Institute for
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Process Technology

Radial Multizonal Dryer

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Format Final Public Report

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1. Public Summary

The Radial Multi-Zone Dryer (RMD) is a new type of spray dryer which combines low Capex, low Opex, premium product properties and low specific energy consumption. The RMD is an intensified spray drying technology which combines a very short residence time in a central zone with high air temperature with rapid transfer to a peripheral zone with mild air temperature. This trajectory yields better product properties than powder produced in conventional spray dryers. Furthermore, high temperature drying improves energy efficiency, thus reducing the specific energy consumption of drying and so the carbon footprint of dried (dairy and other) products. Improved product properties relate to e.g., nutritional value (mild processing) as well as to functionality (e.g., solubility) of the product. Due to intensified drying, the size, viz. footprint, of the dryer will be smaller than of conventional spray dryers, thus reducing investments in equipment, building and operation. In addition, centrifugal forces in the dryer efficiently separate powder particles from the drying air, meaning integration of particles separation in the dryer chamber and so further reduced investments in equipment to separate particles from the drying air downstream of the dryer.

The development of the innovative and new RMD drying concept started at TRL1-2 about 10 years ago. During a following project we managed to develop the technology further towards TRL3-4, and finally a pilot plant on semi-industrial/pilot scale was built with an evaporation capacity of 100 kg water per hour.

Despite the fact that the principle of the technology has been proven on this small scale many fundamental questions remain to be answered with respect to control of product quality, specific energy consumption, particle trajectories in relation to drying properties, wall contamination and fouling of the atomization nozzles. The RMD project aimed at getting an understanding of these phenomena by combining experimental research, CFD modelling and energy optimization scenarios. The scale of the experimental dryer depends on the relevant particle size, atomizer and particle trajectory needed to match the desired drying behavior. Design and construction of such a dryer has been part of the project. As preliminary results showed that studying the RMD concept on an experimental unit a drying capacity of 100-250 kg water evaporation per hour is needed to be able to study the nature of the wall contamination and flow dynamics and to get an indication on product properties, a 100 kg/h pilot dryer has been designed, constructed and validated. Milk powder has been used as the selected model system. Product properties of dried milk powder have been analyzed and it turned out that further optimization of drying conditions is needed to realize and control the desired product properties.

Due to size and complexity of the RMD dryer and the utility equipment, design, construction and start-up have taken much more time than planned. In combination with limitations due to Covid-19 available time for product trials and study of operation conditions and its effect on product properties was limited.

Nevertheless, design capacity of 100 kg water evaporation per hour has been proven and a big step forward has been made in reduction of fouling and in controlling the (symmetrical) air flow in the drying chamber. Some features of RMD, like control of axial transport of powder along the chamber wall were successful, while other features, like vortex induced powder separation, need further optimization

Milk concentrate however has a complex drying behavior due to its glass transition and stickiness. In further design and optimization of the RMD it would be beneficial to use a less critical model system that is easier to dry. In a follow-up project the product properties of other model systems (food) will be carefully analyzed and compared with those obtained with a reference technology.

A Computational Fluid Dynamics (CFD) model was further developed and validated to facilitate scale-up and optimization. PIV (particle image velocimetry) measurements under varying operating conditions were planned for extensive CFD model validation. It turned out, however, that the combination of PIV and RMD was too complex and that it was not possible to implement PIV. For additional model validation it still is worthwhile to explore other measuring methods to measure particle and/or air velocity.

Much insight was created by CFD model simulation by studying changes in lay-out of the dryer chamber, variation in process conditions and by carrying out a parameter sensitivity analysis (e.g., heat losses and

penetration of atomization jet). In order to improve the quality of the CFD simulations information on particle size distribution and on particle velocity are necessary. If research with two fluid nozzle is being continued its performance has to be characterized in the spray box of UT.

The energy savings were evaluated, and a business case studied. Compared to the spray dryer which uses an estimated 3.9 kJ per g water evaporated, the estimated energy use of the vortex chamber is 2.45 kJ of heat and 0.4 kJ of work per g water evaporated. Even when correcting for the costs of electricity (roughly twice that of gas per unit of energy), the vortex chamber operates at lower operational energy expenses of 83%, which is a 17% gain in costs or, if electricity is produced CO_2 neutral, a 37% reduction in CO_2 emission can be achieved

Future research should focus on extending runtime of the dryer, on the effect of process conditions on product properties, and on minimizing the specific energy consumption.

All that information will be needed to make a conceptual design of a demonstration scale, i.e. small production scale, RMD, which is the next step in the route towards a full-scale production dryer. Meanwhile follow-up has been organized to optimize RMD technology and CIP, and to validate three other model systems with new project partners to take RMD technology to a next level.

2. Follow-up project

Results, findings and recommendations will be used to define the program of the follow-up project, meaning that design, process conditions and model system will be challenged and re-considered.

Future research should focus on extending the runtime of the dryer, on the effect of process conditions on product properties, and on minimizing the specific energy consumption, repeatability of the results of longer trials and on transient effects. This information is necessary before thinking of further scale-up of the dryer. Information about Sauter Mean Diameter (SMD) of the droplets, distribution and velocity is important to properly assess the experimental spray and to implement it in CFD. If research with two fluid nozzle is being continued its performance should characterized in the spray box of UT.

Finally, all results will be translated to make a conceptual design of a demonstration scale, i.e., small production scale, RMD, which is the next step in the route towards a full-scale production dryer. Meanwhile a follow-up has been organized to optimize the RMD technology and CIP, and to validate three other model systems with new project partners to take the RMD technology to a next level in the 2-years project ENGENDER that started on 1st of July 2021.

3. Communication and Dissemination

a. Activities

Project page on ISPT website

A project page was developed for the Radial Multi-zone Dryer project: https://ispt.eu/projects/rmzd/.
Also, a project poster was made available on the project page:
file:///C:/Users/Anne.vanderzwaan/Downloads/Project-Poster-DR-20-10-RMD-Radial-Multizone-Dryer.pdf .
The poster was presented during the ISPT Symposia in 2018, 2019 and 2020.

News items in ISPT newsletter

A news item was published on 1 February 2018 as well in the ISPT newsletter as on the website just before the kick-off of the project took place. https://ispt.eu/news/multi-radial-drying-project-kicks-off-march-2018/ .

The next news item on the final project results accomplished in the RMD project will be published in the ISPT newsletter of July/August 2021. Also, a LinkedIn post will be referring to our news item.

b. Public references

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Thesis Defences

The thesis defence of both Thomas Tourneur of UCLouvain as of Umair Jamil Ur Rahman is expected in Q3-Q4 2021.

4. Acknowledgement

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