IFPRI Project Abstract

Spray Drying Kinetics and Morphology

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Project Objective:

The aim of the project is to investigate the influence of the rheological properties of spray solutions on the morphological properties of particles during spray drying. The mathematical relationships developed will also take into account the kinetics of the drying of the particles in the drying chamber.

Approach:

The objectives of the project will be achieved through the following steps:
- detailed rheological tests of aqueous solutions of the selected substance will be carried out over a wide range of concentrations and temperatures;
- tests of the co-current spray drying process of the tested solutions (for selected process conditions) will be carried out to obtain powders for morphological tests;
- the kinetics of droplet drying are carried out in a specially designed and constructed column in which the monodisperse droplet chain is dried by the free-fall method;
- the relationships between the rheological properties of the solutions, the drying kinetics and the process parameters as well as the particle morphology are determined using neural networks.

Recent Results:

Adaptation of the existing equipment to the project requirements

The preparatory work for the drying plant this year focused on converting the plant from a counter-current to a co- current. Since the drying column had not been operated in direct current for many years, all elements of the plant had to be checked during this work. The most important tasks in reconfiguring the plant included:

1. Replacing the elements of the air supply and the powder assembly. In the previous configuration, the hot air was supplied through the distribution ring at the bottom of the column. Now it is directed to the upper part of the column, where it is evenly distributed in the chamber thanks to a mesh layer. At the bottom, there is a cone to collect the air and the powdered material. This change required the modification of the air connections.

2. Installation of a new air heater. All heating elements were replaced in the existing heater. Overvoltage and overcurrent protection devices were installed. The total output of the new heater is 73 kW.
3. Replacing the insulation in the slurry pipe.
4. Calibration of the Coriolis flow metre. The Coriolis flow metre controls the pump that feeds the dryer with a solution. It also measures the temperature and density of the flowing liquid.
5. Replacing the rotor of the mono pump to increase the stability of the liquid flow.
6. Test and calibration of the elements of the control and data acquisition system.
7. New control and data acquisition system for the operation of the tower.
8. Calibration and teach-in of the PiD drivers.
9. In addition, 200 hermetically sealed glass containers with a capacity of 2 litres were ordered for product collection and storage.

All work to change the configuration of the drying tower has been completed. Some delays from the original plan resulted from conducting PhD research, which was extended due to the Covid 19 pandemic.

Spray drying experiments

The powder for further morphological analysis was obtained from a stainless steel drying tower with a diameter of 0.5 m and a height of 9 m, which was operated using the co-current phase flow method.
Clean and hot air was supplied to the drying chamber at the top of the tower. The air with the product that left the drying chamber was dedusted in a cyclone system and, after cooling to the permissible temperature, thoroughly cleaned in a bag philtre and released into the atmosphere. The dry material for further analysis was collected from the cyclones.
The aqueous maltodextrin solution was prepared in a thermostated tank using a belt stirrer. The solution was fed to the nozzle through a thermostated pipe using a monopump (Moyno, USA). A thermostated hollow cone nozzle (Spraying System, USA) with a 1 mm orifice was used to atomise the solution.

The spray dryer was operated in co-current mode at fixed air flow of 200 Nm3·h^{-1}. Drying conditions were varied by selecting different concentrations of feed, temperature of feed and temperature of inlet air. The variable process conditions are listed in Table 1.

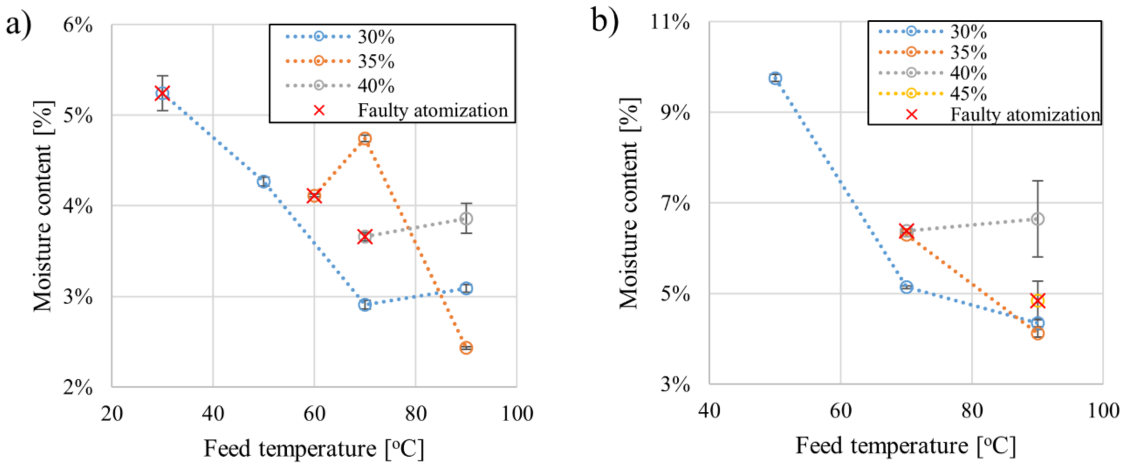
Table 1 Variable process parameters

Feed concentration, wt. %	30, 35, 40, 45, 50
Feed temperature, °C	30, 50, 70, 90
Inlet air temperature, °C	170, 200
Feed flow rate, kg/h	8, 10, 12

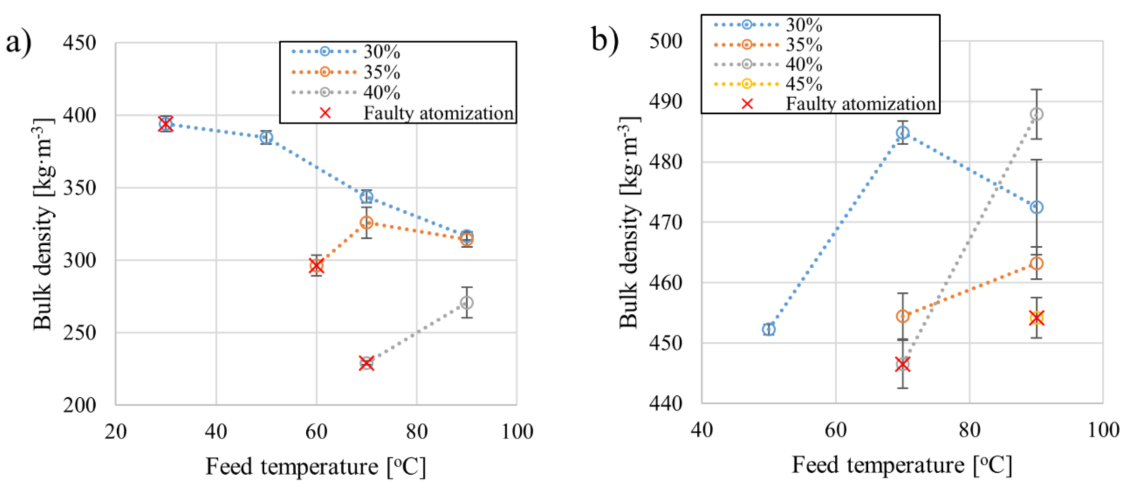
Analyses of powders obtained during spray-drying tests are currently underway. The following parameters of the powders will be determined:
- moisture content
- bulk density

- apparent density
- specific density
- porosity of the bed and of a single particle
- Diameter distributions and corresponding Rosin-Rammler distribution curves,
- Sorption isotherms,
- Images from an optical microscope,
- Images from an electron microscope (SEM),

First examples of obtained results:



Effect of feed temperature on product bulk density at inlet air temperature a) 200 °C, b) 170 °C



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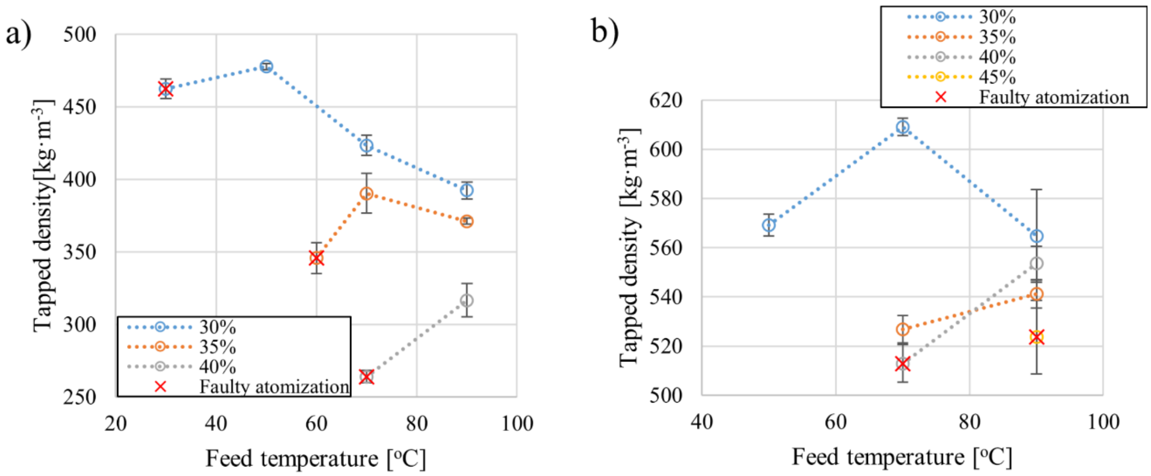

Effect of feed temperature on product tapped density at inlet air temperature a) 200 °C, b) 170 °C

Construction of SDD column

The column for drying a single droplet free-falling in a drying chamber aims to develop a new technique for measuring the evaporation rate and determining the critical moisture content under conditions corresponding to spray drying.

A new technique has been developed to measure the temperature of the particle using an IR camera without knowing the actual emissivity of the particle. A series of tests were performed with a specially designed thermostatic chamber. The results of the measurements confirmed the theory that if the ambient temperature (including the walls) is equal to the temperature of the object under test, the effect of emissivity on the temperature reading from the IR camera can be neglected.

A number of discussions were held with suppliers of IR cameras and a device was selected: the FLIR X6901sc SLS camera with a readout rate of 1004Hz and a resolution of 640x512 pixels. The camera has the ability to mount additional optics allowing for a higher zoom to capture 100-300 micron droplets.

Since the purchase of the camera significantly exceeds the project budget, it will be rented for the duration of the study.

In addition, a monodisperse droplet generator that can work for viscous liquids at higher temperatures (up to 200°C) has been ordered.

The droplet generator, along with a control, thermostat system, isolation system and a series of terminations that allow the generation of droplets of different diameters, will be delivered in July 2023.

Next Steps:

1. Further analysis of the morphology of the powders obtained in the experiments.
2. Investigate the relationship between the properties of the sputtered solution and the properties of the product after spray drying.
3. Construction of a column to study the drying kinetics of a single drop.
4. Determining the drying curves and critical moisture content of materials subjected to spray drying.