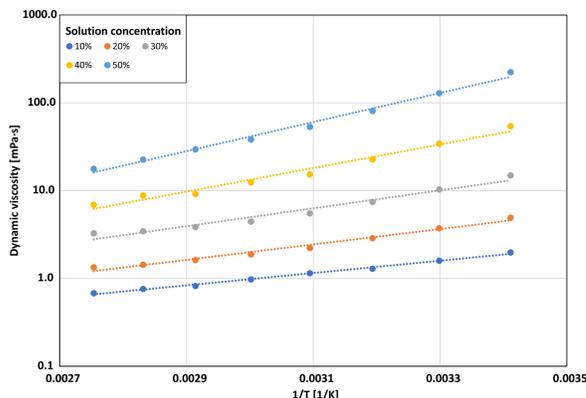


INTRODUCTION

The quality and structure of powders obtained during spray drying depends on many factors, such as: type of dried material, method of atomization, method of phase mixing, process parameters and the geometry of the drying chamber. The aim of the project is to determine the relationship between the rheological properties (density, viscosity and surface tension) and drying kinetics of the aqueous maltodextrin (DE12) solutions on the structure and quality of the powder produced by the spray drying. The project consists of four main stages: In the first stage, the rheological properties of aqueous maltodextrin solutions in a wide range of concentrations and temperatures will be tested. In the second stage, a series of spray drying experiments will be performed for selected process parameters. The process will be carried out in a co-current system in order to minimize the impact of the agglomeration process on the structure of the product. The collected powder samples will be analyzed in terms of morphological properties. In the third stage of the project, experiments of drying single drops of a solution by the free-fall method will be carried out. Instantaneous measurement of the particle temperature made with the use of a thermal imaging camera will allow to determine, based on the energy balance, the instantaneous rate of evaporation of moisture. The obtained drying curves will allow the fitting of mathematical models in the literature to determine the influence of the process parameters on the drying speed. The aim of the final stage of the work will be to determine the correlation between rheological properties and drying speed and the properties of powders after spray drying. In this step, machine learning methods will be used to predict product particle morphology based on a wide range of input parameters.

Solutions rheology

Rheological measurements were made with the Physica MR 301 rotational rheometer manufactured by Anton Paar. The measurements were carried out in the temperature range of 20-90 °C with the use of a dedicated system of CC27-SN32556 coaxial cylinders used for rheological tests of low-viscosity media. The flow and viscosity curves were determined in the range of shear rate from 1 to 500 s⁻¹.



Dependence of viscosity on reciprocal of temperature for aqueous maltodextrin solutions.

For all tested concentrations, a typical negative temperature dependence of the change in viscosity was observed, which was described by the two-parameter Andrade exponential model of the form:

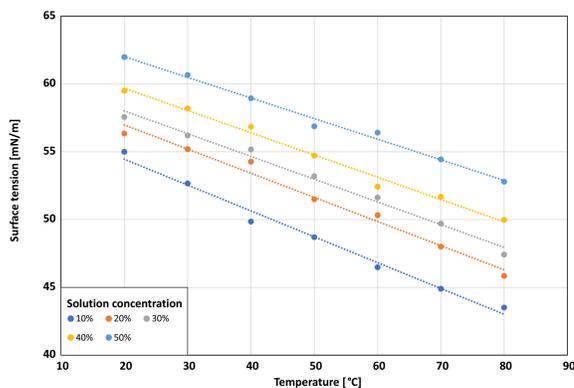
$$\eta = A \cdot \exp\left(\frac{B}{T}\right)$$

Parameters A and B of the two-parameter exponential model used were correlated with the concentrations of the tested solutions ($c_{s,0}$), obtaining linear dependences:

$$A = -2 \cdot 10^{-4} \cdot c_{s,0} + 0.009$$

$$B = 54.702 \cdot c_{s,0} + 939.46$$

Surface tension measurements were made with the K100K (RÜSS) tensiometer, using the ring method (Du Noüy) in the temperature range of 20-80 °C.



Dependence of surface tension on temperature for aqueous maltodextrin solutions.

For all tested concentrations, a typical negative temperature dependence of the surface tension change was observed, which was described by a linear relationship:

$$\sigma = C \cdot T + D$$

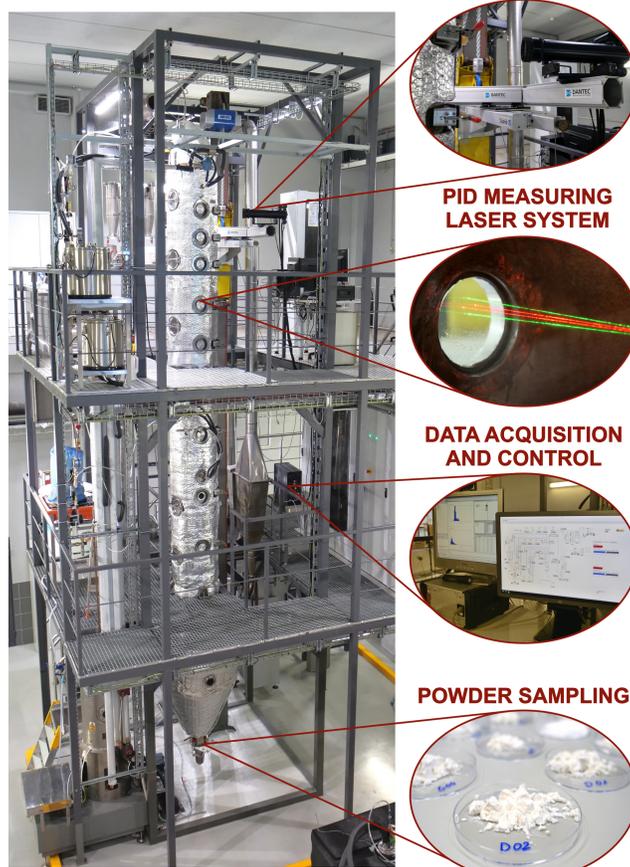
Parameters C and D of the two-parameter exponential model used were correlated with the concentrations of the tested solutions ($c_{s,0}$), obtaining linear dependences:

$$C = 9 \cdot 10^{-4} \cdot c_{s,0} - 0.1978$$

$$D = 0.1601 \cdot c_{s,0} + 56.838$$

Measurements of surface tension were not carried out at the temperature of 90 °C, due to too fast evaporation of the solvent and solidification of the solution on its surface. High temperature and large contact surface with air lead to local concentration of the solution, which could lead to measurement errors related to the change of concentration.

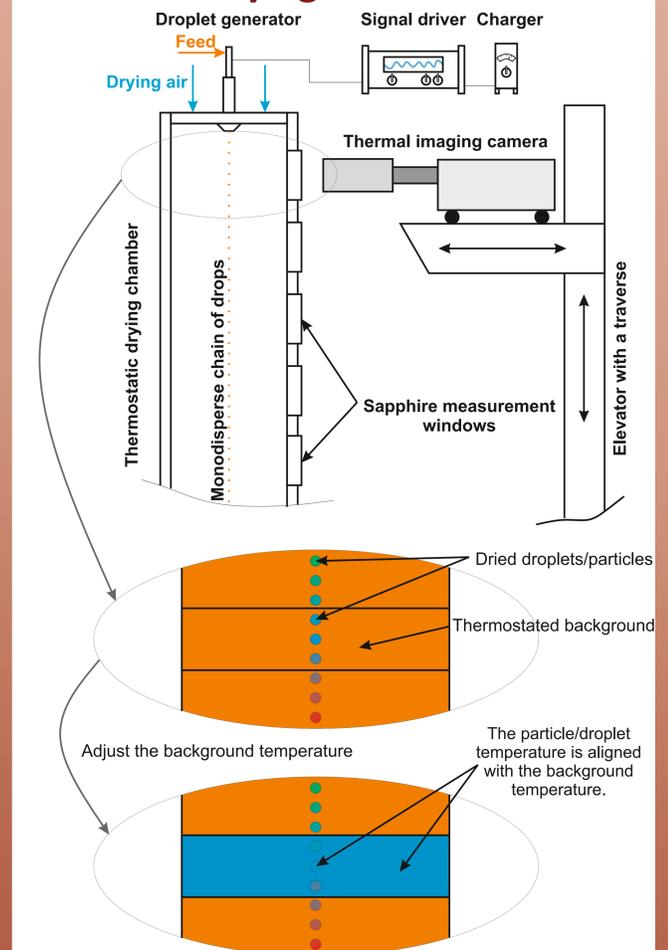
Spray drying experiments



Experimental set-up for spray drying processes.

The experimental rig designed and constructed at the Lodz University of Technology allows to study the phenomena occurring during spray drying inside the drying chamber for a wide range of process parameters. The installed LDA and PDA systems allow to determine the kinetics of changes in particle morphology during moisture evaporation, such as drying shrinkage, puffing, droplet coalescence and particle agglomeration. The spray drying process can be carried out in two ways: co- and counter-current. Depending on the material or the desired material structure, the column can be switched to a different phase contact method. A series of measurement windows allows the collection of a samples of powders at different column heights. This allows for precise observation of changes in the structure of the material that occur during spraying.

Drying kinetics



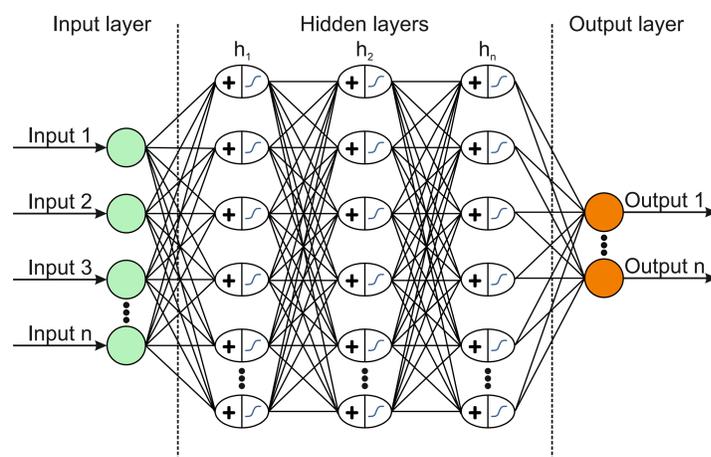
$$\frac{dm_p}{dt} = \frac{dT_p}{dt} m_p c_p - \alpha_p A_p (T_A - T_p) \Delta H_v$$

Based on the energy balance of a particle, it is possible to determine the flux of the evaporated liquid from the particle. The obtained curve of particle moisture content change over time can be approximated by one of the two-parameter drying models such as the Henderson-Pabis model or the Page model or the four-parameter Midilla-Kucuk model. Parameters obtained in this way can be used in the training of neural networks.

Neural network

Slurry properties
Drying kinetic

- Viscosity
- Surface tension
- Density
- Drying model parameters



Powder properties

- Mean diameter
- Porosity
- Bulk density