AVEKA Group

Challenges and Opportunities in Spray Drying

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CEO & FOUNDER

Particle Processing Services
Toll Manufacturing
Research & Development
Innovative Solutions

Presentation Outline

- Overview of *AVEKA*
- Spray Drying Process
- Particle Formation and Types in Spray Drying
- Spray Drying Applications
- Economics of Spray Drying
- Examples
- Conclusions

AVEKA Group Overview

- Particle Technology Company focused on contract manufacturing
- Spin-off of 3M in 1994
- Comprised of 5 separate companies
- ISO certifications / food-grade certifications
- Currently 200 employees

Spray Drying Definition and Product Form

Definition:

- Drying of atomized droplets to form free-flowing powder

Raw Material Characteristics

- Raw materials can be solutions or slurries
- Typically feed solutions/slurries are aqueous
- Feed typically between 10-60% solids

Powder Characteristics:

- 5-100 µm
- Spheres, bubbles, raisin, or shard shape

Critical Process Parameters

- Inlet and outlet temperature (80/200 °C)
- Atomization method
- Feed rate of solution/slurry and air flow rate

Spray Drying Uses and Industries

Food

Catalysts

Pharmaceuticals

Agriculture Chemicals

Polymers

Ceramics

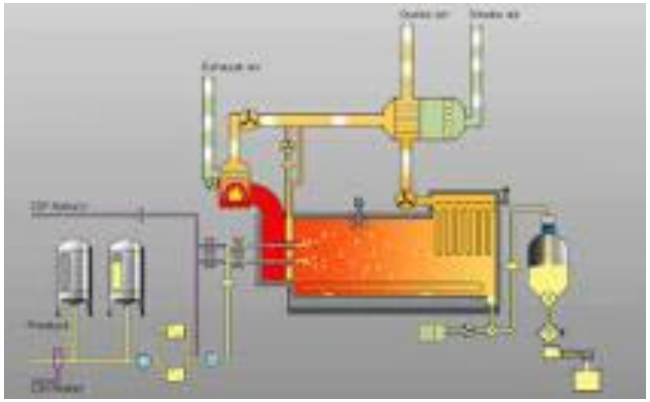
Animal Feed

Spray Drying Equipment

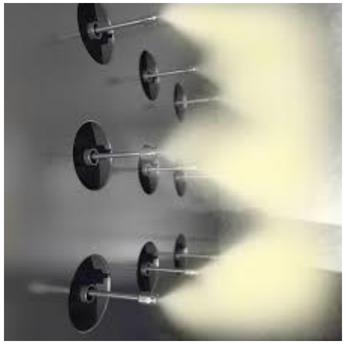
Büchi Lab Dryer

Niro Mobile Minor

Niro Pilot Dryer



Box Dryer

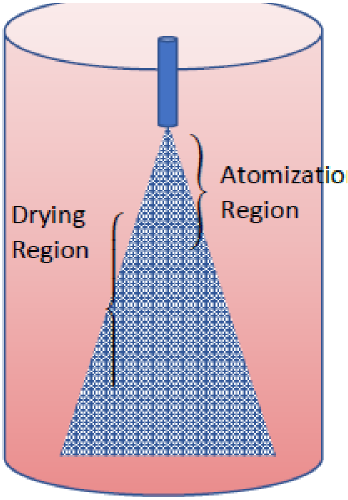


High Pressure Atomization

Production Bustle Dryer

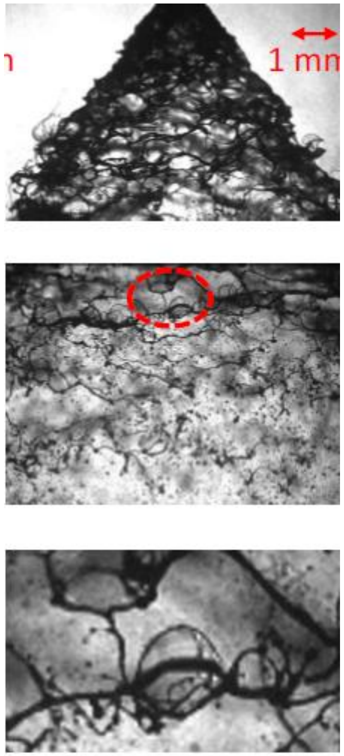
Production Tower Dryer

Atomization Methods

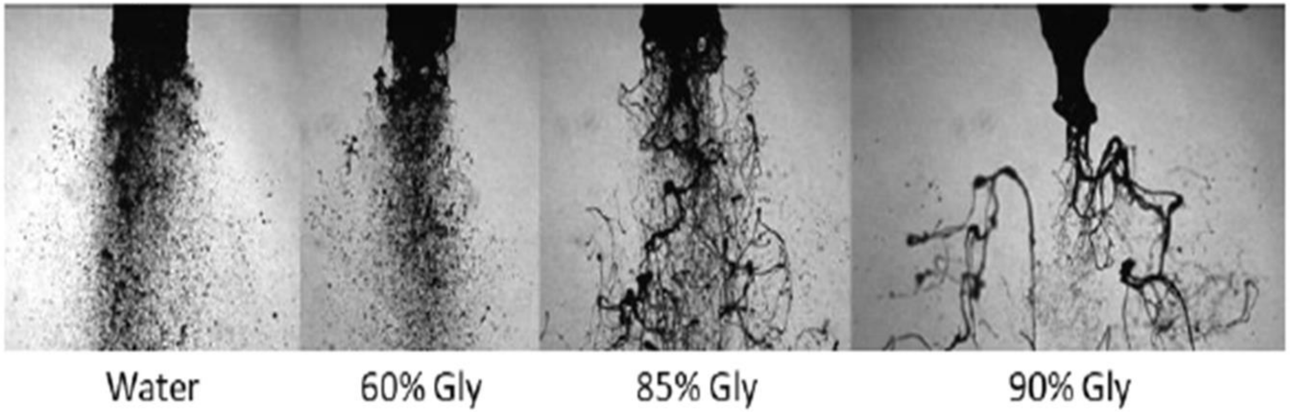


Atomization and Drying Zones in a spray chamber

Rotary Atomization (Rayleigh Breakup)



Swirl Cone Atomization



Single Fluid Atomization vs. Viscosity

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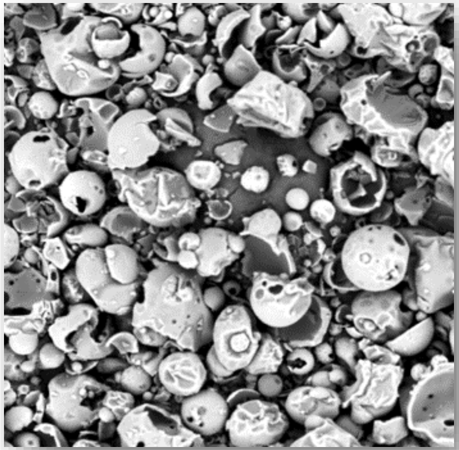
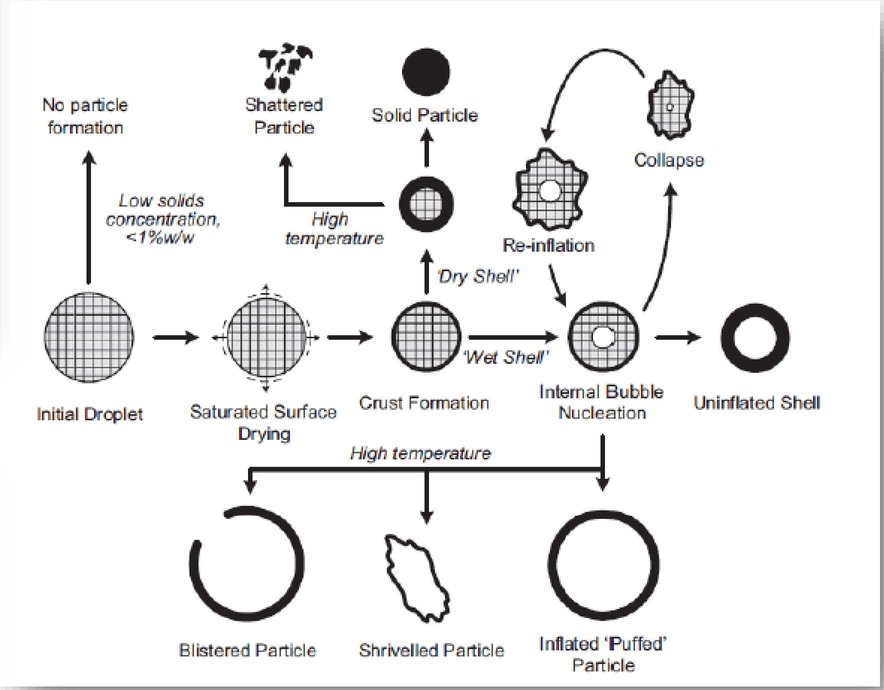
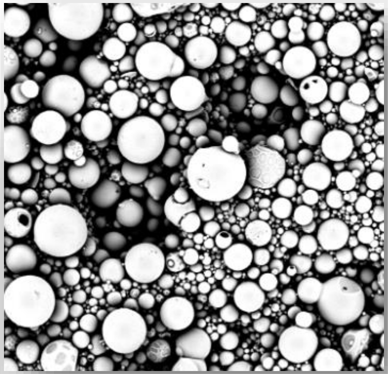
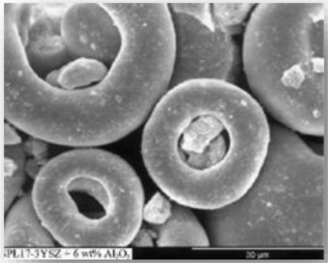
Product Form from Spray Drying



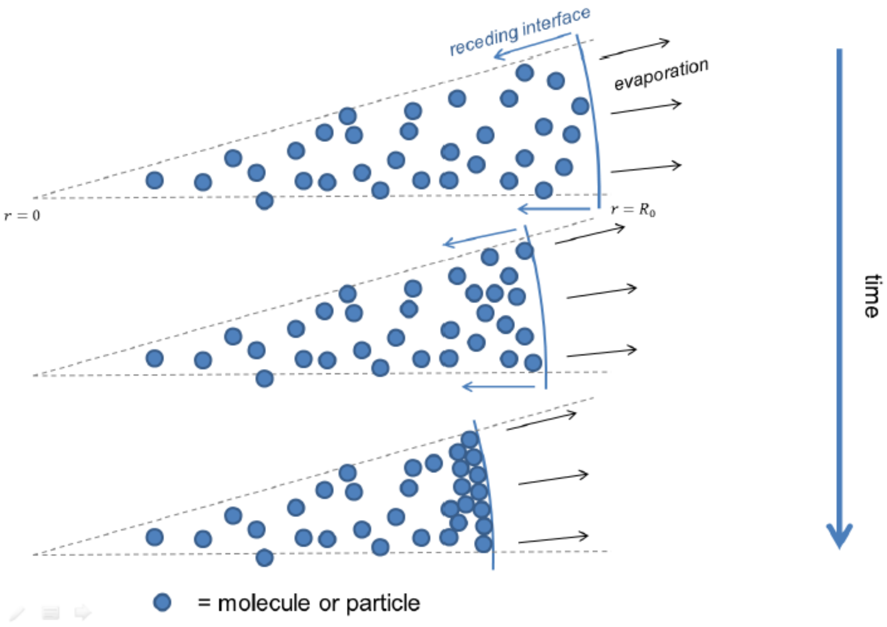


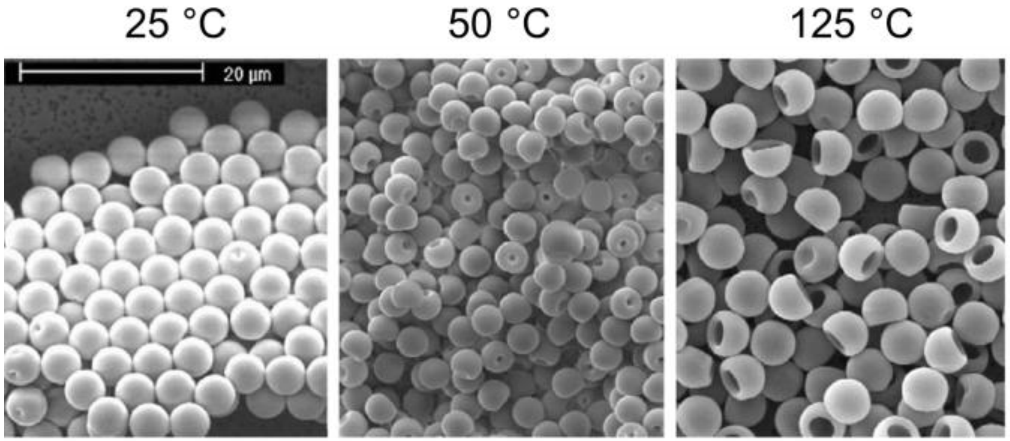




Andrew Bayly IFPRI Review SAR 38-17 2015

Particle Formation Mechanism





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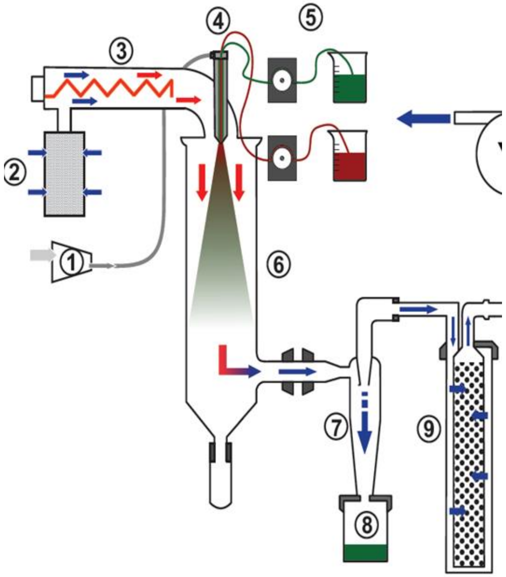
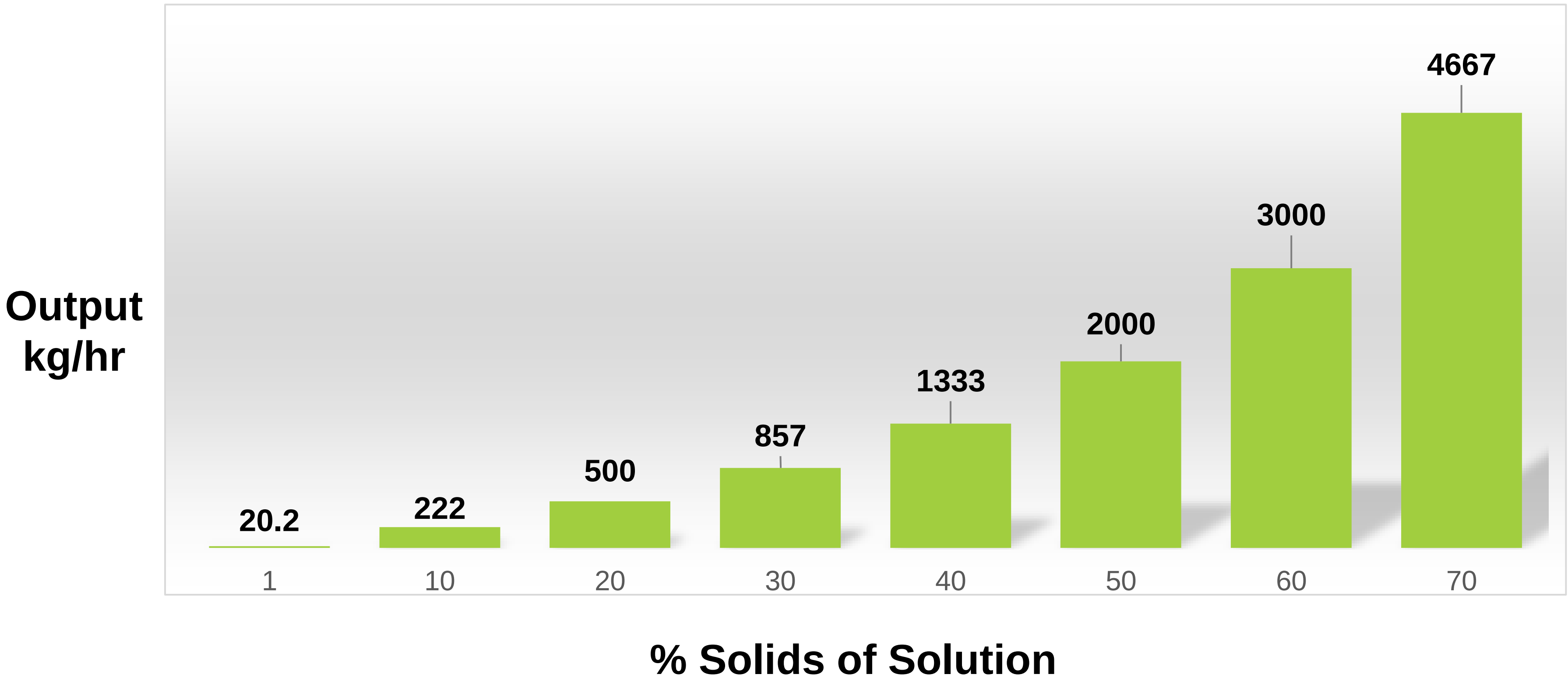
Economics of Particle Processing
Spray Drying - an Illustrative Example

Cost of Spray Drying Equipment: $30,000,000

- Process Parameters:
  - Input Solids
  - Drying Rate
- Yields: 98-99%
- Operating Income: $500-700/hour



Spray Drying Economics I



Spray Drying Economics II

Assumptions

- 19%, 20%, and 21% solids
- 80%, 90%, and 95% Operational Time
- 2000 kg/hr Water Evaporation Rate

% Solids	Dried Product kg/hr	80% (7008 hr/yr)	90% (7884 hr/yr)	95% (8322 hr/yr)
19	469	3,286,752	3,697,596	3,903,018
20	500	3,504,000	3,942,000	4,161,000
21	532	3,728,256	4,194,288	4,427,304

Spray Drying Economics III

Assumptions

- 19%, 20%, and 21% solids
- 80% Operational Time
- 1900, 2000, 2100 kg/hr Water Evaporation Rate

% Solids	1900 kg/hr kg/hr Product	2000 kg/hr kg/hr Product	2100 kg/hr kg/hr Product
19	446	469	499
20	475	500	525
21	505	532	558

Spray Drying Economics IV

Assume the Yield is 98%

Therefore, at 2000 kg/hr evaporation rate the actual output is 490 kg/hr not 500 kg/hr

However, product typically has 8% retained water or an actual theoretical yield of 543 kg/hr (but the yield is calculated on 500 kg/hr not 543 kg/hr)

Where is the lost 53 kg/hr product?

Economic Overview

CHALLENGES	OPPORTUNITIES
Water Evaporation Rate	% Relative Humidity
	Preventative Maintenance
% Solids on Solutions	Atomization Assists
	Viscosity of Solution
Yields	Poor Collection
	Wall Sticking and Pneumatic Conveying
Operation Time	Cleaning Cycle Times
	Preventative Maintenance

The Examples…. Finally

Effect of Dryer and Drying Conditions

- Scaling up a new product

Standard Drying

- Yeast
- Yeast cell wall
- Aluminum sulfate/ Sodium Succinate
- Vegetable Proteins

Hard to process materials

- Sodium Acetate

When there are no explanations

- Water, Ozone, Ions

- Statement of need
- How we approached the problem
- Analysis of results

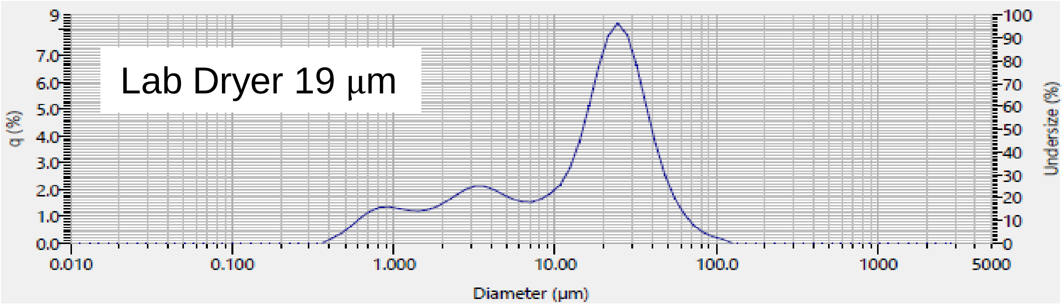
Scaling up a new spray dried material

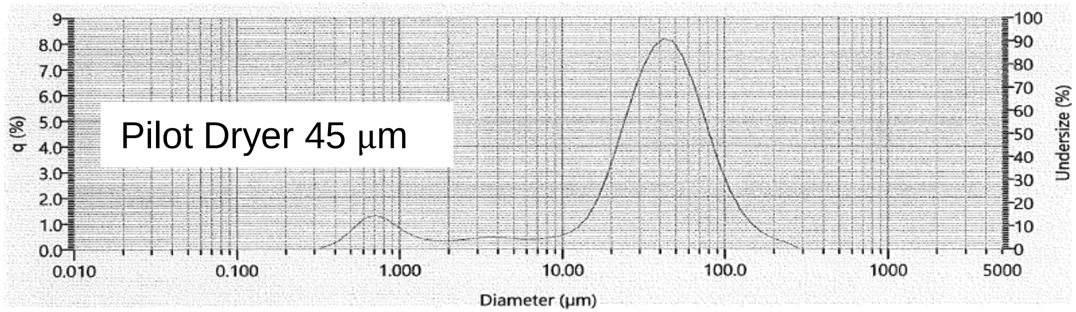
Statement of challenge

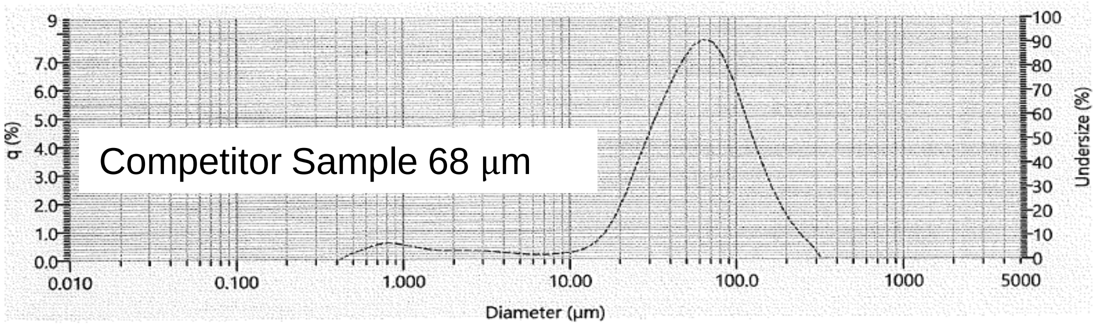
- Polymer for Ag applications

- Replicate current material
  - Particle size
  - Flowability

The Result – particle size too small in first lab test and in pilot test



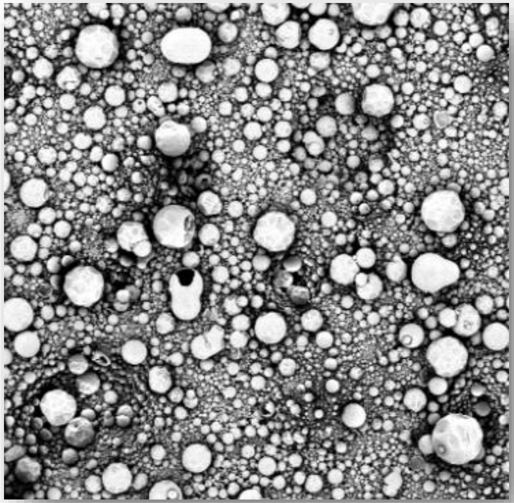




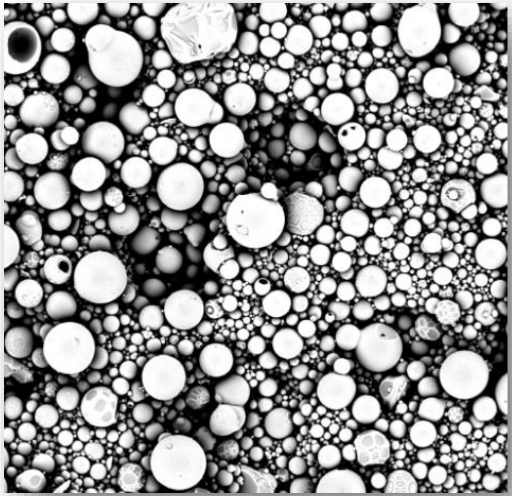
Scaling-up New Material

Explanations and Expectations for Scaling-up

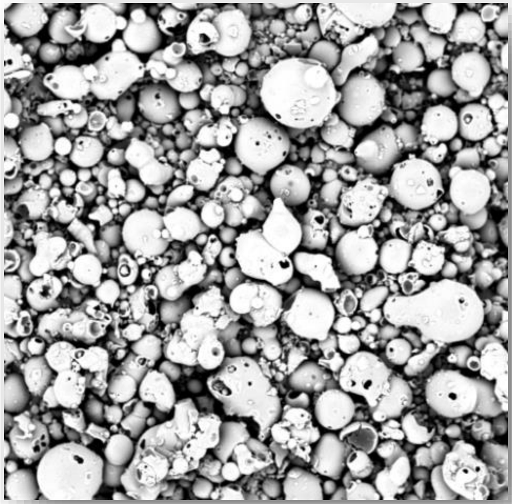
1) Smaller droplets in smaller dryer
2) Peclet Number higher in larger dryer – hollow particles to produce larger particle
3) Production dryer is an agglomerating dryer



Lab Dryer 19 µm



Pilot Dryer 45 µm



Competitor Product 68 µm

WHAT WENT WRONG?

- Nothing

  Process scale-up is always a challenge with multiple options to consider

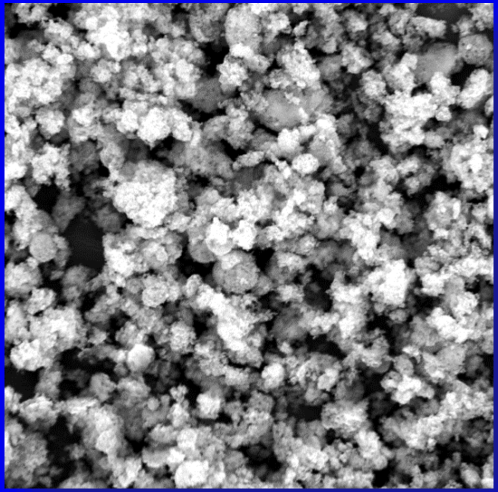
THE REALITY

- Proof of concept complete with adjustments to be made in final scale-up

Spray Drying Spherical Powder

Statement of challenge

Spray Drying produced correct size, but not desired sphericity

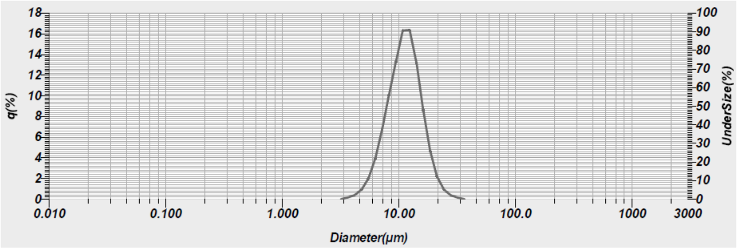


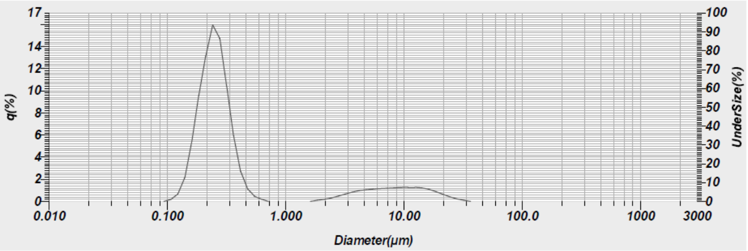
The Result

Spay drying after bead milling produced the desired material

Starting Material

Mean PSD = 11.7 µm

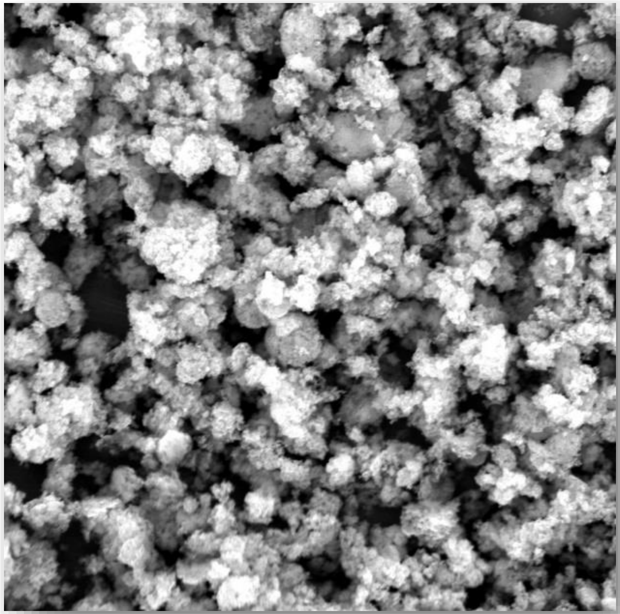


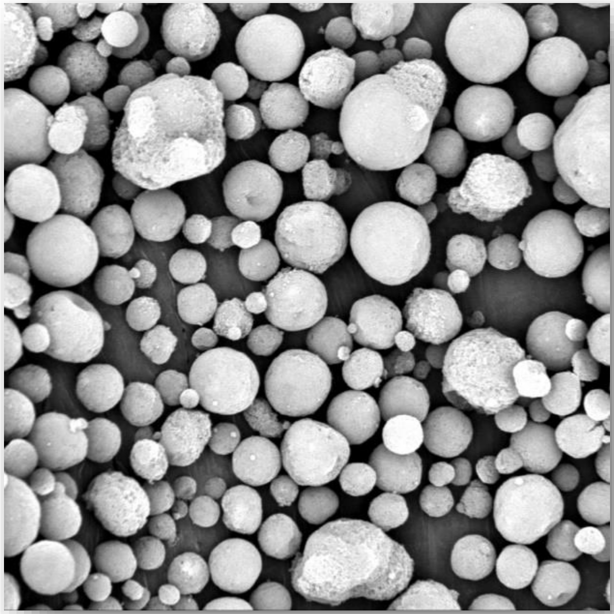


Milled Material

Mean PSD = 1.9 µm

Spray Drying Milled Starting Material





SEM (5000x) of spray-dried silica without (left) and with (right) prior bead milling

Drying of Vegetable Protein

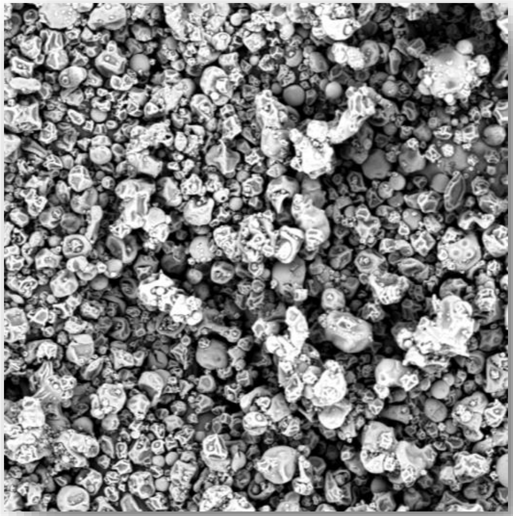
Statement of challenge

Spray dry vegetable protein

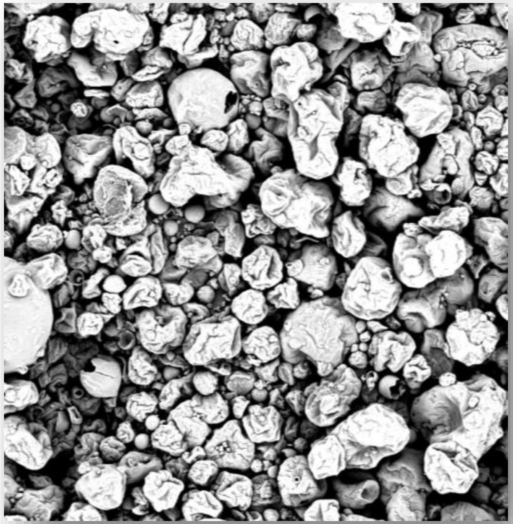
- Protein 1 64 µm
- Protein 2 92 µm
- Protein 3 55 µm

The Result

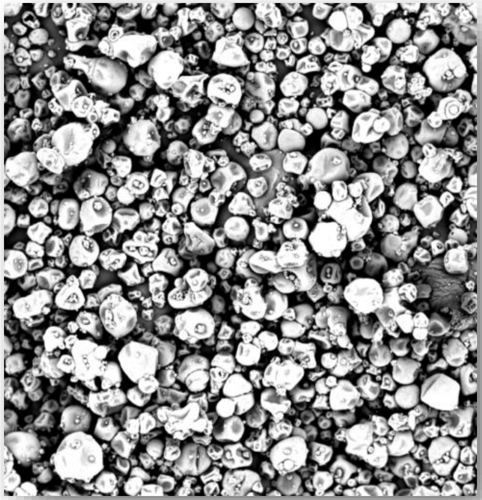
- PSD varies due to vegetable source, but structure is similar



Protein 1



Protein 2



Protein 3

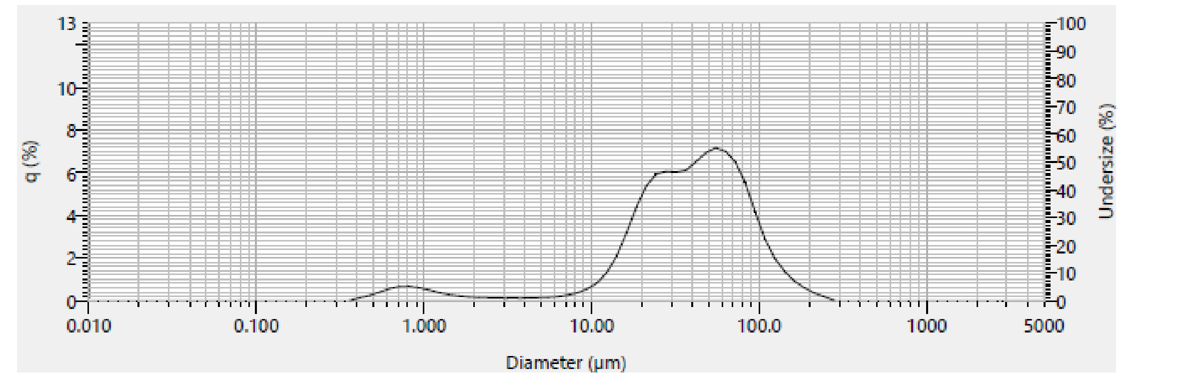
Spray Drying of yeast materials

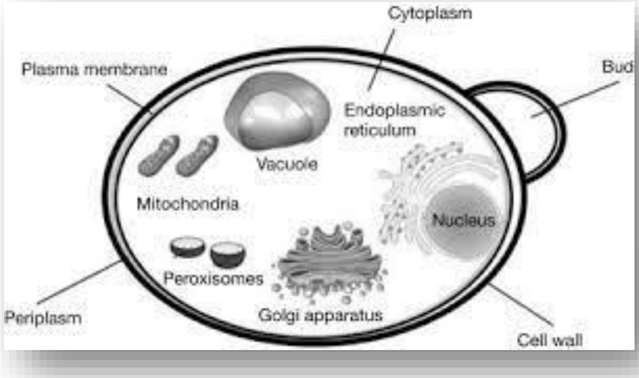
Statement of challenge

- Why do different yeast sources provide different results during drying?
  - Particle shape
  - Flowability

Results

- Deactivated yeast dries to make small particle dependent on yeast source





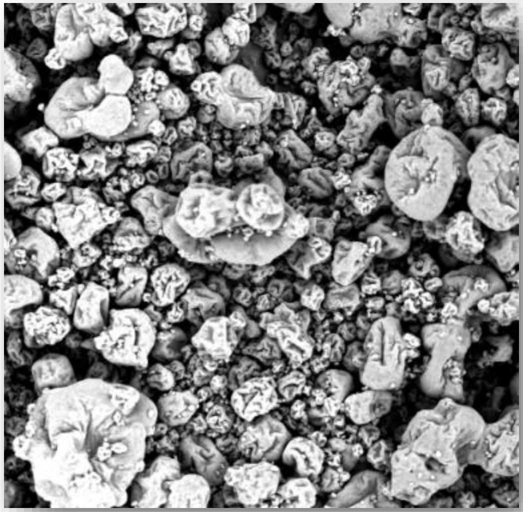
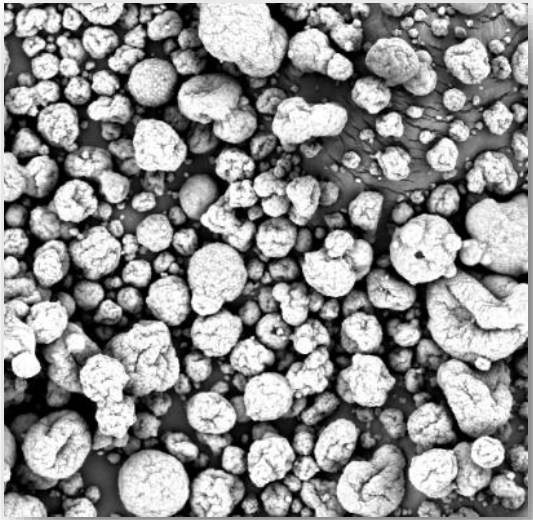
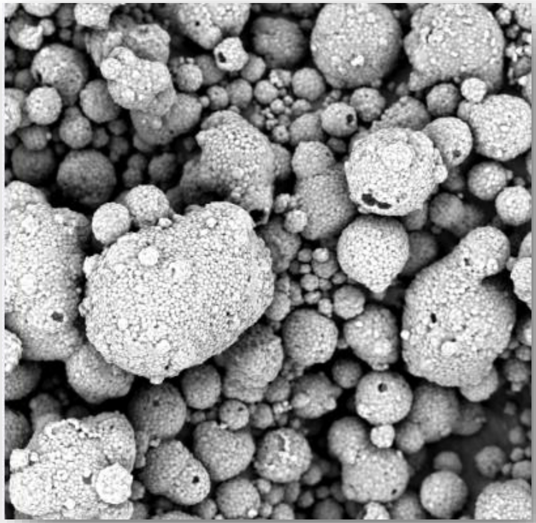
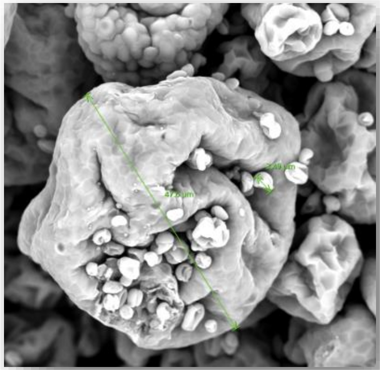
WHAT IS HAPPENING?

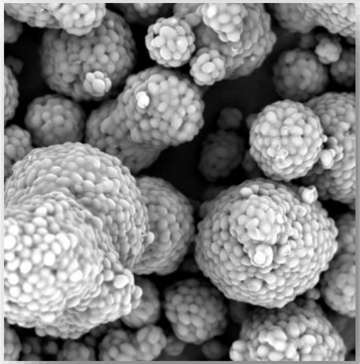
- Dried deactivated yeast has varying amounts of lysed cells and extract during drying (particle and binder)

THE REALITY

- The resulting particle has different strengths due to the binder – limiting attrition and flow issues

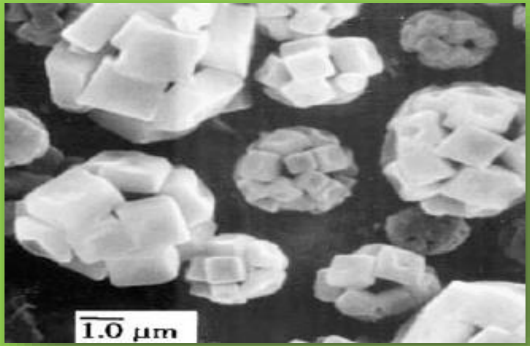
SEM of Spray Dried Yeasts



Spray Drying and Crystallization

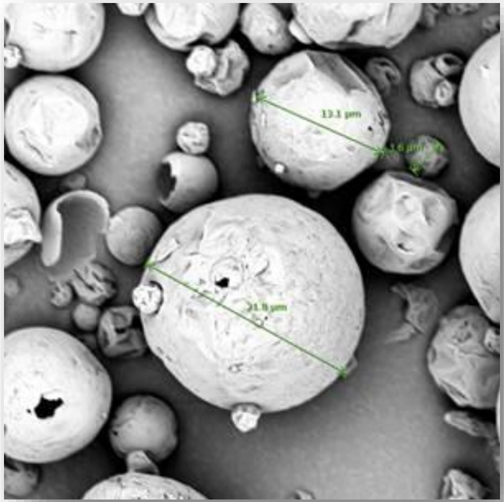
NaCl (Vehring 2008)



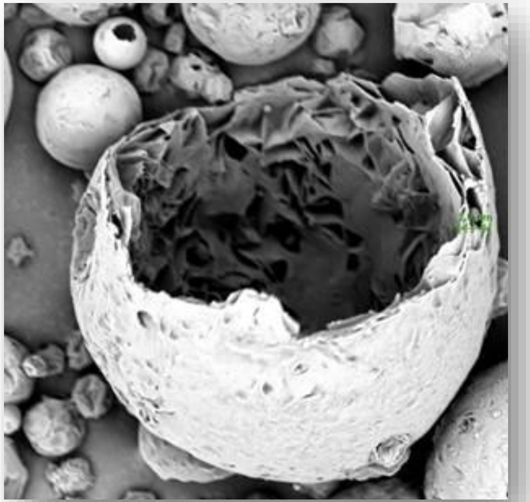
Statement of challenge

Dry sodium succinate to stable product

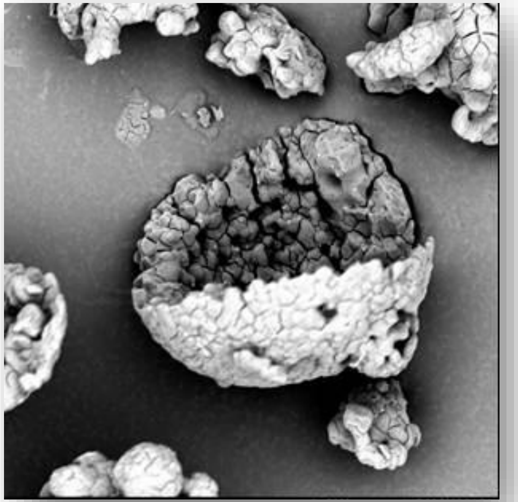
Sodium Succinate



After Drying



Upon Exposure to Humid Air



Hard to Dry Materials

Statement of challenge

- Dry a material that is both cohesive and water absorbing
- Sodium Acetate

Product drying is dependent on:

- Neutralization pH (higher better)
- Atmospheric RH (lower better)
- Addition of dry air in pneumatic conveying

Product stability after drying is dependent on:

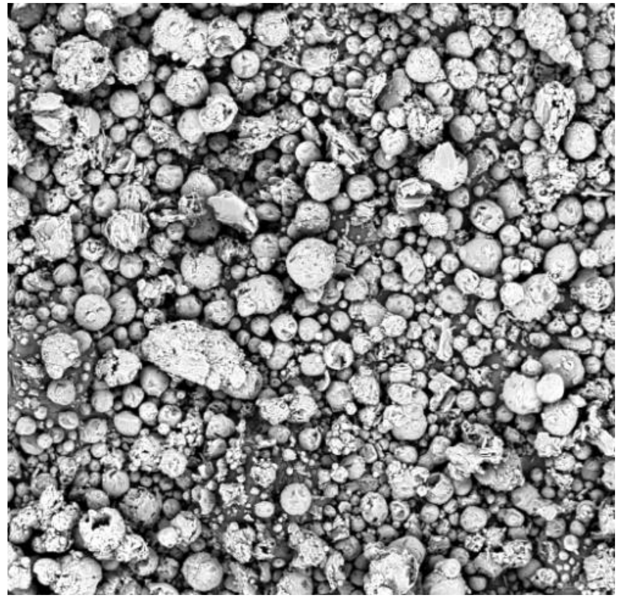
- Storage temperature and RH during drying

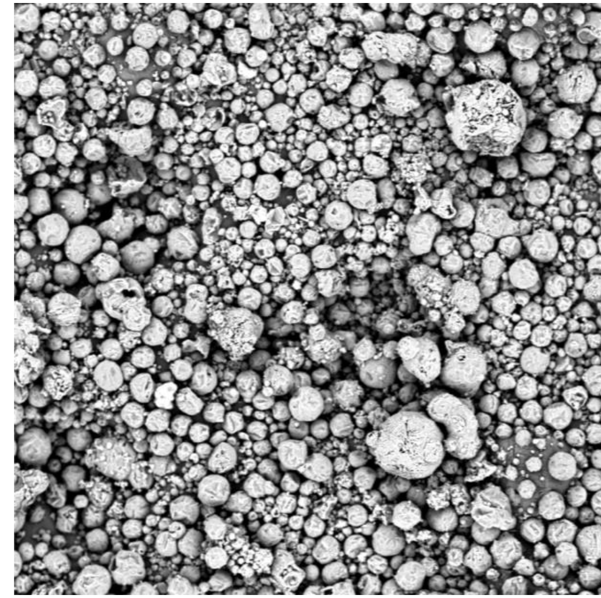
SEM Analysis of Sodium Acetate

Prepared at:

Sample 1 - High pH

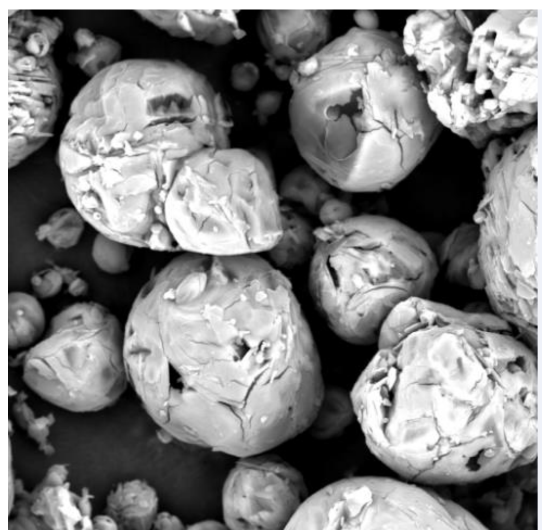
Sample 2 - Low pH

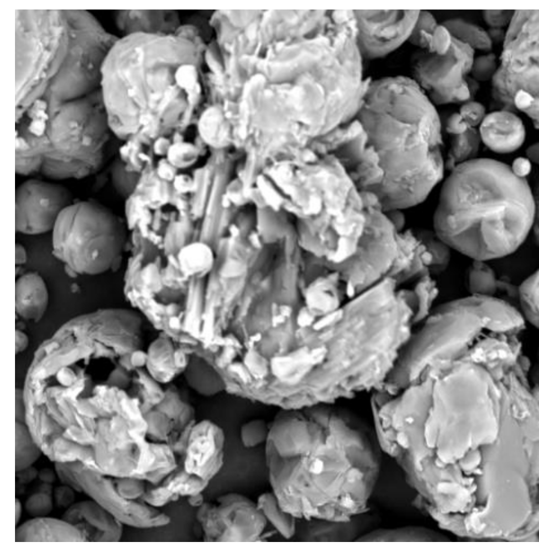




Low pH

High pH





When All Else Fails –

Blame Water Vapor, Ozone, Atmospheric Ions

Plasma Cutters, Spray Dryers and Metal Detectors

While spray drying in plant, plasma cutting was being done in same building 100 meters away and behind 3 doors.

Powder set off metal detector during and after plasma cutting.

Plasma Cutters, Spray Dryers and Metal Detectors

No Metal Contamination was found by ICP analysis

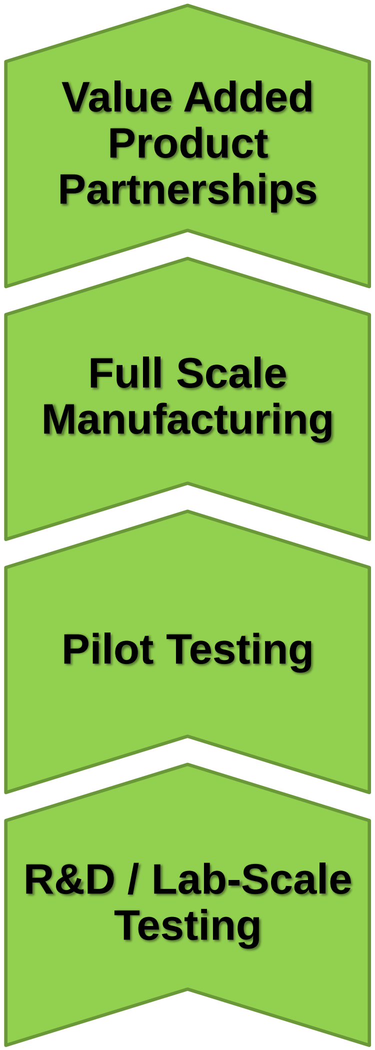
Charge contamination is known to trigger metal detector

Charge did not dissipate after 3 months

What is happening?

Summary

- Spray Drying can be straight forward but:
  - Particle shape and size will vary and can affect your final product
  - Economy of drying is sensitive to yields and feed % solids
- Process conditions and materials are critical
- Be prepared to be surprised even with simple systems



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