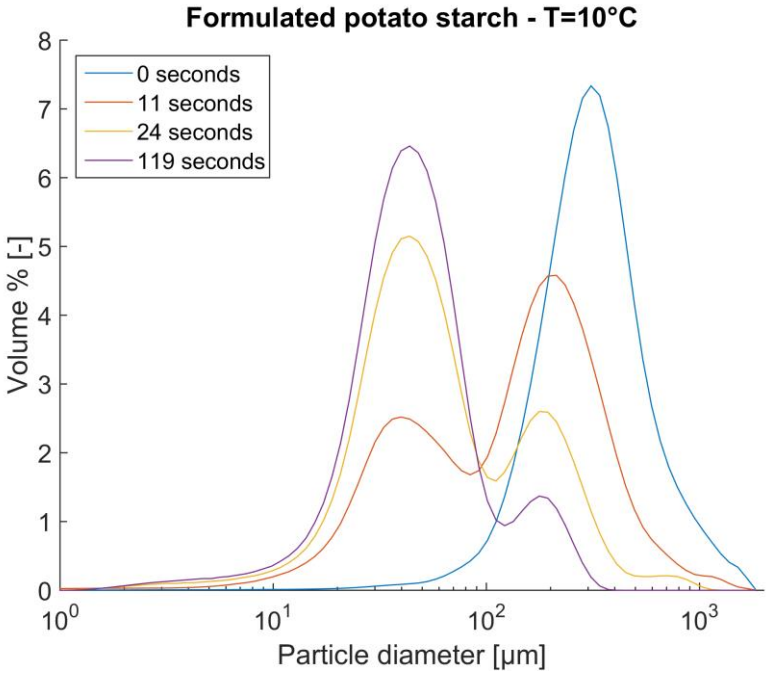
A PSD is obtained over time, giving insight how the distribution is affected

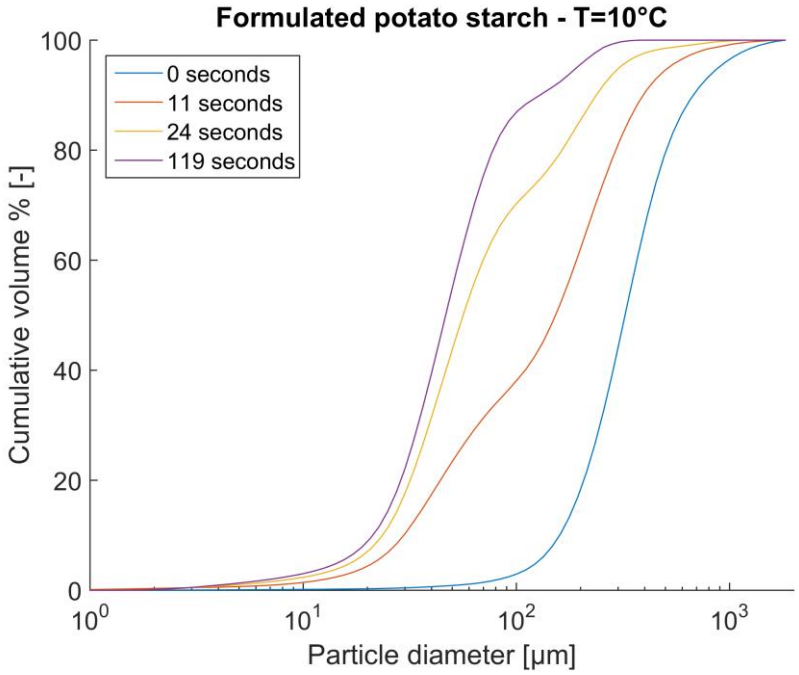


Laser diffraction
PSD

Static version

A PSD is obtained over time, giving insight how the distribution is affected

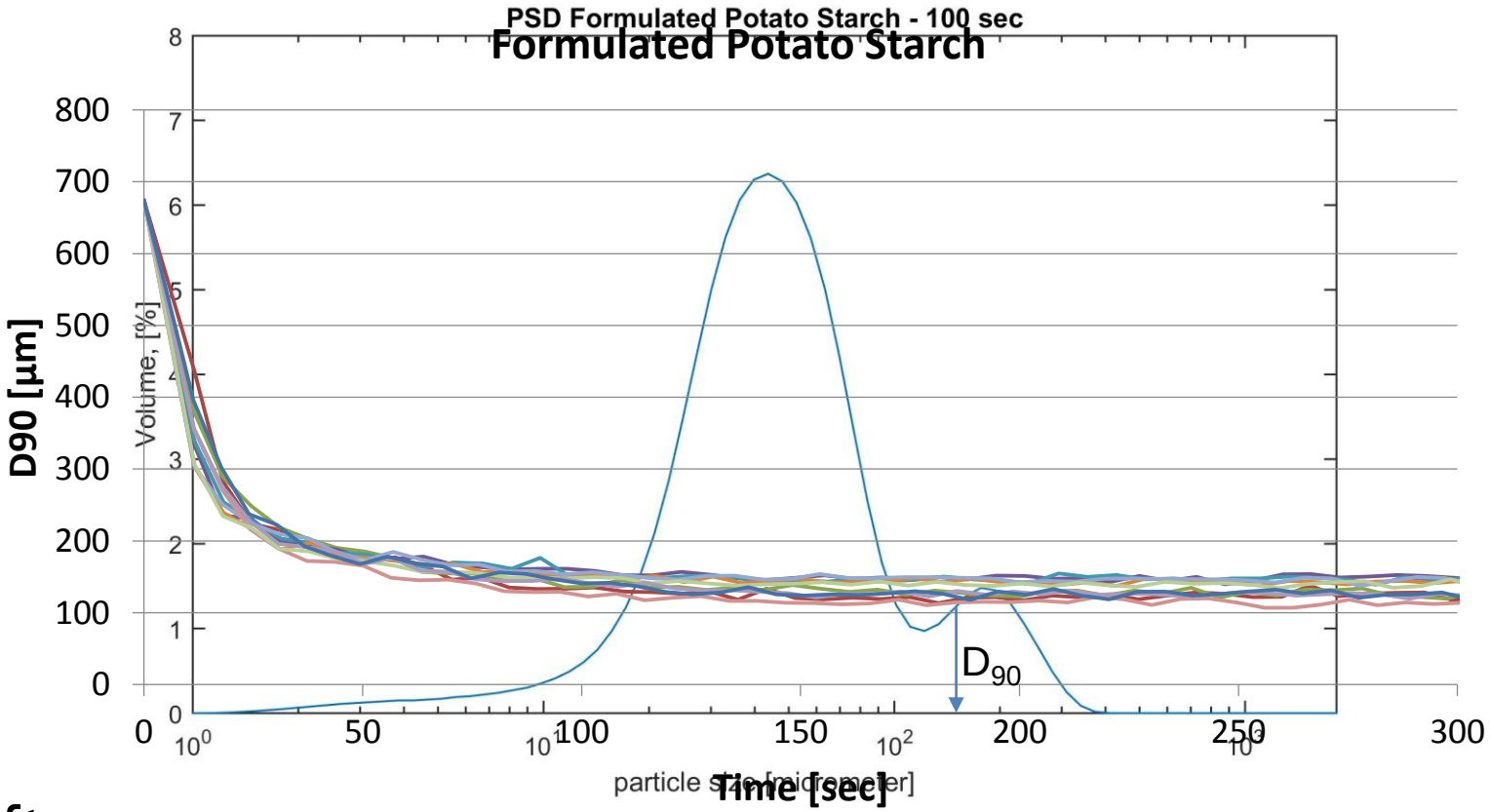




Laser diffraction

D90

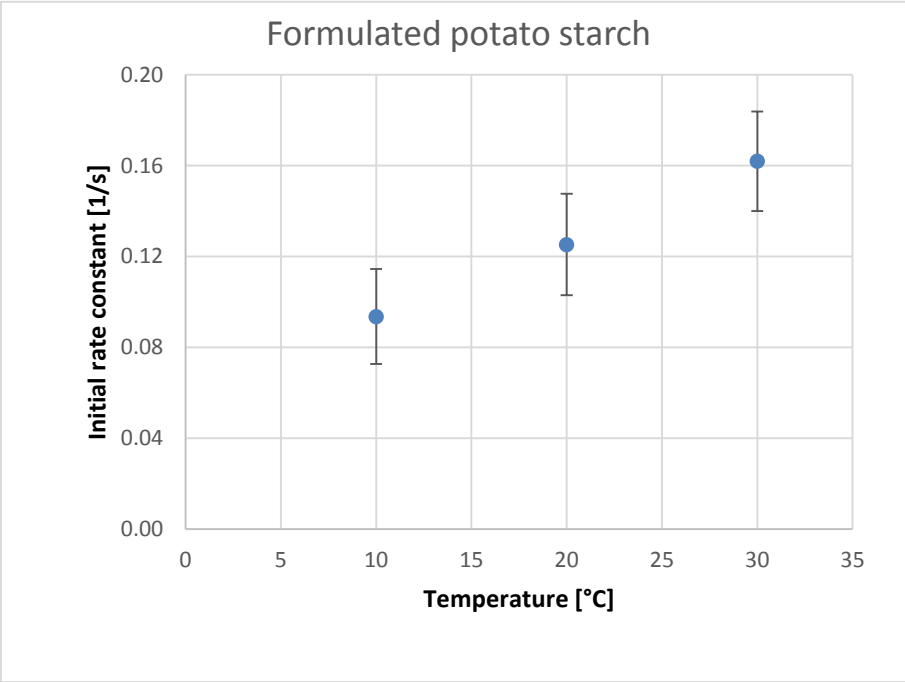
Following the D90 over time gives us insight into how fast a particle disintegrates



Laser diffraction

Results

A higher temperature will lead to a higher rate constant and thereby also a faster disintegration time



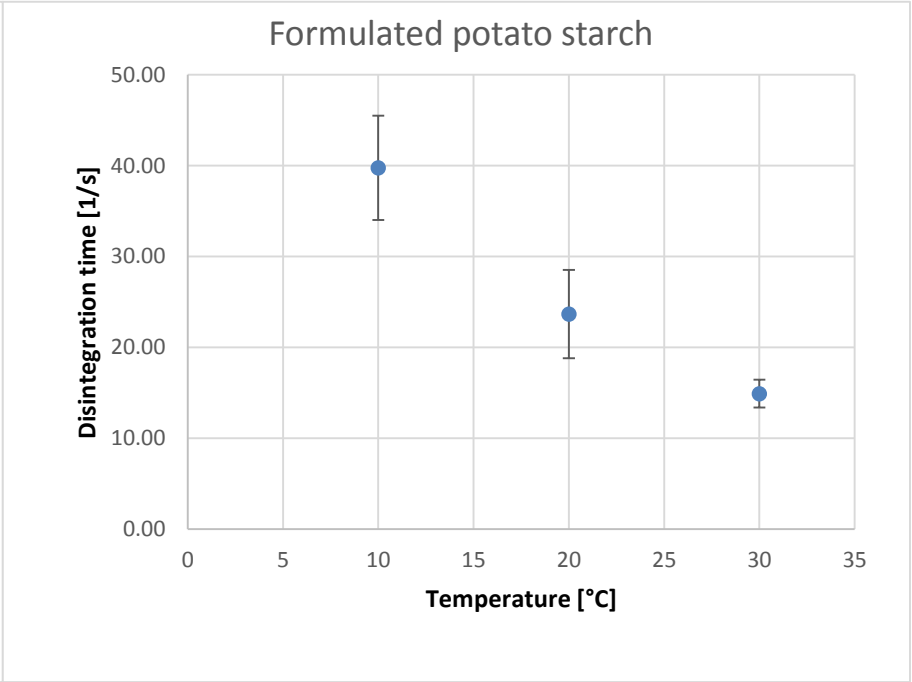
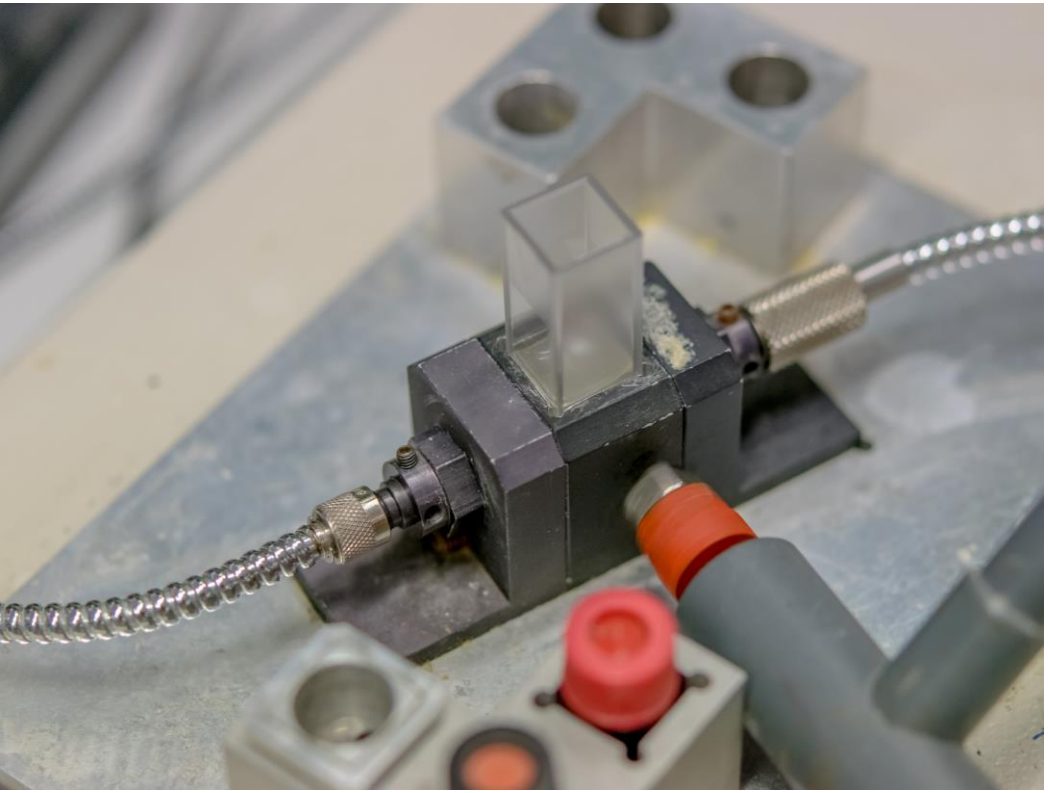


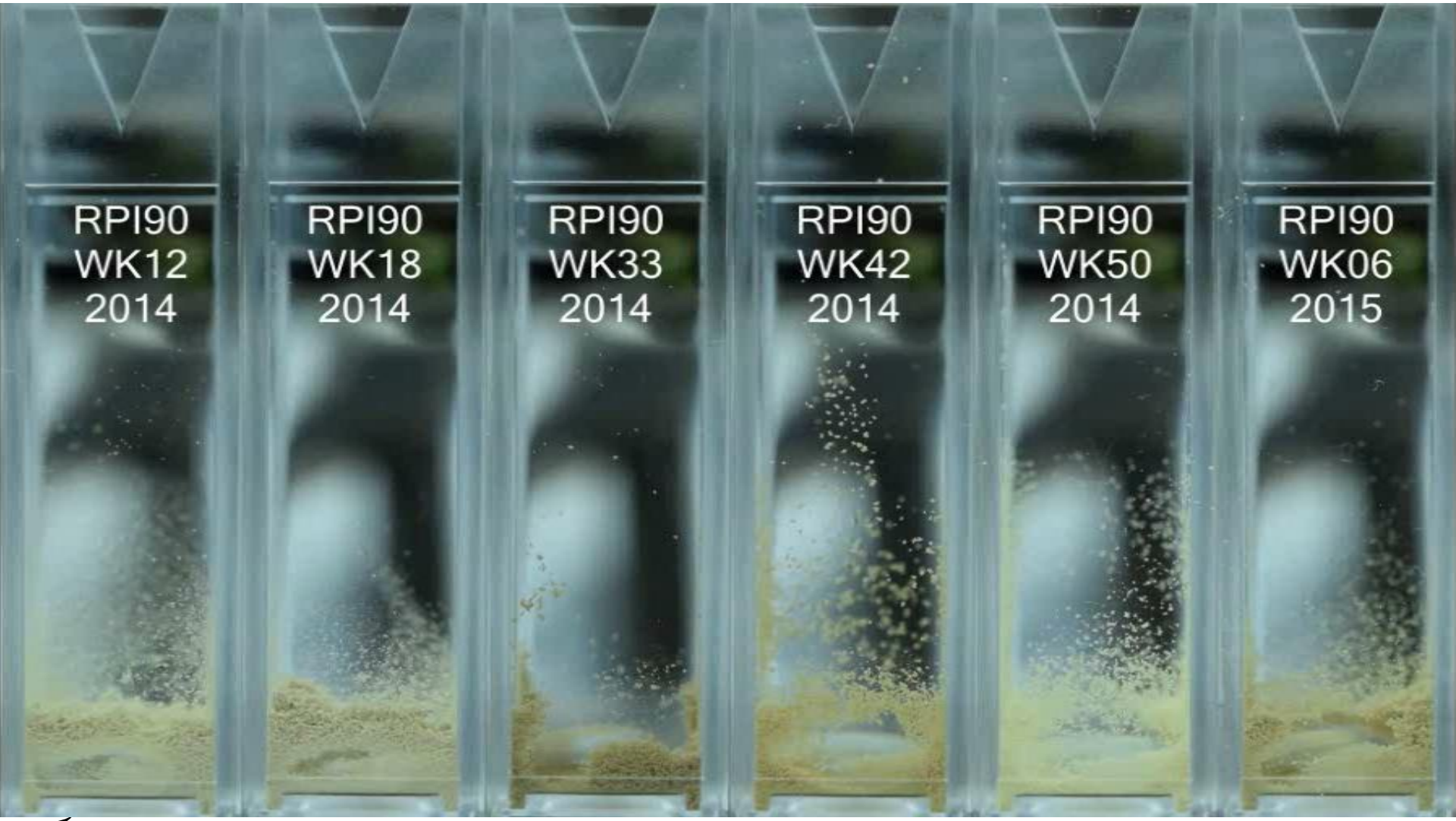
Photo-spectrometry

Obscuration



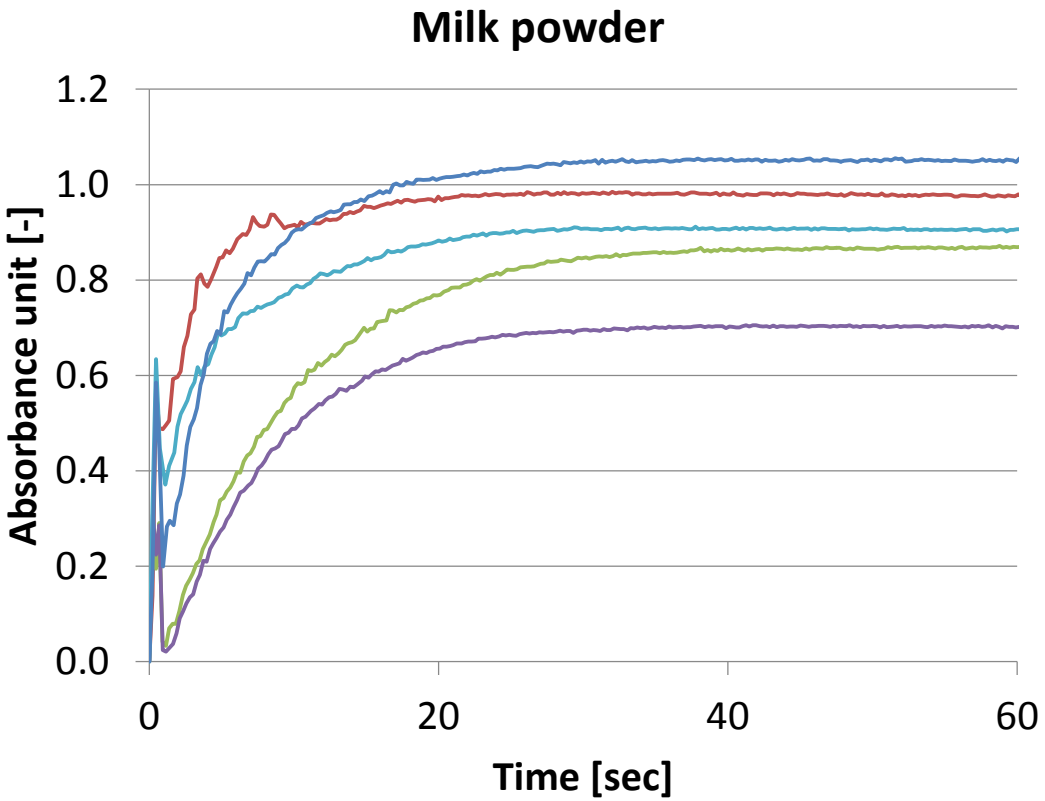
- Powder and a magnetic stirrer are added to a cuvet
- Water is added from the top
- Light is passed through the sample
- As the particles disintegrate they block more light
- If soluble components are present they disappear over time, letting more light pass

Spectrophotometry



Spectrophotometry

Introduction

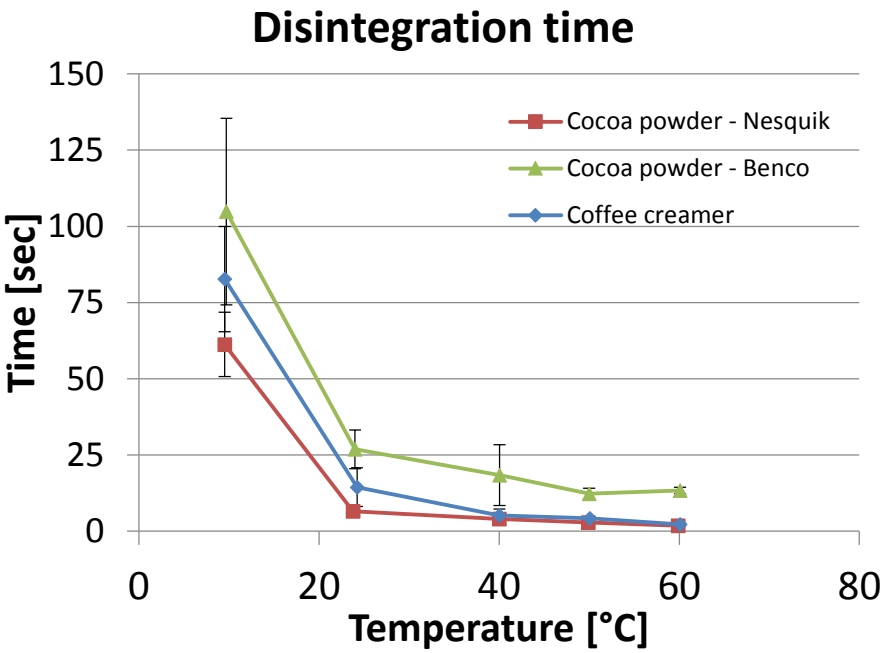


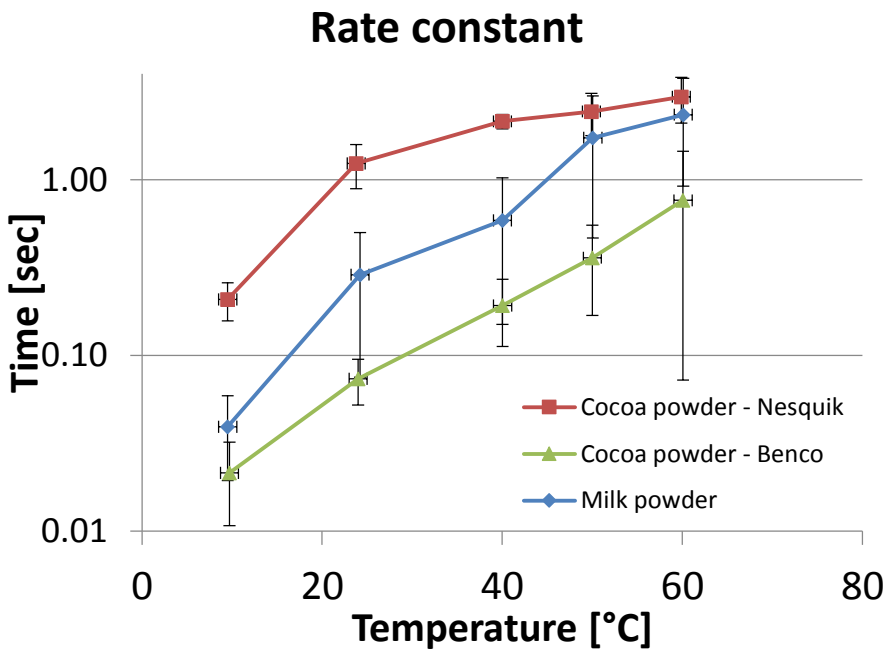
- Peaks at the beginning are caused by the initial addition of the powder
- Disintegration follows a exponential function
- Variations in the final value are caused by different concentrations

Spectrophotometry

Changing temperature

Same behaviour is observed as for laser diffraction





The questions

- How can we quantify the disintegration time?
  - Laser diffraction and photo-spectrometry seem to work
- Can the existing models be used for consumer product?
  - Literature models that described dispersion/dissolution rate can also be applied to describe the disintegration of different powders. TO BE PROVEN YET
- What dependency exist for the rate constant?
  - Temperature effect on both measurement methods are in agreement with each other and with literature [1]

[1] Larsen, Gåserød and Smidsrød – 2003

Issues

- Difficult to study disintegration on its own, e.g. when wetting is already critical
- Determination of time constants for the four stages will tell us where to opimise our formulations
- Model description of disintegration still to be proven
- Sinkability also difficult to determine. Will be dealt with in next research