

Computational Simulations of Scraped Surface Freezer Operation



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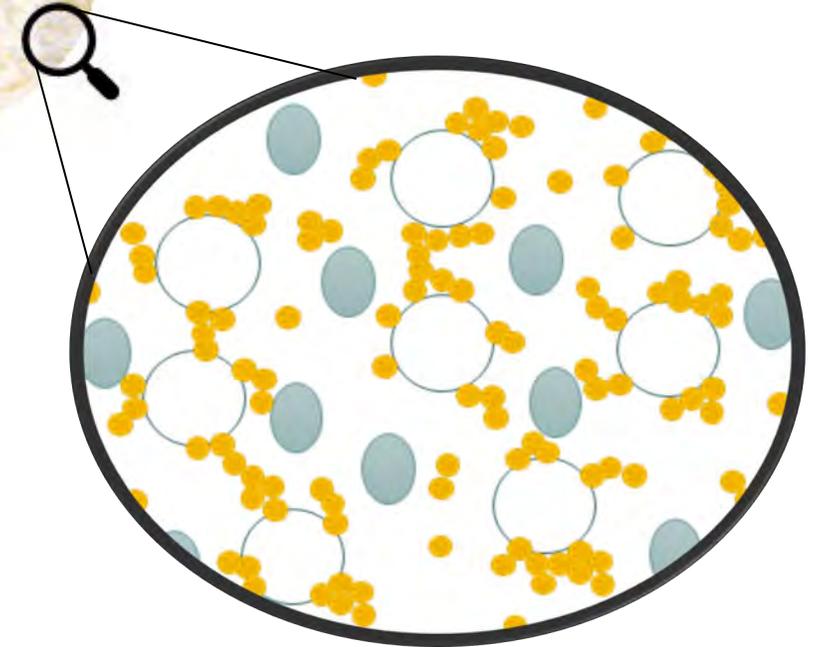
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Ice Cream: Composition and Mixing

1. Composition

- Ice Crystals
- Air Cells
- Fat Globule Clusters
- Liquid Serum Phase



2. Affect quality and acceptability



ice crystal

air cell



fat globule

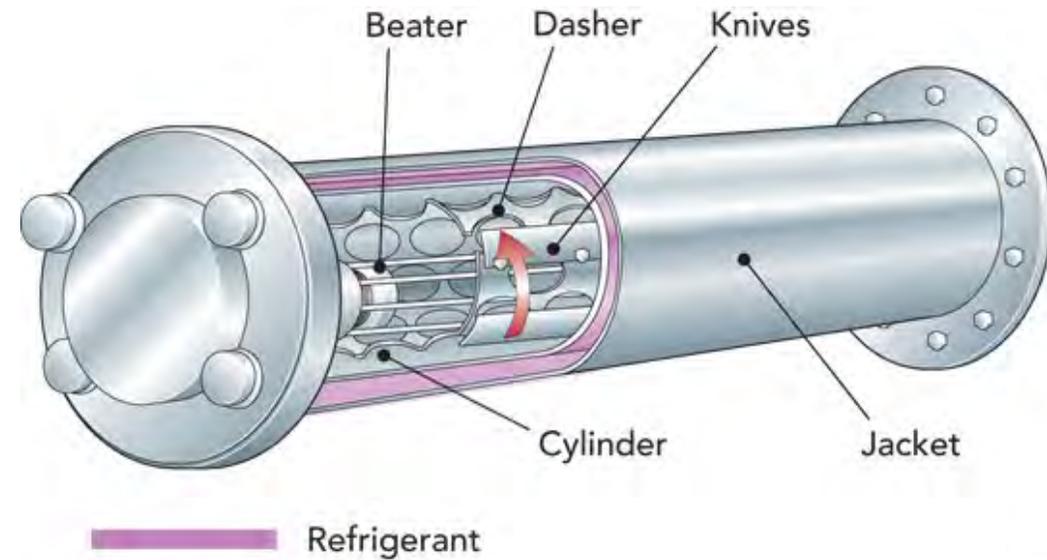


partially coalesced
fat network

The Scraped Surface Freezer

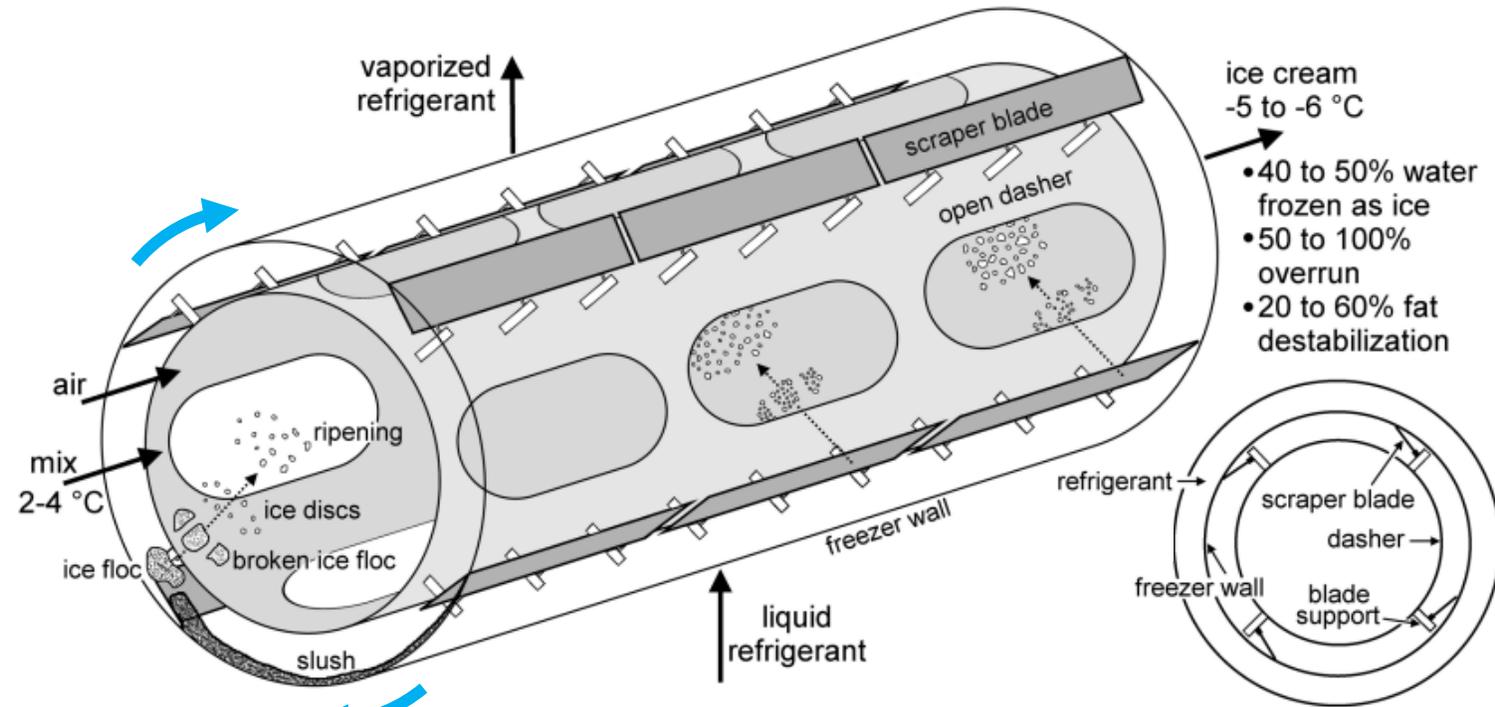


Tetra Pak CF700 A2



Role of parts

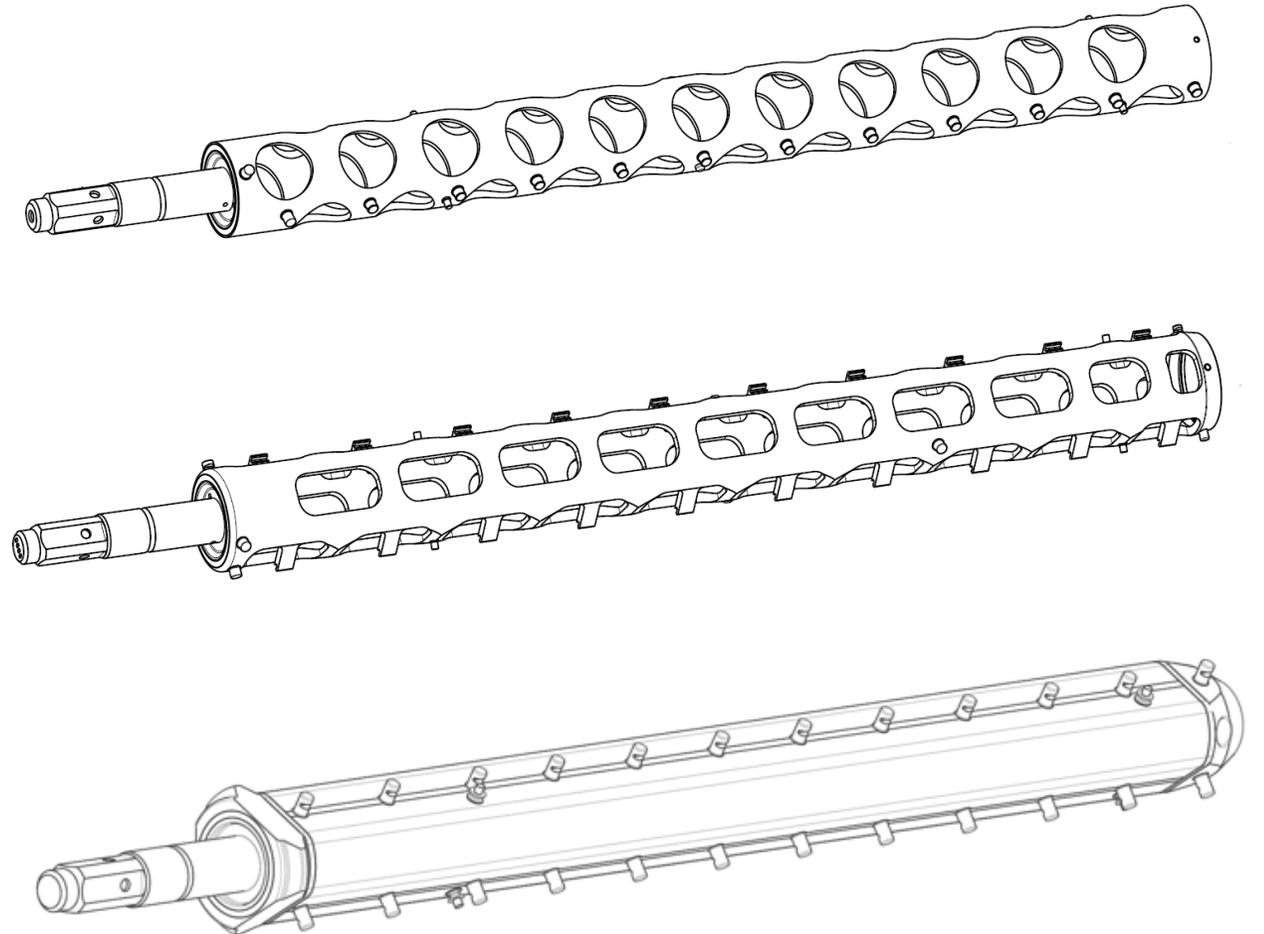
- Dasher
 - Mixing
 - Air incorporation and size reduction
 - Partial coalescence of fat
- Scraper blades
 - Scrape freezing ice cream from cylinder wall
- Beater
 - Agitation



Specific Problem Statements

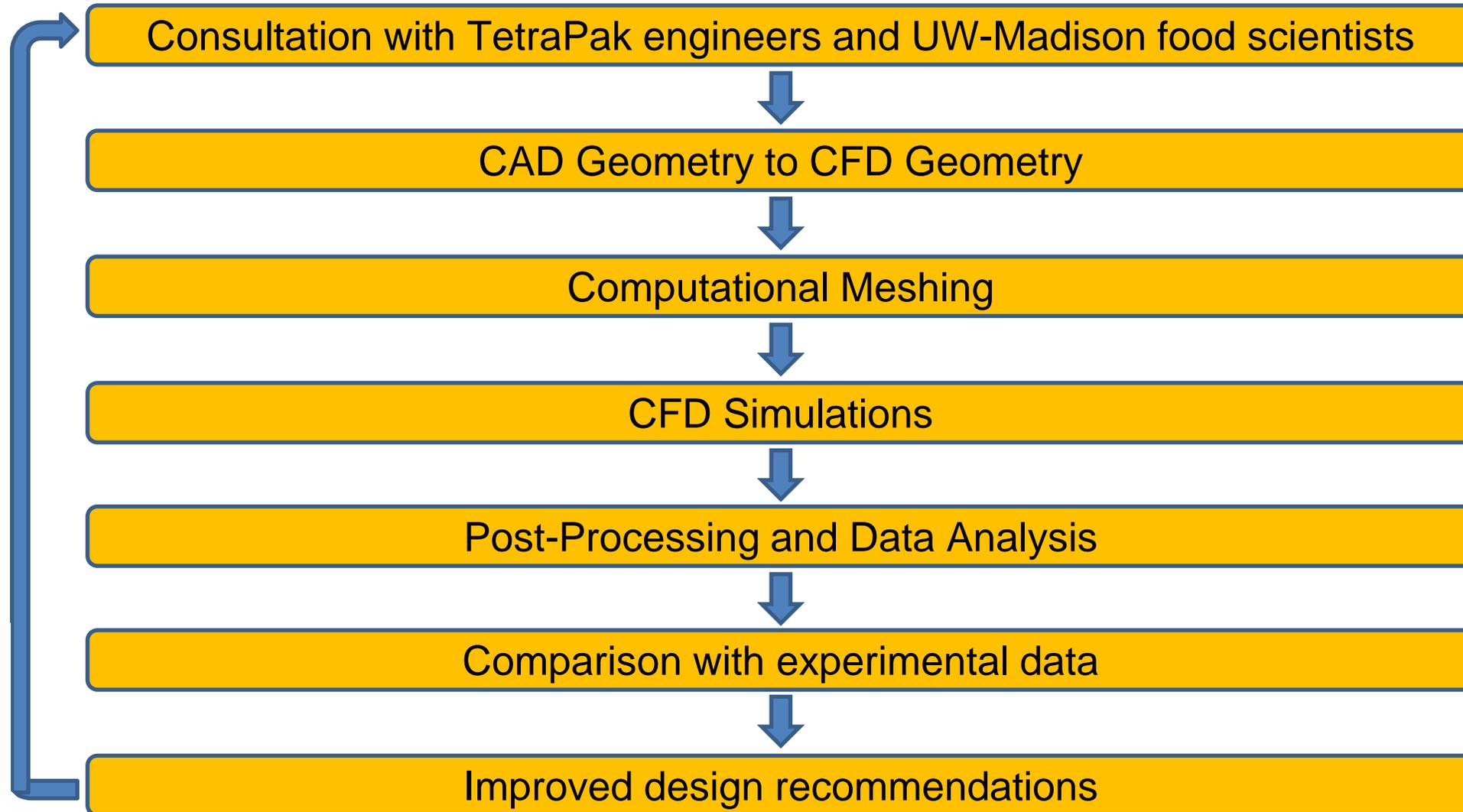
- Complex SSF are still largely designed by **trial and error**, with limited understanding of mixing patterns (fluid dynamics and heat & mass transfer occurring in the SSF).
- SSF designs are also typically based on proprietary findings within each manufacturer.

Scraped surface freezer (SSF) dasher designs





Overall Procedure: Modeling by Computational Fluid Dynamics (CFD) and Experimental Verification



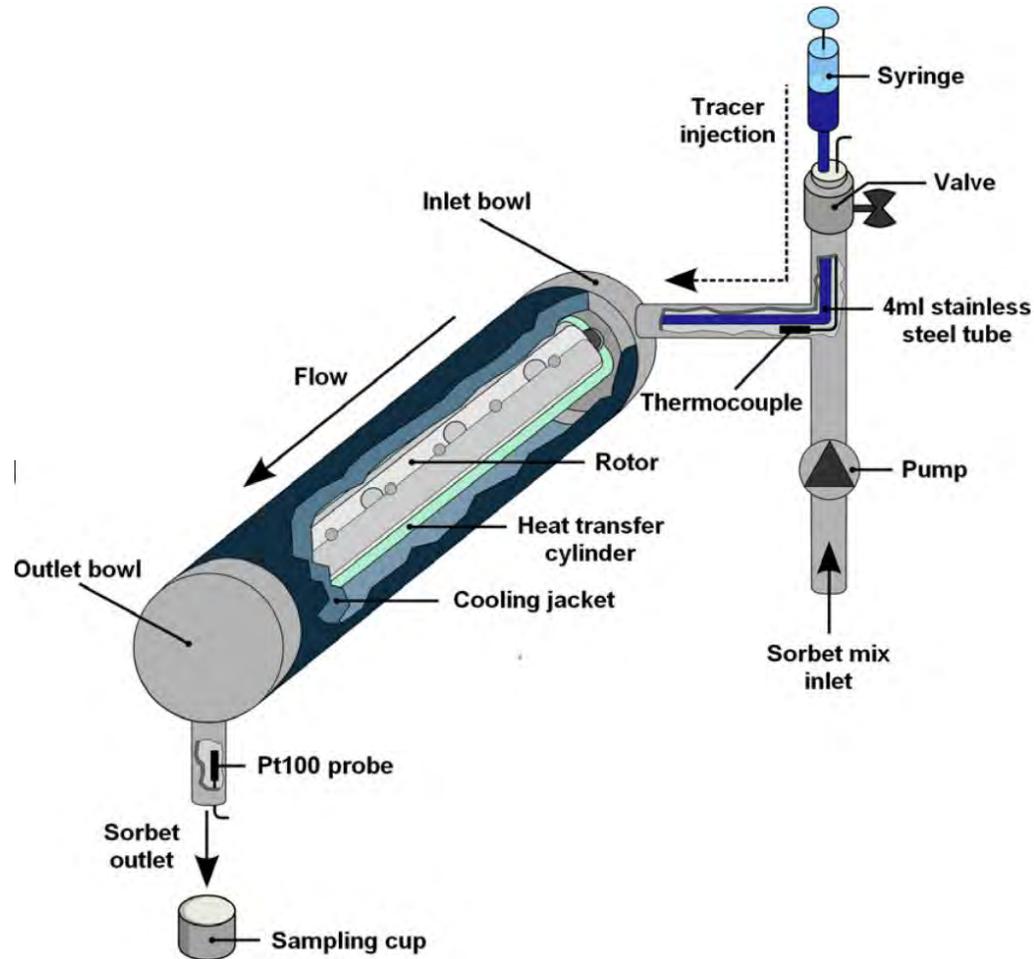


Research Objectives

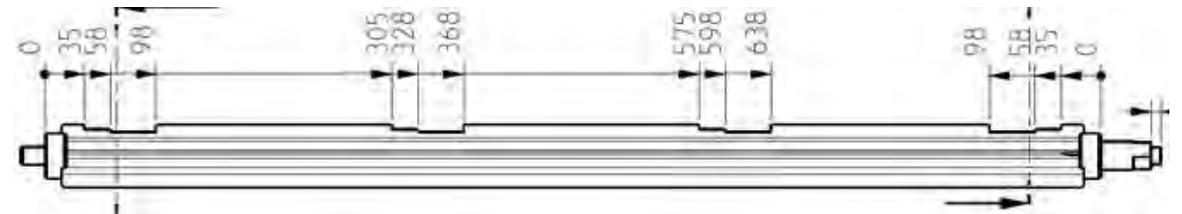
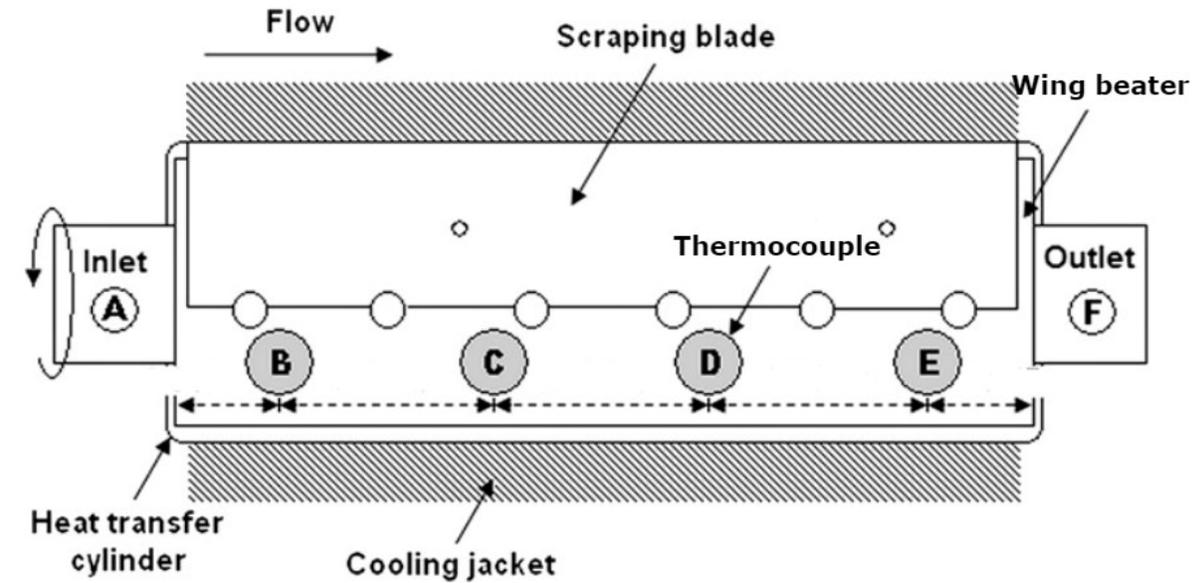
- Simulate standard dasher SSF setup with operating conditions of current experimental setup.
- Validate CFD model outcomes by:
 - Monitoring residence time distribution.
 - Monitoring mixing patterns and heat & mass transfer.
- Once model is validated using CFD the SSF design can be changed, also operating parameters such as dasher speed and volumetric flow rate can be adjusted.
- A series of computational simulations for different operating parameters will be conducted to improve SSF design.

Experimental validation of the CFD results

Setup for injection of tracer

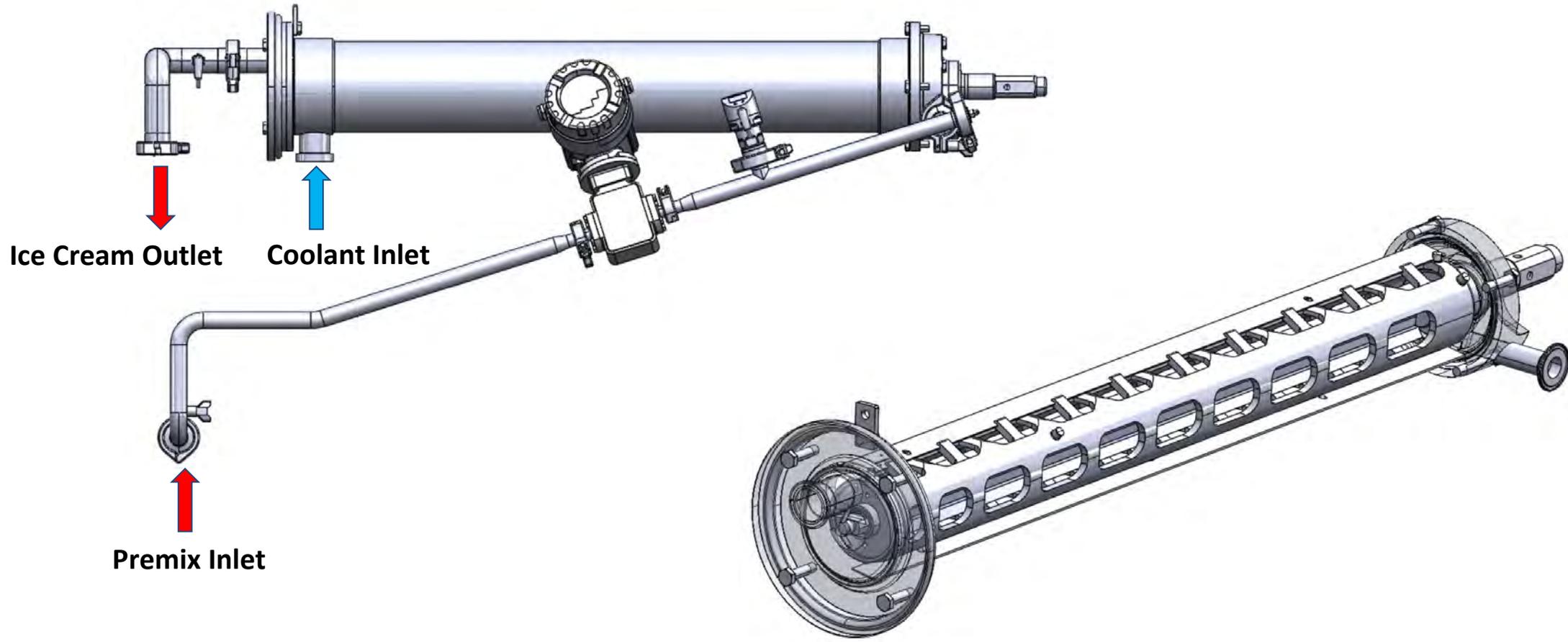


Setup for temperature reading



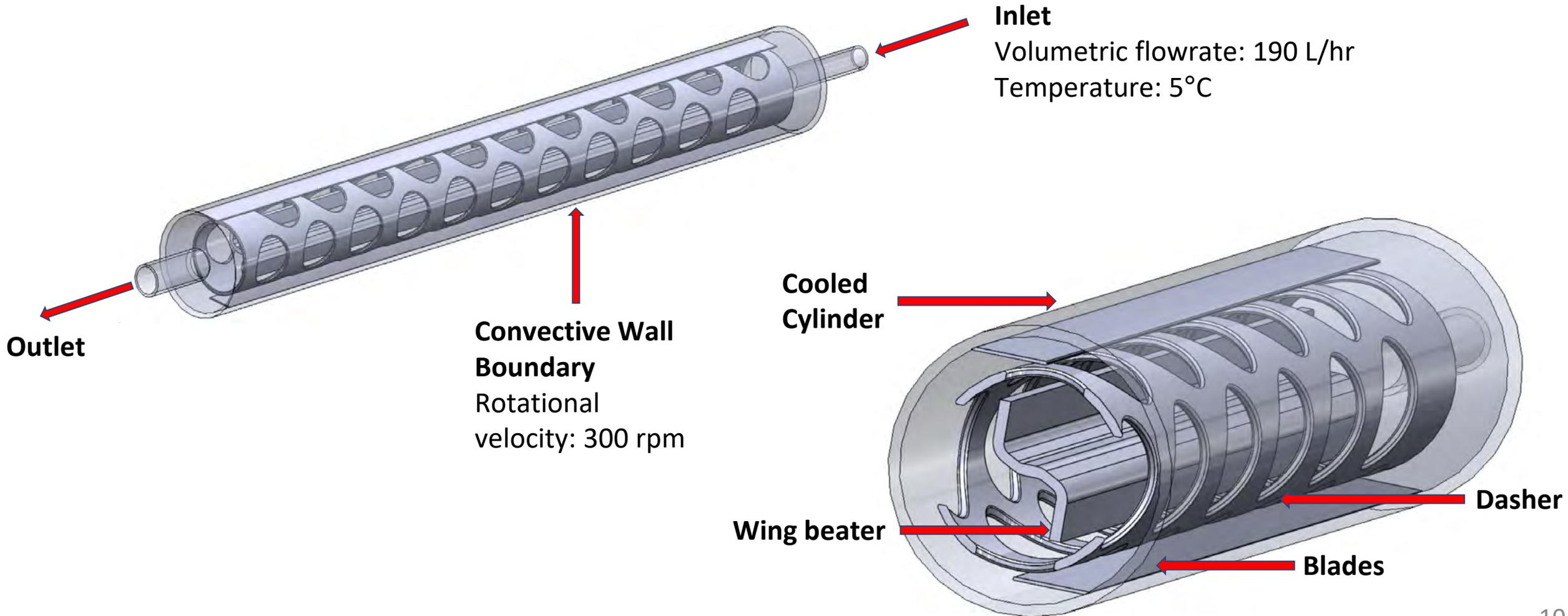


Tetra Pak Scraped Surface Freezer (SSF)

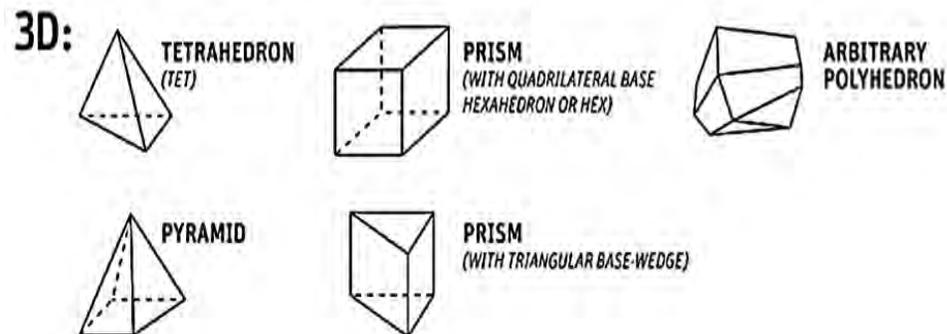
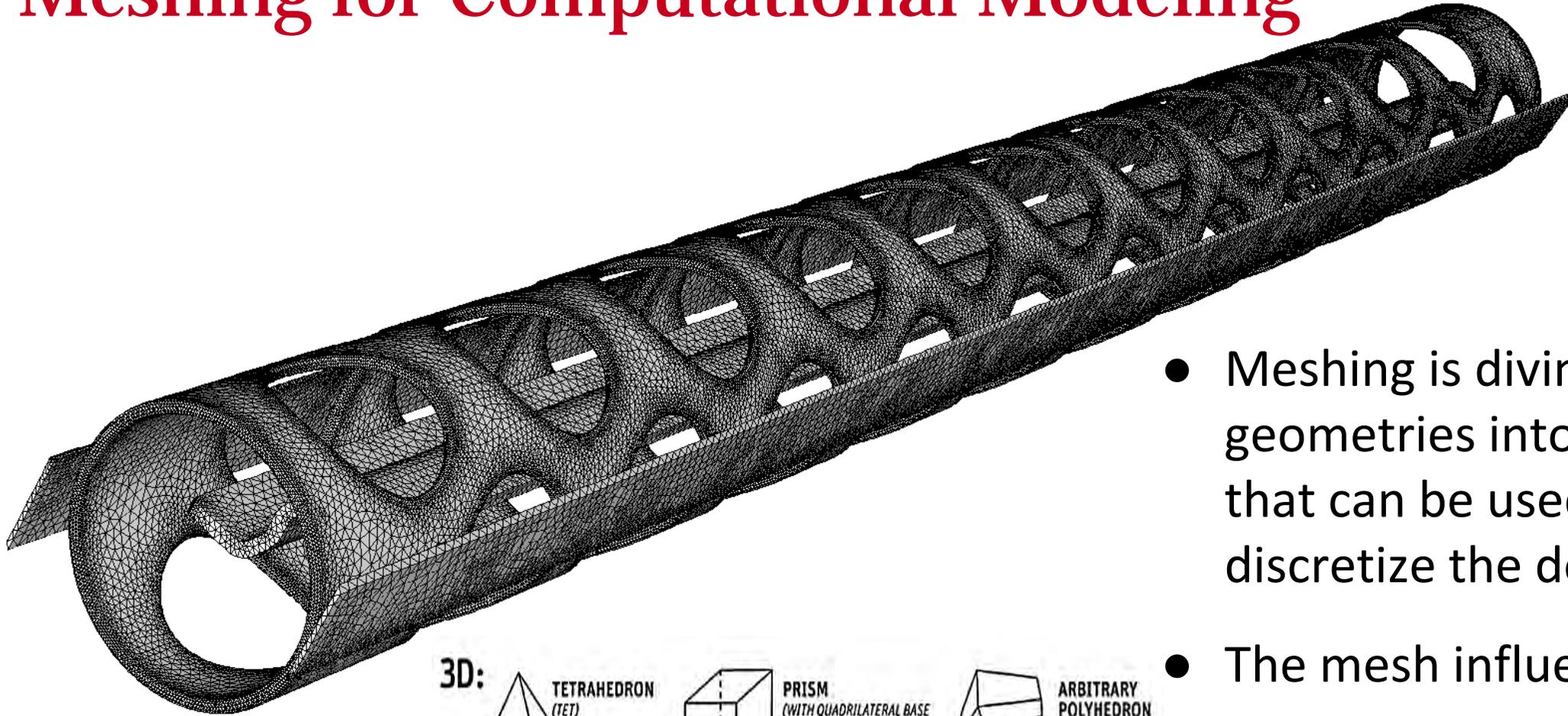




Computational Modeling and Boundary Conditions



Meshing for Computational Modeling



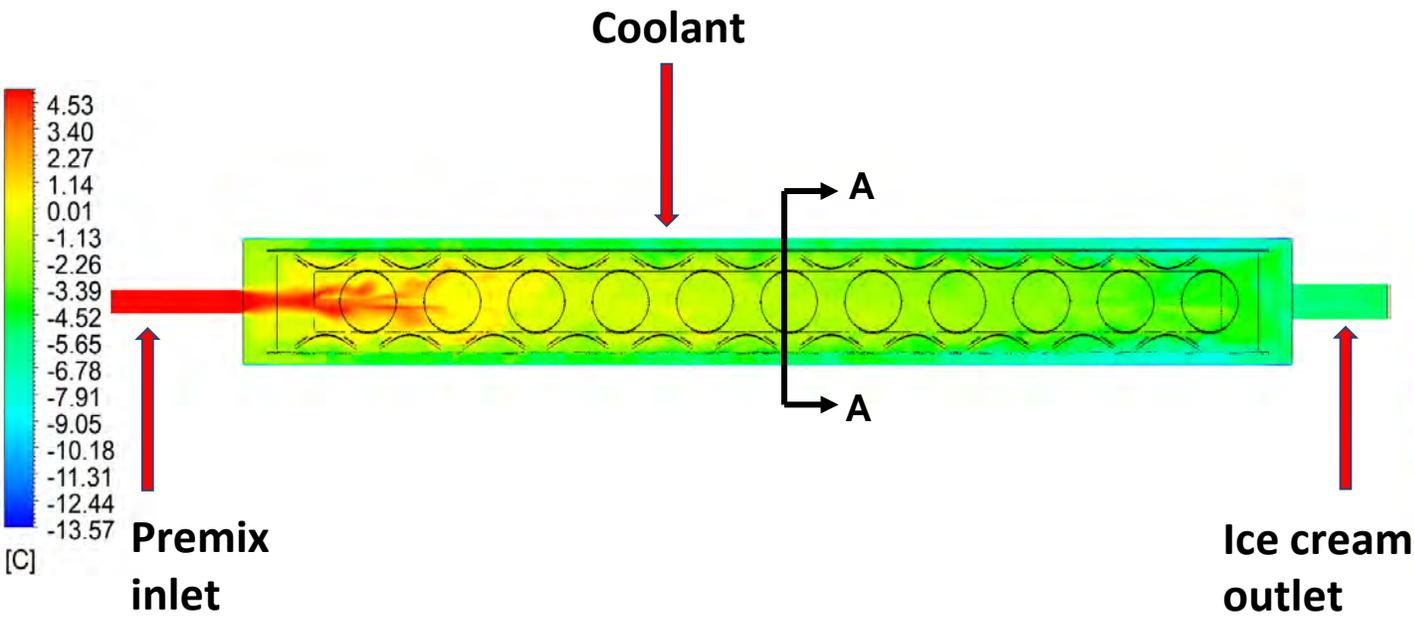
- Meshing is dividing complex geometries into elements that can be used to discretize the domain.
- The mesh influences the accuracy, convergence and speed of the solution.



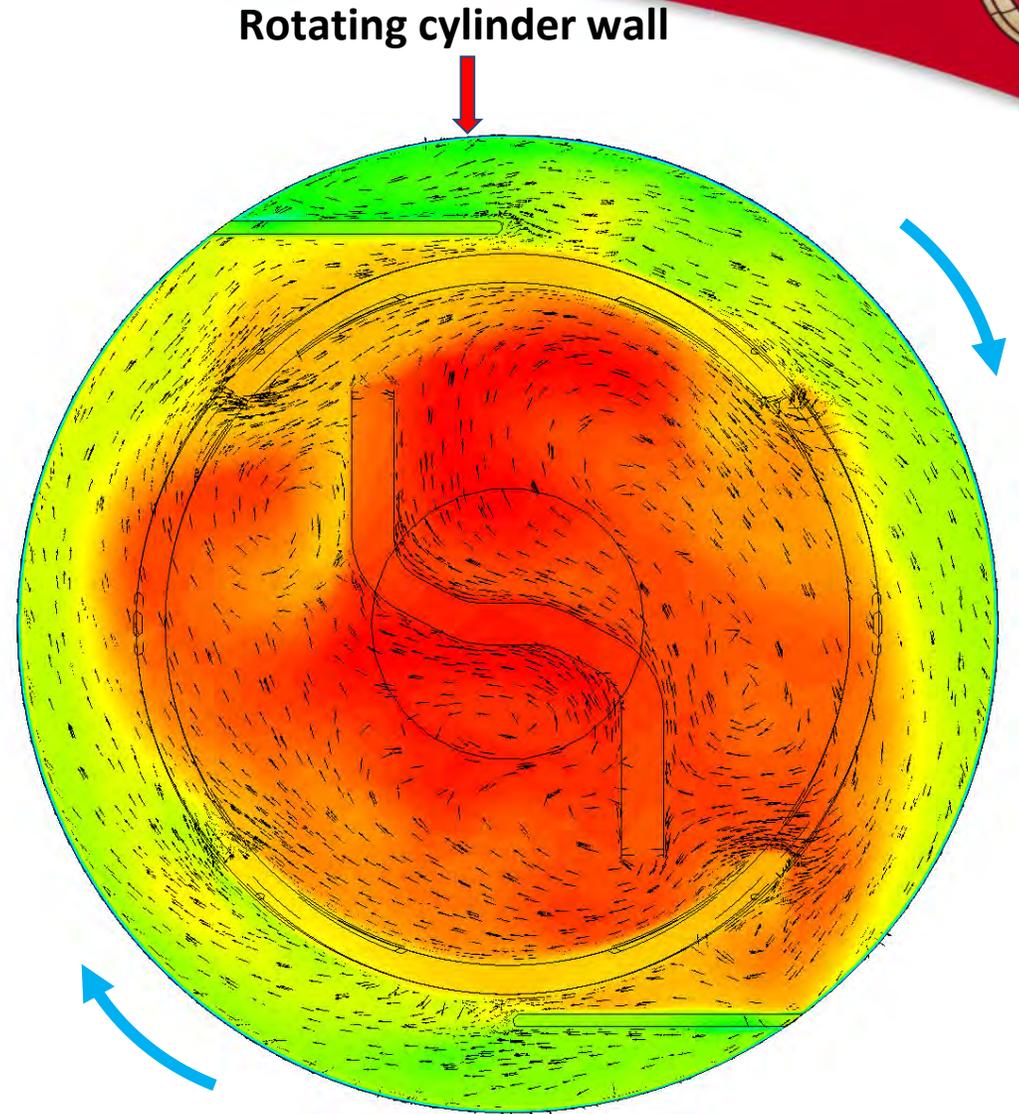
Spinning Dasher and Blades (actual speed at 300 rpm) slow-motion



CFD Outcomes



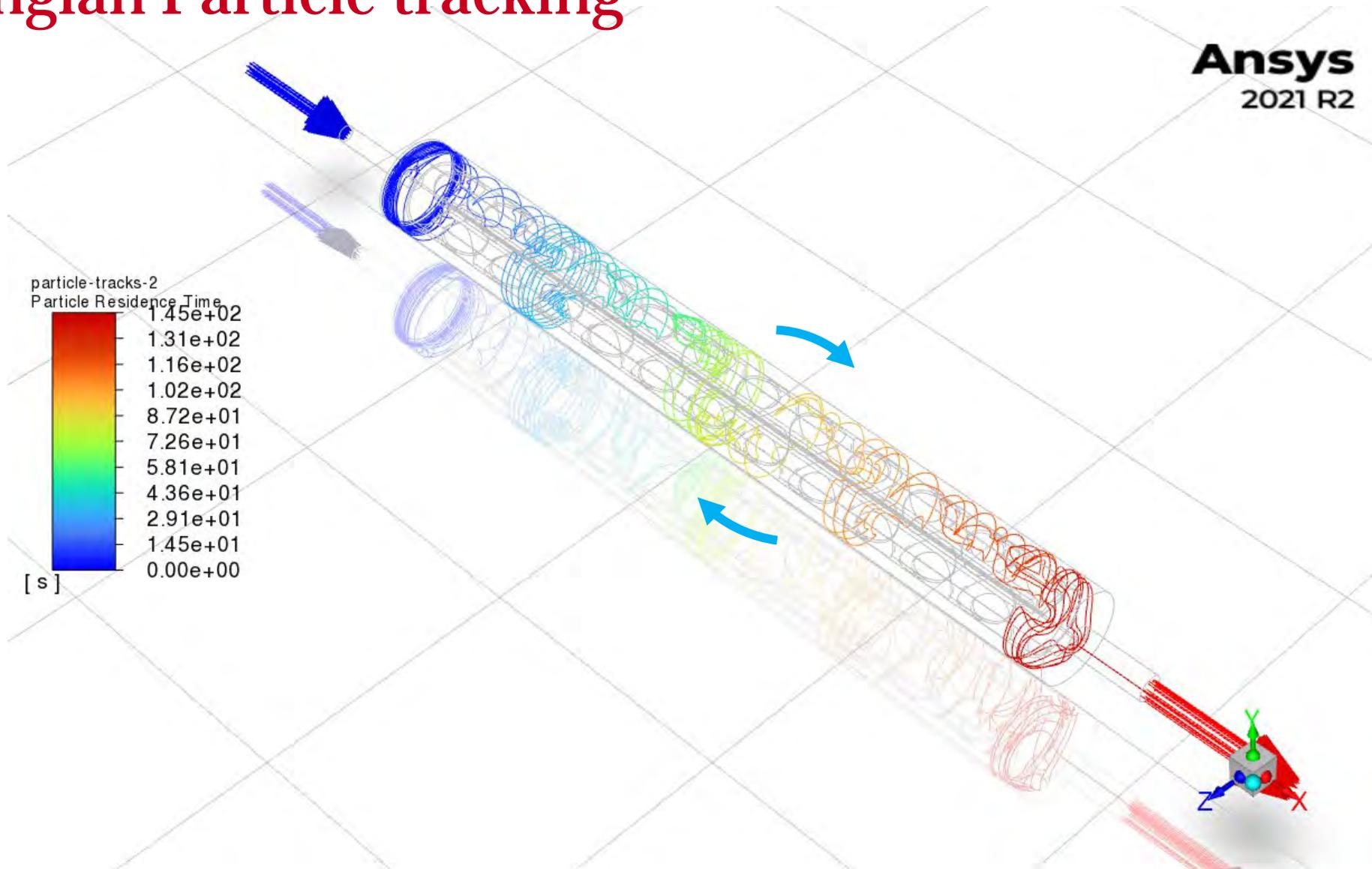
Temperature contour side view



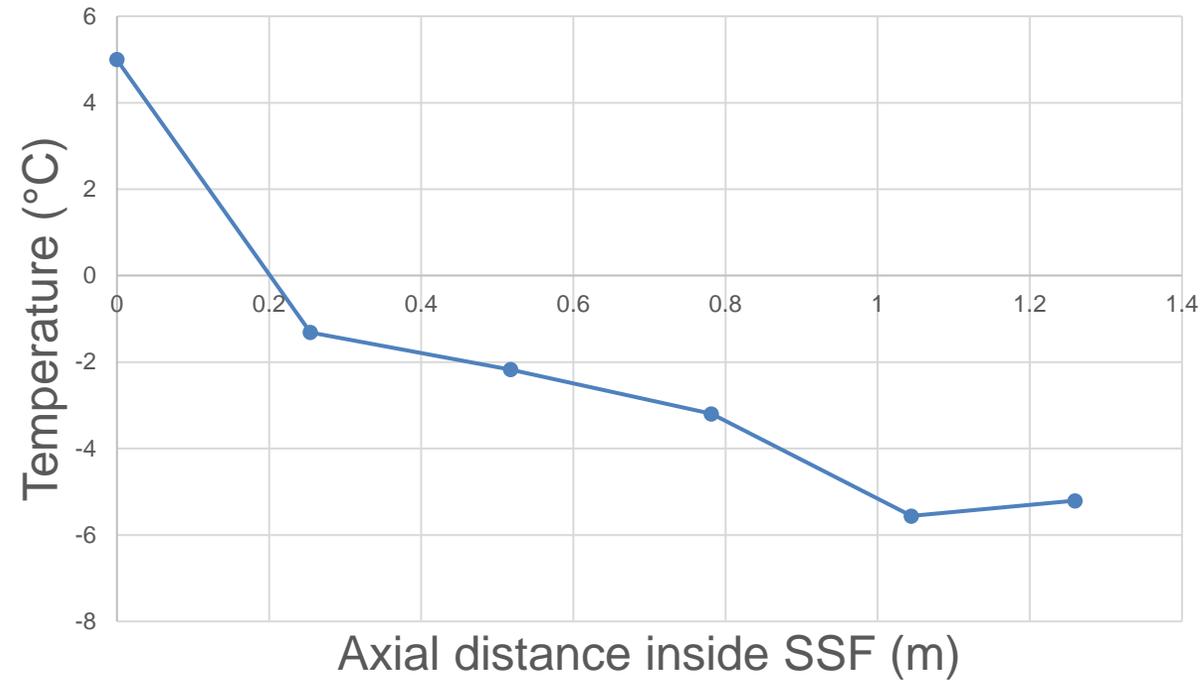
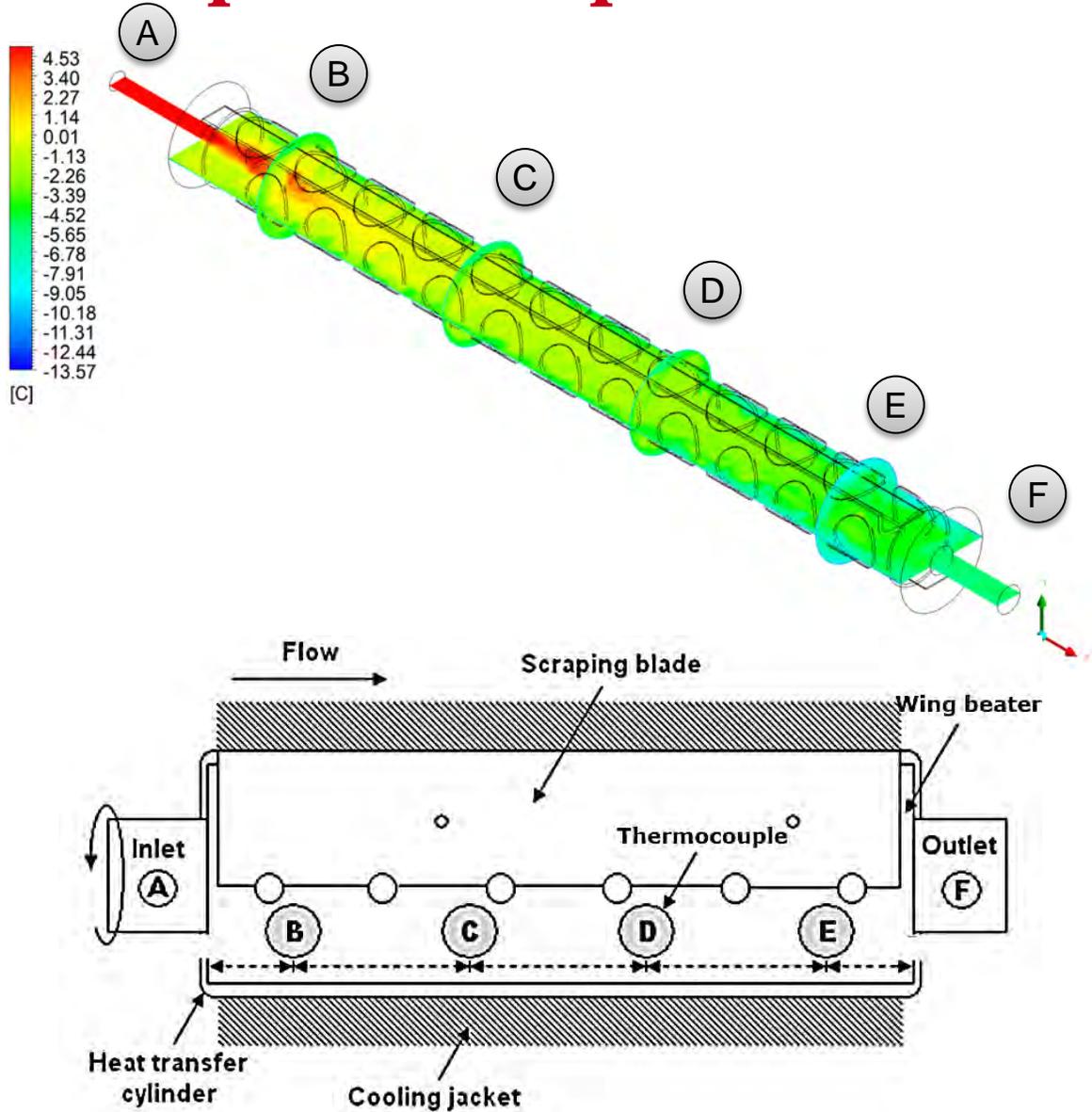
Temperature contour and velocity profile cross section

Lagrangian Particle tracking

Ansys
2021 R2



Temperature profile validation

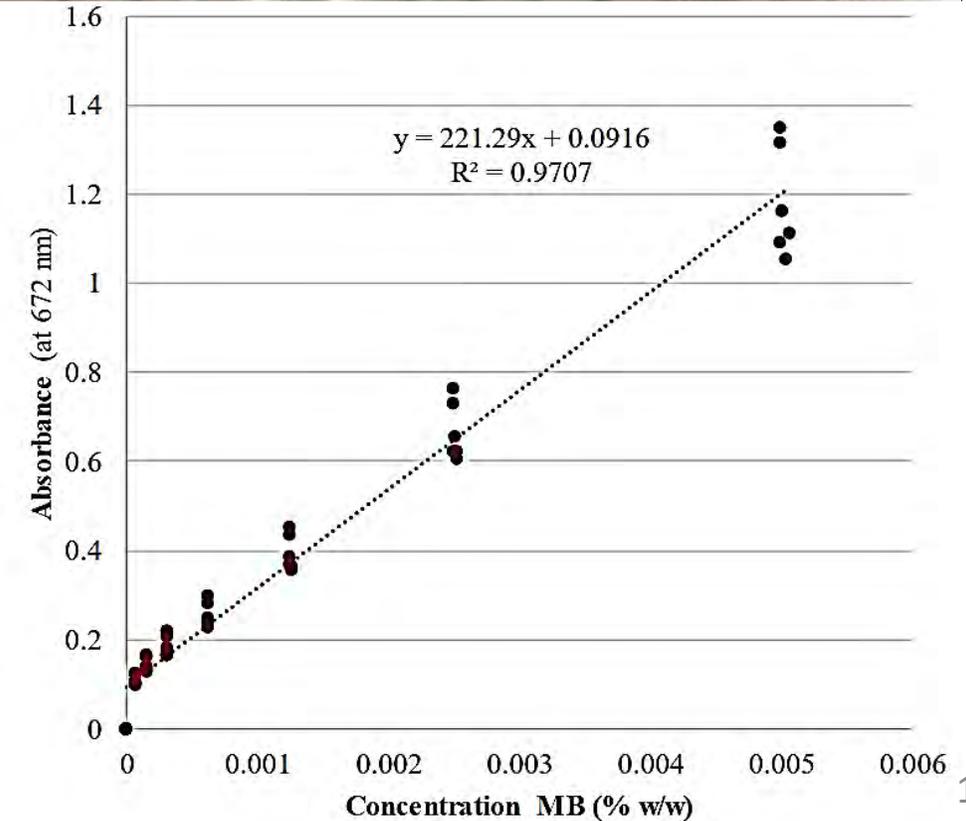
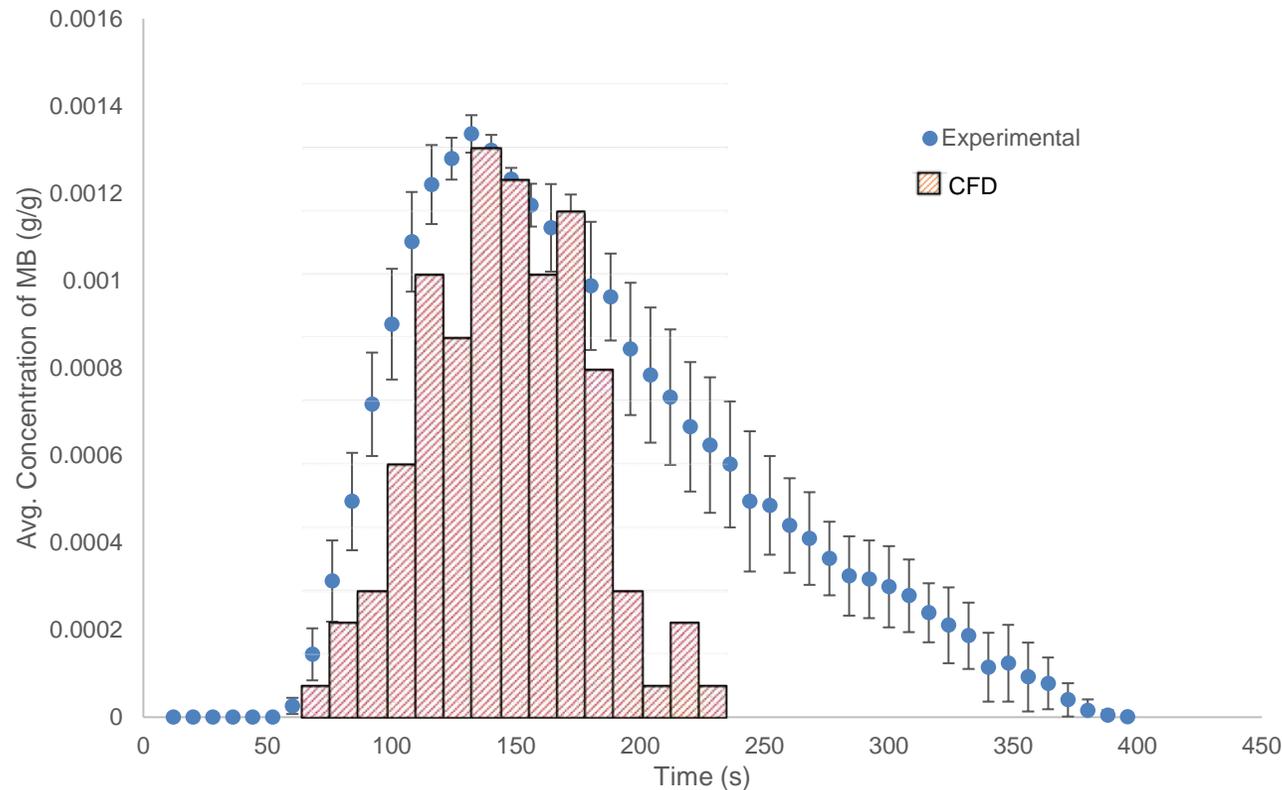




Residence Time Distribution

- Ice cream samples collected at regular intervals and absorbance measured using spectrophotometer

Standard dasher + wing beater





Conclusion

- Computational simulations were successfully computed, and we can now visualize mixing patterns and heat & mass transfer.
- More work still must be done in collaboration with the department of food science on the residence time distribution.
- With better understanding of the parameters that influence heat transfer, shear, and mixing along with ice formation and air cell breakdown within the SSF that will arise from this research will point to strategies to improve SSF design and lead to frozen desserts with healthier attributes.



Thank you!