AVEKA Group

Fluid Bed Processing: Drying, Agglomeration and Particle Coating

April 29, 2021

Particle Processing Services

Toll Manufacturing

Research & Development

Innovative Solutions





PRESENTED BY: WILLIE HENDRICKSON, CEO & FOUNDER

Presentation Outline

- Overview of AVEKA
- Particle processing 101 – the big 6
- Particle processing dilemmas
- Drying methods
- Agglomeration methods
- Particle coating methods
- Derek Geldart and powder flow/fluidization
- Examples
- Opportunities
- 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 290 employees

ISO 9001:2015

FDA APPROVED

Food Safety System Certification 22000

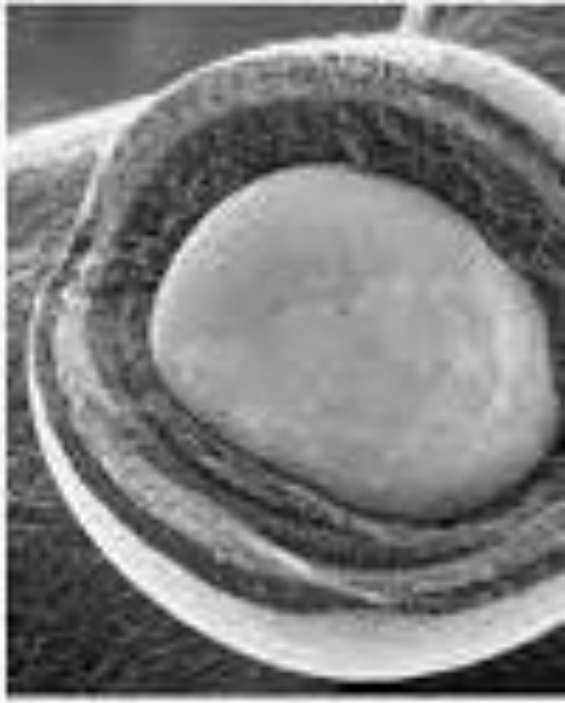
NSF ISR

QUALITY ASSURANCE INTERNATIONAL CERTIFIED ORGANIC

Particle Processing:

The Big Six:

- Characterization
- Flow/Blending
- Size Reduction
- Drying
- Agglomeration
- Particle Coating



What are Engineered Particles?

- Size Controlled
- Multicomponent
- Tightly Adjusted Composition
- Complex Structure or Shape
- Functional Property
- Chemically or Biologically Active
- Controlled Release

Processing Dilemmas

- Available equipment dilemma
- Volume/Scalability dilemma
- Powder flow dilemma
- Functionality dilemma

Drying Technologies

- Spray Drying
- Tray Drying
- Roll Drying
- Fluid Bed Drying
- Ring Drying
- Turbulizers

Agglomeration

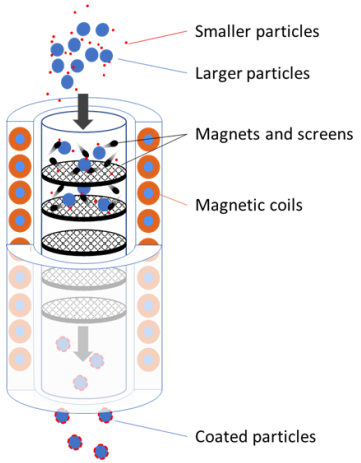
Multiple techniques for particle formation

- High Shear Agglomeration
  - Bella Mixer
  - Turbulizer
- Fluid Bed – Spray Agglomeration
- Extrusion Agglomeration

Particle Coating

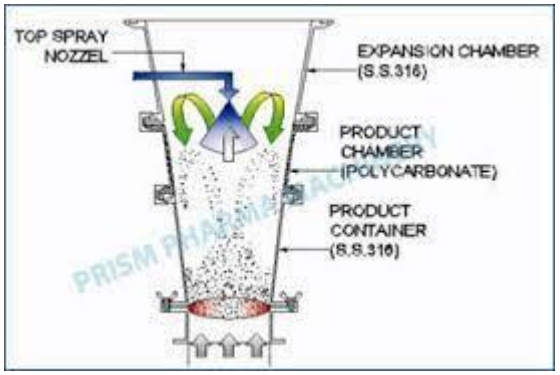
Multiple techniques for particle coating

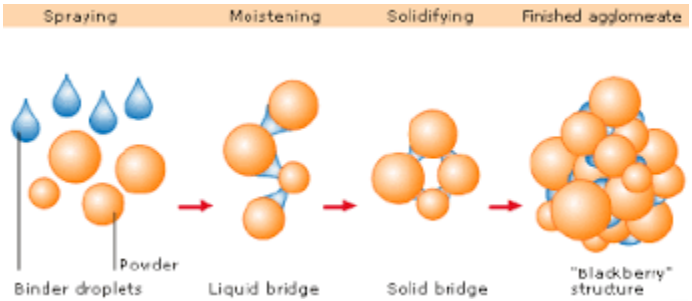
- Mixing
  - V-Blender
  - Ribbon Blender
  - Zig-zag Mixer
- Fluid Bed – Wurster Coating
- Tablet Coating
- MAIC

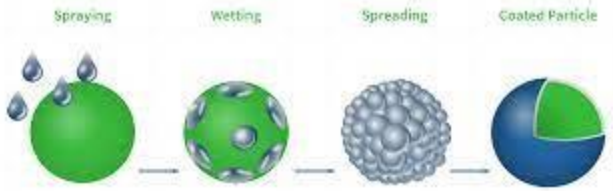


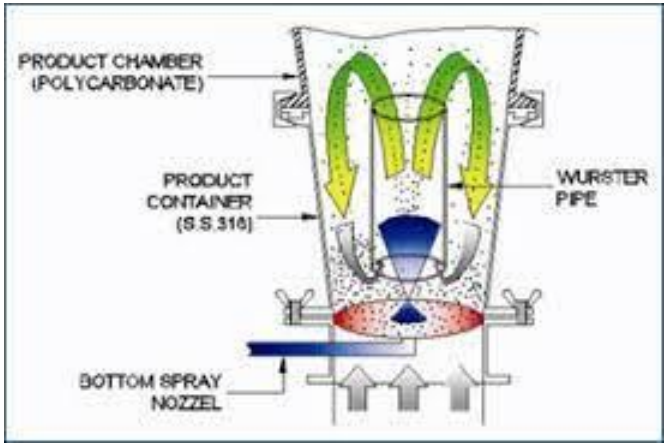
What Makes a Fluid Bed So Versatile

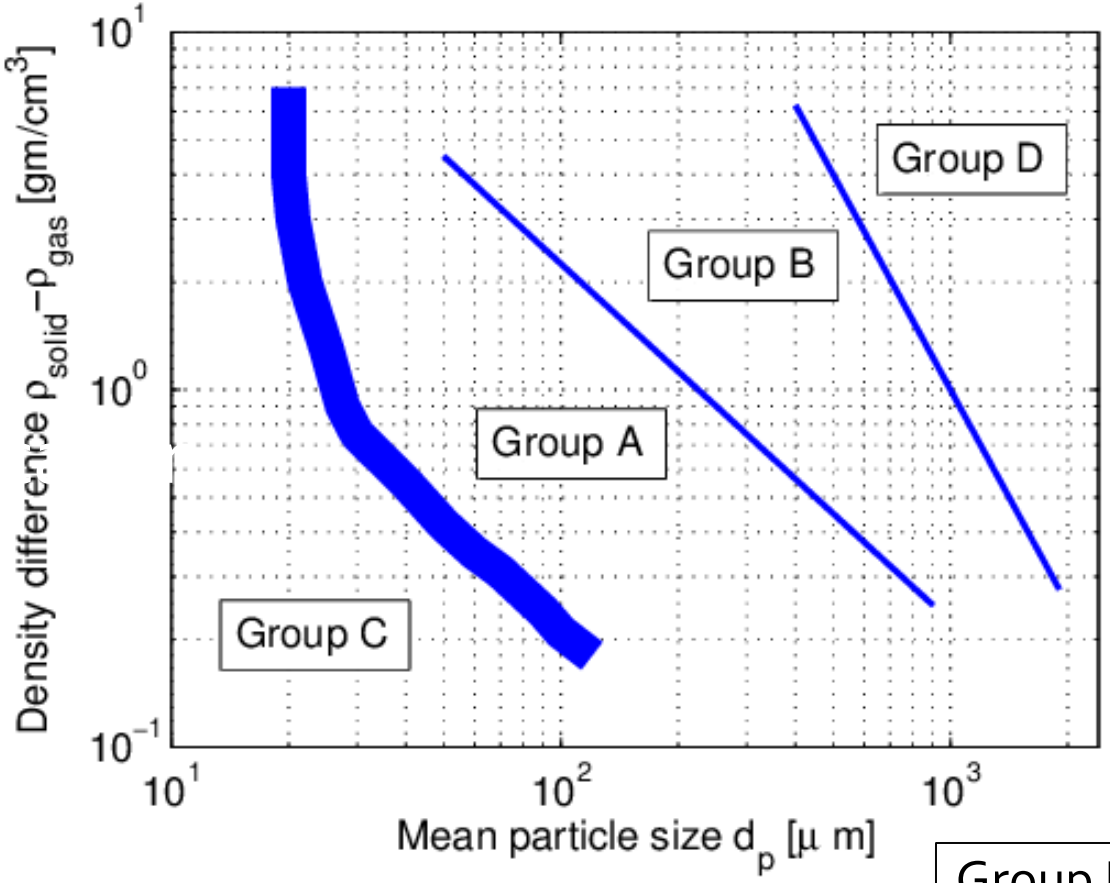
- No Spray – Drying
- Top Spray – Agglomeration, Coating
- Bottom Spray – Coating
- Tangential Spray - Coating











Group B	Sand-Like
Group A	Aeratable
Group C	Cohesive
Group D	Spoutable

Functionality in Fluid Bed Processing

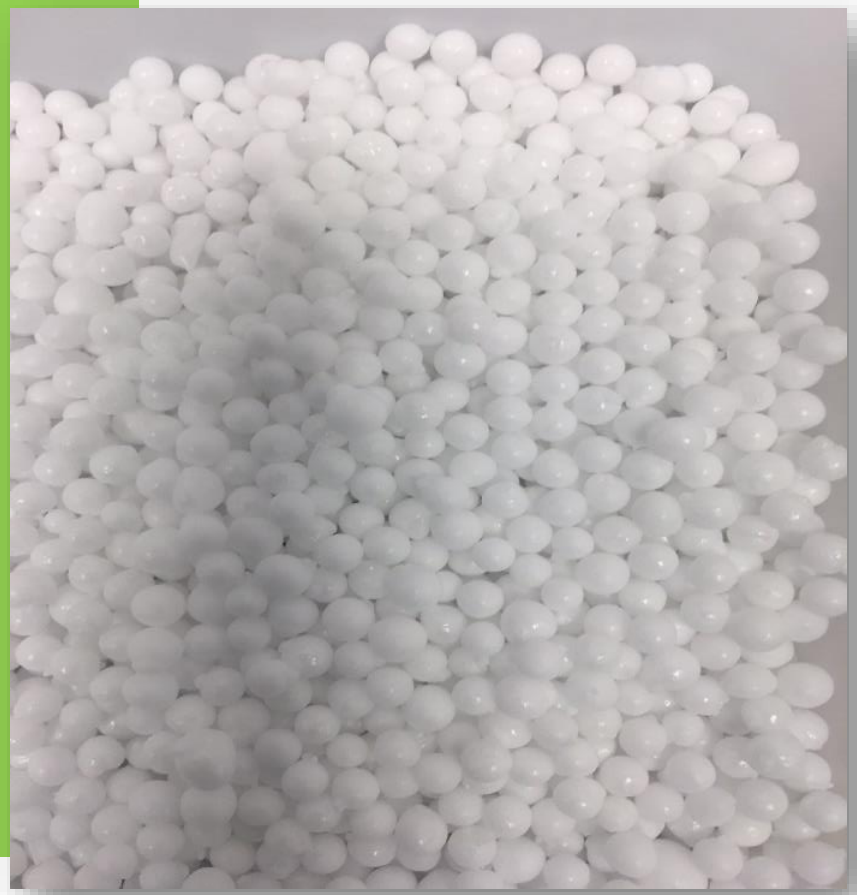
- Water Activity
- Powder Flow
- Dedusting
- Controlled Release
- Wettability
- Surface Modification
  - Surface Energy
  - Color

The Examples…. Finally

Drying of Particles
- Walnut Shells
- Encapsulated Oils
- Active Biologicals

Agglomeration
- Food Powders for Wettability
- Food Powders for Improved Flow

Particle Coating
- Color Change
- Controlled Release



- Statement of need
- How we approached the problem
- Why we chose fluid bed processing

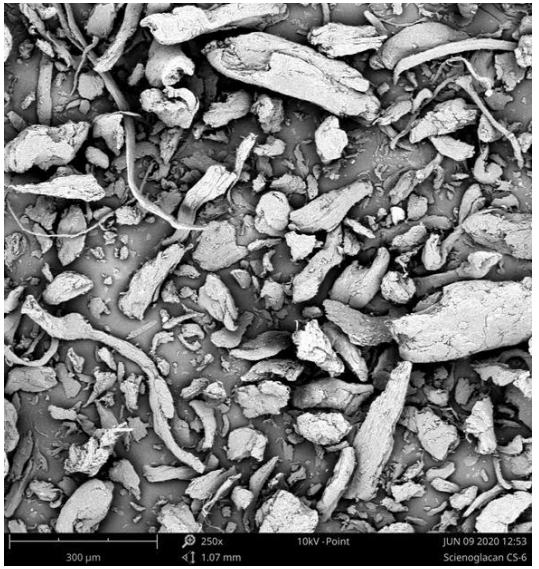
Drying Using Fluid Beds

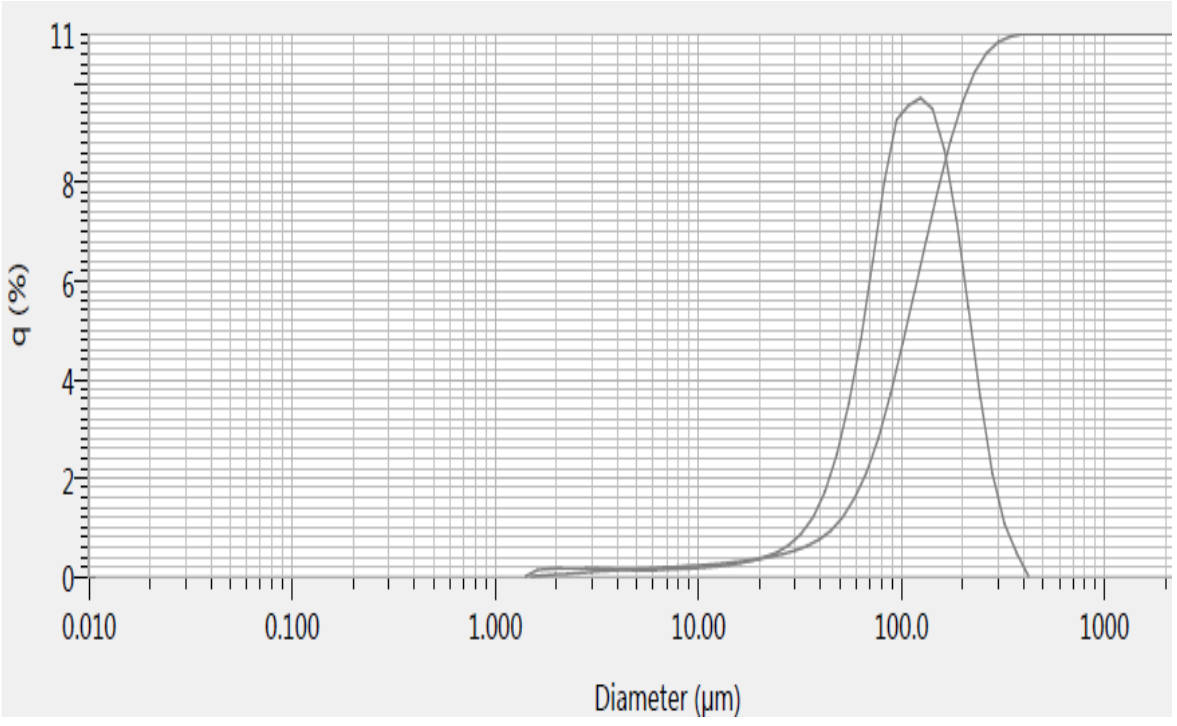
Statement of challenge

- Dry Bio-fiber
  - % moisture dropped from 9.2 to 2.8% in 30 minutes
- Drying Walnut Shells
  - % moisture dropped from >40% to 2 % in 60 minutes

The Result

- PSD did not change during drying





WHAT WENT WRONG?

- Nothing
  - Fluid bed drying is useful for a variety of materials (density, shape, etc)

THE REALITY

- Fluid beds useful for wet cakes (10-70% moisture)

Drying Using Fluid Beds

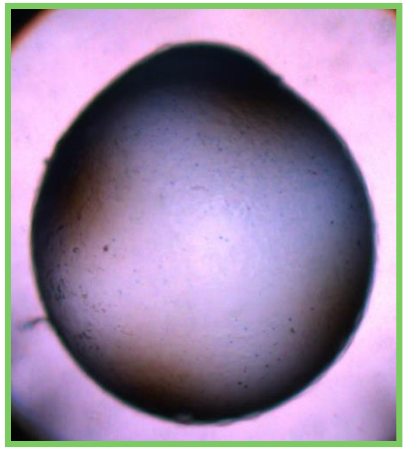
Statement of challenge

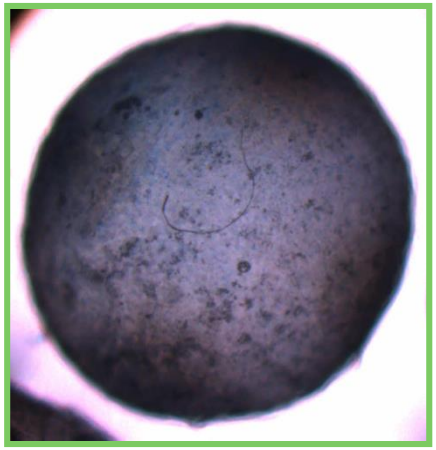
- Dry Encapsulated Beads
  - Temperature sensitive
  - Very Fragile
- Dry Live Microbe Matrices
  - Very temperature sensitive

The Result

- Microbes had 90% viability after drying

- Encapsulated beads were more spherical with fluid bed drying and had stronger shells with fluid bed drying





WHAT WENT WRONG?

- Nothing
  - This is standard process for temperature sensitive materials at AVEKA
- Shape preservation much better with fluid beds

THE REALITY

- This process is standard at AVEKA instead of freeze drying for live biologics

Agglomeration Using Fluid Beds

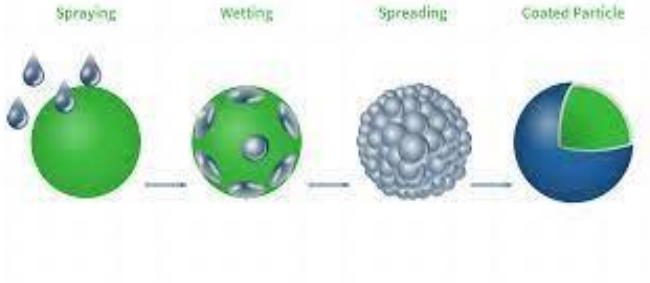
Statement of challenge

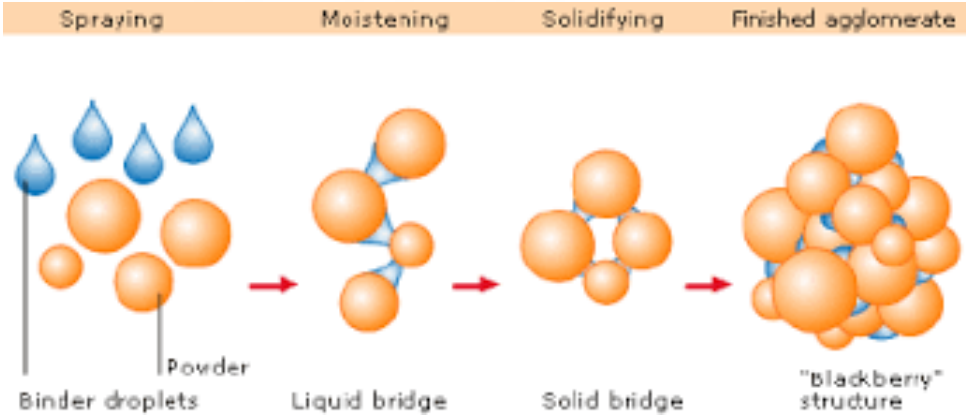
- Agglomerate Dairy Powders to improve dispersibility by capillary absorption

The Result

Dispersion Times

- Raw Material >90 sec
- Fast Water Addition >90 sec
- Slow Water Addition 24 sec
- Low Water Addition 17 sec





WHAT WENT WRONG?

- Nothing
- Agglomeration shown to produce better dissolution for dairy products

THE REALITY

- Process proven
- Customer took in house for processing

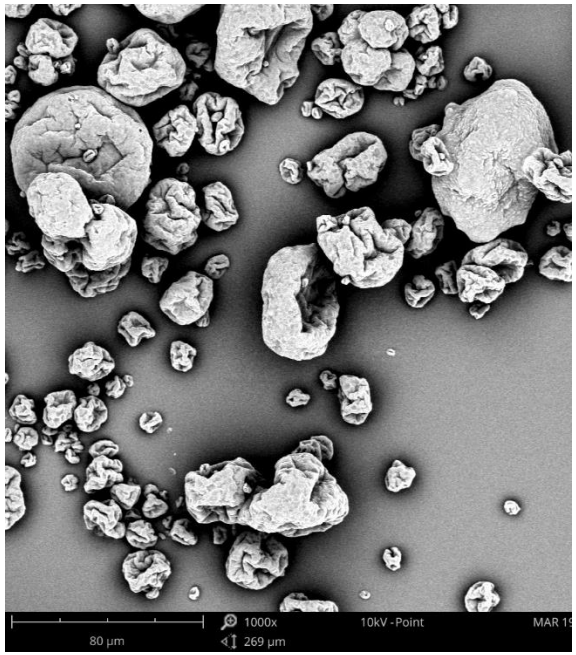
Agglomeration Using Fluid Beds

Statement of challenge

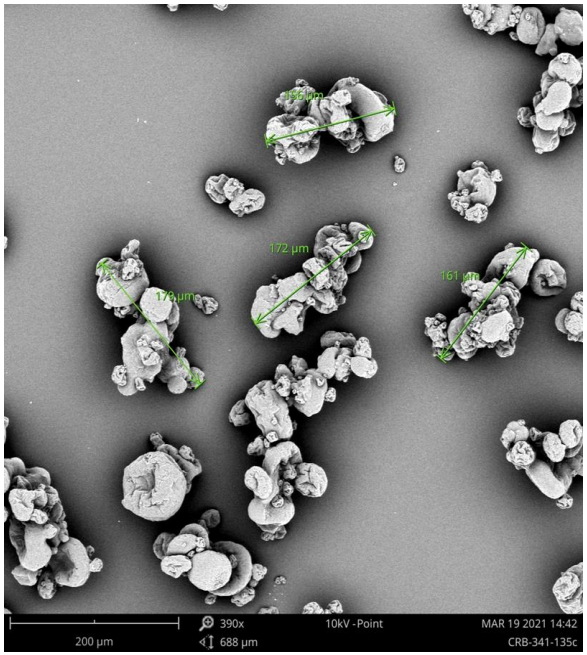
- Improve spray dried material flow
  - Agglomeration with water
  - Agglomeration with added binder
- Decreased Dustiness

Particle Size Distributions (microns)

	D_{10}	D_{10}	D_{10}
Raw Material	15	50	113
Agglomerated with Water	87	202	380
Agglomerated with Binder	75	174	324

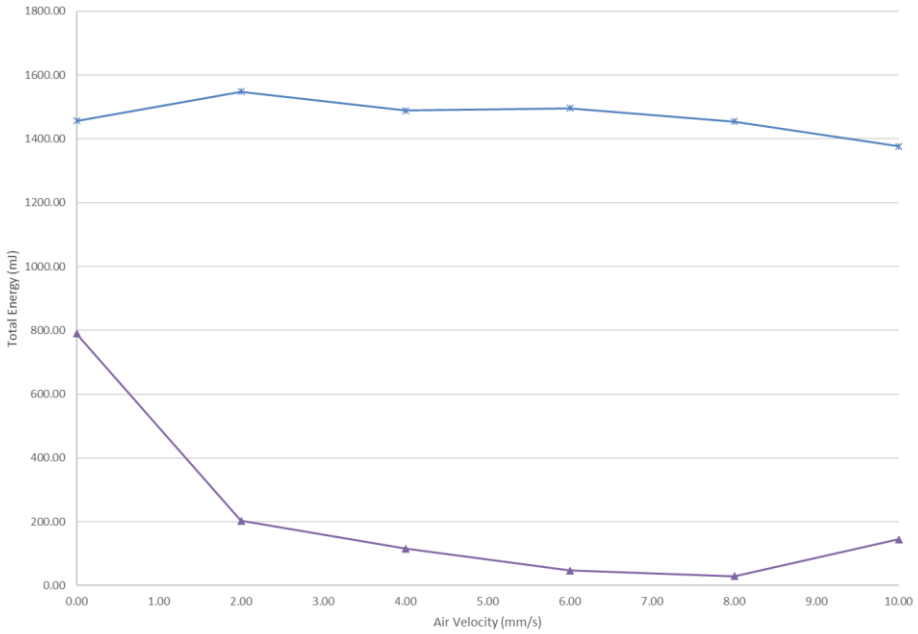


Raw Material



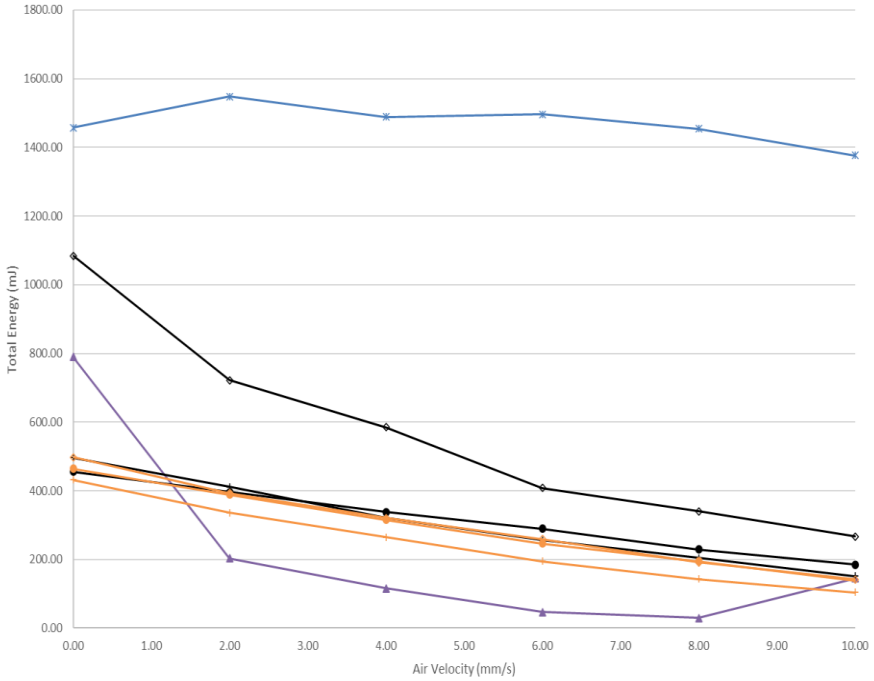
Agglomerated Material

Aeration
(Reference Materials)



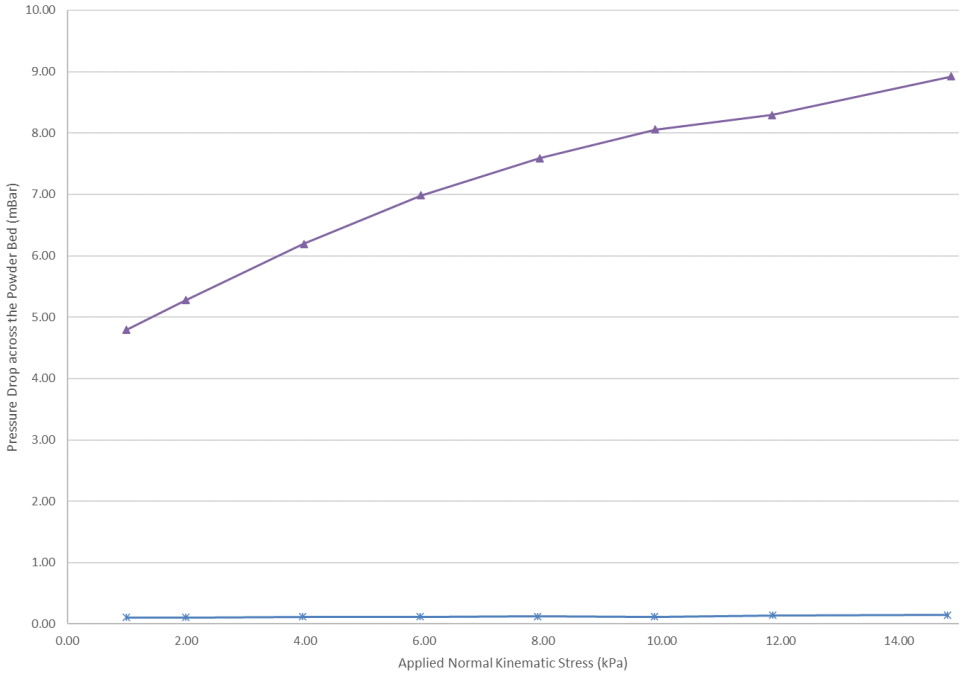
- General theory: as air is forced through a powder bed, the resistance to flow decreases (fluidization of powder beds)
- Gold-standard powders
  - Flow energy decreases small amount
  - Mostly insensitive to changes over this range of air flow speeds

Aeration (Agglomerated Samples)



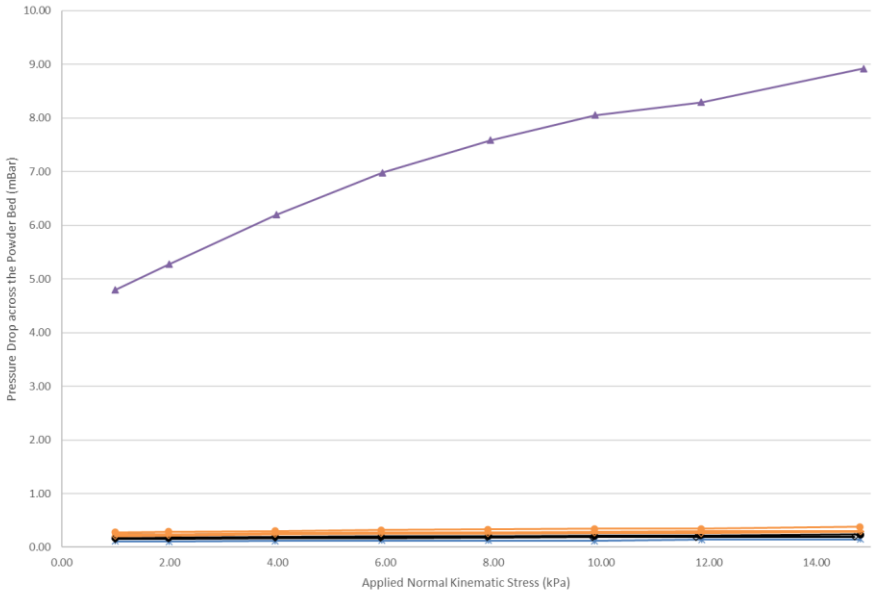
- Agglomerated powders all start with lower flow energy (1 exception)
- Response to increased air flow is linear, not big drop
- The water content does not appear to be a big factor here
- Flow has changed to something closer to gold standard (lower flow energy, but similar linear response)

Permeability (Reference Materials)



- General theory: the more difficult it is for air to pass through a powder, the higher the pressure drop (shows efficiently packed powders)
- Gold-standard powders
  - Near-zero pressure drop for all
  - Air passes freely through these powders

Permeability (Agglomerated Samples)



- All agglomerated powders
  - Near-zero pressure drop for all
  - Air passes freely through these powders
  - Match gold standard
- Differentiation of the test samples difficult at this resolution

WHAT WENT WRONG?

- Nothing
  - Fluid bed material was less dusty
  - Fluid bed material flowed better than spray dried material, but not better than flake material

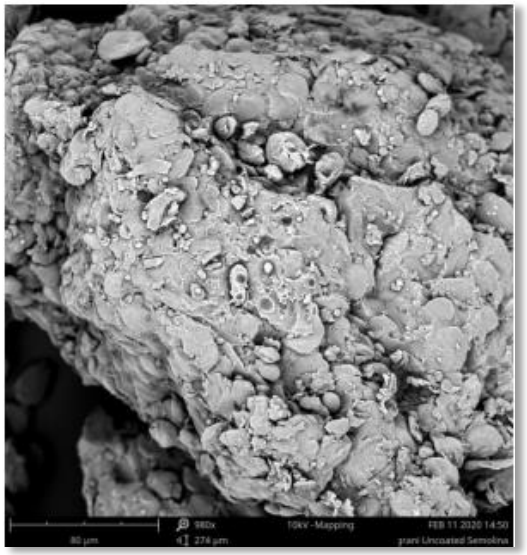
THE REALITY

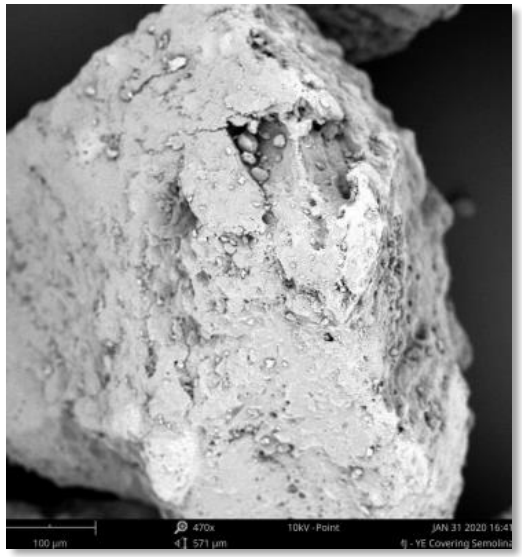
- Process improvements still being looked at for production

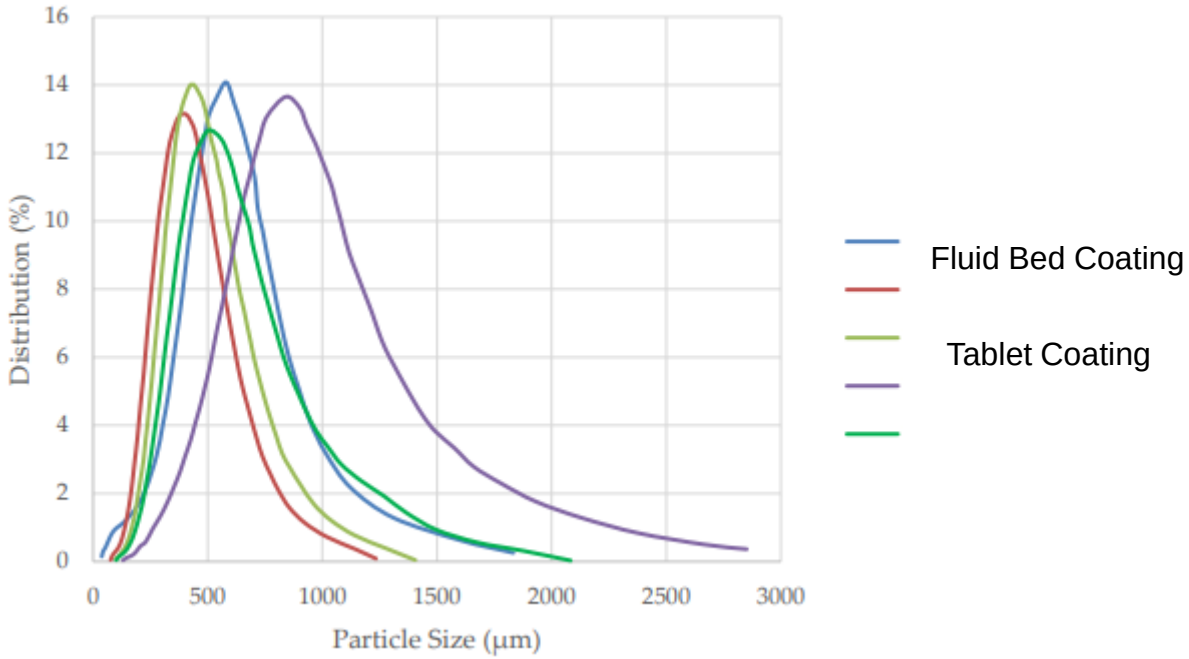
Coating Using Fluid Beds

- Statement of challenge
- Coating of ground seed for flavor delivery
  - Minimal agglomeration
  - Functional coating ~20%
- Comparison to tablet coating

Results







WHAT WENT WRONG?

- Nothing
- Fluid Bed was more better coating than tablet coating
- Less agglomeration

THE REALITY

- Process went to production

Particles from Liquids: Prilling

Rayleigh Breakup

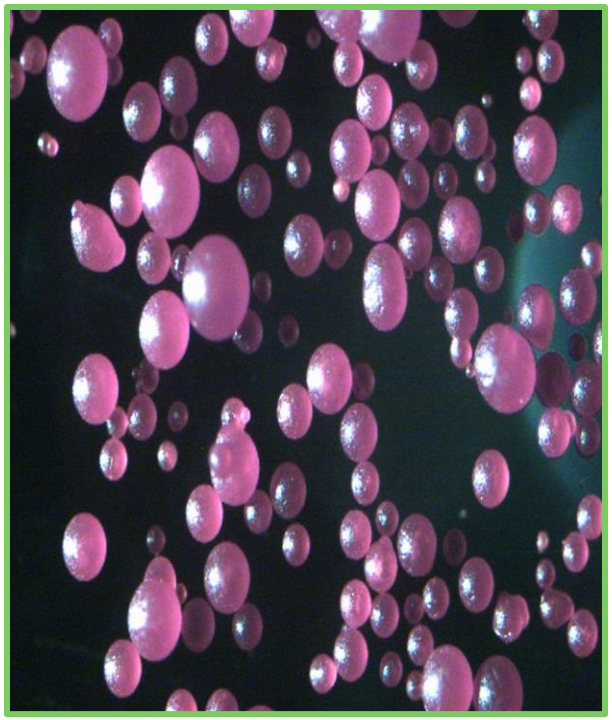
- Spherical particles (10-2000 micron)
- Up to 50% active loading
- Matrix: phytosterols, hydrogenated oils, PLA
- Actives: oils, flavors, particles, CMC, biocides
- Throughputs: 1 – 2000 lb/hr

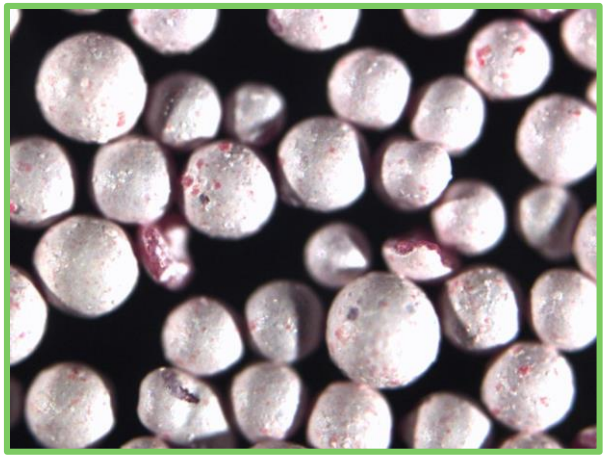
Coating Using Fluid Beds

Statement of challenge

- Coating of Colored Prills for color change upon melting
  - Fat Prill
  - Water Soluble Dye
  - Titania Coating in starch

The Material





Color Changing Result

Dough

Baked

ENCAPSULATION 101

Shell Perfection vs. Diffusivities

WHAT WENT WRONG?

- Dye leaked through coating in dough matrix

THE SOLUTION

- Microencapsulation 101
- Switch to water insoluble dye
- Add another layer

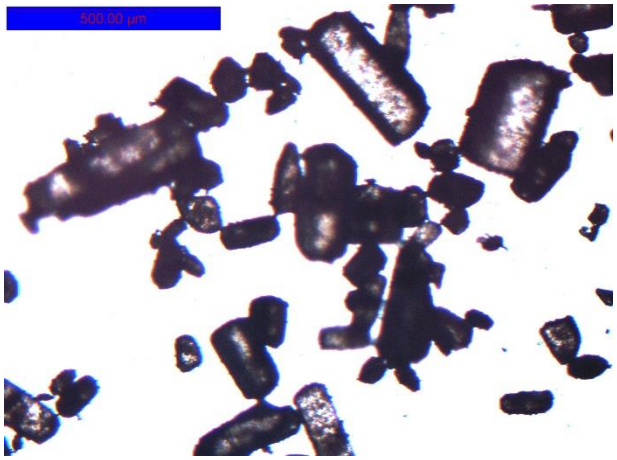
Coating Using Fluid Beds

Statement of challenge

- Coat Creatine with Shellac for stomach bypass and release in small intestine
  - Shellac well known enteric coating (pH dependent solubility)
  - Test for release at

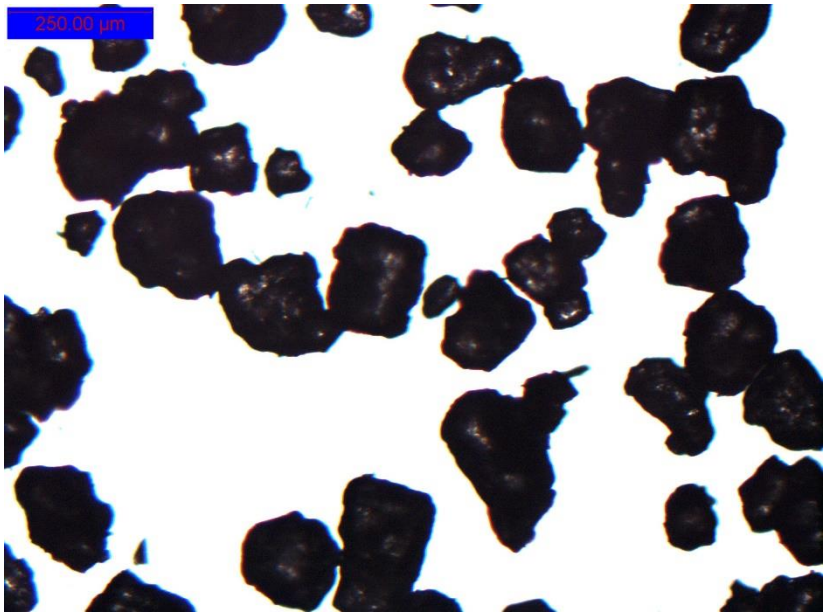
    pH 1 and 7 as a function of time

The Result

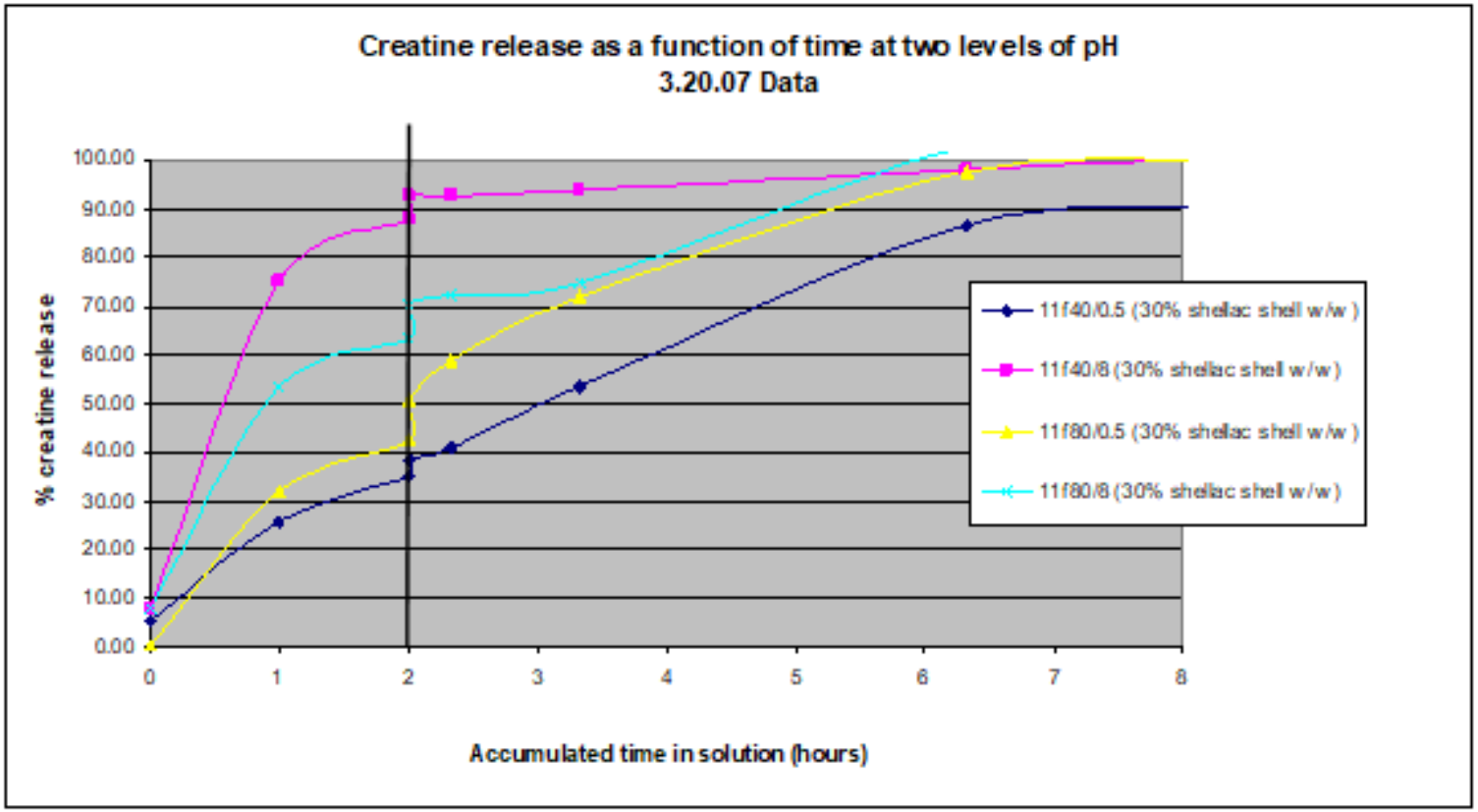


Uncoated Creatine

Coated Creatine 30%



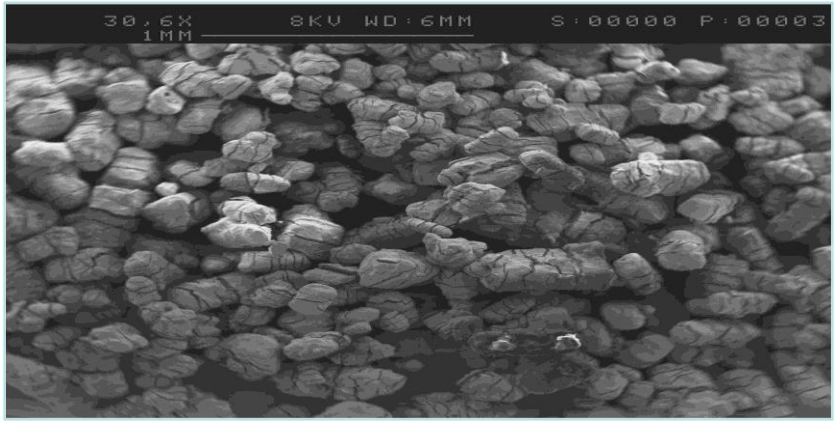
Creatine Release



WHAT WENT WRONG?

- Coating process was good but drying was flawed

THE REALITY



So What Did I Leave Out?

MAJOR USES OF FLUID BEDS

- Pharmaceutical Agglomeration
- Food Agglomeration for dispersibility and dedusting
- Success for controlled release of fluid bed coated particles

EQUIPMENT VARIATIONS

- Batch vs. continuous fluid beds
- Spray drying/fluid bed combined systems
  - Final drying
  - Cooling
  - Agglomeration

Fluid Bed Processing Thoughts

RESOURCES

International Fine Particle Research Institute (IFPRI)
www.ifpri.net

Jim Litster University of Sheffield (James.litster@sheffield.ac.uk)

Karen Hapgood Deakin University (Karen.Hapgood@deakin.edu.au)

Glatt, Vector, GEA

IDEAS FOR THE FUTURE

Fluidization of nanoparticles:

Using magnetic fields
- USP 7,658,340

Using microjets
- USP 8,439,283

Using rotating fluid beds
- USP 6,197,369

Summary

- Fluid bed processing is versatile
  - Drying
  - Agglomeration
  - Coating
- Process conditions and materials are critical
- It is hard to analyze too much

- Contact Information:
  - Willie Hendrickson
  - aveka@aveka.com
  - 651-730-1729