Lodz University of Technology
Faculty of Process and Environmental Engineering

IFPRI
International Fine Particle Research Institute

EFFECT OF FEED PROPERTIES AND LOCAL DRYING KINETIC ON PARTICLE MORPHOLOGY IN SPRAY DRYING

Maciej JASKULSKI, Weronika BAŁDYS, Marcin PIĄTKOWSKI

Aim of the project

Slurry properties

- Viscosity
- Surface tension
- Density

Parameters range:
Solid content: 30-50%
Temperature: 50-90°C

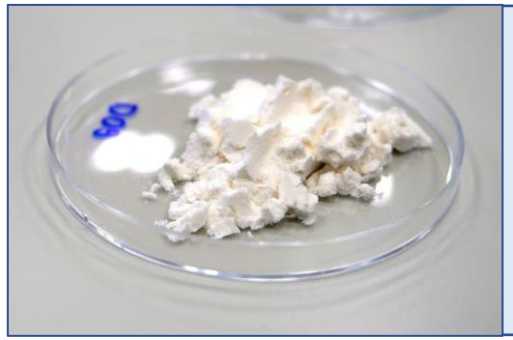
Spray drying

- Co-current spray drying experiments
- Feed mass flow rates 8, 10, 12 kg/h
- Drying air temp. 170°C, 200°C
- Drying air flow rate
- 200 Nm^3/h

Drying kinetics

LOADING.....

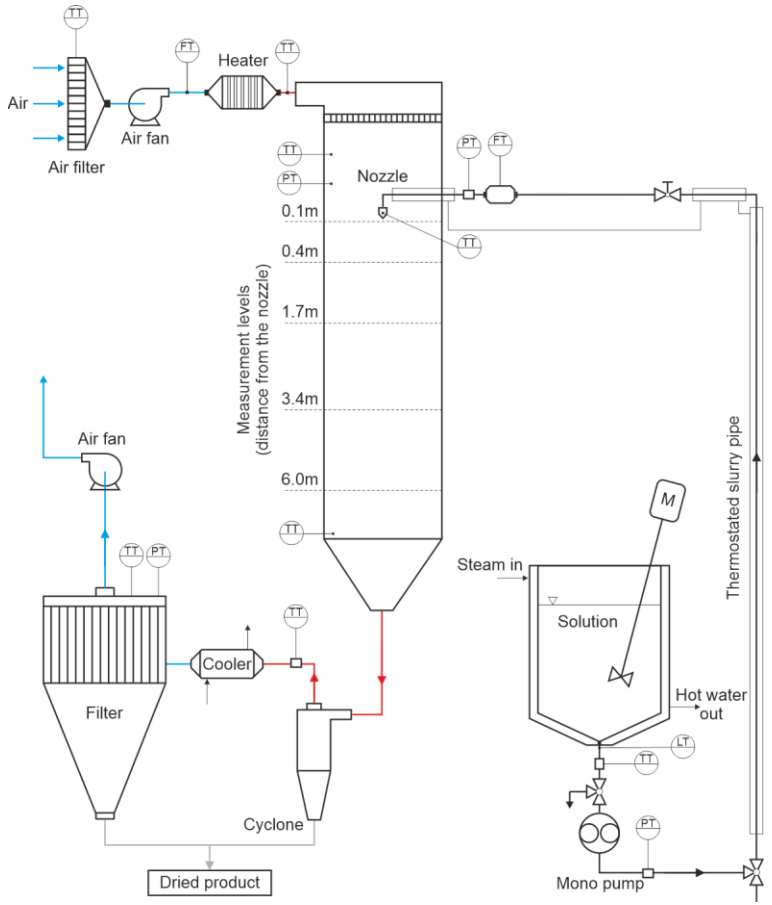
- SDD free fall experiments
- Determination of drying model parameters
- Determination of critical moisture content



Determining the relationship between the rheological properties of feed and the conditions of the process and the morphological properties of particles.

Presentation plan

Spray drying test results



Spray-drying installation

V_L = 8 kg/h, T_G = 170 °C	Feed temperature [°C]			
C_{malt} [wt.%]	30	50	70	90
30		8.9	10.7	11.3
35			9.1	10.2
40			6.3	8.7
45				7.1
50				

V_L = 8 kg/h, T_G = 200 °C	Feed temperature [°C]			
C_{malt} [wt.%]	30	50	70	90
30	7.2	9.1	10.5	11.1
35		7.9	9.3	10.5
40			8.1	8.8
45				
50				

V_L = 10 kg/h, T_G = 170 °C	Feed temperature [°C]			
C_{malt} [wt.%]	30	50	70	90
30	11.8		16.5	18.3
35		12.0	14.9	16.1
40			11.7	14.4
45				11.0
50				

V_L = 10 kg/h, T_G = 200 °C	Feed temperature [°C]			
C_{malt} [wt.%]	30	50	70	90
30	11.1	15.0	16.8	18.5
35		11.4	14.8	15.9
40			11.4	14.4
45				11.1
50				

V_L = 12 kg/h, T_G = 170 °C	Feed temperature [°C]			
C_{malt} [wt.%]	30	50	70	90
30			24.5	27.8
35		18.2	21.6	24.1
40				21
45				17.1
50				13.8

V_L = 12 kg/h, T_G = 200 °C	Feed temperature [°C]			
C_{malt} [wt.%]	30	50	70	90
30	23.0	21.6	25.2	27.5
35	14.6	18.0	21.5	24.0
40			17.9	25.5
45				17.9
50				24.9

Operational windows at different feed temperatures, feed concentrations, feed flow rates and gas temperatures. Numbers in cells show pressure (in bars) of the liquid atomizer.

Collected powder samples

Presentation plan

- Aim of the project
- **Spray derying experiments**
- Samples and results
- InfraRed Temperature for Unknown Coefficients
- New droplet generator
- Summary

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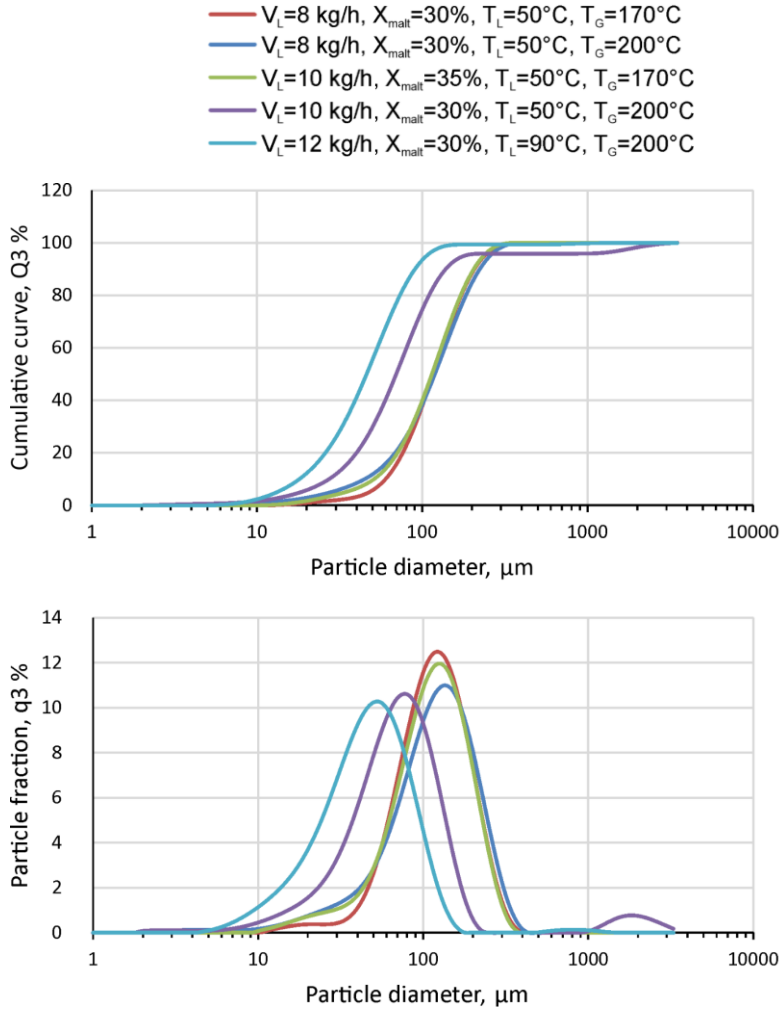
Paricle particle distribution

Malvern MasterSizer 3000



Particle size distribution of collected samples

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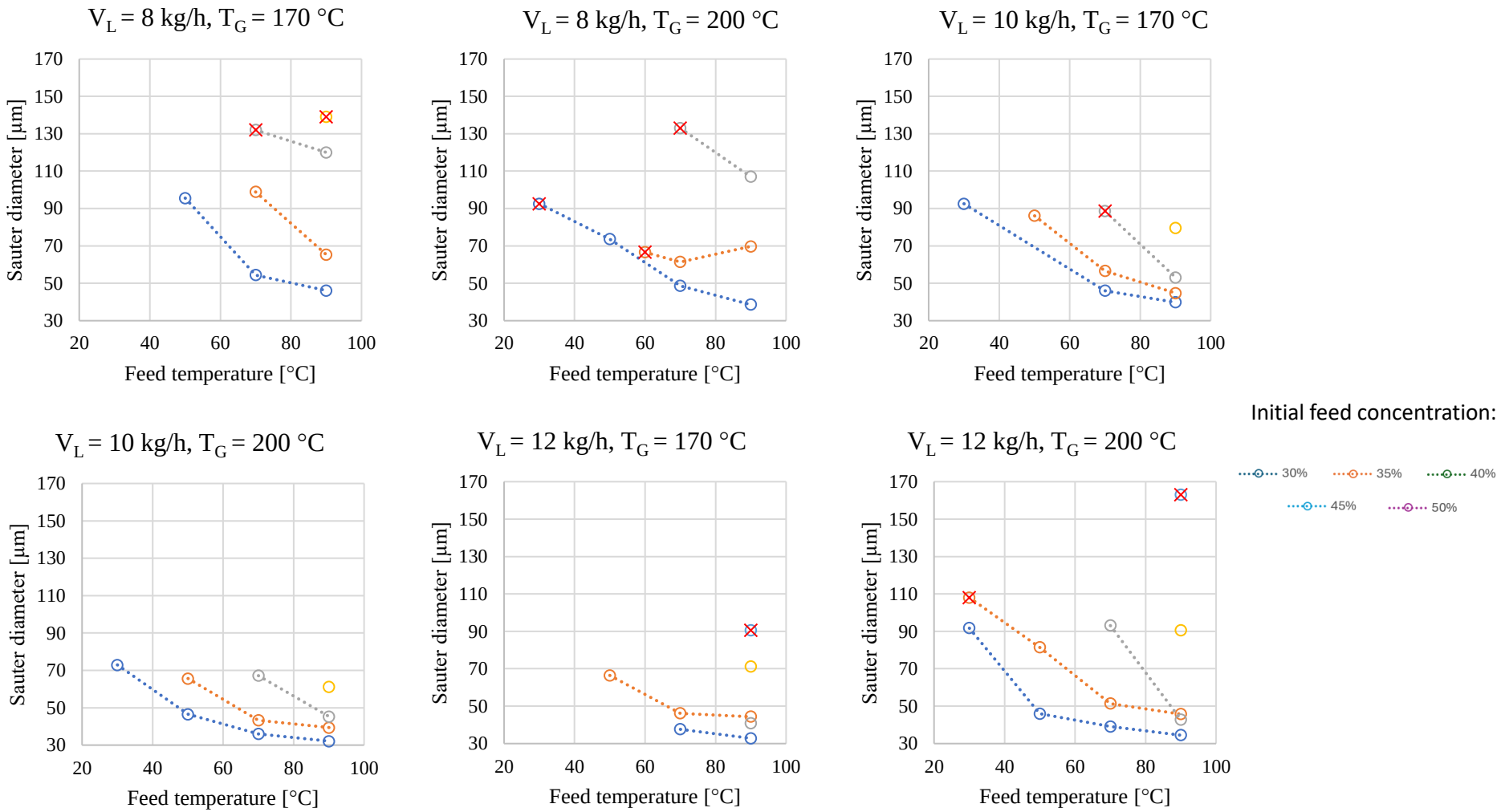
Paricle size distribution- mean sauter diameter



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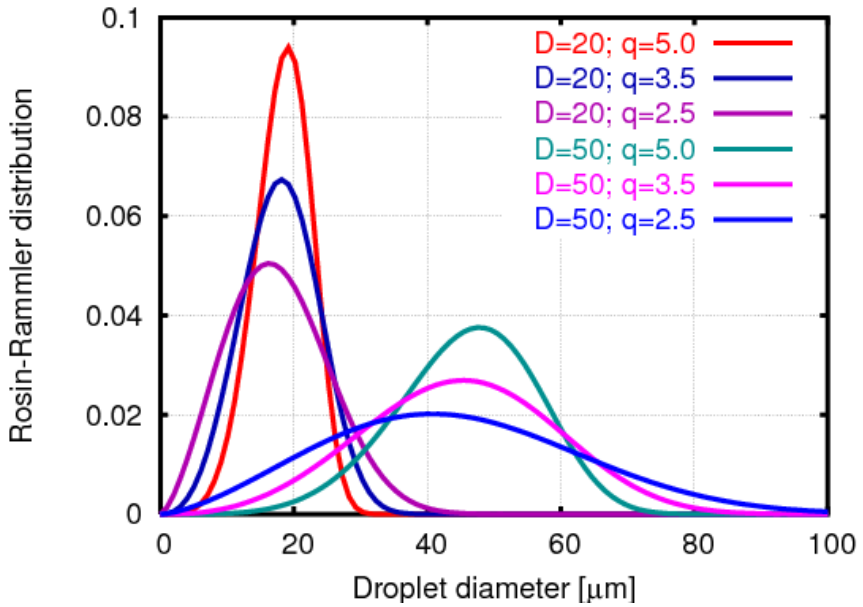
Paricle size distribution- spread parameter

The particle size distribution is described with the Rosin-Rammler equation:

$$Y_d = e^{-\left(\frac{d}{d_{av}}\right)^q}$$



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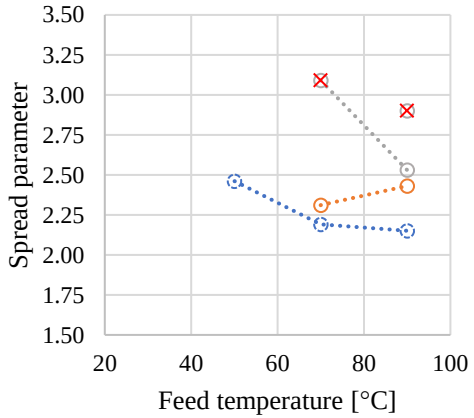
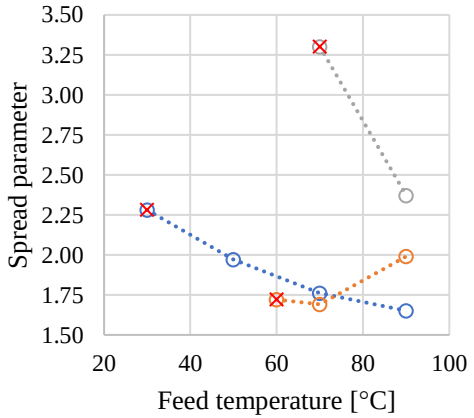
Paricle size distribution- spread parameter

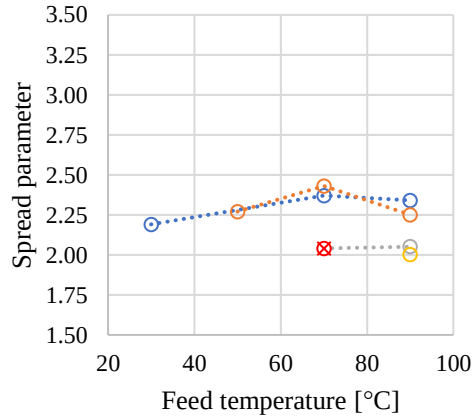
V_L = 8 kg/h, T_G = 170 °C



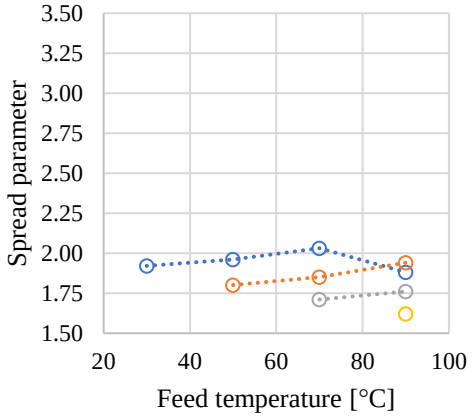
V_L = 8 kg/h, T_G = 200 °C



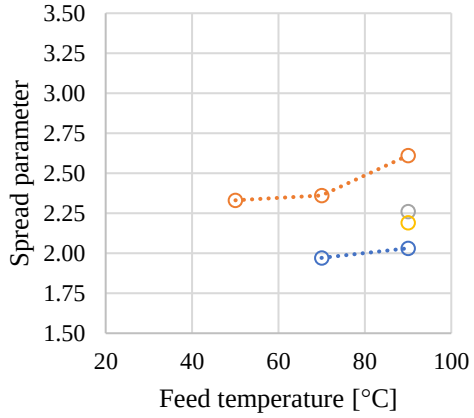
V_L = 10 kg/h, T_G = 170 °C



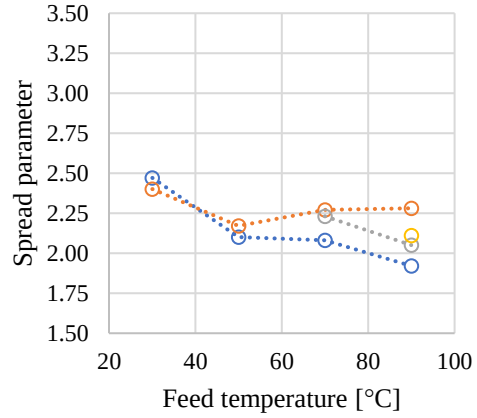
V_L = 10 kg/h, T_G = 200 °C



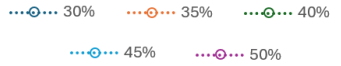
V_L = 12 kg/h, T_G = 170 °C



V_L = 12 kg/h, T_G = 200 °C



Initial feed concentration:



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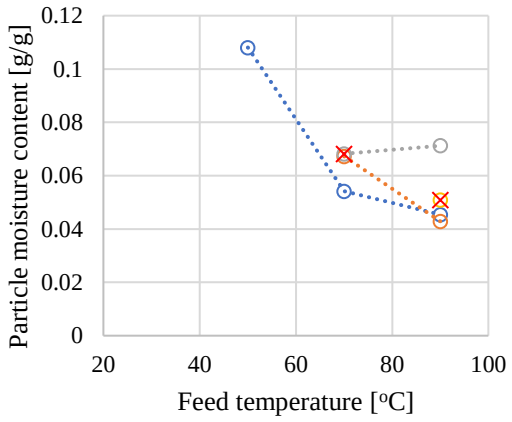
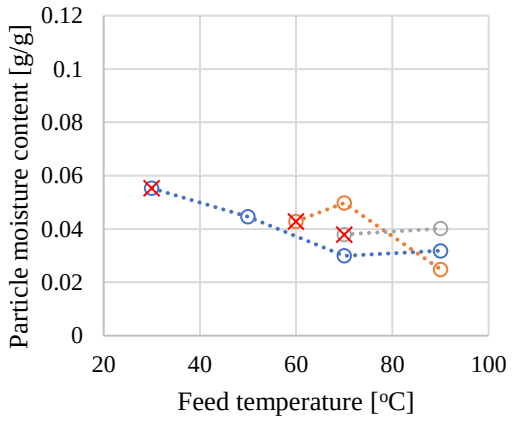
Paricle properties- moisture content

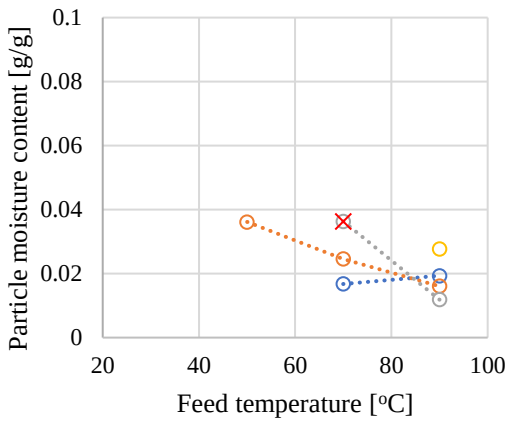
V_L = 8 kg/h, T_G = 170 °C



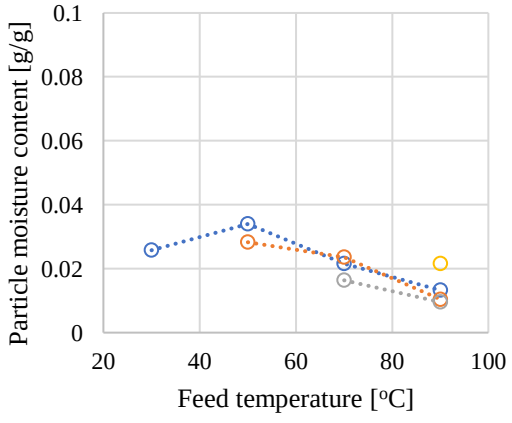
V_L = 8 kg/h, T_G = 200 °C



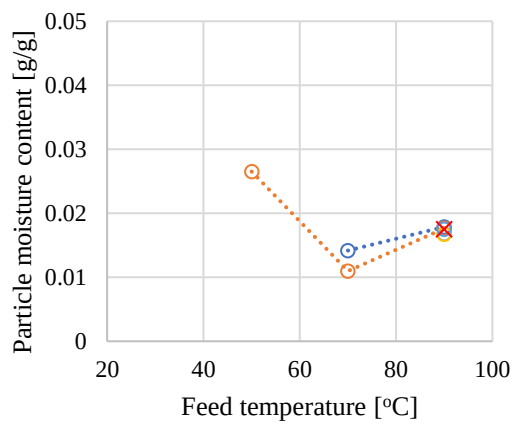
V_L = 10 kg/h, T_G = 170 °C



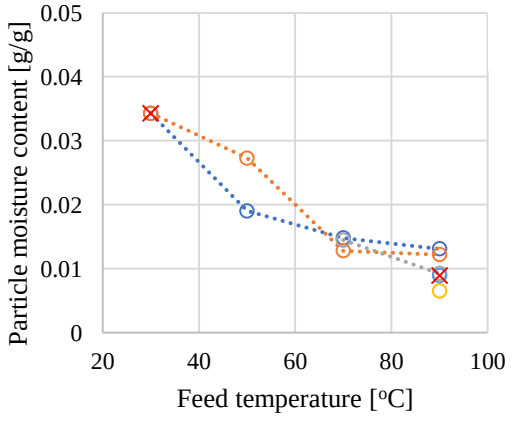
V_L = 10 kg/h, T_G = 200 °C



V_L = 12 kg/h, T_G = 170 °C



V_L = 12 kg/h, T_G = 200 °C



Initial feed concentration:

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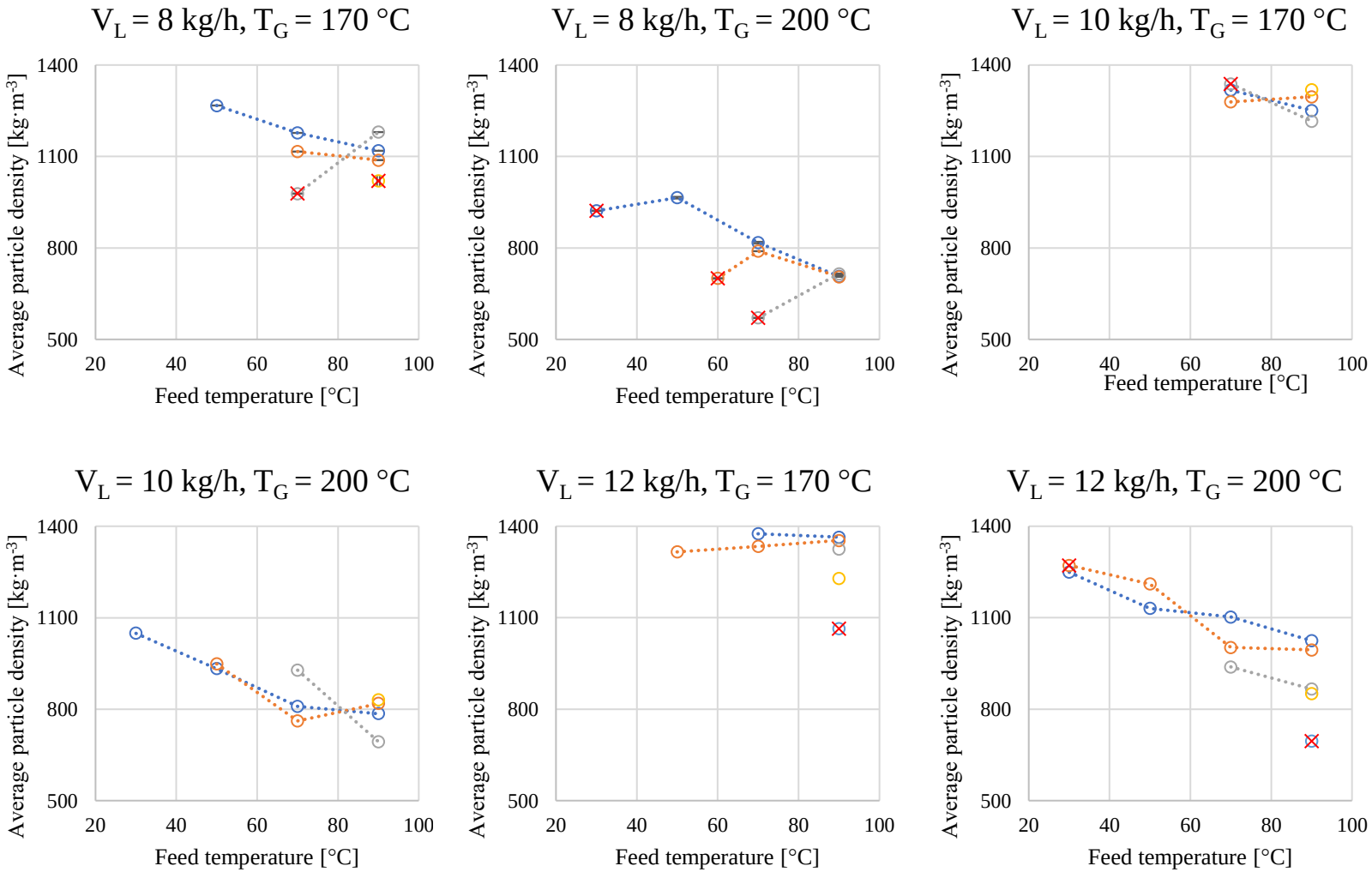
Paricle properties- average particle density



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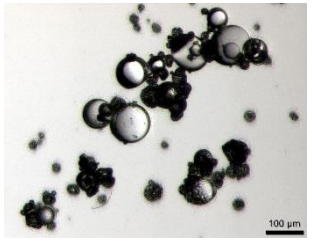
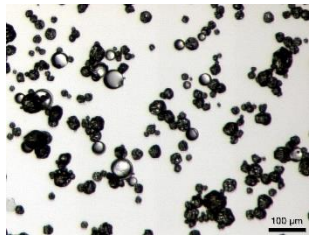
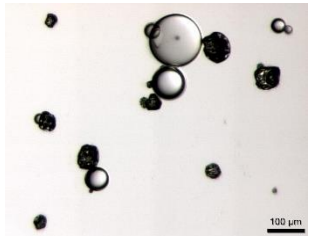
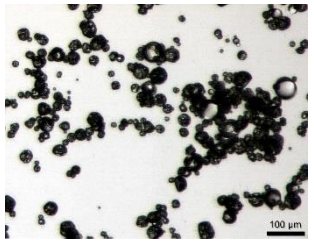
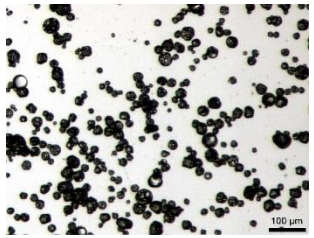
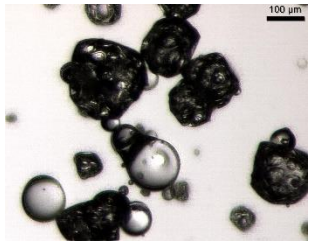
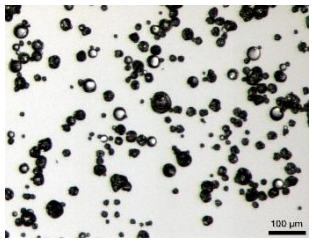
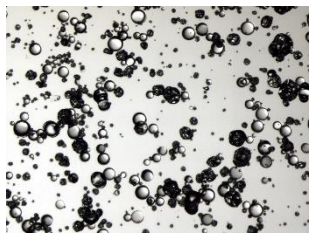
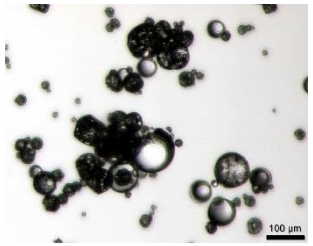
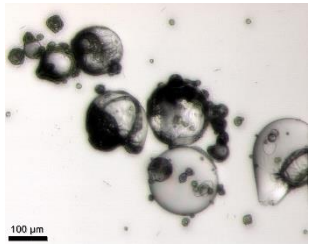
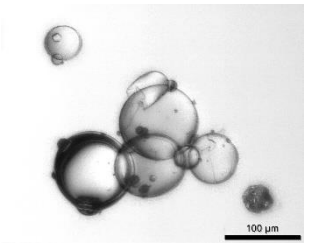
Paricle properties- microscopy analisys

	30%	35%	40%	45%	50%
8 kg/h 200° C					
8 kg/h 170° C					
12 kg/h 200° C					

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Paricle properties- microscopy analisys

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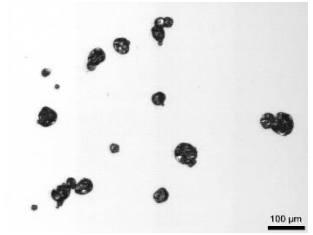
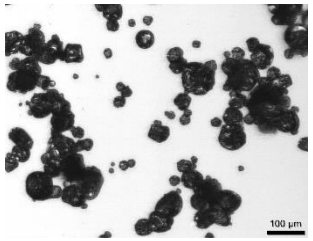
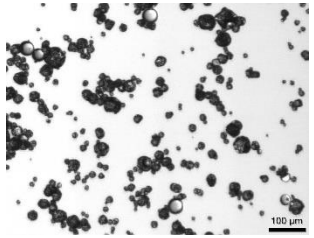
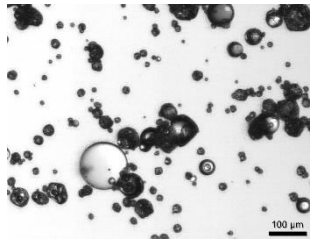
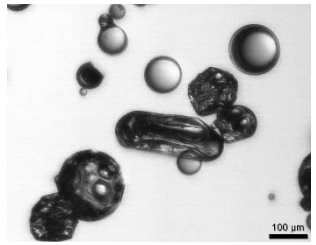
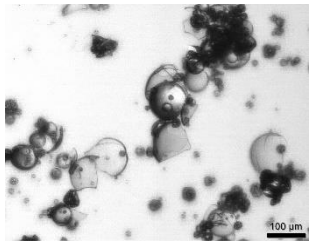
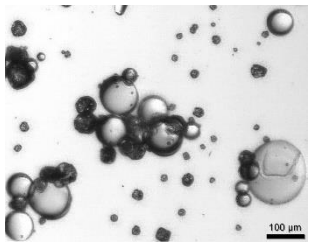
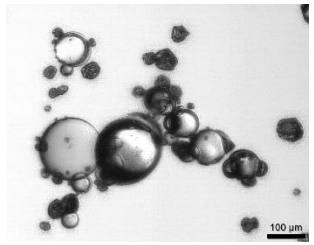
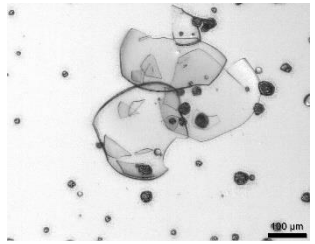
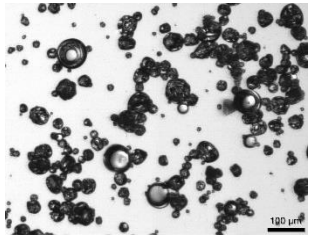
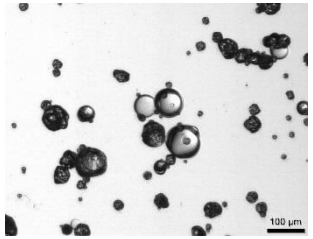
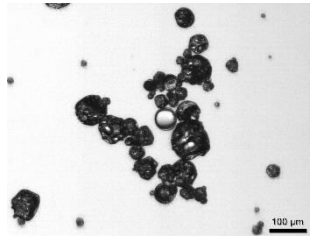
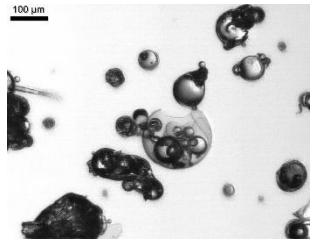
12 kg/h 170° C					
10 kg/h 200° C					
10 kg/h 170° C					

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Paricle properties- Powder flowability

Carr index and Hausner coefficient for powders dried at 170 °C at the solution flow rate of 8 kg/h

Initial concentration [%]	Feed temperature [°C]	Carr index [%]	Hausner coef. [-]	Flowability
30%	50	21%	1.26	Sufficient
	70	20%	1.26	Fair/Good
	90	16%	1.20	Good
35%	70	14%	1.16	Very good
	90	14%	1.17	Very good
40%	70	13%	1.15	Very good
	90	12%	1.13	Very good
45%	90	13%	1.15	Very good

Carr index and Hausner coefficient for powders dried at 200 °C at the solution flow rate of 8 kg/h

Initial concentration [%]	Feed temperature [°C]	Carr index [%]	Hausner coef. [-]	Flowability
30%	30	15%	1.17	Very good
	50	19%	1.24	Good
	70	19%	1.23	Good
	90	19%	1.24	Good
35%	60	14%	1.17	Very good
	70	17%	1.20	Good
	90	15%	1.18	Very good
40%	70	13%	1.15	Very good
	90	15%	1.17	Very good

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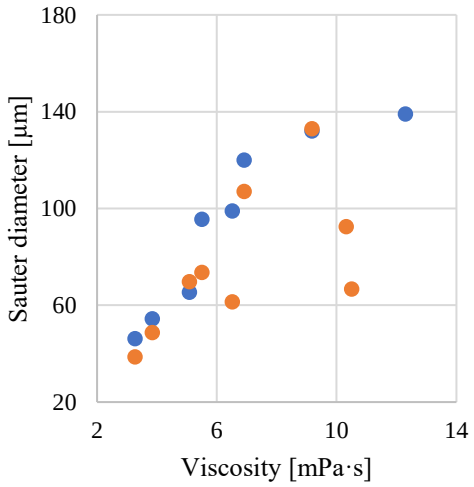
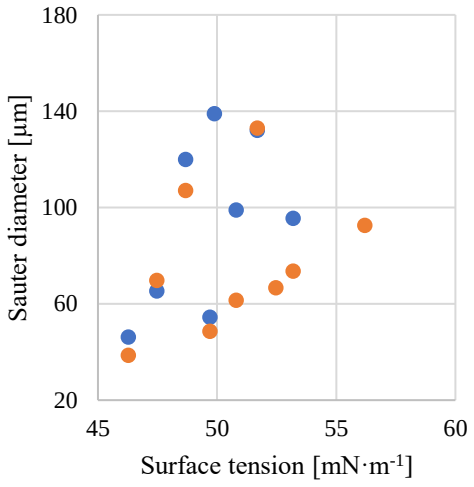
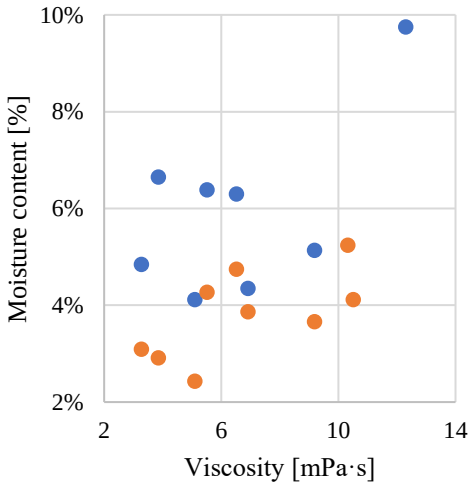
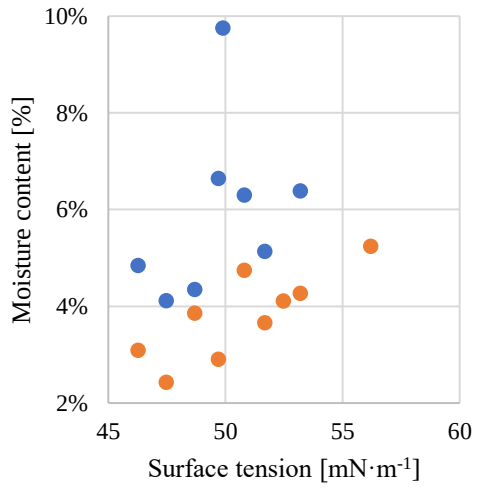
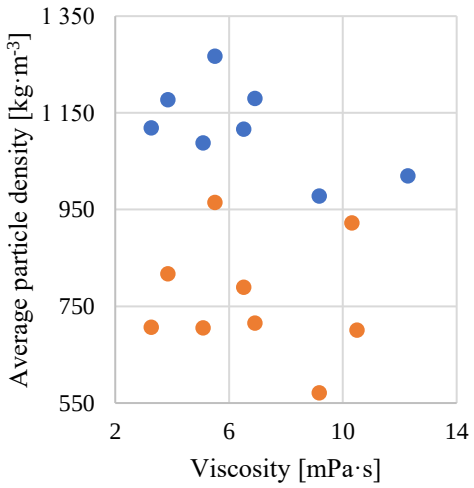
Dependence between rheology and powder properties

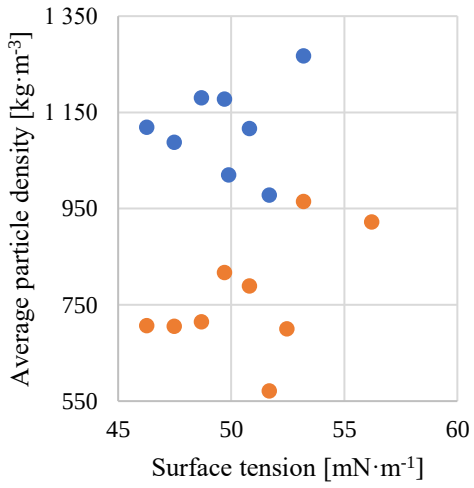










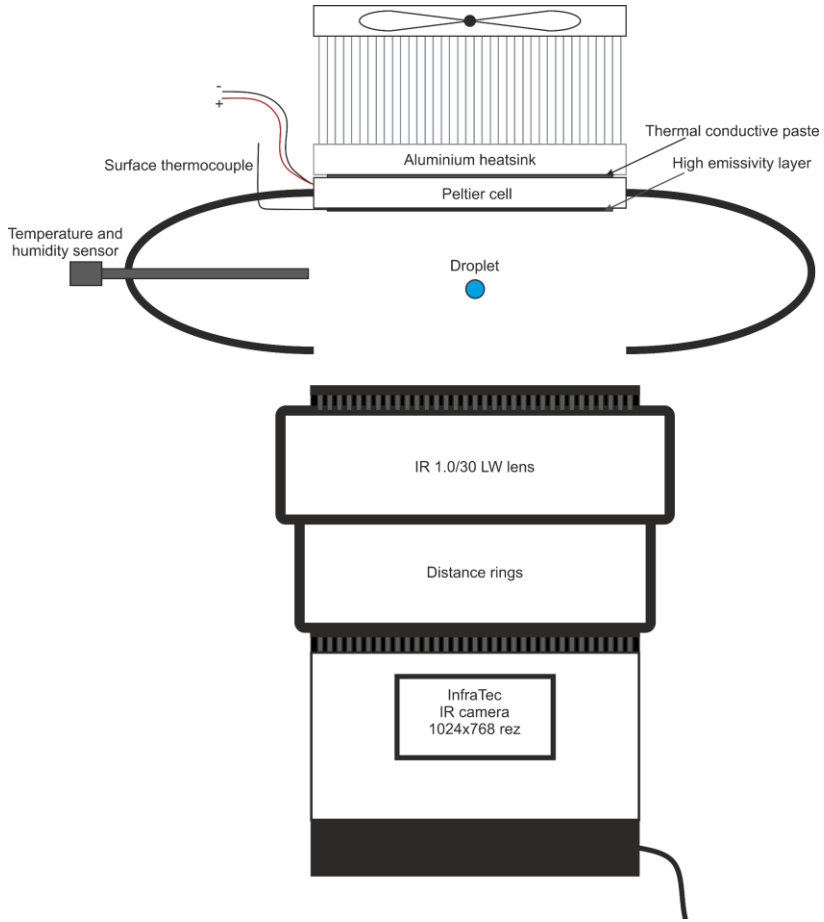


Blue and orange dots correspond to drying gas temperature of 170 °C and 200 °C respectively.

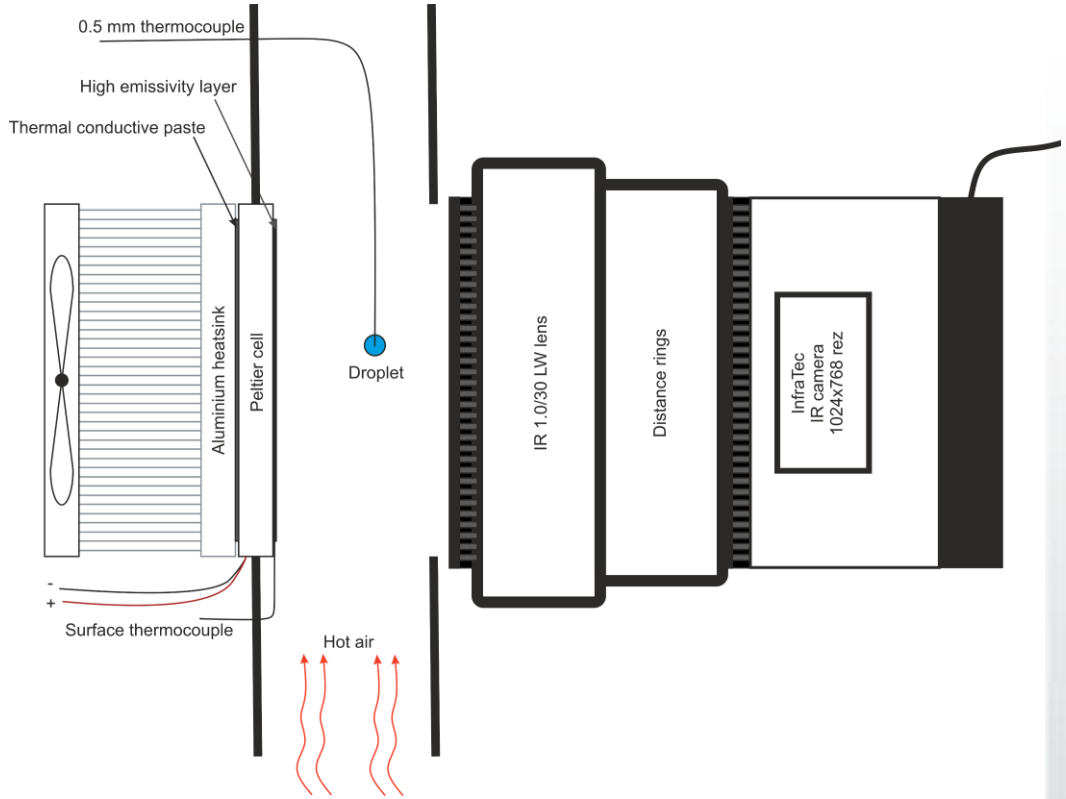
Presentation plan

- Aim of the project
- Spray derying experiments
- **Samples and results**
- InfraRed Temperature for Unknown Coefficients
- New droplet generator
- Summary

IRTUC (InfraRed Temperature for Unknown Coefficients)



Top view of IRTUC prototype



Site view of IRTUC prototype

Presentation plan

- Aim of the project
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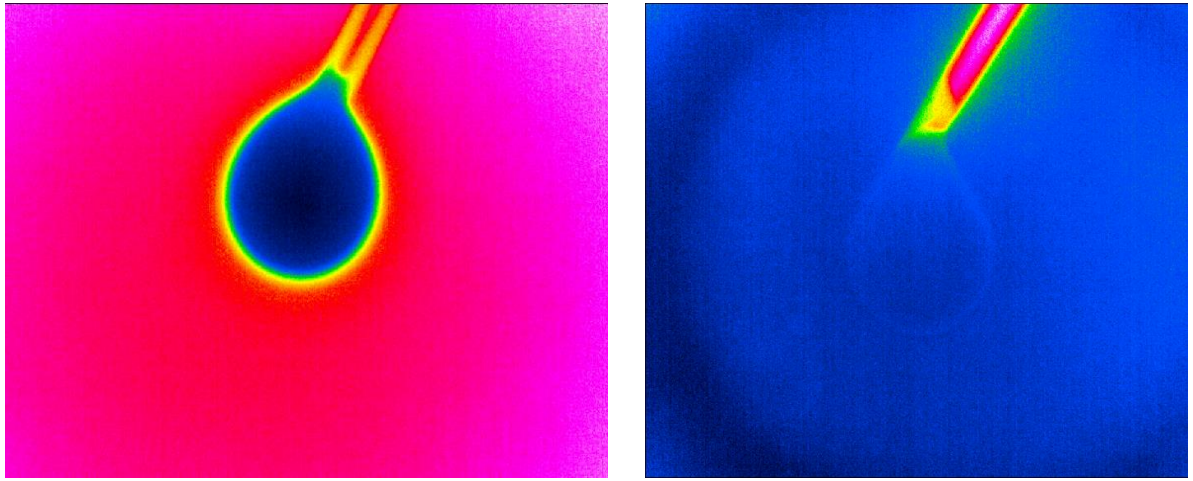
IRTUC (InfraRed Temperature for Unknown Coefficients)
Test 1- determination of wet-bulb temperature- ambient temperature

Lab air:
temperature = 22.3 °C
Humidity = 31.2 %

wet-bulb temperature = 12.8 °C
Droplet temperature: = 14.1 °C
Peltier surface temperature: = 12°C



Images from InfraTec Camera

Presentation plan

- Aim of the project
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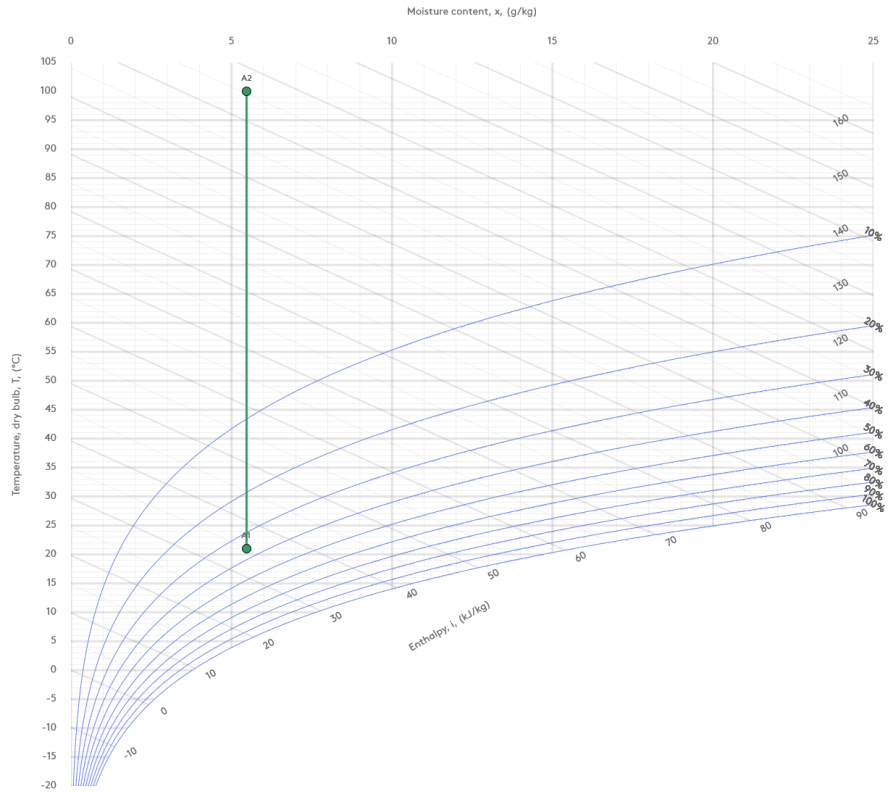
- New droplet generator
- Summary

IRTUC (InfraRed Temperature for Unknown Coefficients)
Test 2- determination of wet-bulb temperature – hot air stream



A1 1			•••
Temperature	21	°C	
Relative humidity	36	%	
Moisture content	5,47	g/kg	=
Enthalpy	35,1	kJ/kg	
Air flow	1	m³/s	
Power	96,7	kW	
Sensible power	96,7	kW	
Water	-0	l/min	
A2 A2			•••
Temperature	100	°C	
Relative humidity	1	%	
Moisture content	5,47	g/kg	=
Enthalpy	115,71	kJ/kg	

Lab air:
temperature = 100 °C
Humidity < 1 %

wet-bulb temperature = 40.9°C
Peltier surface temperature: = 41.2 °C

Presentation plan

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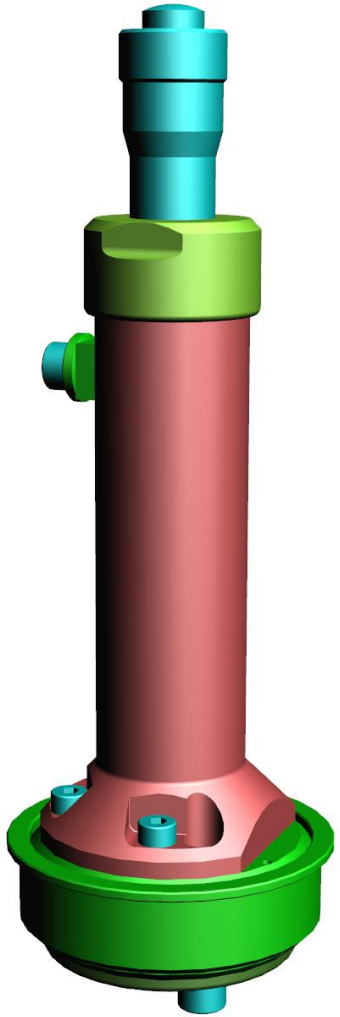
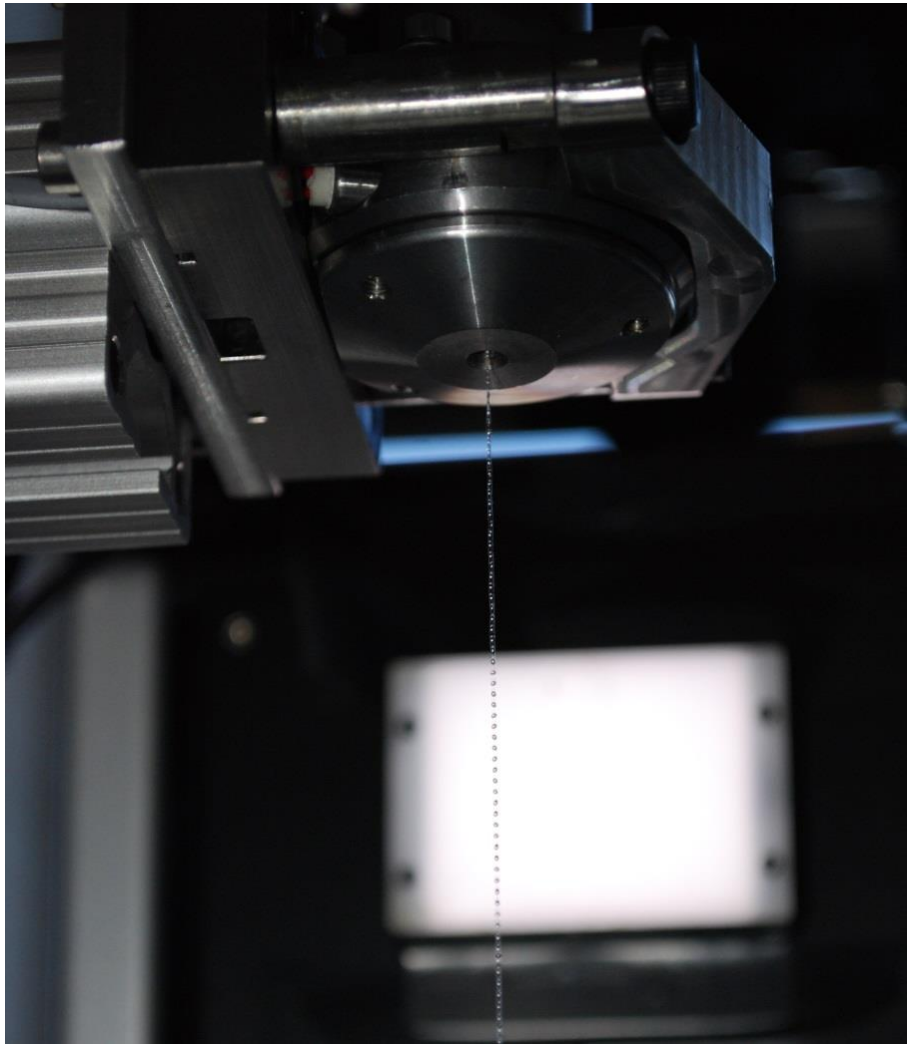
IRTUC (InfraRed Temperature for Unknown Coefficients)

Possible sources of error:

- **accuracy of thermocouples: a Class 1 thermocouple may have an accuracy of ±0.5°C.**
- **large colour gradient of the camera: 30 colours with an accuracy of ±0.05°C.**
- **increase in sensitivity of the Peltier cell power supply.**
- **"freezing" of particles - need to use a droplet generator.**

„Old” TNO droplet generator





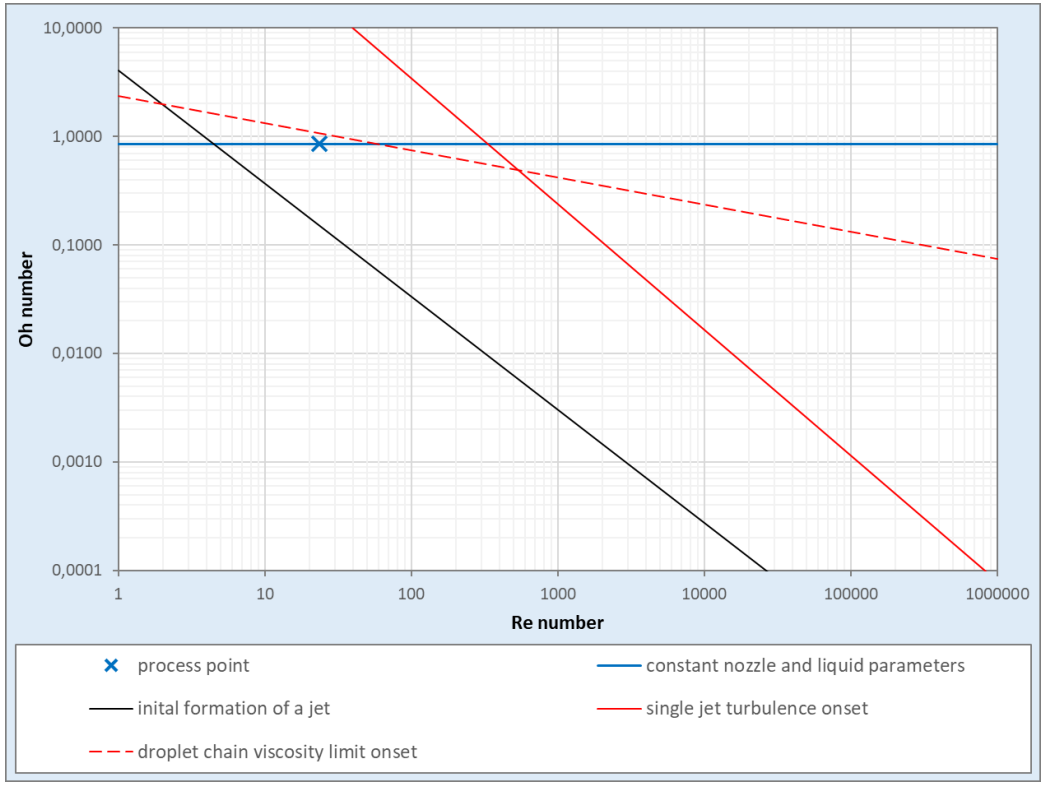
Droplet chain generated by the TNO nozzle

Presentation plan

- Aim of the project
- Spray derying experiments
- Samples and results
- InfraRed Temperature for Unknown Coefficients
- **New droplet generato**
- Summary

„New" droplet generator design

Liquid parameters:		
ρ	1250	kg/m³
η	0,06035	Pa s
σ	0,0535	N/m
Process parameters:		
nozzle diameter D	75	µm
mass flow per nozzle	5	g/min
Calculations:		
pressure effort Δp_{min}	1,42	bar
average liquid velocity	15,09	m/s
unexcited jet length	68,2	mm
Frequenz (k=0,7)	44831	Hz



Test of droplet generator for the maltodextrin solutions

Presentation plan

- Aim of the project
- Spray derying experiments
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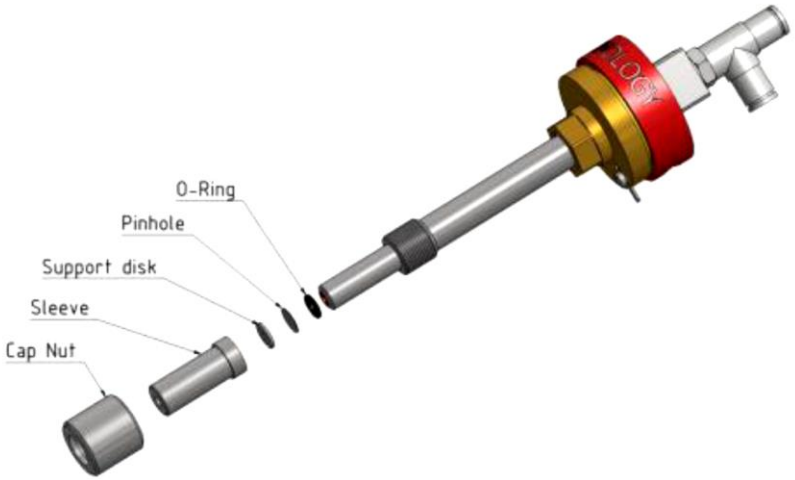
- InfraRed Temperature for Unknown Coefficients
- **New droplet generator**
- Summary

„New" droplet generator design

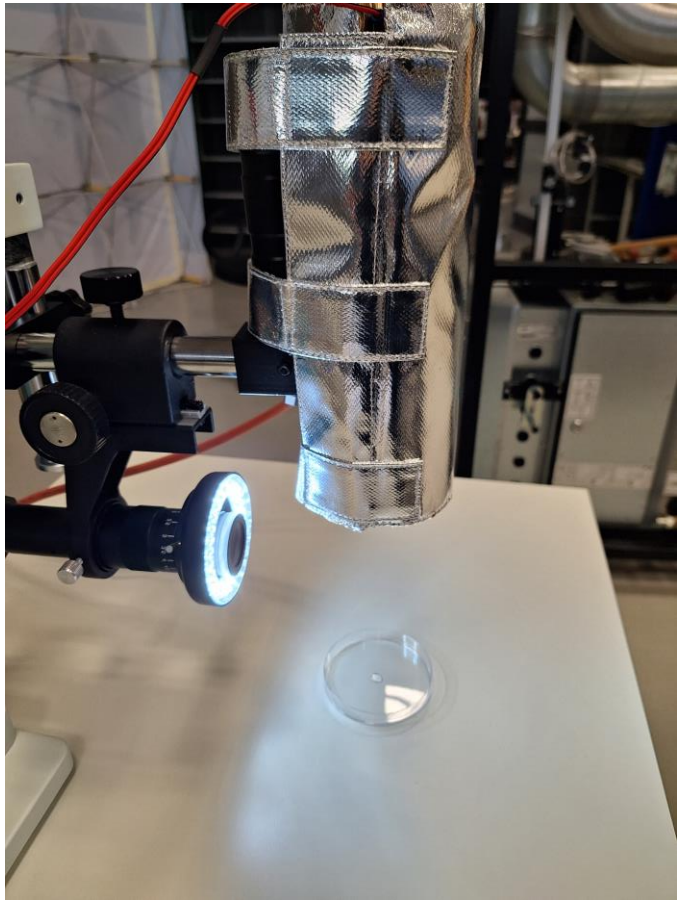


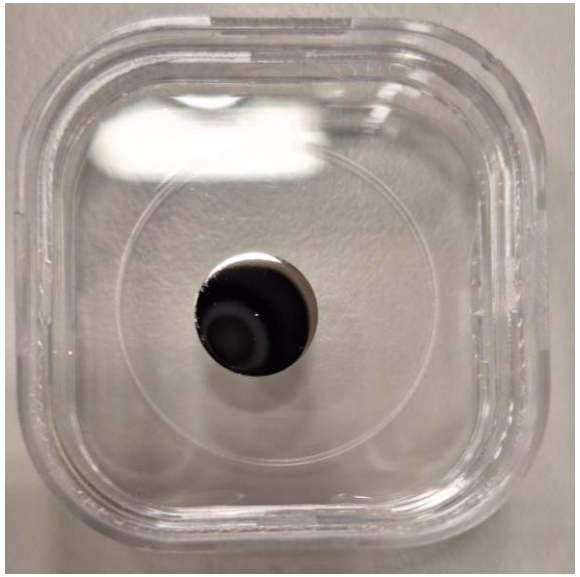
New dropet generator with heating jacket

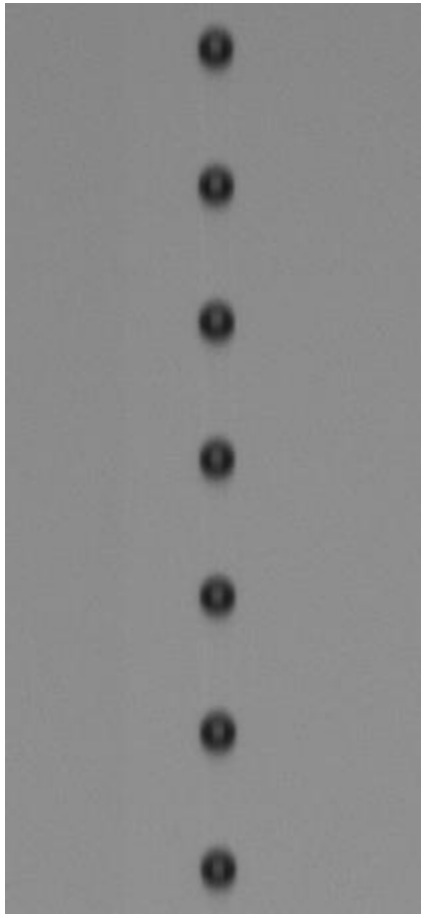
Presentation plan

- Aim of the project
- Spray derying experiments
- Samples and results
- InfraRed Temperature for Unknown Coefficients
- **New droplet generator**
- Summary

„New” droplet generator design







Tests of new droplet generator, plate with pinhole, generated droplet chain.

Presentation plan

- Aim of the project
- Spray derying experiments
- Samples and results
- InfraRed Temperature for Unknown Coefficients
- **New droplet generator**
- Summary

Topic	Status
	1st year
1. Adaptation of the existing equipment to the project requirements.	Done
2. Selection of suitable experimental media and determination of quality criteria.	Done
3. Measurements of rheological properties of aqueous solutions of selected materials.	Done
4. Design of particle free fall SDD measurement system;	Done
	2nd year
1. Carrying out experimental drying processes and analysis of powder morphology obtained from different slurries and process parameters:	Done
- Identification of the effect of feed properties, feed rate, air flow rate, drying temperature on powder morphology;	Done
- Specification of mathematical relationships describing the drying and powder properties;	Done
2. Experimental determination of critical moisture content of dried materials.	In progress- SDD tower is under construction
3. Construction and test of free fall drying kinetic determination system.	
	3nd year
1. Mathematical modeling of changes in powder morphology depending on process parameters and feed rheological properties.	In progress- master thesis in preparation
2. Carrying out experiments with the use of free fall drying kinetic system	In progress- SDD tower is under construction

Presentation plan

- Aim of the project
- Spray derying experiments
- Samples and results
- InfraRed Temperature for Unknown Coefficients
- New droplet generato
- **Summary**

Thank you for your attention