

Spray drying, fluid bed granulation and flexomix granulation

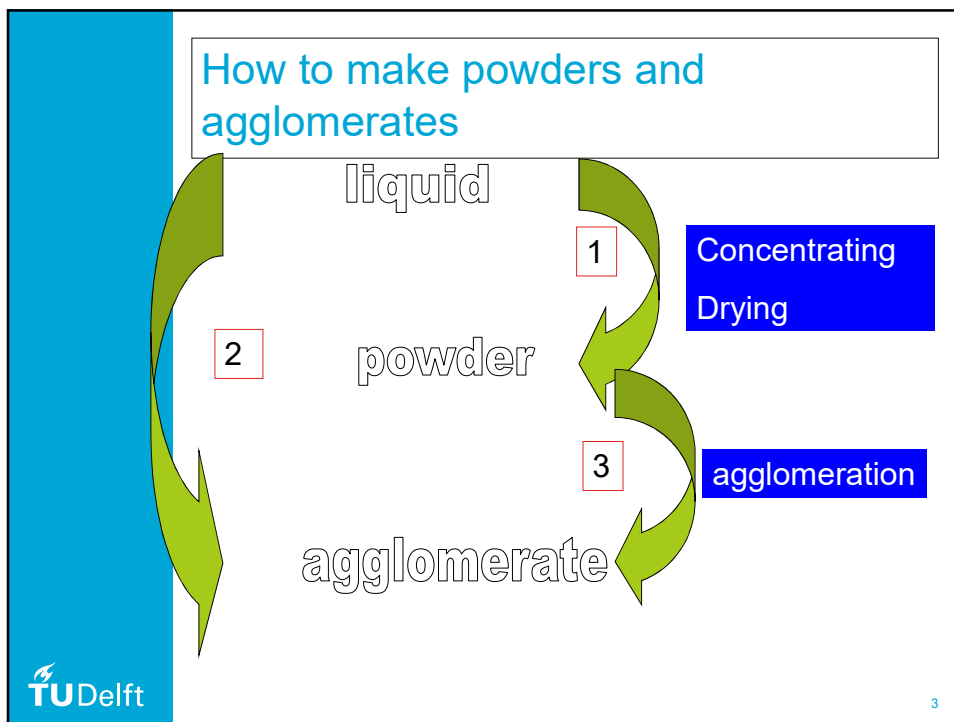
Gabrie Meesters

Product and Process Engineering group

April 2019

Content

- Drying and stickyness
- Spray drying
- Fluid bed agglomeration
- Granulation in a Flex-o-mix



Liquid to Powder (LP)	Liquid to Agglomerate (LA)	Powder to Agglomerate (PA)
<ul style="list-style-type: none"> • Spray drying • Flash drying 	<ul style="list-style-type: none"> • Multi stage drying • Filtermat • Fluid bed agglomeration • AGT • Procell • Cont. fluid bed aggl. • Fluid bed coating • Pan coating • Drum coating • (Prilling) 	<ul style="list-style-type: none"> - Low shear granulation - Pan and drum granulation - Low-medium shear granulation - High Shear granulation - Fluid bed granulation - Extrusion - Pelletising - Briquetting - Tableting - (Sintering)

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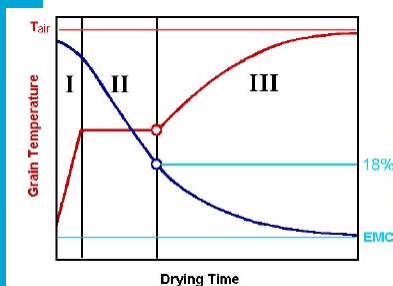
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Drying

- Drying is simple, isn't it?
- Just remove the liquid and what remains is the solid material
-but is it that simple?



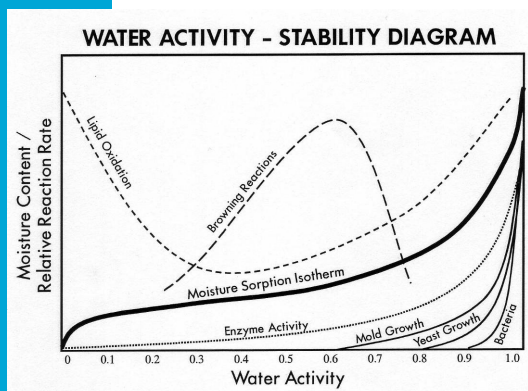
I. Preheating period (drying rate is almost 0)

II. Constant-rate period (drying rate is constant in time)

III. Falling-rate period (drying rate declines over time)

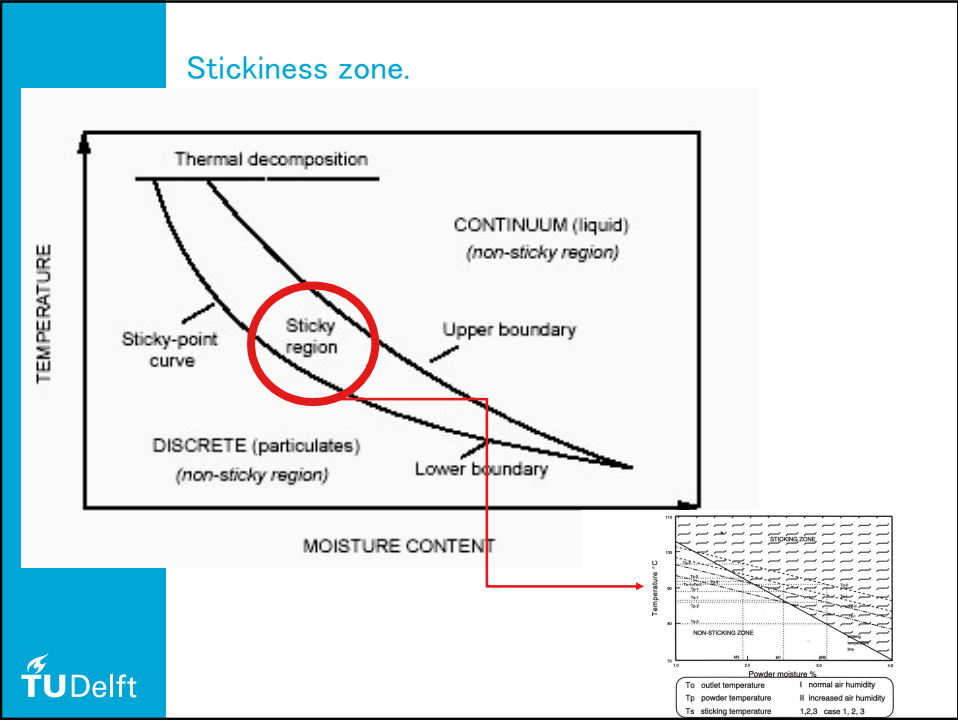
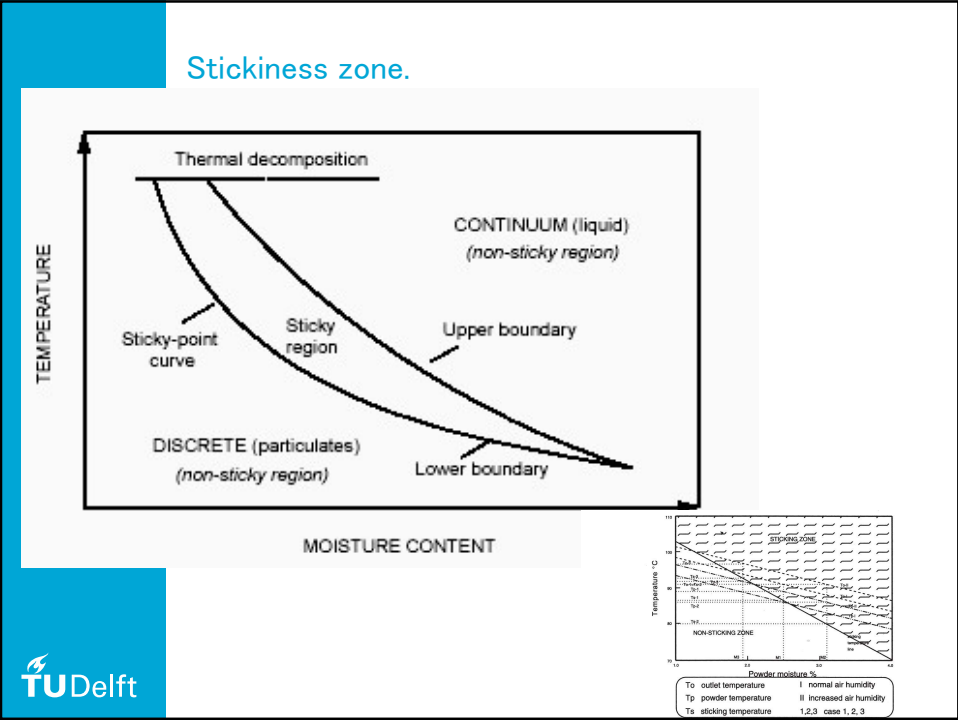
EMC=end (equil.) moisture content

Chemical/Biochemical Stability

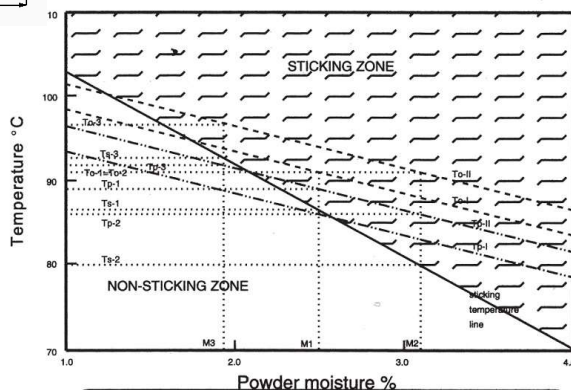
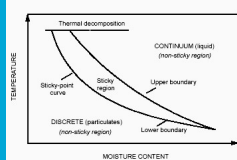


- Reaction Types:
 - Amine-Carbonyl (Maillard reactions)
 - Oxidation
 - Hydrolysis
 - Re-arrangement reactions
 - Enzymatic

Water activity serves as a map to predict what types of reactions will occur based on the composition of the product.



Stickiness zone.

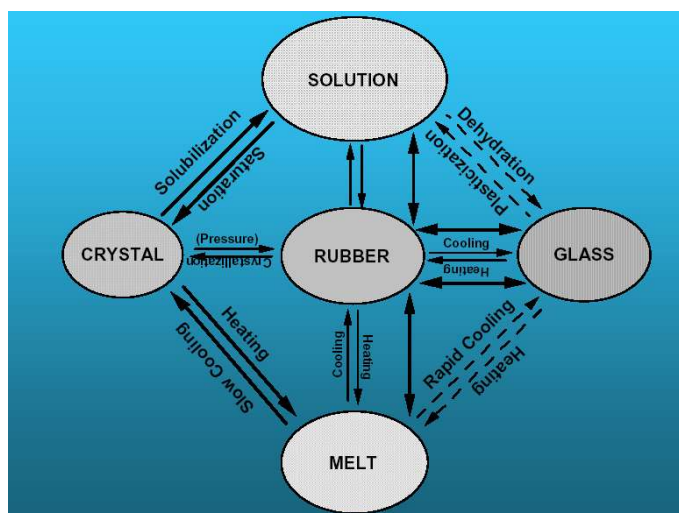


- To outlet temperature
- Tp powder temperature
- Ts sticking temperature
- I normal air humidity
- II increased air humidity
- 1,2,3 case 1, 2, 3



Crystalline and Glass-Rubber Transitions

Amorphous Glass
 ↔
 Amorphous Rubber (sticky)
 ↓
 Crystal



Stickiness

Stickiness (T_s) occurs at point where the structure of the amorphous powder is changed (irreversible) and depends amongst others on T & RH.

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Candy sugar

Cane sugar

Beet sugar

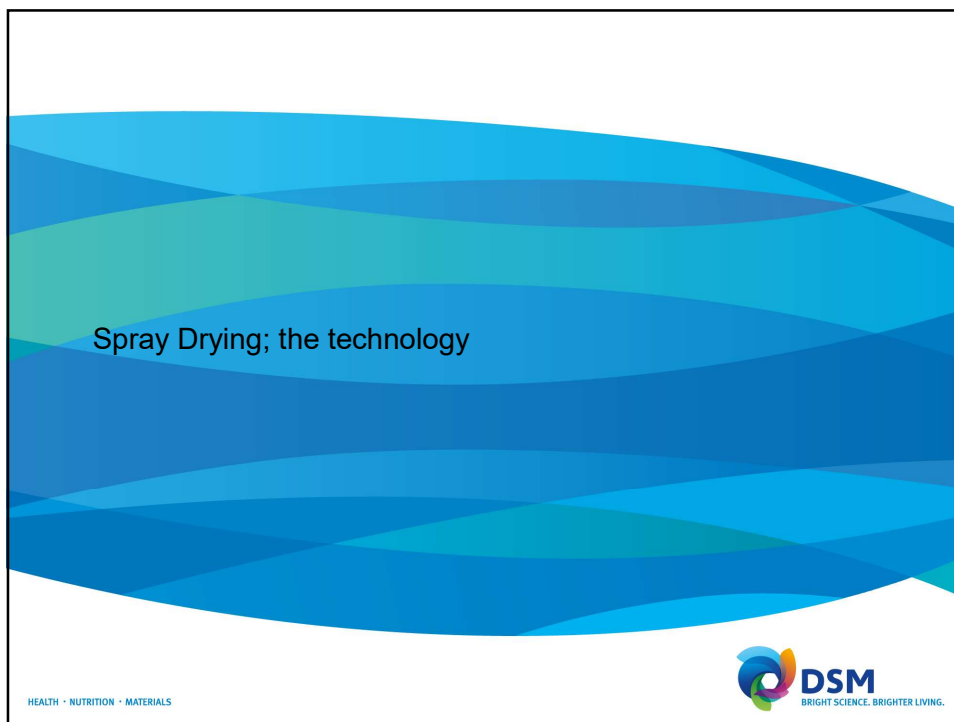
icing sugar

Cotton candy

Caster sugar

Sugar cubes

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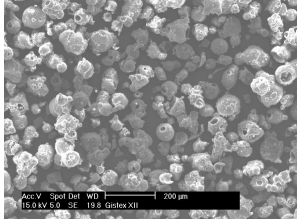



Spray drying

Spray drying is a unit operation where a fluid feed is transformed into a dry form by spraying it into a gaseous medium.

Basically 4 phases

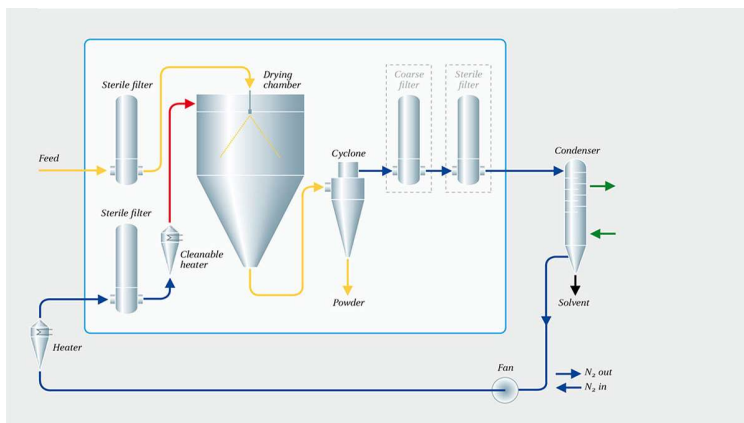
- Atomisation
- Contact between air and spray
- Drying the spray
- Separation of the dried product.

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Single Stage Spray Dryer

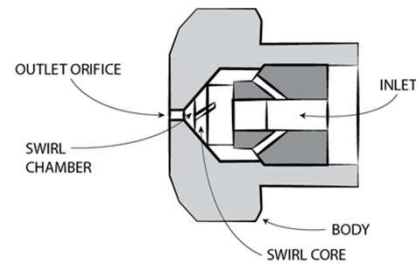


Spray drying: From liquid to powder

- Differentiation on basis of nozzles:

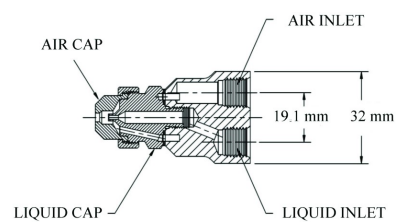


Pressure nozzle



- Operating pressure 60-120 bar
- Needs constant liquid feed
- Limited size adjustment of droplets
- Relative large amounts of liquids sprayed
- Scale up by multiple nozzles

Twin fluid nozzles



- Fluctuating liquid flow allowed
- Liquid break up by air stream
- Relative low flow rates
- Scale up by multiple nozzles

Rotary atomisers



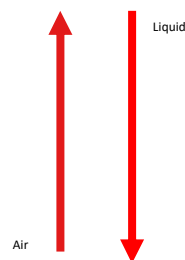
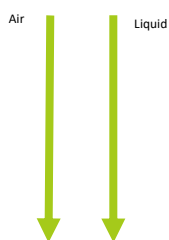
- Very large flow rates possible
- Dispersion of the liquid by centrifugal force and shear
- Fluctuating liquid flows allowed
- Scale up by higher rotational speed and larger wheel; no multiple atomisers are used

Spray drying

- Powder quality can be affected by varying drying condition.
 - Temperature feed.
 - Inlet temperature
 - Atomisation pressure
 - Airflow
 - Etc.
- Examples:
 - Higher (bulk) density => low inlet temperature and high atomisation pressure.
 - At a given inlet temperature a lower atomisation pressure gives bigger but more fragile particles (dust formation).

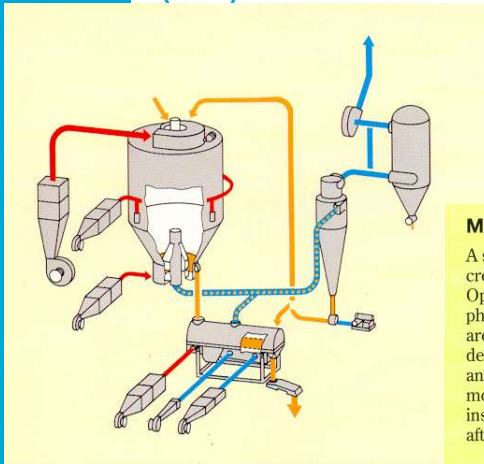
Spray Drying

- Co-current vs Counter current drying
- When to chose one or the other?



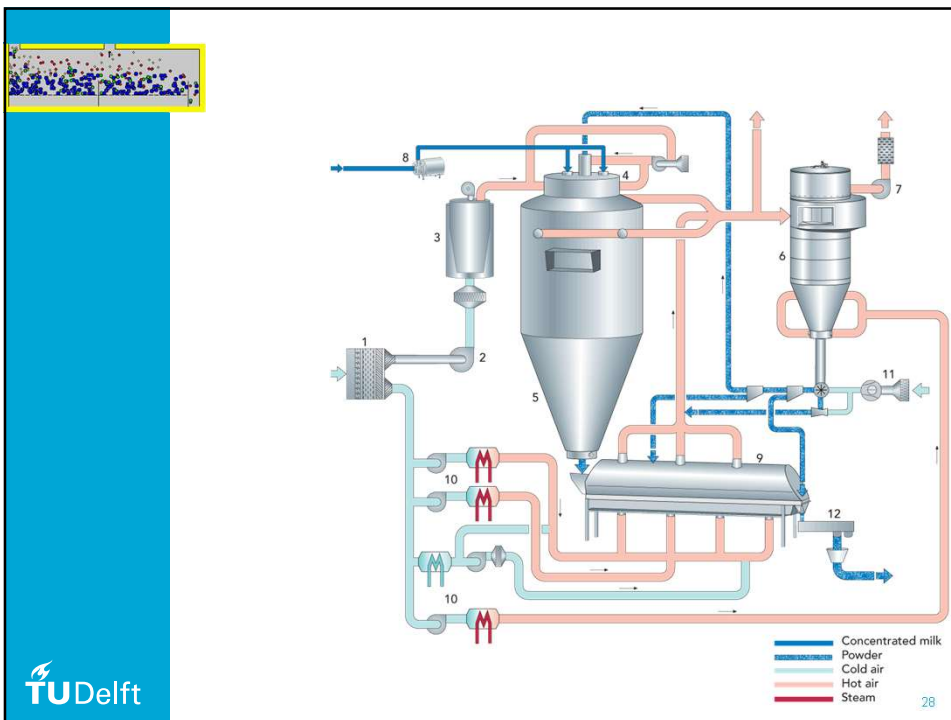
Multi Stage Spray Drying

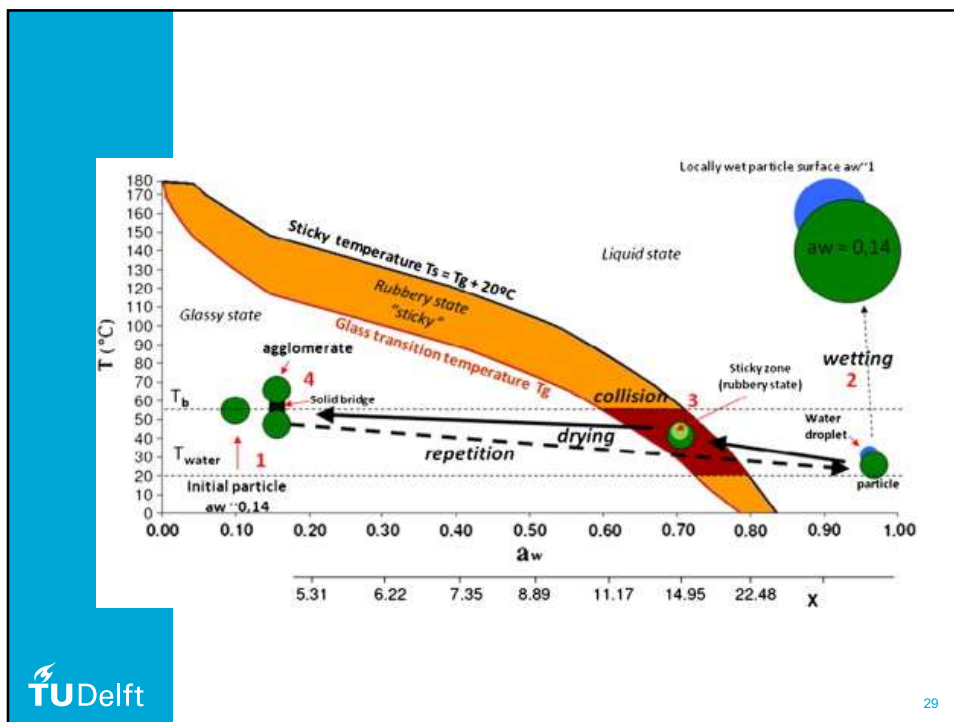
Intergrated Spray Dryer (Gea-Niro) (LA)



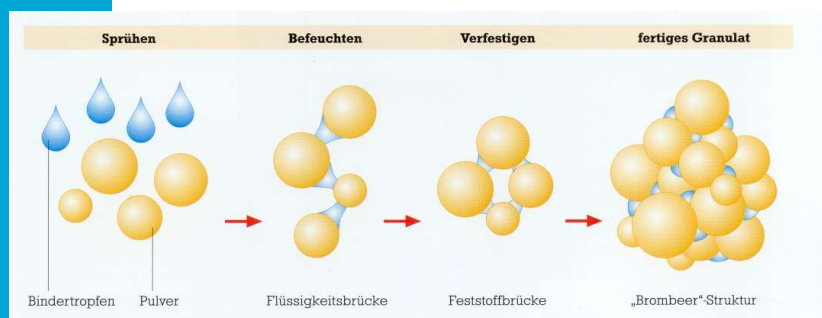
Multi-stage dryer

A spray dryer with integrated fluid bed. The spray is created by either a rotary atomizer or nozzles. Operational flexibility enables a wide range of physical properties to be met. Agglomerated powders are produced and thermal efficiency is excellent. This design concept is successful for drying hygroscopic and sticky products which are difficult to handle in more conventional designs. A vibrating fluid bed installed under the drying chamber acts as an after-dryer/cooler.



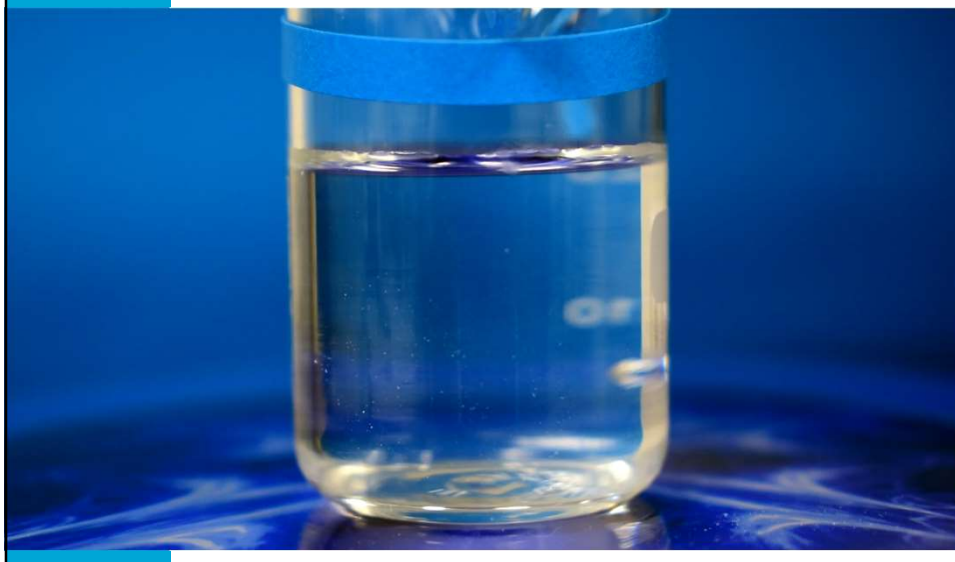


Mechanism of Spray drying and agglomeration



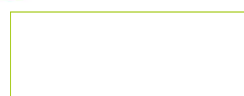
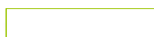
Droplet-solid interactions
 Droplet droplet interaction
 Solid- solid interactions

Coffee creamer

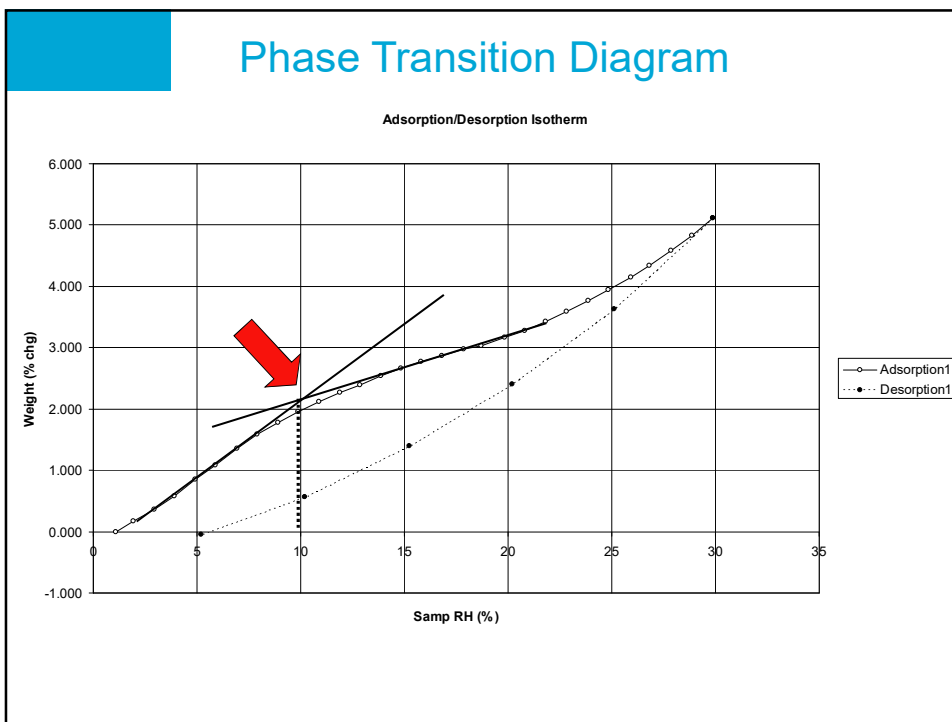


Dynamic Vapor Sorption DVS

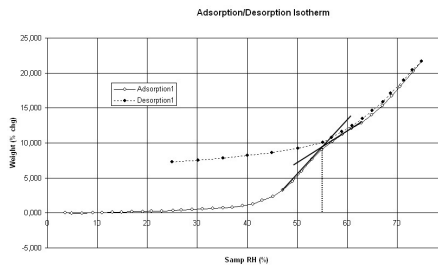
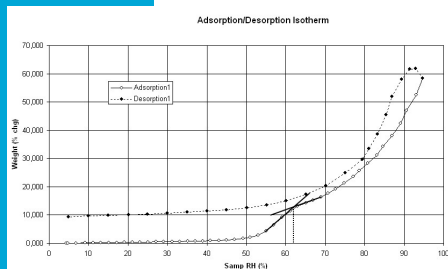
How to get your drying settings
without fouling of the dryer



Phase Transition Diagram

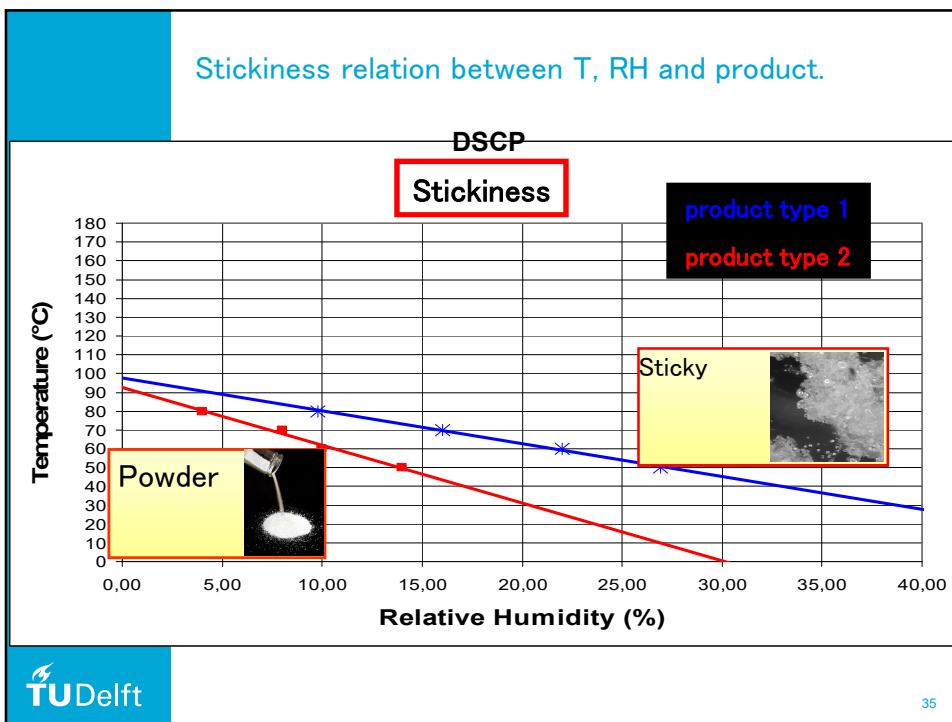


DVS at different temps

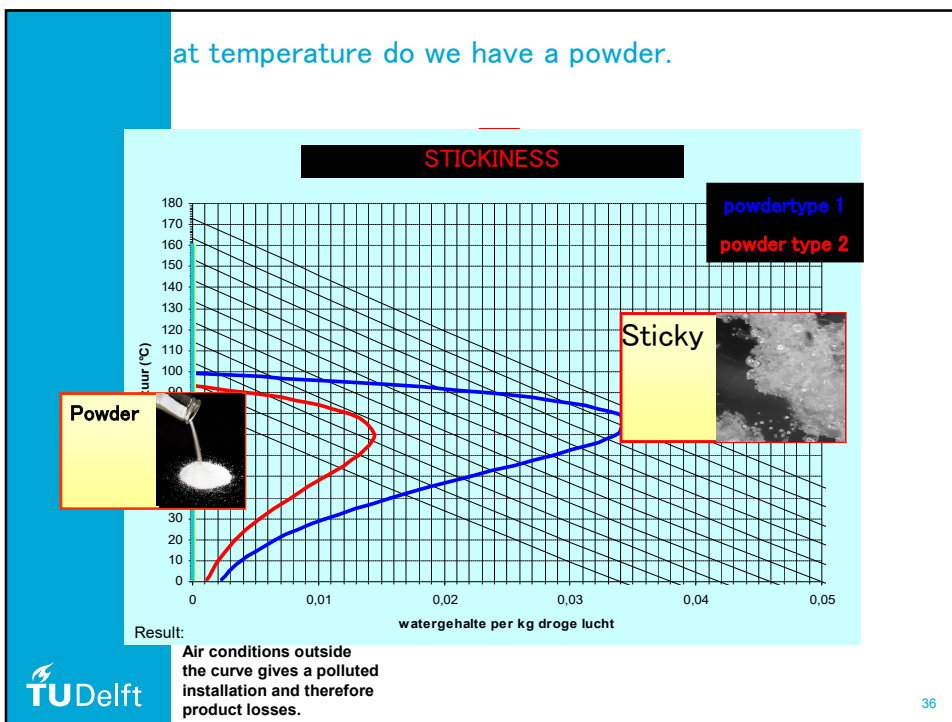


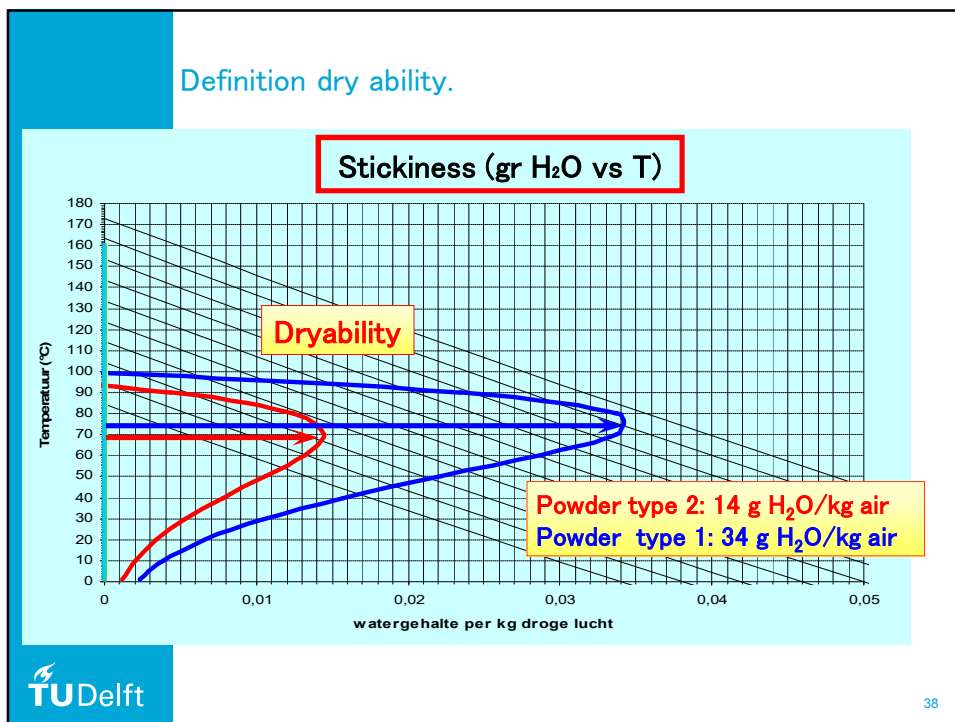
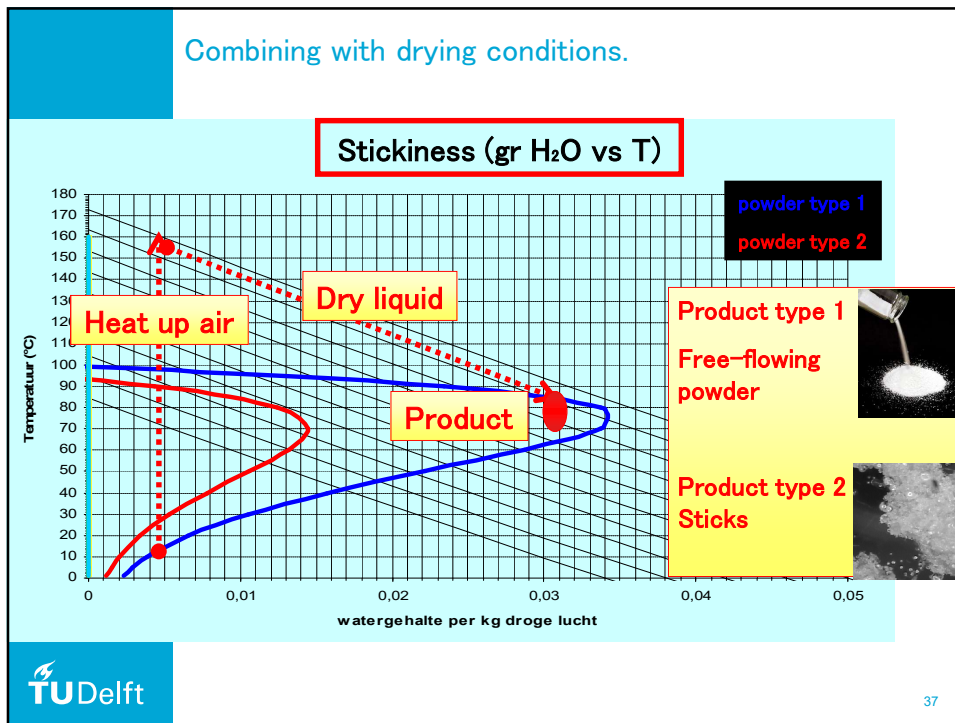
at 25°C (left) shows phase change at about 62% RH
 at 35°C (right) shows phase change at about 56% RH

Stickiness relation between T, RH and product.



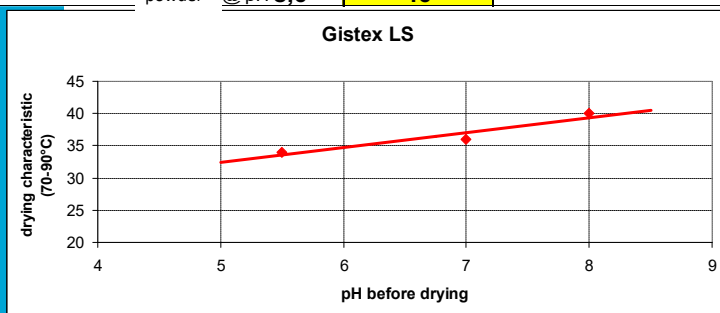
at temperature do we have a powder.



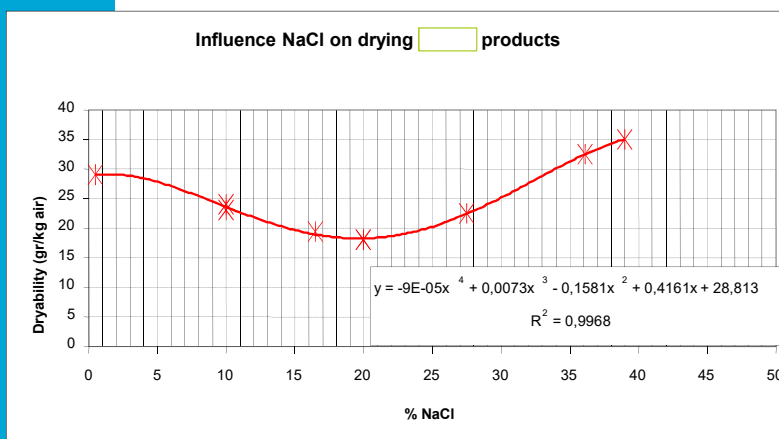


pH before drying of the product

Batch	Description	Drying characteristic @ 70-80°C	Remark
1	powder @ pH 5,5	34	
2	powder @ pH 7,0	36	
3	powder @ pH 8,0	40	



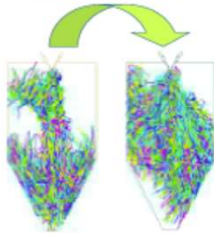


Influence NaCl content on drying.




NIZO Solution Phase 2: Optimise air flow

- NIZO track record: serious fouling solved by simulation of optimised configuration of atomisation system
- Modeling dryer with CFD
 - ES-SprayDry to calculate distribution inside the dryer
- Detailed simulation of equipment configuration
 - 24 atomisation nozzles (8 lances)
 - air outlet in conical part
- Configuration details applied to model spray drying operation
 - Undesired short cut flow identified as source of problem
 - CFD used to simulate optimisation of equipment configuration
 - Air distribution optimised: problem solved!


Together to the next level

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Future reading





Food Chemistry 132 (2012) 1693–1698

Contents lists available at ScienceDirect

Food Chemistry


journal homepage: www.elsevier.com/locate/foodchem

Developments in glass transition determination in foods using moisture sorption isotherms

Brady P. Carter^{a,*}, Shelly J. Schmidt^{b,1}

^a Deacon Devices, Inc., 2365 Northeast Hopkins Court, Pullman, WA 99163, United States
^b Department of Food Science and Human Nutrition, University of Illinois at Urbana-Champaign, 367 Reiser Hall, 905 South Goodwin Ave., Urbana, IL 61820, United States



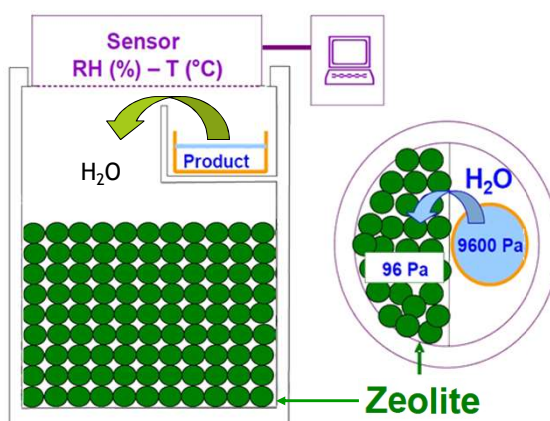
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SPD²P method by P. Schuck, INRA, France

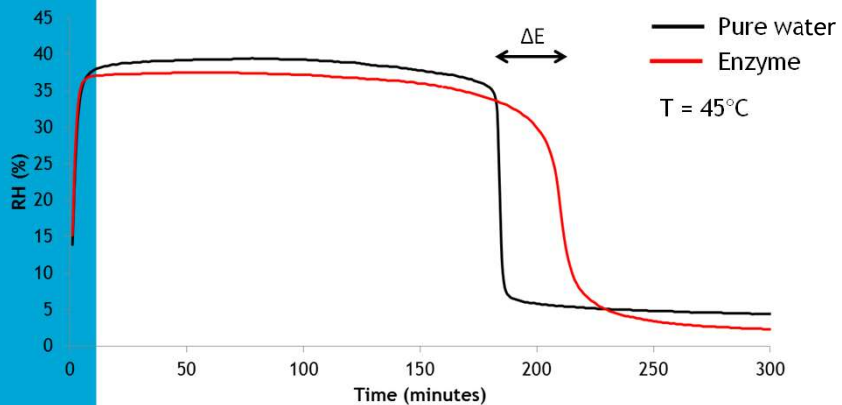


HEALTH · NUTRITION · MATERIALS

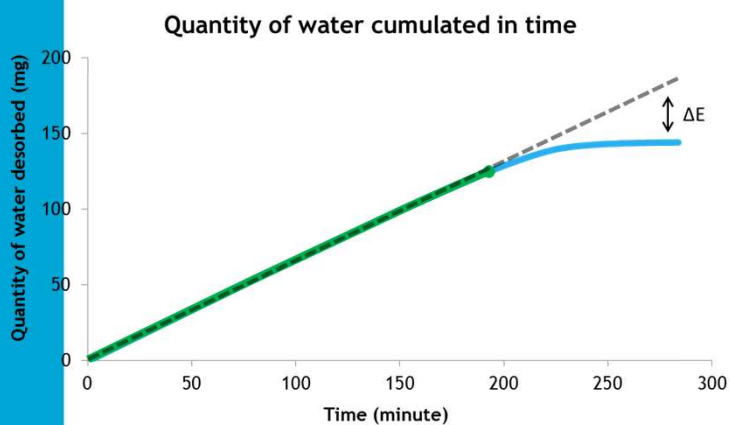
The drying by desorption equipment



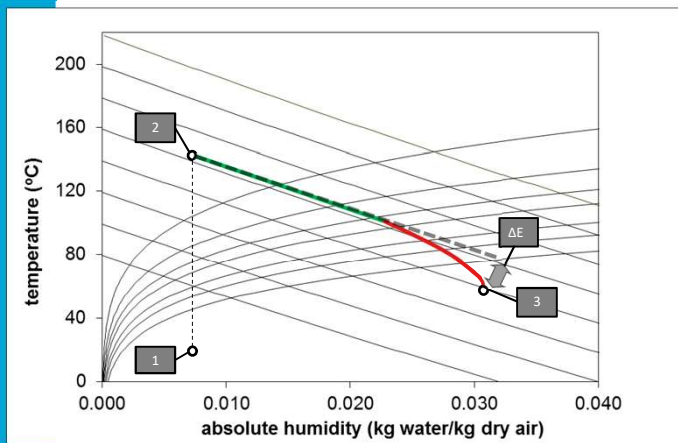
Drying by desorption comparison with water



SD²P software

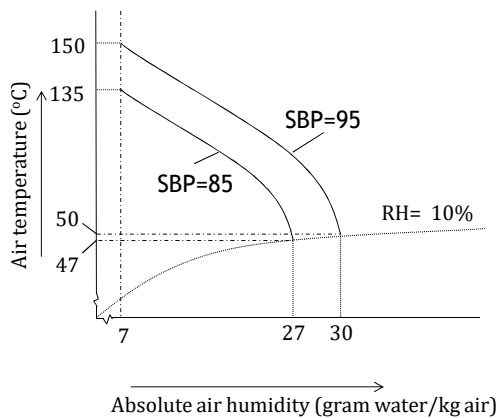


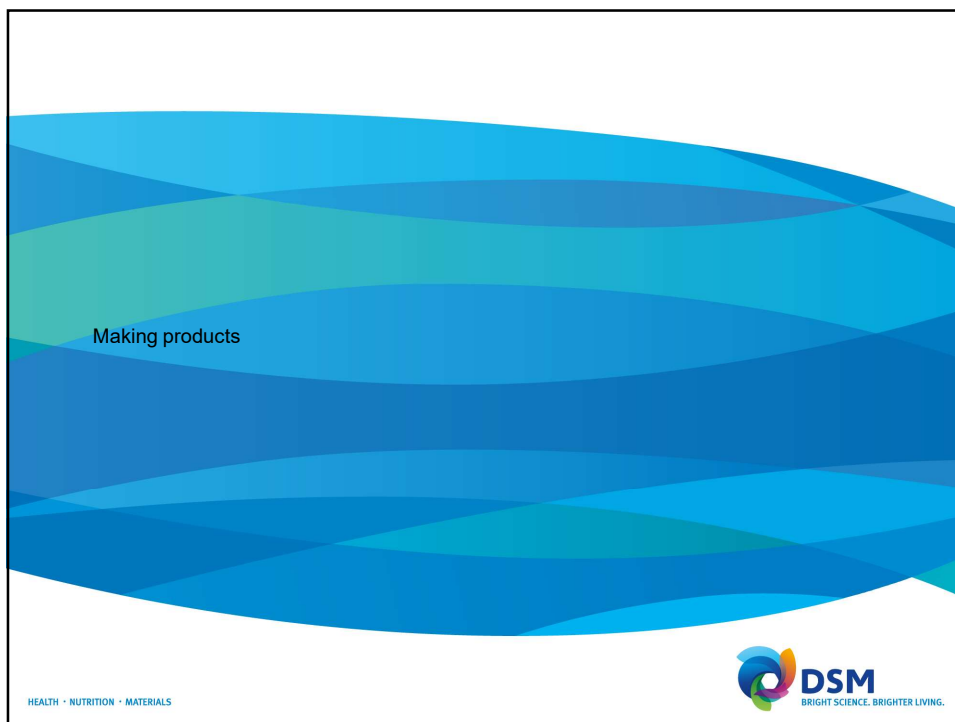
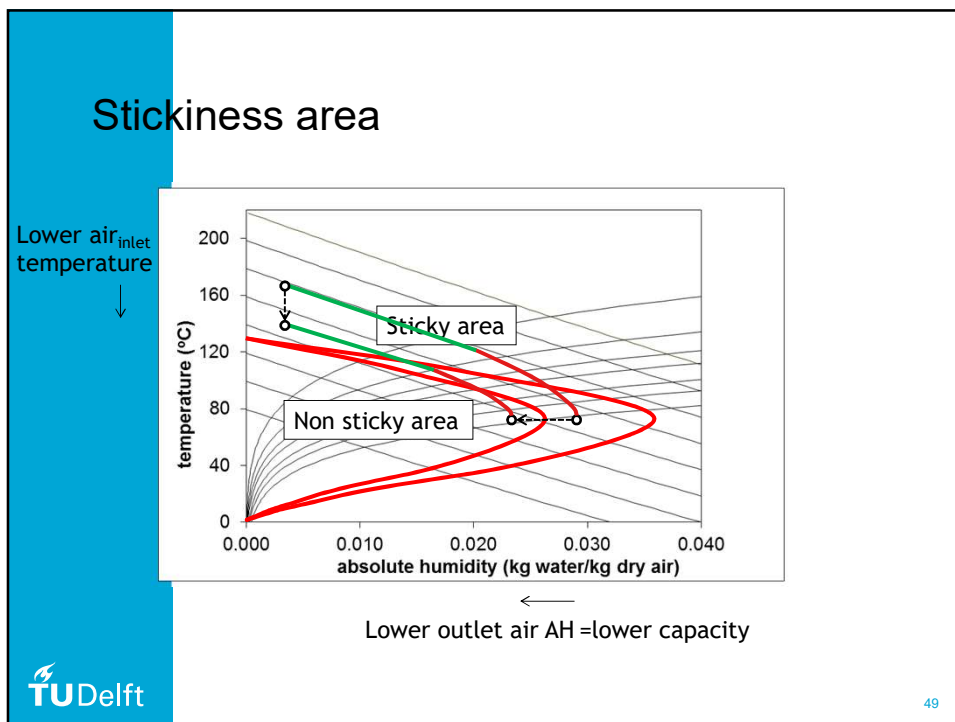
SD²P software



Example SBP

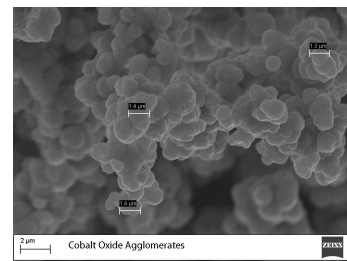
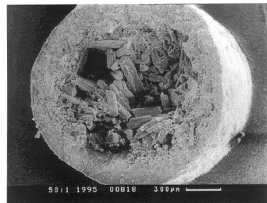
	Normal product	Deviating product
SBP (%)	95	85
AH _{airinlet} (g/kg)	7	7
AH _{airoutlet} (g/kg)	30	27
T _{airinlet} (°C)	150	135
T _{airoutlet} (°C)	60	57
Concentrate flow (l/h)	380	342





Drying and agglomeration often go hand in hand

Making agglomerates/granulates is most of the time required

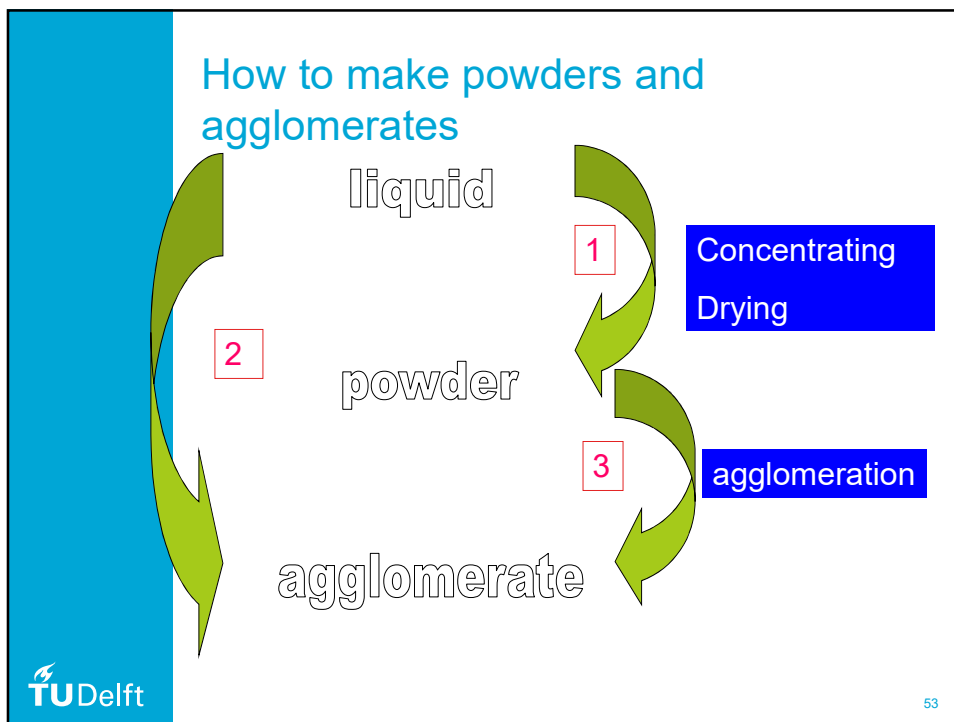


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Aim of making agglomerates

- Changing particle size distribution
- Changing flow behaviour
- Instant products
- reducing lumping
- de-dusting
- decrease segregation
- changing porosity and density
- Increase wettability and disperability
- etc

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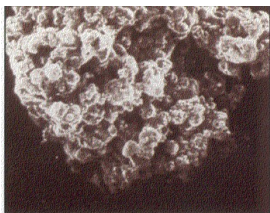
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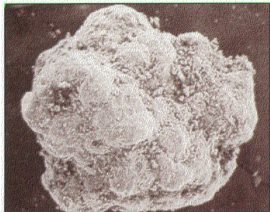
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Flash drying			
Spray drying		<ul style="list-style-type: none"> •Multi stage drying •Filtermat •Fluid bed agglomeration •AGT •Procell •Cont. fluid bed aggl. •Fluid bed coating •Pan coating •Drum coating •(Prilling) 	<ul style="list-style-type: none"> - Low shear granulation - Pan and drum granulation - Low-medium shear granulation - High Shear granulation - Fluid bed granulation - Extrusion - Pelletising - Briquetting - Tableting - (Sintering)

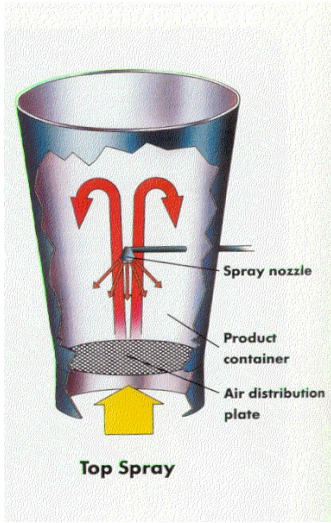
Top Spray Fluidised bed granulation (LA)



Instantized flavor granule

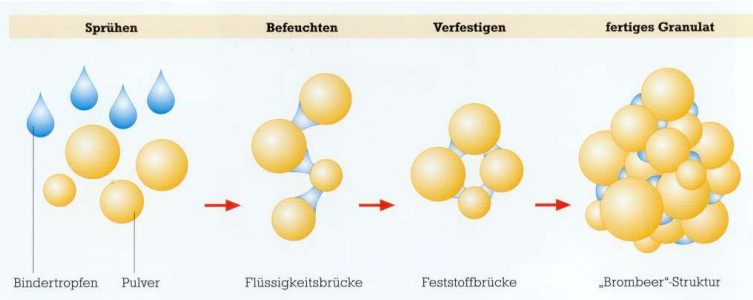


Granulated pharmaceutical



Top Spray

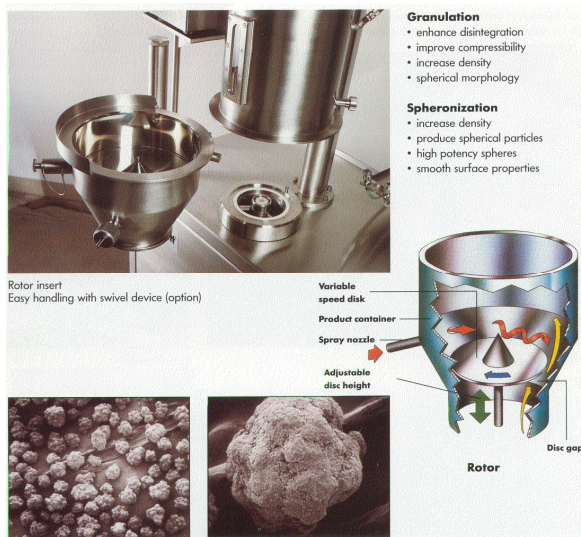
Mechanism top spray fluid bed agglomeration



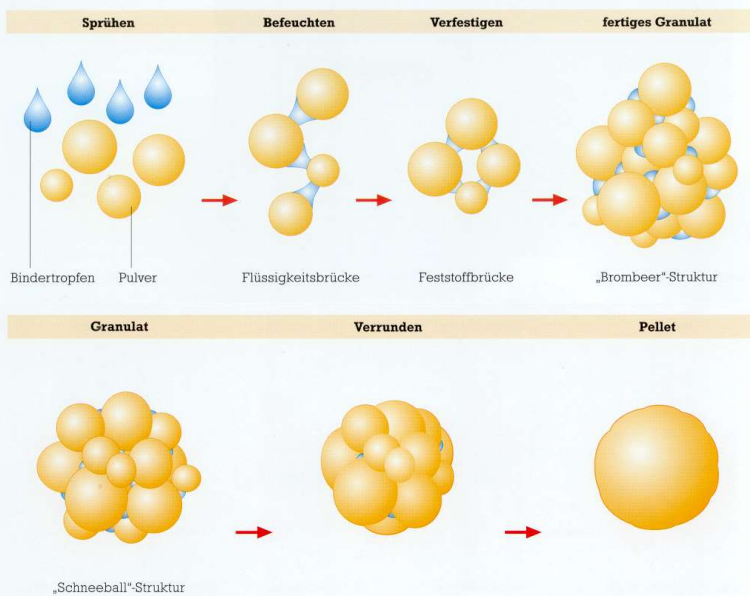
Fluid bed agglomerates examples




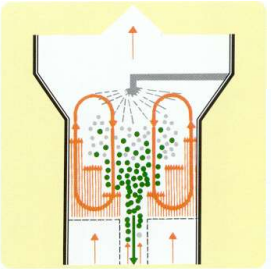
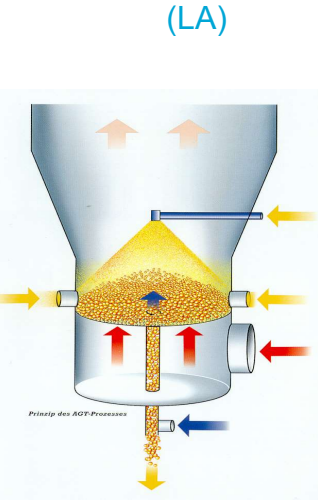
Side Spray Fluidised bed granulation (LA)



Mechanism Side spray fluid bed




AGT-process; Continuous Granulation (LA)


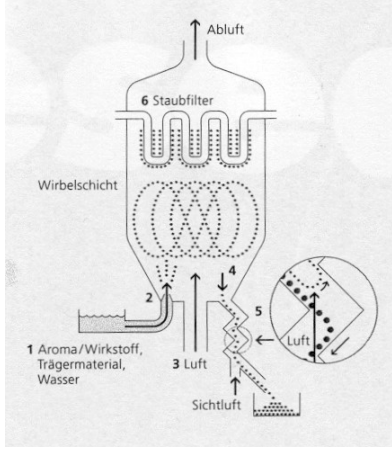





Continuous Fluid Bed Granulating/Agglomerating

- Layering Granulation
- Agglomeration
- Energy Efficient
- Continuous Process
- Dustfree Product
- Uniform Particle Size
- Consistent Product Quality

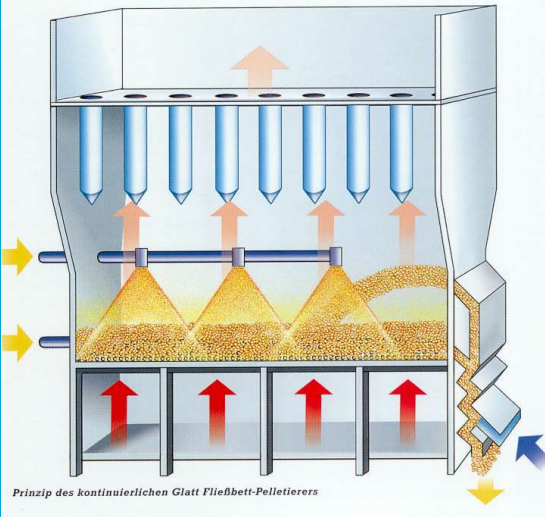



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AGT-process (LA)


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AGT (GFG)

Prinzip des kontinuierlichen Glatt Fließbett-Pelletierers

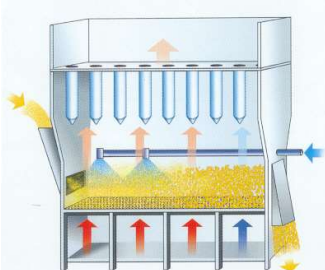

Granulat: Pottasche

REM-Aufnahme, Pellets | 200 µm

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Continuous Fluidised Bed granulator

Prinzip des kontinuierlichen Granulations-Prozesses

Glatt Fließbett-Granulator GFG 500

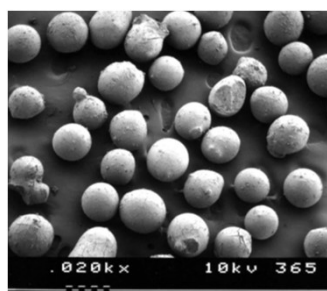
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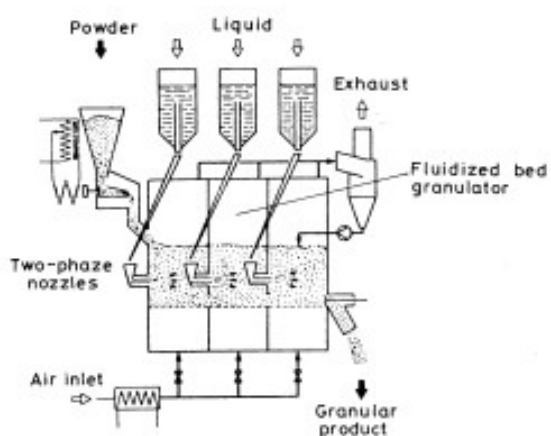
Fluid bed agglomerated product

Typical formulation

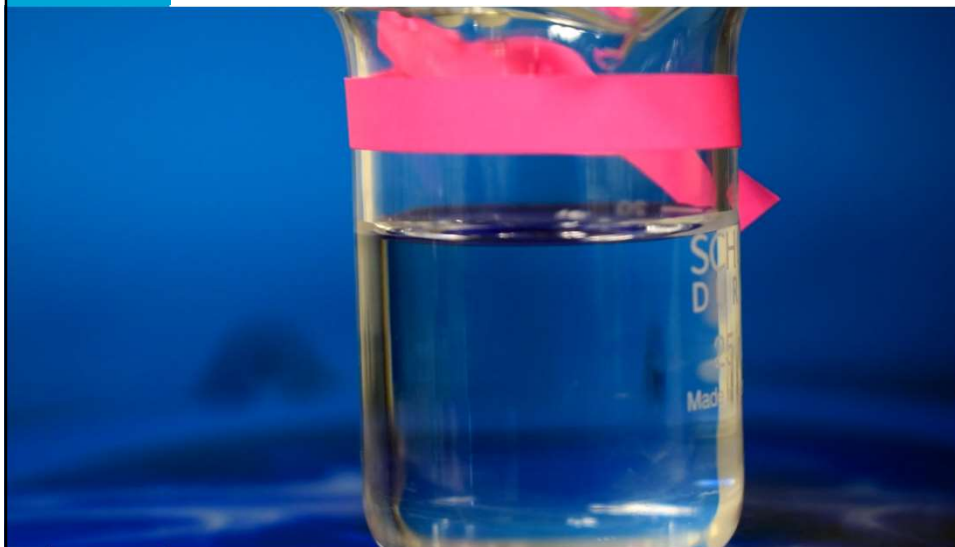
- & Water 50%
- & Maltodextrine 35%
- & Liquid flavour 15%



Multi compartment continuous Fluidised Bed granulator



Fluid bed agglomerate



What if things go wrong....



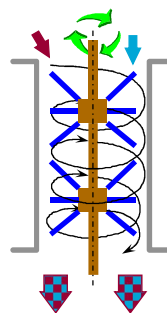
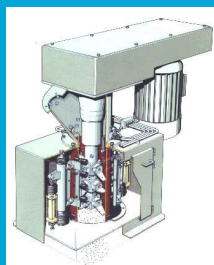
Flexomix



Low / medium shear granulation Flexomix (Hosokawa) (PA)

**Continuous
Wet
Agglomeration**
for instantizing

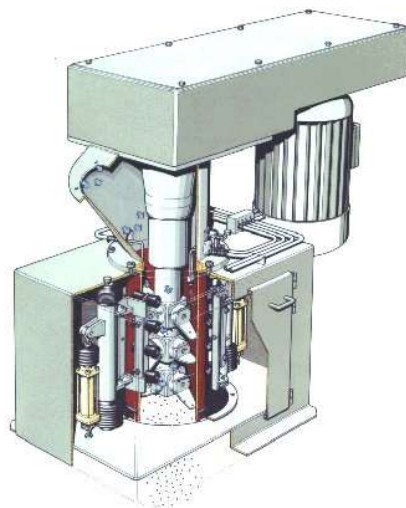
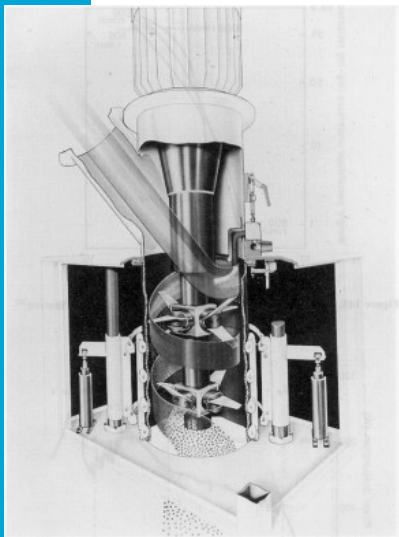
- Endproduct particles 0.2 - 1.2 mm
- Excellent free flowing
- Instant products
- > 300 kg/h



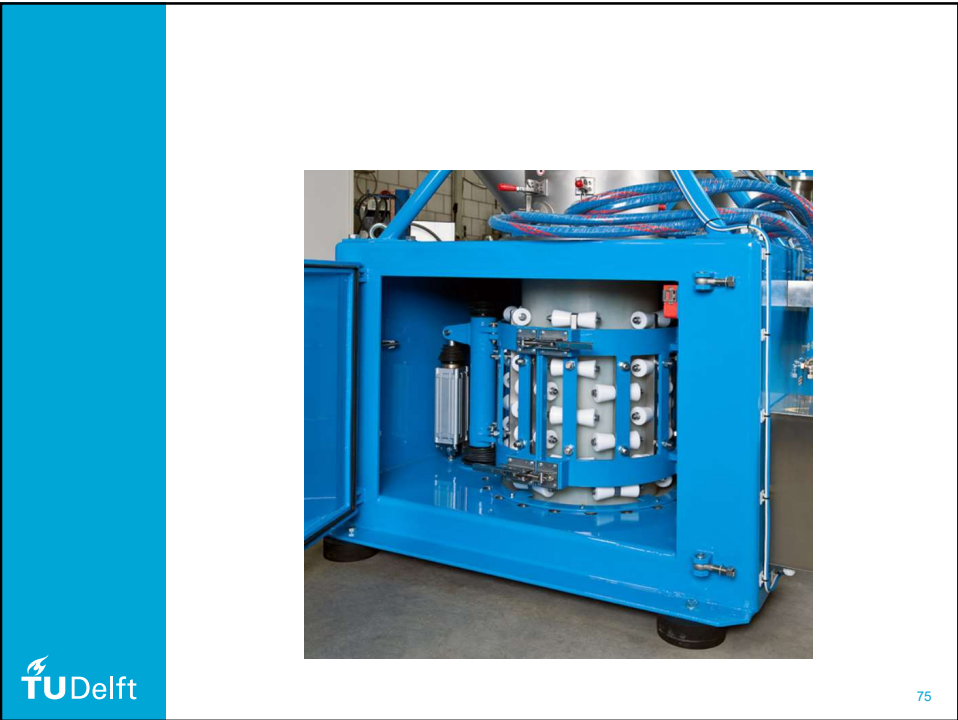
Instant mixing "The Schugi Principle"



Flexomix (Hosokawa)



Flexomix mixing/granulation unit



Concluding

- Drying is not simple, esp not for food products
- Drying characteristics measurements are a good tool to help understanding what phases the powder goes through
- There is more knowledge developed on predicting drying, but still we are not at that point that we stick a probe in a liquid and read the settings for the dryer
- New technologies are developed but the drying problem remains also with the new technologies
- We should continue to work on understanding drying better and develop tools to predict drying behaviour from liquid to granule
- **Product performance is leading in choosing the right technology**



Thank you

