# ME – PhD Thesis Colloquium

## Rotary atomization of Non-Newtonian liquids for Spray drying applications

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## ABSTRACT

The agriculture sector faces food wastage as a significant problem throughout the country due to shortage of basic storage infrastructure and logistic amenities. Spray drying can be used to transform perishable food products, in their liquid form, into a dried powder product. In powder form, their nutritional values are preserved along with a higher shelf life and require very small storage space. Proteins, vitamins, and fibrous constituents impart complex rheological properties to solutions of food products. Spray drying primarily involves atomizing the feed into fine droplets in a hot gas environment which are then rapidly dried to form a solid powder at a specific temperature and pressure. Thus, the mode of atomization plays a crucial role along with the drying characteristics of the resultant droplets. Such solutions of food products exhibit non-Newtonian properties, and the atomization of these solutions differs significantly from that of their Newtonian counterparts. Since properties of the solutions vary between the various agricultural food products, surrogate liquids were identified for both the liquid jet atomization and droplet evaporation studies.

The first part of the study investigates the jet breakup and spray characteristics of xanthan gum solutions (0.1,0.5 and 1.0 wt.%) in distilled water using a rotary atomizer with a perforated rim. The viscoelastic effects of such high molecular-weight polymer solutions on atomization have been investigated. For studying the jet structure, shadowgraph images of size 50x50 $mm^2$ size are acquired, whereas a field of view (FOV) of size 2x2 $mm^2$ is fixed at a distance 45-mm from the atomizer periphery to record images for the drop sizing using particle/drop image analysis (PDIA). At lower rotational speeds < 150000 RPM, minimal atomization is observed due to dominating viscoelastic effects over inertial forces. Therefore, the Sauter mean diameter (SMD) and drop size distributions are obtained for rotational speeds $\geq$ 15000 RPM resulting in SMD values between 10 and 200 $\mu m$, corresponding to Weber numbers in the range of: $1 \leq We_t \leq 75$. The extensional relaxation times are also obtained to quantify the elastic nature of the surrogate solutions. The second part of the study focuses on determining the effect of temperature on the spray characterization of the surrogate solutions. For solutions with dilute polymer concentration (c < 0.1 wt.%), the SMD decreases significantly even at 15,000 RPM due to decrease in solution viscosity. However, for concentrated solutions (c > 0.1 wt.%), the solvent evaporation during the jet breakup increases viscoelastic effects, consequently delaying the atomization of such solutions. Therefore, large SMD values are observed for the concentrated surrogate solutions at higher temperatures.

The third and final part of the study investigates single droplet drying characteristics of a surrogate solution (16 wt.%-fructose, 11.2 wt.%-glucose, 4.8 wt.%-sucrose in water) in a pendant droplet setup. When subjected to transverse hot air flow to simulate the conditions in a dryer, the droplets exhibit a two-stage drying process. There is a constant drying rate period followed by a falling drying rate period on initiation of solid crust layer formation, which is defined by solute saturation solubility. A two-stage single droplet drying model is then developed to study these phenomena under various environmental conditions. The mass and heat transfer balance at the drop surface in both stages, along with relevant boundary conditions, are used to obtain the droplet mass, diameter, and temperature evolution as the water content within the drop decreases with time. The model is observed to predict the experimental data reasonably well, following which it is used to predict the evaporation time scales for realistic droplet sizes and temperatures prevalent in a spray dryer. Overall, the current study has led to an improved understanding of jet breakup, atomization, and evaporation characteristics under convective conditions of non-Newtonian solutions that typically represent solutions of food products. Moreover, rotary atomization has been shown to be a very effective strategy for spray drying applications. Furthermore, data obtained in the present work on droplet sizes and evaporation timescales can be used to design a compact, portable spray dryer tailored for agricultural food products.


## ABOUT THE SPEAKER

Amitesh Kumar Chaudhary is a PhD student in the Department of Mechanical Engineering at IISc Bangalore. He completed his B.Tech. in Mechanical Engineering from the National Institute of Technology (NIT) Srinagar. He then joined IISc Bangalore as a PhD student under the Prime Minister's Research Fellow (PMRF) scholarship. His research interests include fluid mechanics, heat transfer, rheology and image processing.