ON-LINE MONITORING OF FOOD PROCESSES USING SUBSURFACE LASER SCATTERING

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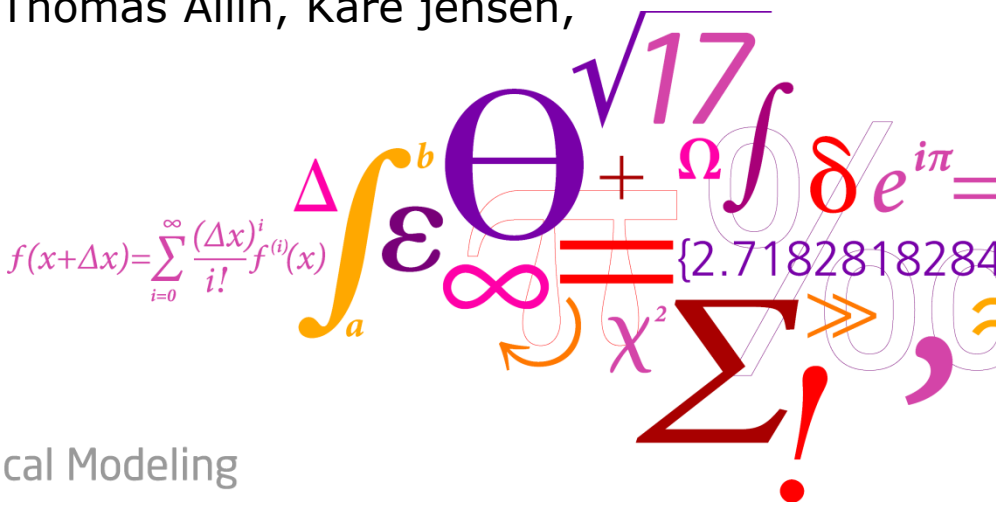


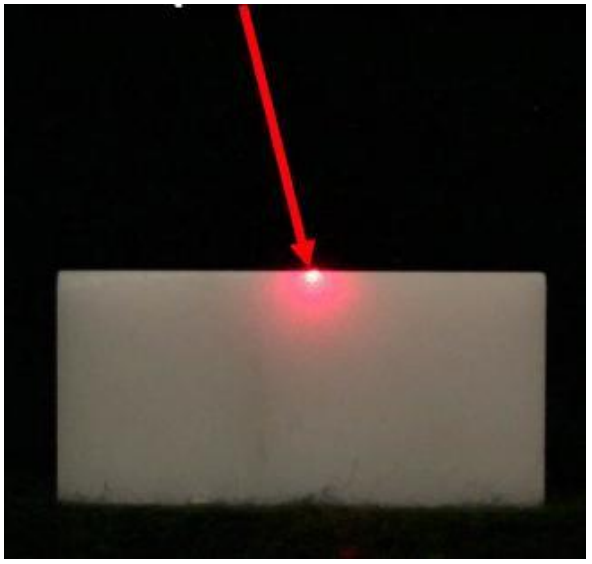
DTU Informatics
Department of Informatics and Mathematical Modeling

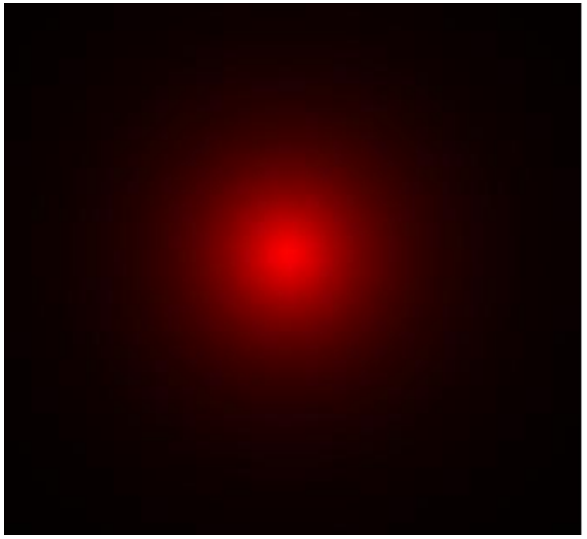
Sub-surface Laser Scattering (SLS)

Principle

The sample is illuminated using one or more laser beams and the image of the light spot backscatter is collected.

Data are then treated automatically in order to predict the physical characteristic according to strength and dispersion of backscatter.





Simulation studies

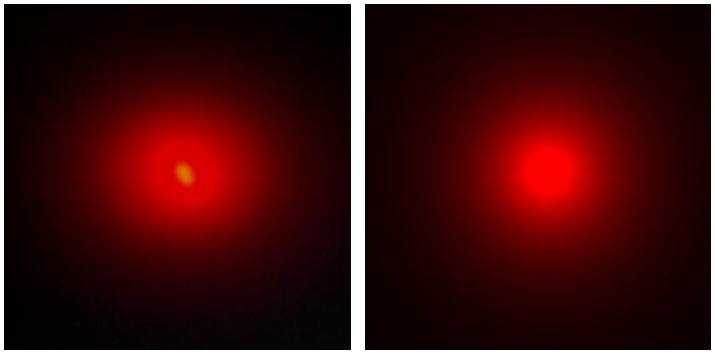
- How does light interact with colloidal systems like milk?
- Can we obtain qualitative and quantitative knowledge from simulations?
- Efficient simulation algorithms are coming up in the field of realistic rendering in computer graphics

water vitamin B2 protein fat skimmed reduced whole

- Artificially generated milk images based on light scattering simulations
- Rendering Method (Frisvad et al. 2007):
  - Stochastic Ray Tracing (Path Tracing)
  - Photon Mapping for caustics
  - Switching to isotropic scattering when far from boundaries (Similarity Theory)
- Rendering time:
  - Using a grid of more than 100 CPUs
  - Approximately 24 hours

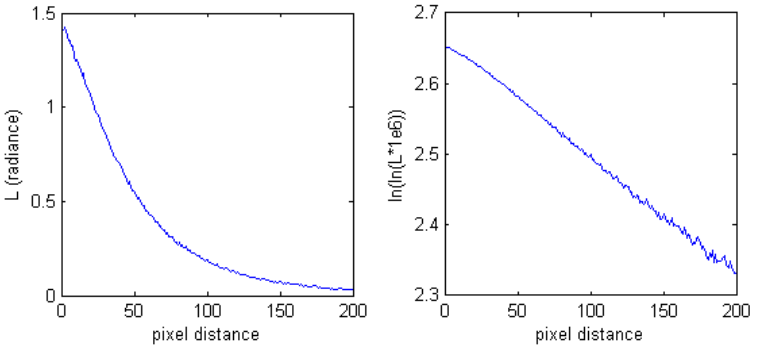
Simulating laser in milk

Example: 650 nm laser pen (c. 1 mW) in skim milk (fat: 0.1 wt.-%)



photo

rendering

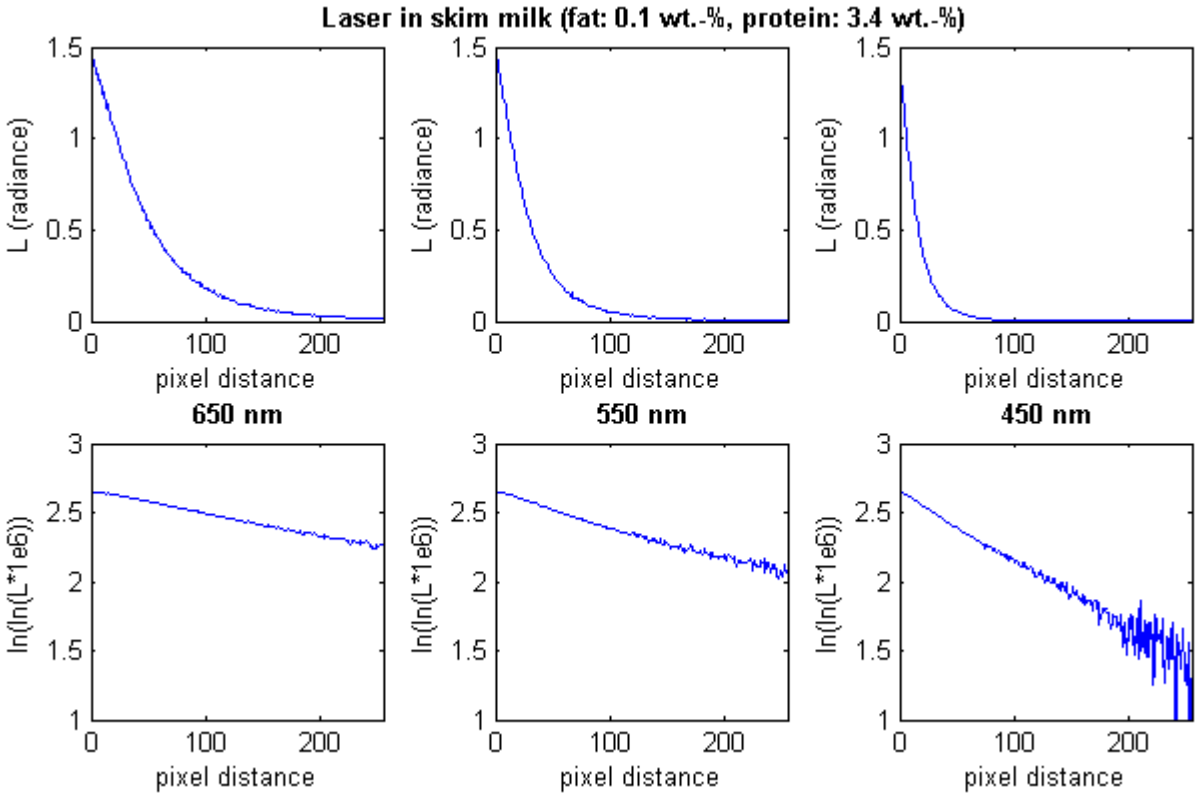


curve from center

- Milk is highly scattering
- A laser source is small and collimated
- Consequence: High variance in Monte Carlo simulation
- Many samples required = long rendering time

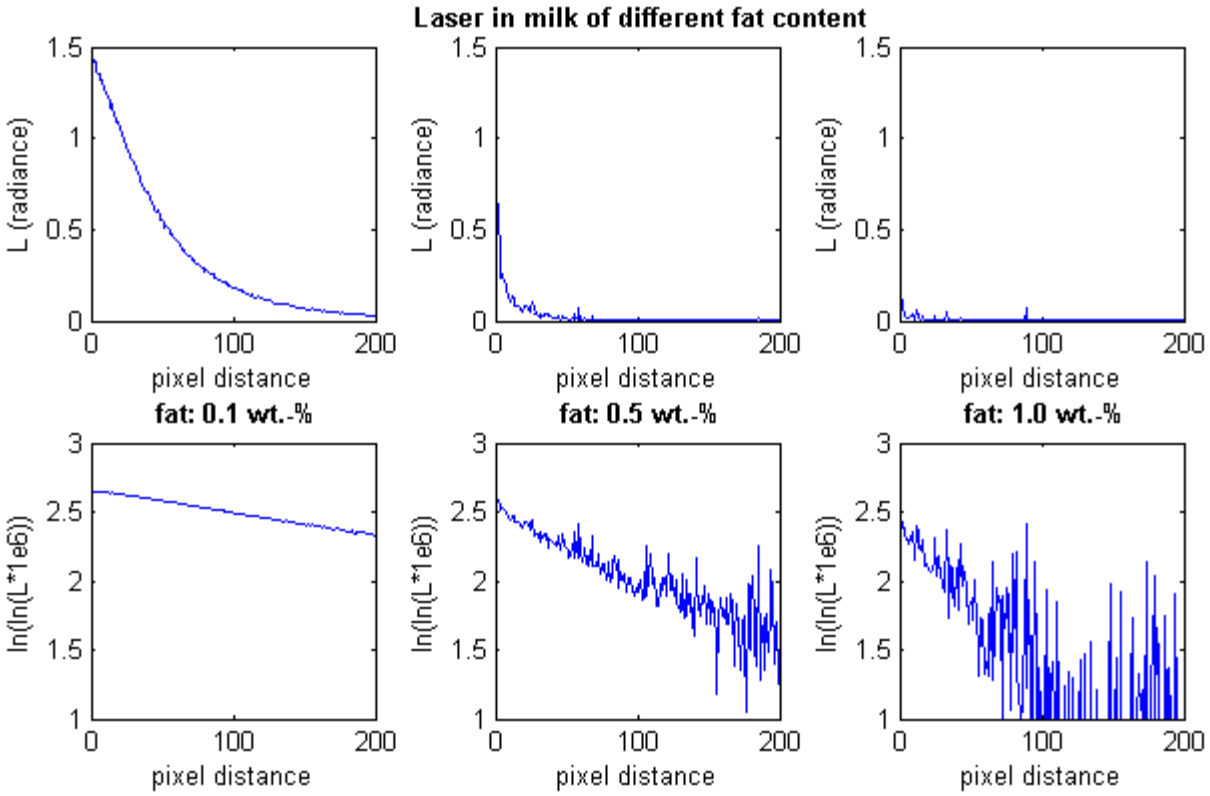
Preliminary observations

- SLS decreases with increasing wavelength



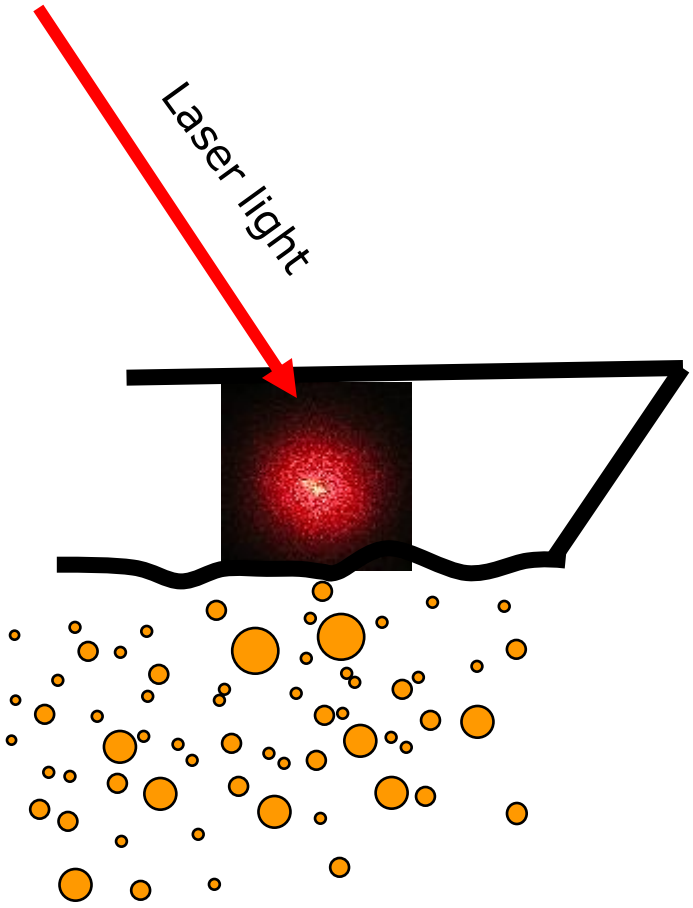
Preliminary observations

- SLS increases with increasing fat content

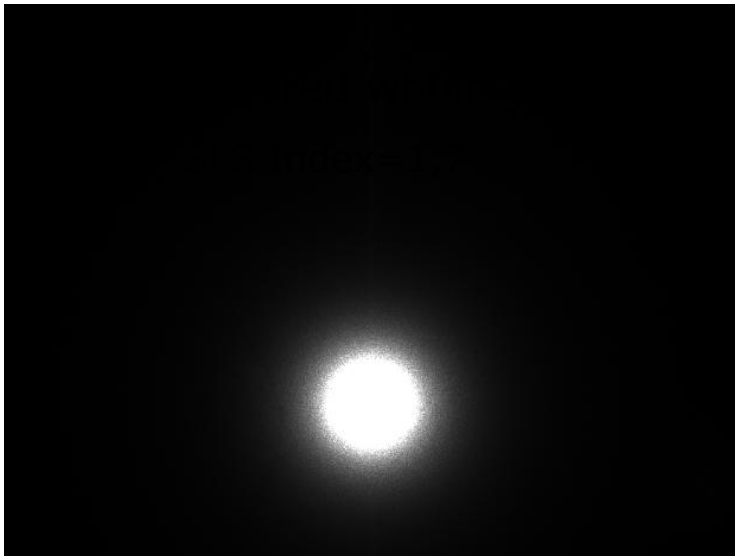


Sub-surface laser scattering

- Halo defined by product structure and chemistry.
  - Particle size
  - Concentration
  - Absorption
  - Refractive index
- Use: formulation and online
  - Drinks
  - Emulsions
  - Foam/bread
  - Gels
  - Suspensions



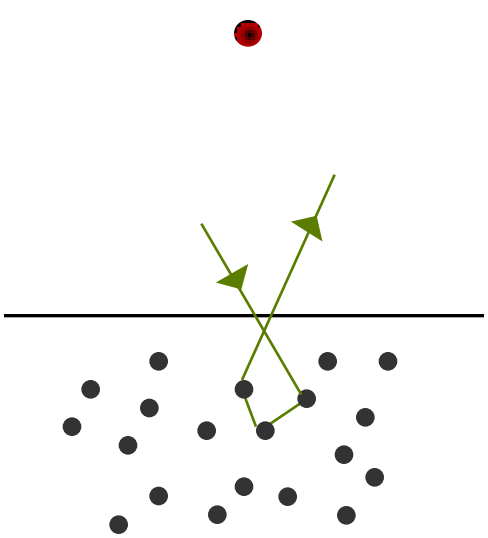
Sub-surface Laser Scattering (SLS)



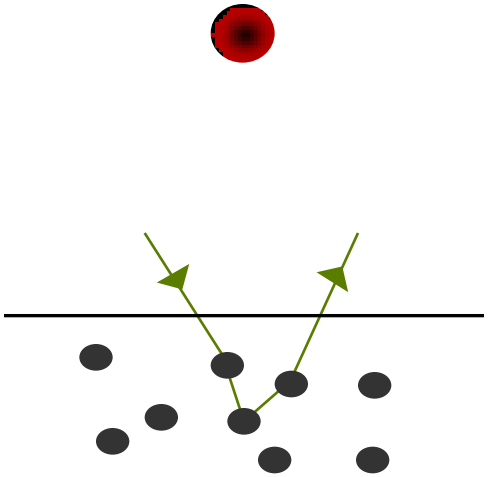
Example:
SLS slope using a laser of 650 nm

New possibilities with multiple SLS wavelengths from 375 nm to 1050 nm.

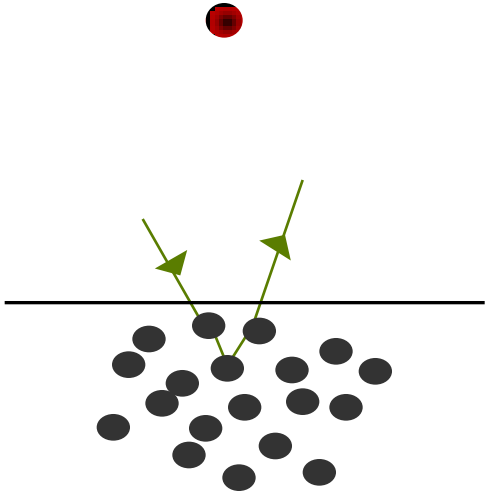
Sub-surface Laser Scattering (SLS)



Small particles
Small dot
(High SLS)



Large particles
Large dot
(Low SLS)

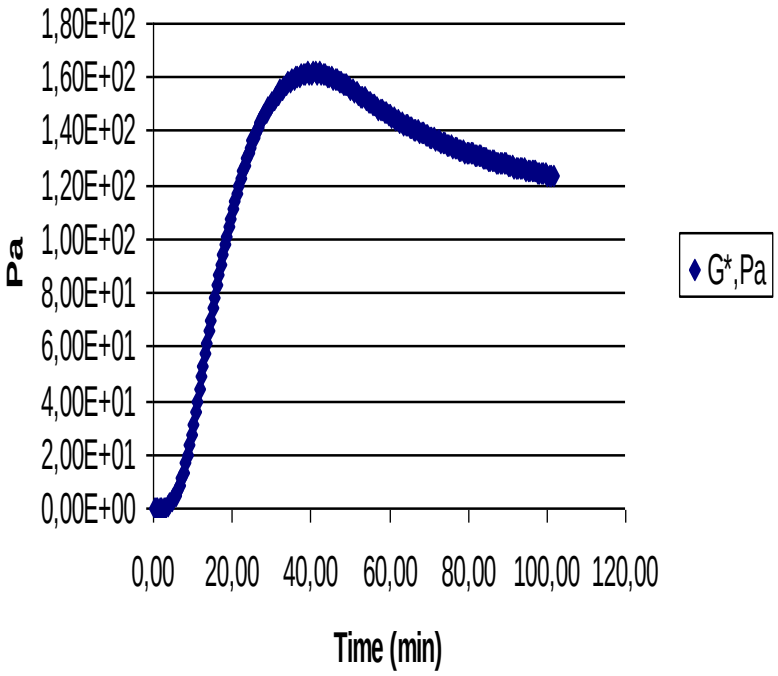


High concentration
Small dot
(Higher SLS)

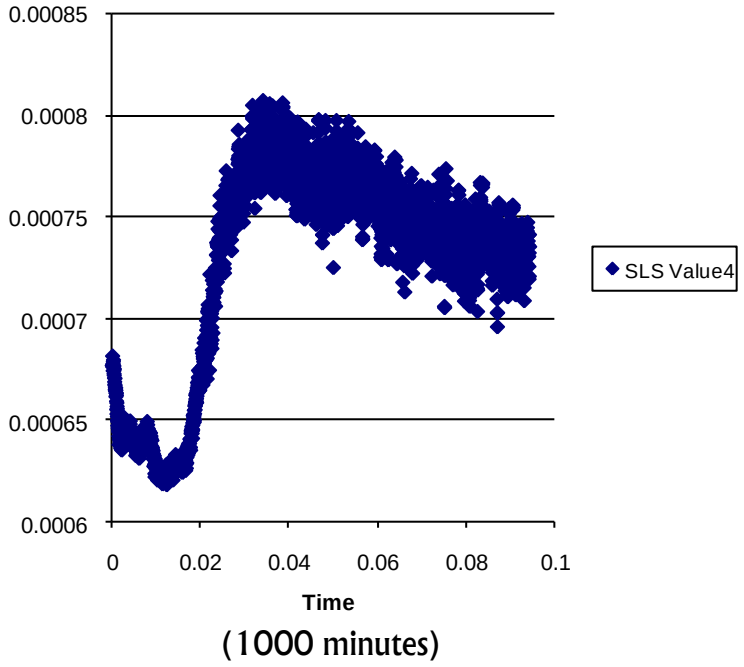
High concentration $\Rightarrow$ high SLS
Large particle size $\Rightarrow$ low SLS
Reflection $\Rightarrow$ high y

Optical rheology in milk fermentation

Rheology



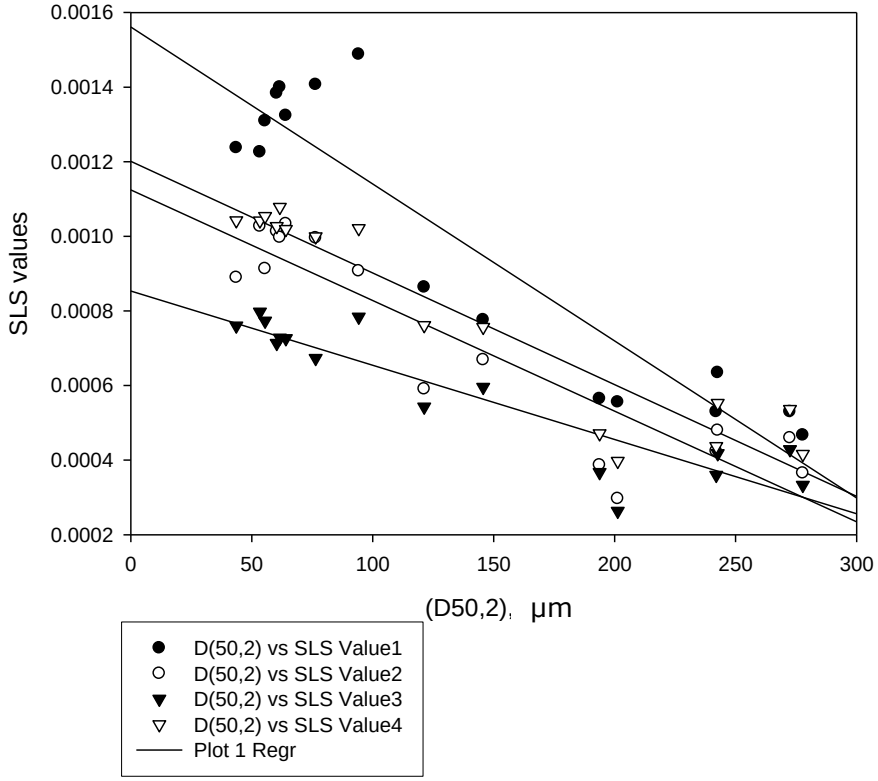
SLS slope



Source: Danisco

Foam bubble size estimation

Whipped cream and egg white foam



Curve 1:
SLS Value 1:
Coefficients:
b[0]1.5610300499e-3
b[1]-4.2075597198e-6
r ²0.8575047787

Curve 2:
SLS Value 2:
Coefficients:
b[0]1.1243021266e-3
b[1]-2.9653834483e-6
r ²0.8398168158

Curve 3:
SLS Value3:
Coefficients:
b[0]8.5329134545e-4
b[1]-1.9897190641e-6
r ²0.8361537302

Curve 4:
SLS Value4:
Coefficients:
b[0]1.200909817e-3
b[1]-2.9935743947e-6
r ²0.8956097736

D(50,2) is a measure of average bubble size

Source: Danisco

Why Use SLS?

- Unique and simple technology solving problems in processing
- Non destructive analysis method
- Results within seconds
- Objective method alternative to sensoric test panels
  - Independent of subjective judgement
- Enhanced production control
  - Follow texture in fermentation process
  - Control whipping process
  - Air bubbles and graininess may be quantified