Engineering for Food and Drink SIG

Hochschule Anhalt
Anhalt University of Applied Sciences

Caking of dairy powders

Frank Schulnies, Prof. Dr. Thomas Kleinschmidt

Powder Handling and Granular Flow
Zoom event on 24/06/2021

Agenda

- Definition and consequences of caking
- Caking mechanism
- Dairy powders
- Material & Methods
- Caking behavior of dairy powders
- Summary

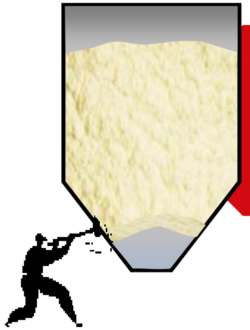
Definition and consequences of caking

- Caking = time consolidation during storage without movement
- Increase of interparticle adhesive forces with time and decrease of flowability
- Result: formation of lumps or massiv block
- About 60 % of powders and bulk solids exhibit caking problems

Definition and consequences of caking

Lowered quality/functionality and loss of product

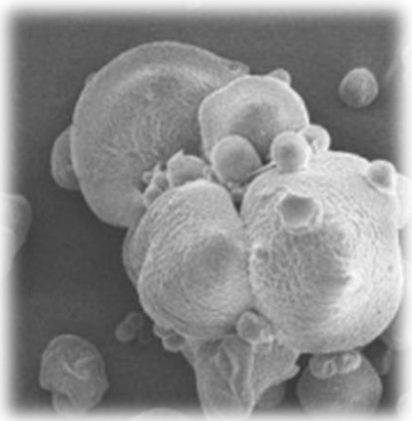
Process interruptions, missed schedules, drop in production rate



de-caking manufacture costs extra time, equipment and man powder

Assumed costs related to caking problems 0.5 % of all finished powders

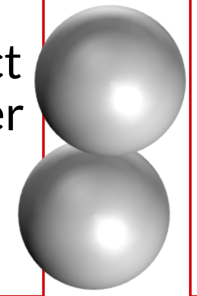
Caking mechanism



- Capillary condensation
- Solid or crystal bridge formation

Humidity caking

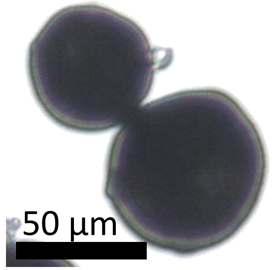
- Particles increase contact area and van der Waals forces
- Interlocking

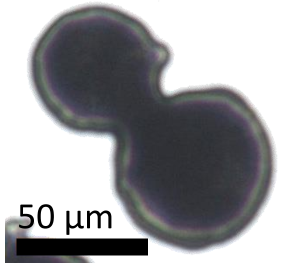


Mechanical caking

- Glass transition, rubbery state
- Sintering
- [T-Tg] governs the caking rate

Amorphous caking





Caking

Raw Materials

Process Parameters

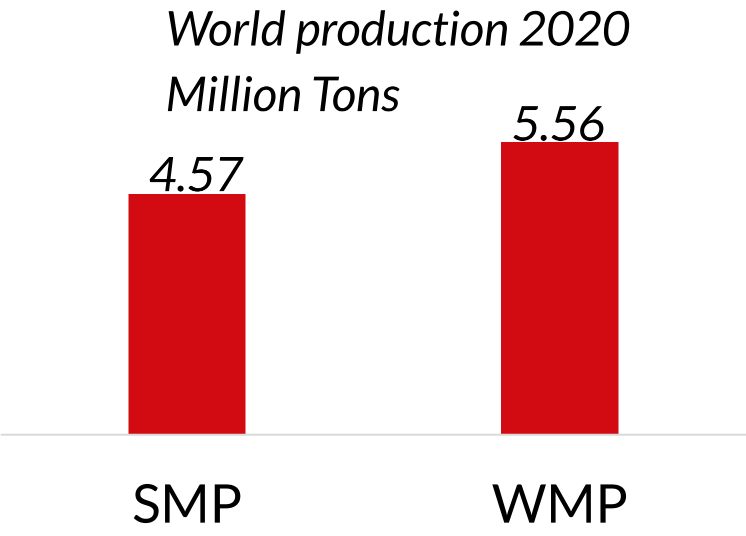
Storage Conditions

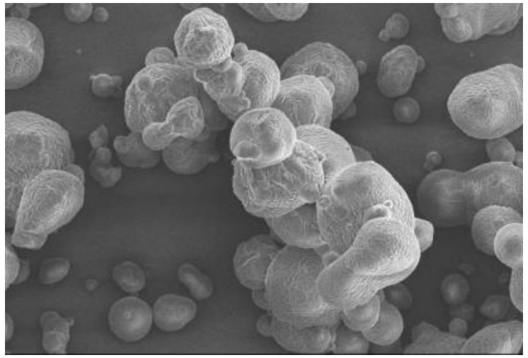
Intrinsic factors

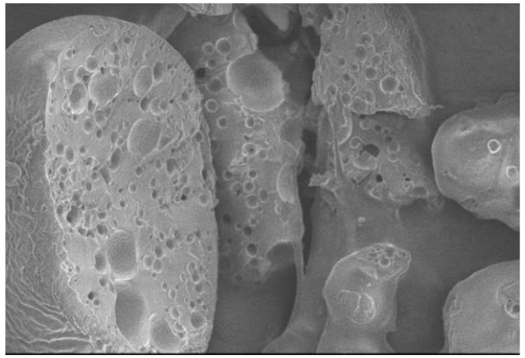
Extrinsic factors

Dairy powders

- Dairy powders made from whole milk (WMP), skim milk (SMP), buttermilk, whey, protein concentrates
- Various application in food industry, infant formula, sports and nutrition foods, bakery products, dry mixes…



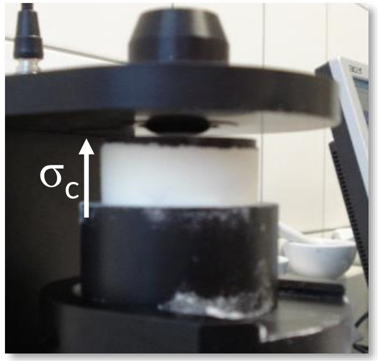


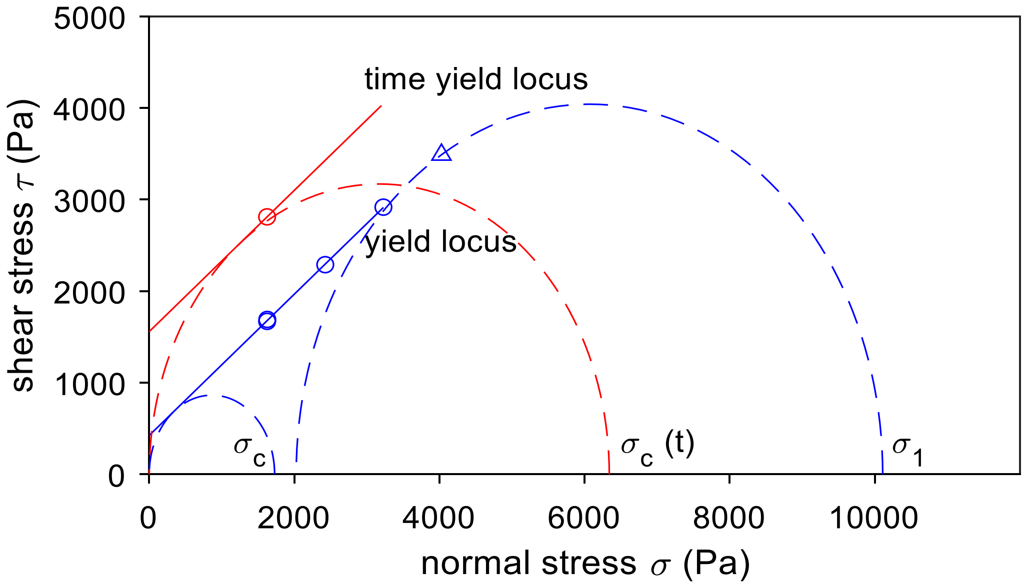


- Spray drying most frequently used technique
- Particle size 10-250 µm, bulk density 300-600 kg/m^3
- 3-6 % residual moisture
- Predominantly amorphous lactose

Material & Methods

- Commerical skim milk powder and milk powders with different fat contents were investigated
- Measuring unconfined yield strength (cake strength) using ring shear tester and uniaxial tester





Material & Methods

- Caking investigation of regular skim milk powder in the glass transition range (amorphous caking)
- Ring shear tester

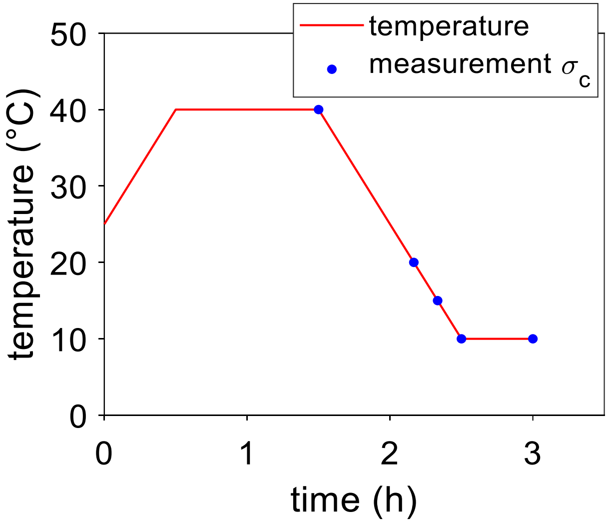
moisture	4 %
protein	35 %
lactose	59 %
fat	0,6 %
particel size d_{50}	96 µm

Storage conditions

Temperature	Realtive humidity	Consolidation pressure
42-50 °C	22 % RH	3-20 kPa

- Caking investigation of milk powders with different fat contents below glass transition
- Uniaxial tester

Powder	Fat	Particle size d_{50}
Cream powder	40 %	155 µm
WMP spray dried	30 %	285 µm
WMP roller dried	26 %	287 µm



Realtive humidity
22 % RH

Consolidation pressure
5 kPa

Caking behavior of dairy powders

Caking of skim milk powder

- Moisture sorption and glass transition
- Glass transition decreases (T_g) with increasing water content and water activity (aw)

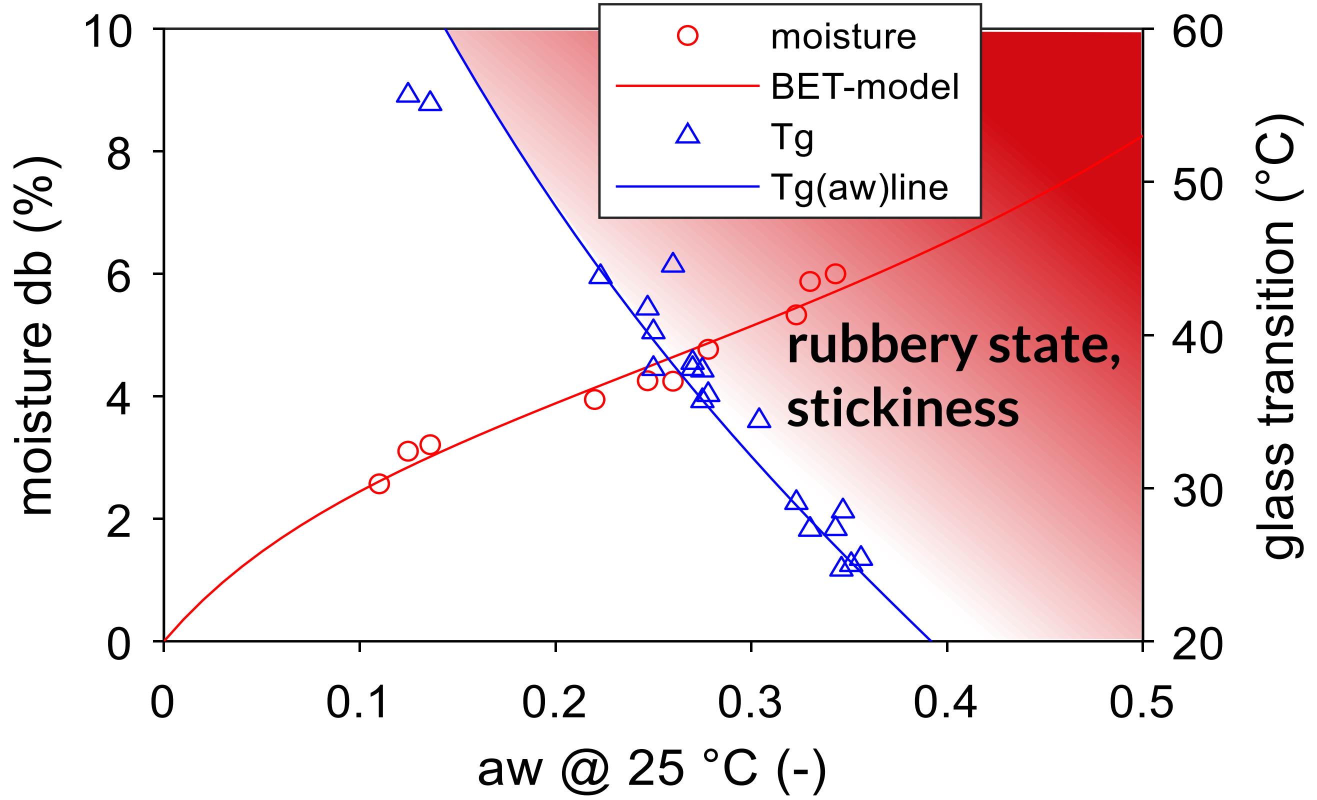
Tg (aw) line, Vuataz (2002)

$$Tg = -425{a_w}^3 + 545{a_w}^2 - 355a_w + 101$$

BET-model

$$M_{db} = \frac{M_0 C aw}{(1 - aw)(1 + (C - 1)aw)}$$

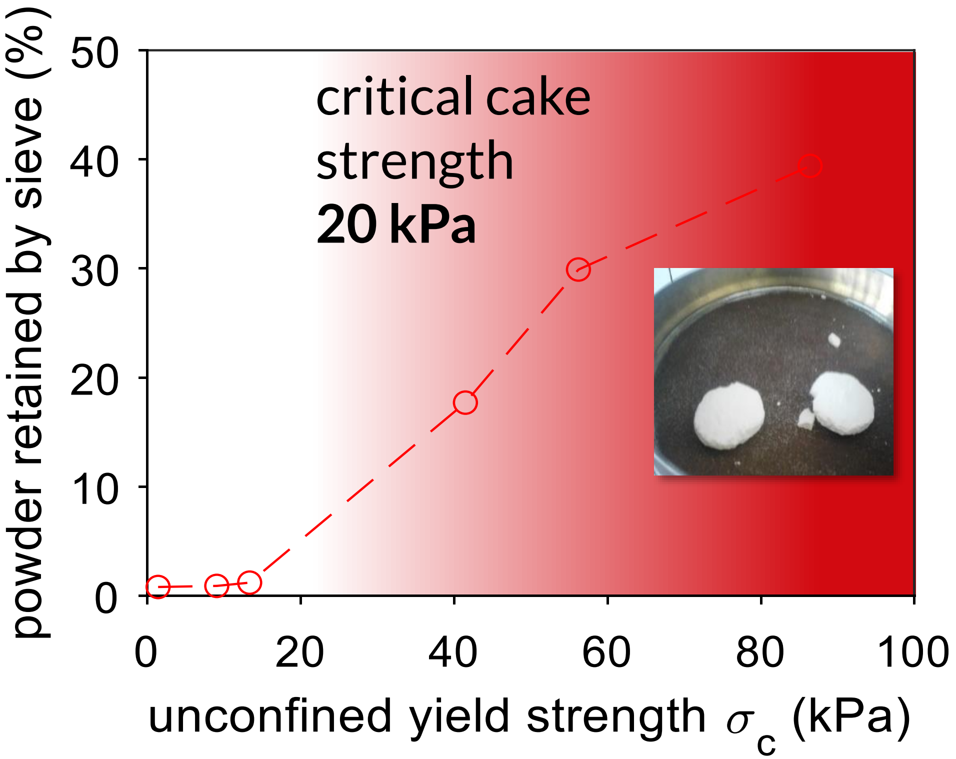
monolayer capacity M_0 *= 4.63 %*
kinetic constant *C = 8.145*



Caking behavior of dairy powders

Caking of skim milk powder

- When is a powder considered as caked ??
- Definition of a critical cake strength
- Sieving of consolidated powder cylinder (caking index)
- Caking time = time to reach 20 kPa



σ_c 0.8 kPa

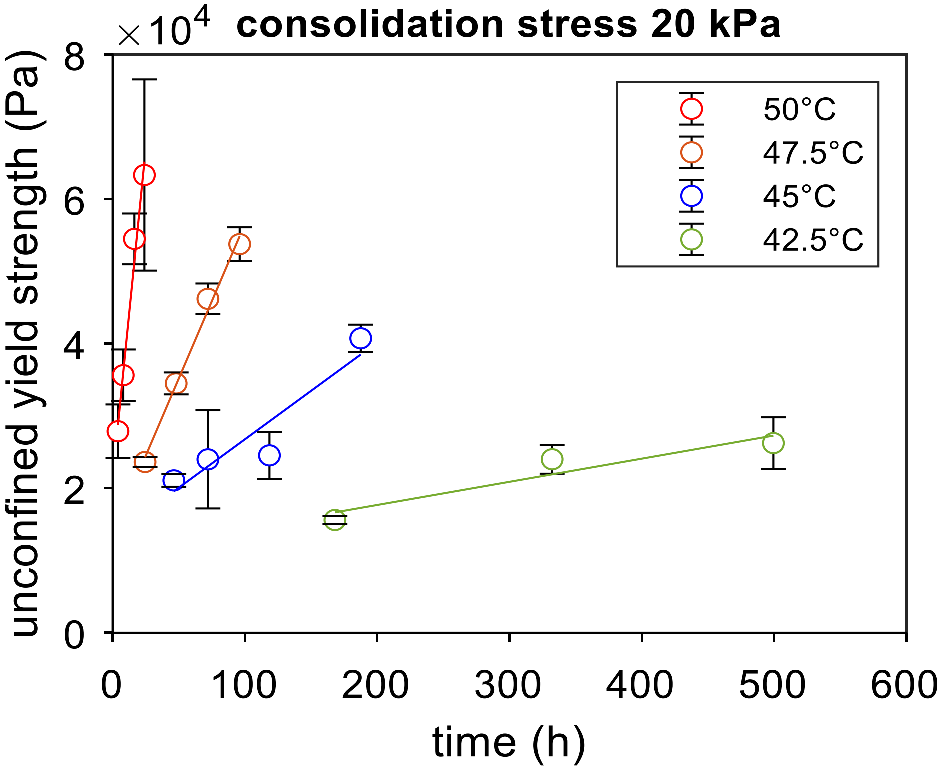
σ_c 12.5 kPa

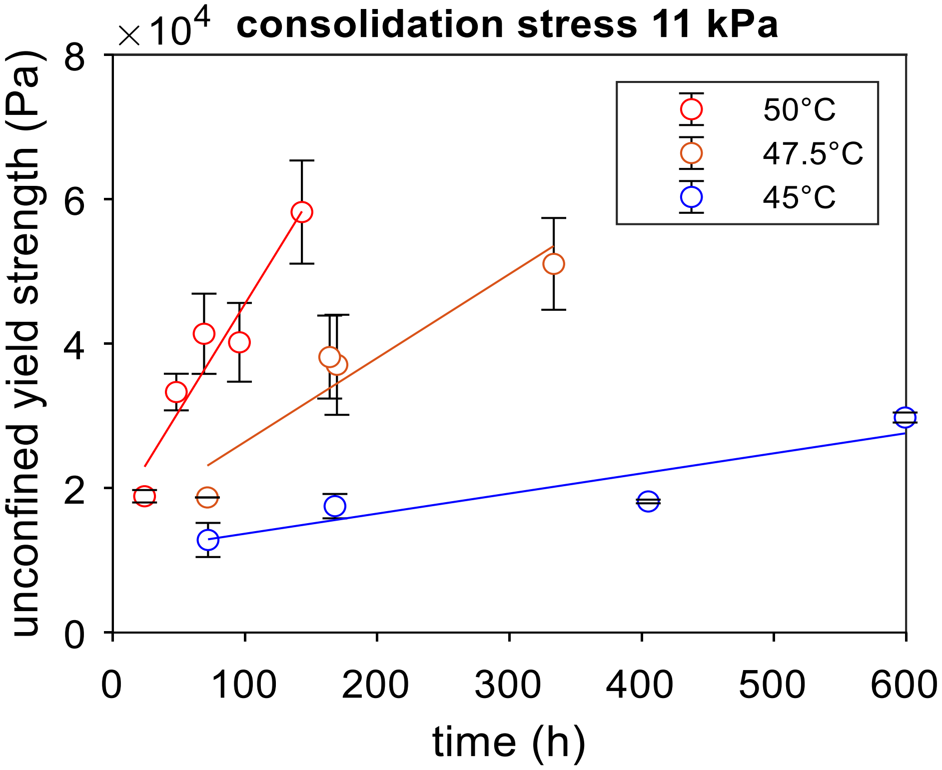
σ_c 29.4 kPa

Caking behavior of dairy powders

Caking of skim milk powder

- Development of unconfined yield strength with storage time

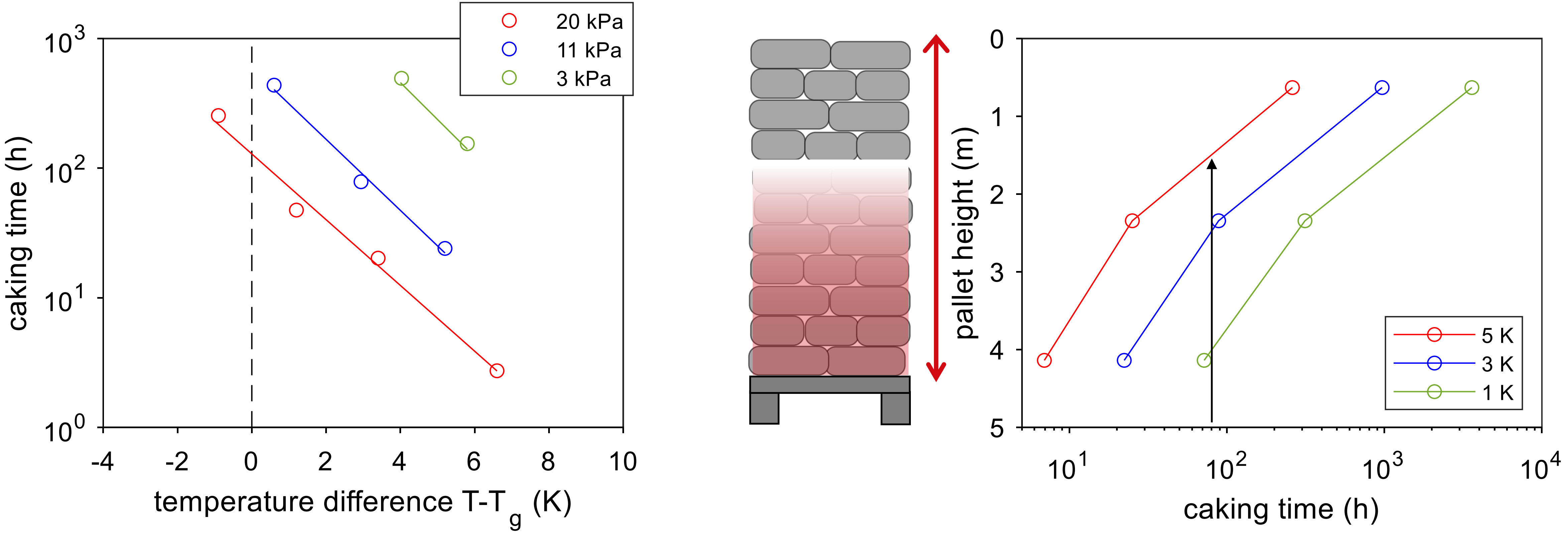




Caking behavior of dairy powders

Caking of skim milk powder

- Caking time decreases with increasing temperature difference [T-Tg] and consolidation stress



Caking behavior of dairy powders

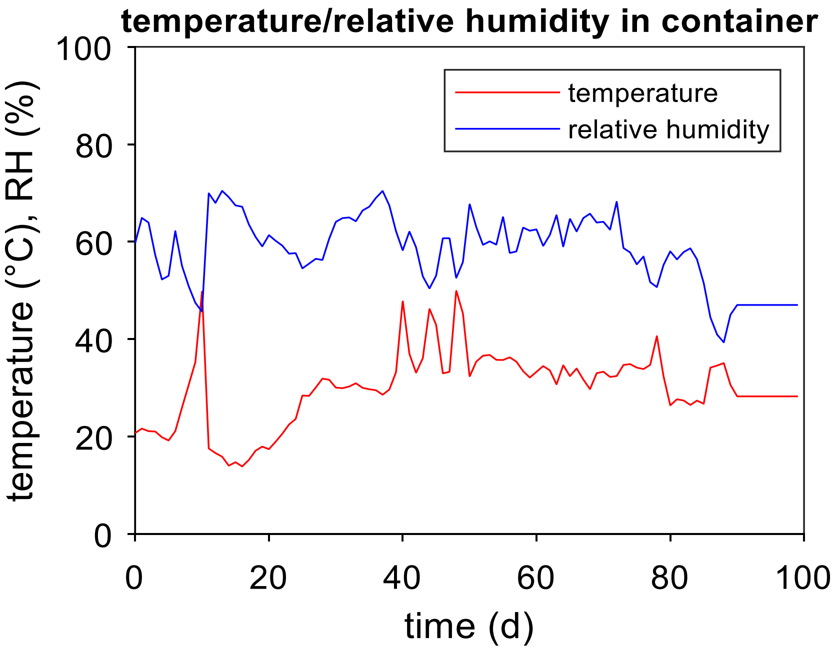
Caking of skim milk powder

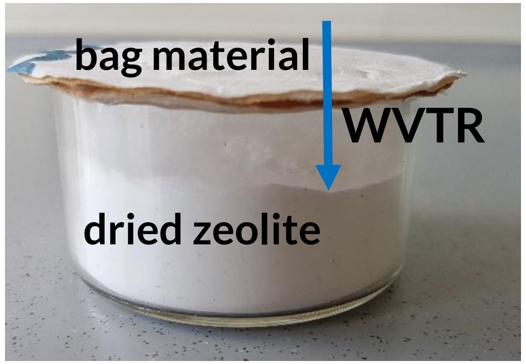
- Simulation of cake strength during container transport of SMP (Hamburg-Malaysia)

Permeation of water vapor through packaging material

$$\frac{dm_{WV}}{dt} = \frac{k}{\delta} * A * p_{sv}(RH - aw)$$

m_{WV}	*mass of water vapor*
k	*permeation coefficient of packaging material*
δ	*thickness of material*
A	*surface area of the bag*
RH	*relative humidity surrounding air*
aw	*water activity powder*
psv	*water vapor pressure at saturation*



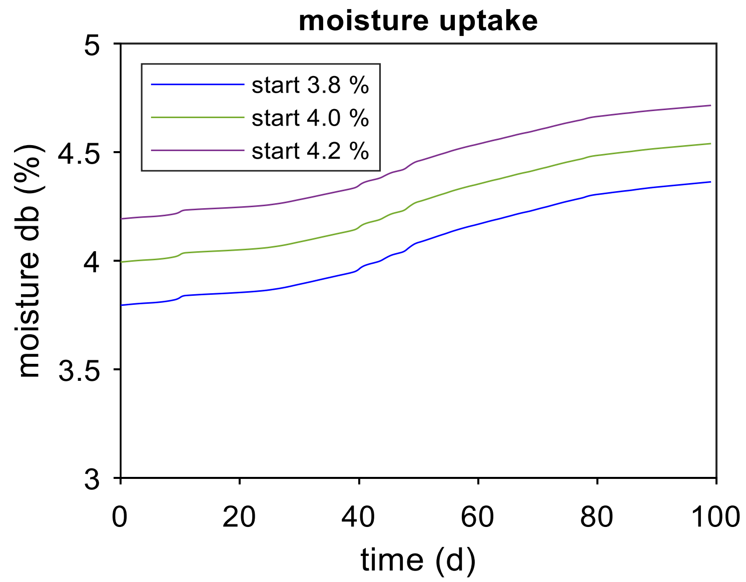


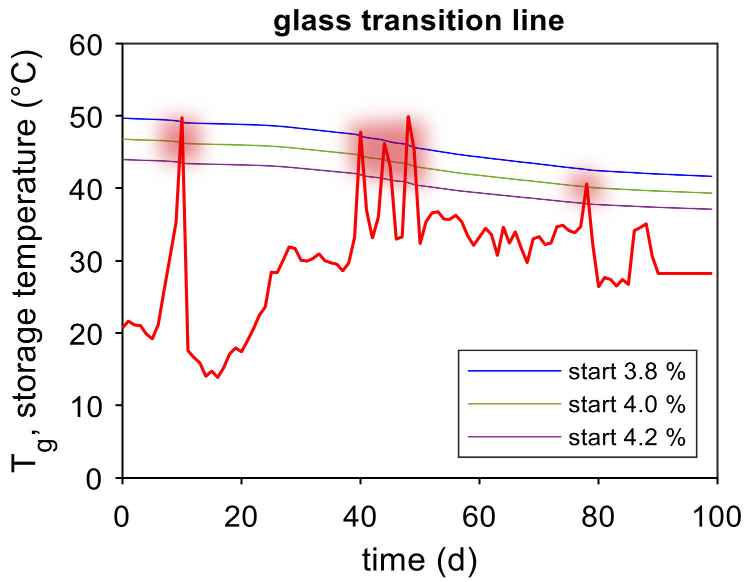
ϑ °C	WVTR = k/δ (g/m²*d*Pa)
15	3,53E-07
23	4,38E-07
35	7,38E-07

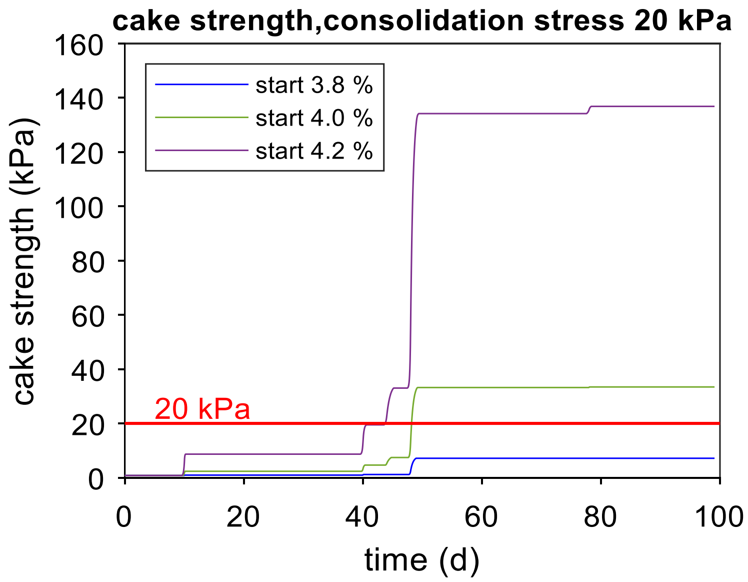
Caking behavior of dairy powders

Caking of skim milk powder

- Development of cake strength during container transport of SMP (Hamburg-Malaysia)
- Adjust initial moisture content (drying conditions) to reduce caking probability







Caking behavior of dairy powders

Caking of skim milk powder

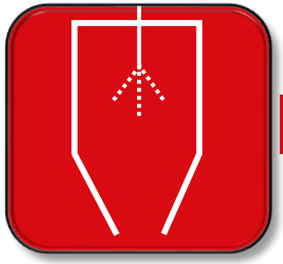
- Process conditions and storage stability

Inlet temperature ± 10°C

Outlet temperature ∓1°C

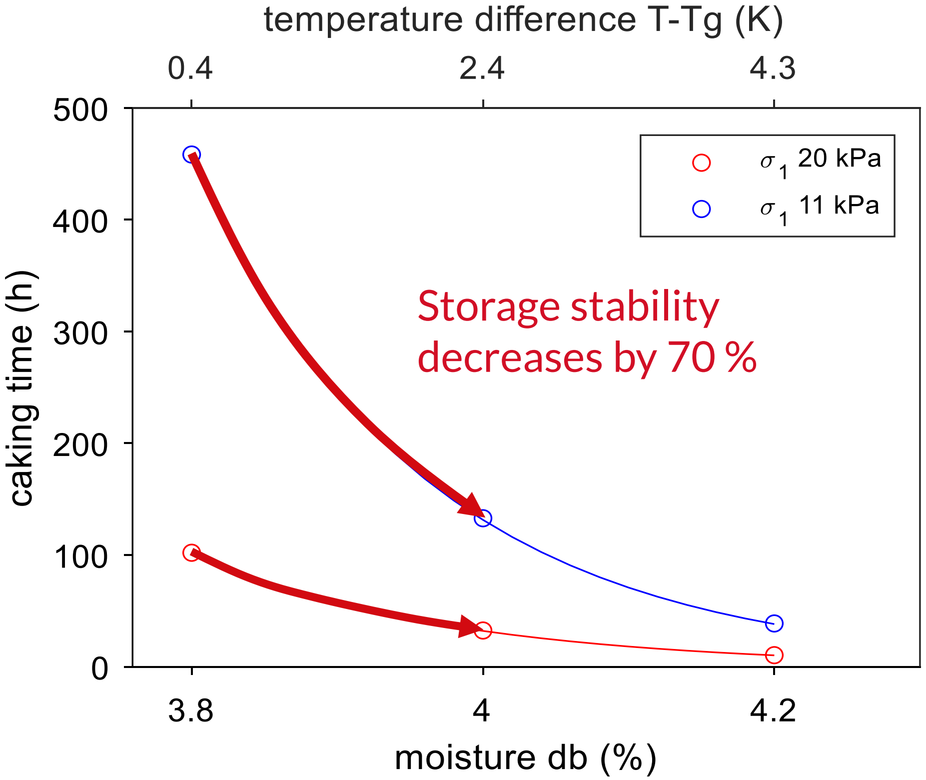
Total solids content ± 1%

Absolute air humidity ± 2.8 g/kg



Powder moisture ± 0.2 %

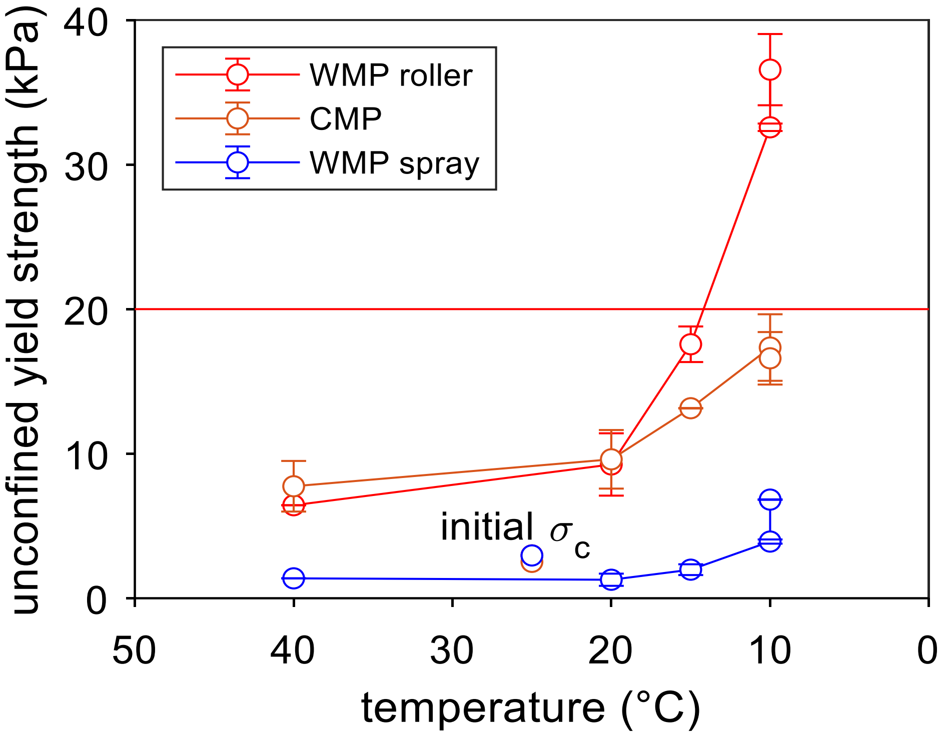
Glass transition ∓ 2 °C



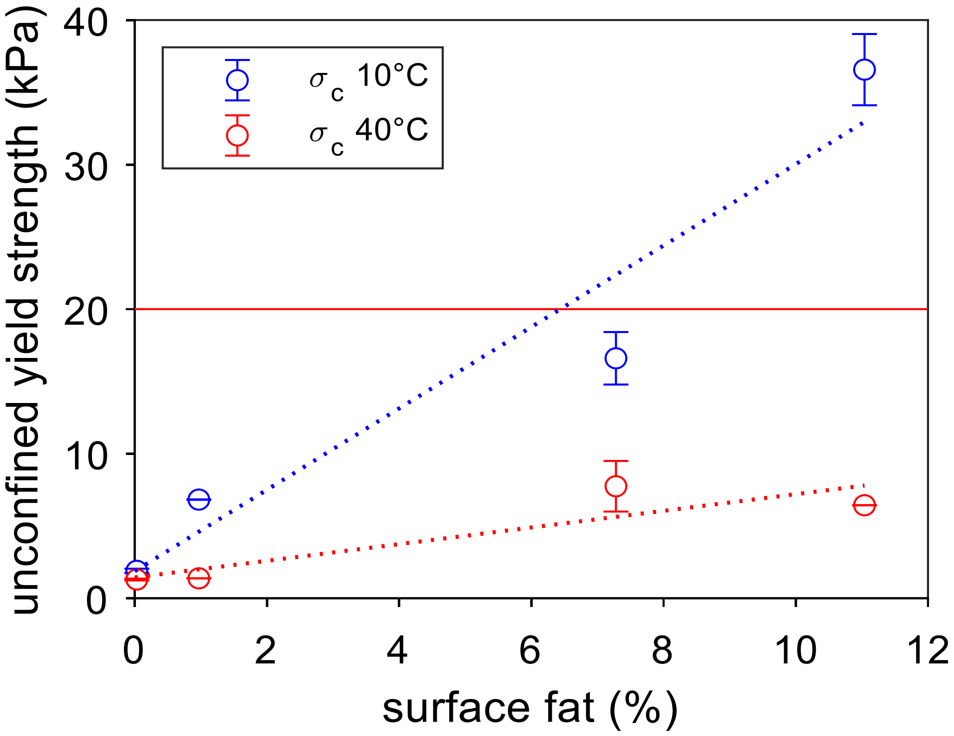
Caking behavior of dairy powders

Caking of milk powders with different fat contents

- Powder strength increases below 20 °C due to crystallisation of liquefied milk fat



- Caking at low temperatures when surface fat content is higher than 6 %



Summary

Amorphous caking of skim milk powder

- Critical cake strength 20 kPa
- Cake strength increases nearly linearly with time above Tg
- Caking time at Tg
  130-600 h
- Caking time decreases sharply with increasing [T-Tg] and storage pressure

Fat caking of milk powders

- Heating to 40°C and cooling: Increase of cake strength below 20°C
- Caking problems when surface fat content higher 6%

Prospect

- Influence of particle size, amorphous content
- Caking behavior under temperature/humidity cycles
- Caking behavior of herbal powders

Thank you for your attention!

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Contact

Frank Schulnies
frank.schulnies@hs-anhalt.de

Hochschule Anhalt
Anhalt University of Applied Sciences
www.hs-anhalt.de

+49 3496 672538

Bernburger Str. 55
06366 Köthen-Germany

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