

# Rheology for Relevant Benchmarking

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Industrial Rheology



**Rheology**

**Tribology**

**Texture**

**Powder Flow**

**Easy, Accessible  
and Economical**

**Sample Testing and Investigations**

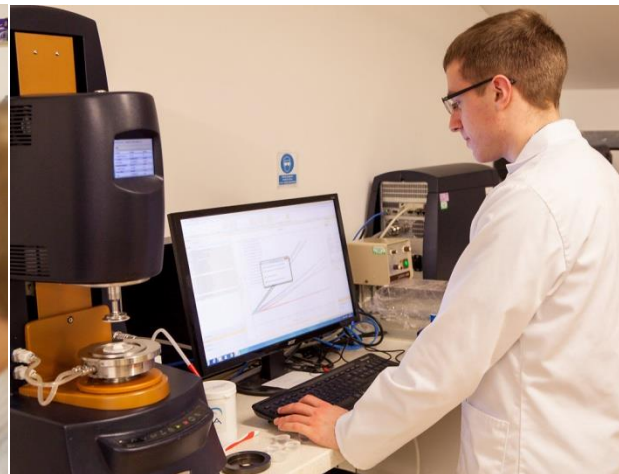
Expert method development and data-analysis with interpretation - for a fraction of the cost of setting up an in-house capability.

**Practical Training Courses**

Hands-on coaching to unlock the value of expensive rheometer installations and extend the reach of viscometer usage.

**Expert Advice and Support**

Test methods, purchasing equipment, troubleshooting measurement issues...



# Overview

- What is our sample?
- Viscosity – Context
- Structure
- Benchmarking needs for different products
- Further considerations

# Rheology:

The study of the  
flow and deformation of matter

Flow



Liquids

Viscous behaviour

Bounce-  
back-  
ability



Deformation



Solids

Elastic behaviour

# Traits of rheologically-complex materials

## Structured liquids

Exhibit solid-like behaviour when at rest but exhibit significant flow when an applied stress exceeds their *yield stress*.

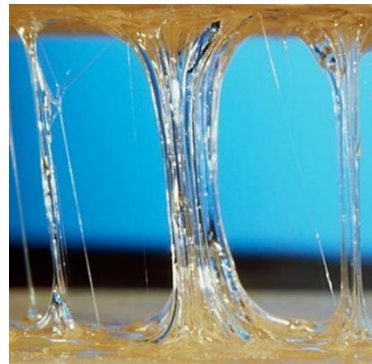


Suspensions: Oral pharmaceuticals, drinks and smoothies, conductive coatings.

Emulsions: Topical creams, mayonnaise.

## Viscoelastics

Liquids that wobble! Viscoelastic liquids often flow readily but can bounce to reveal an elastic aspect.



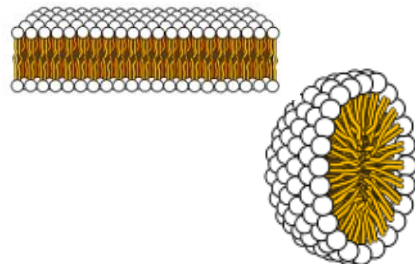
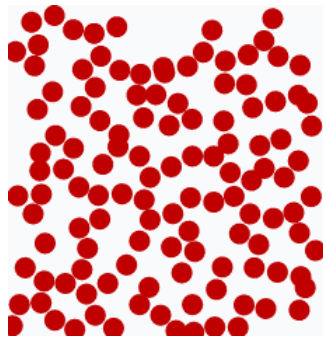
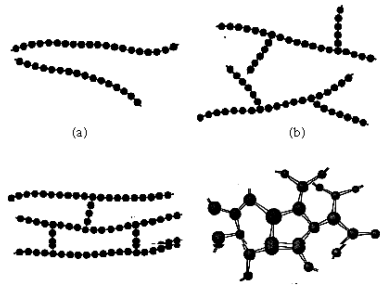
Polymer solutions: topical gels, food gums, hair styling gels.

Surfactant solutions: shower gel, hand soap, foam bath.

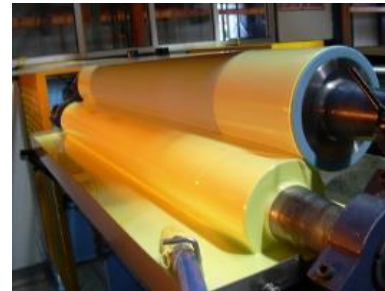
# What determines a product's viscosity?

## Microstructural composition

- Molecular weight of dissolved polymers.
- Dispersed phase volume fraction
- Dispersed particle or droplet size and size distribution
- Particle shape
- Continuous phase viscosity
- Flocculation and interaction



## Measurement (i.e. Environmental) Conditions

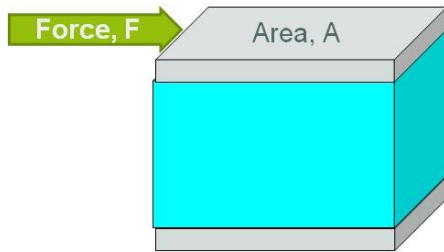


Shear intensity and duration

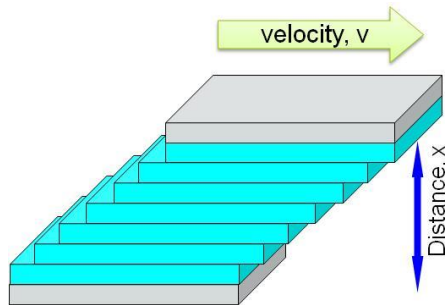


Temperature

# Defined shear measurements



$$\text{Stress, } \sigma = \frac{\text{Force, } F}{\text{Area, } A}$$



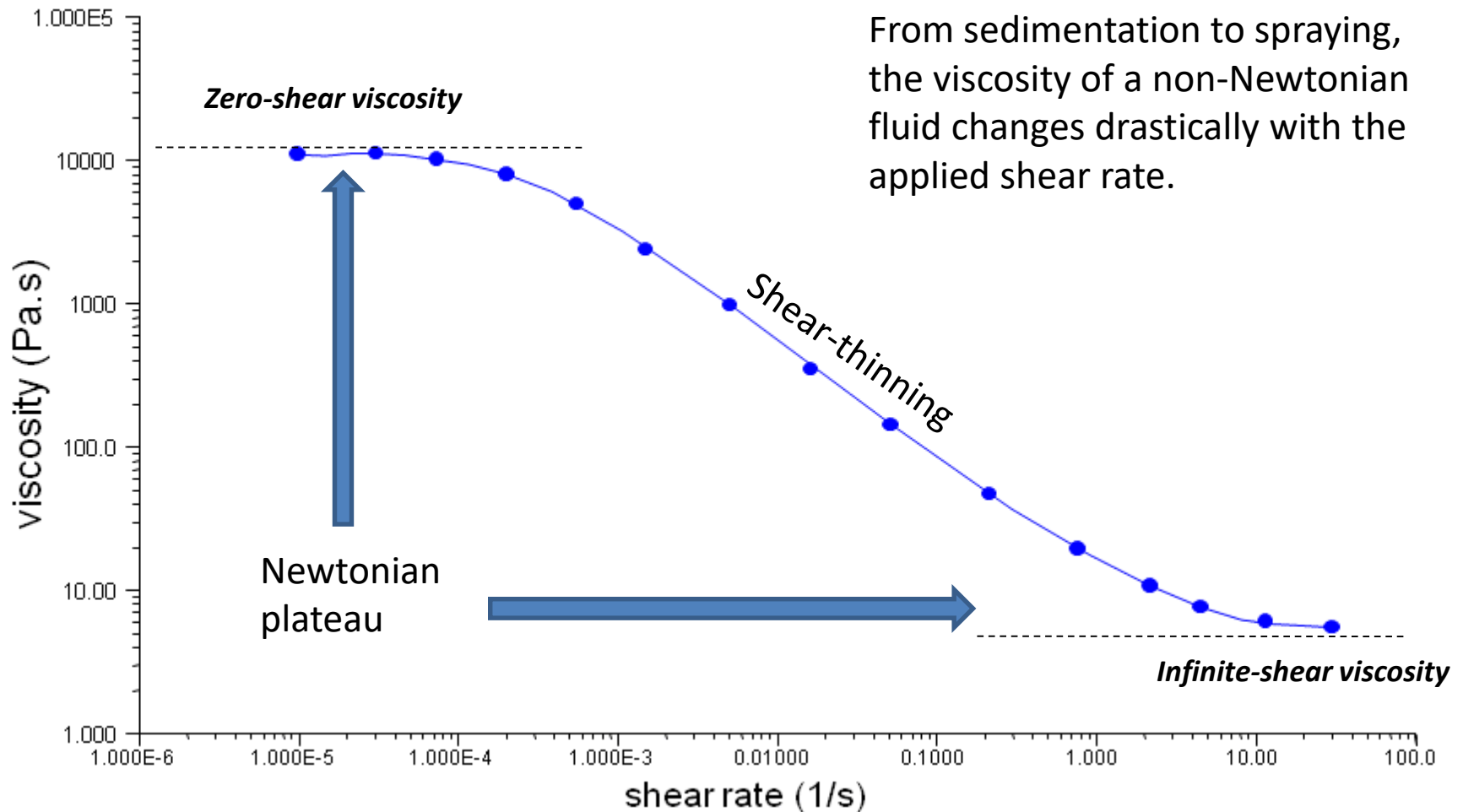
$$\text{Shear rate, } \dot{\gamma} = \frac{dv}{dx}$$

$$\text{Viscosity} = \frac{\text{Shear stress}}{\text{Shear rate}}$$

## “Defined shear” conditions:

- A thin layer of sample is sheared between two surfaces moving relative to each other.
- We can control and accurately measure the force, area, sample thickness and velocity.

# Shear Rate – What are we interested in?

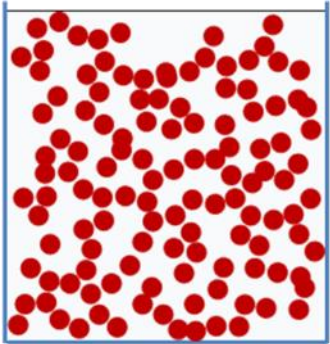




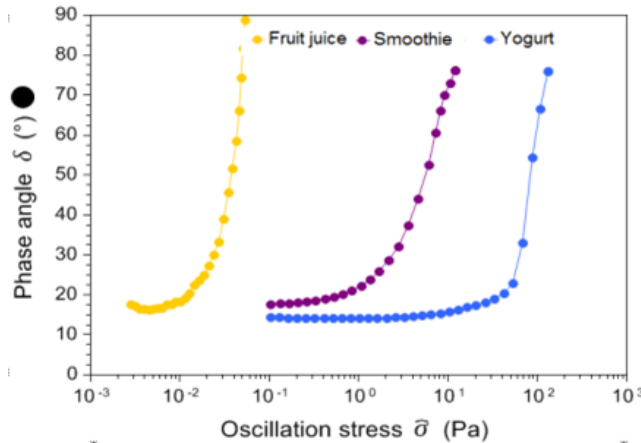
# Relevant shear rate?

Sedimentation	$10^{-6}$ to $10^{-4}$ s <sup>-1</sup>
Draining from surfaces	0.1 to 10 s <sup>-1</sup>
Pouring	10 to 100 s <sup>-1</sup>
Swallowing	10 to 100 s <sup>-1</sup>
Pumping and mixing	100 to 1000 s <sup>-1</sup>
Spreading	$10^2$ to $10^4$ s <sup>-1</sup>
Spraying	$10^5$ to $10^6$ s <sup>-1</sup>

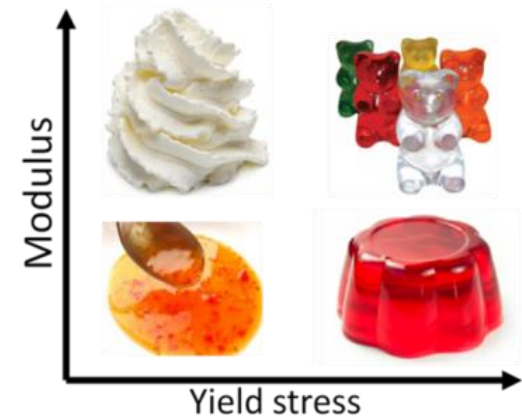
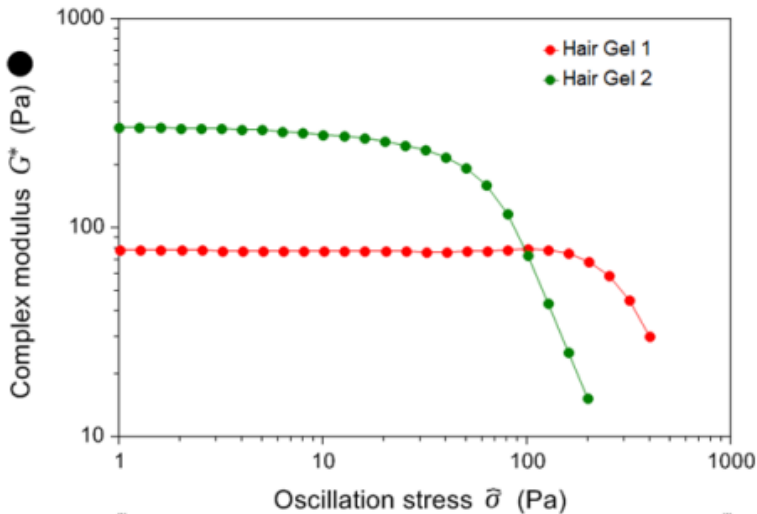
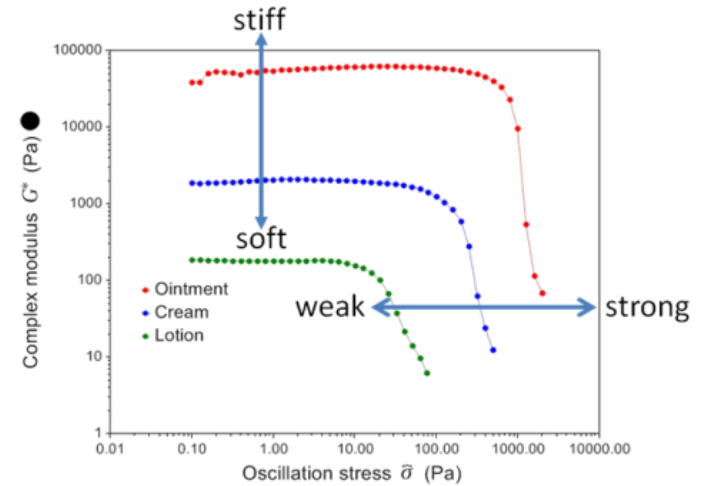
# Structure



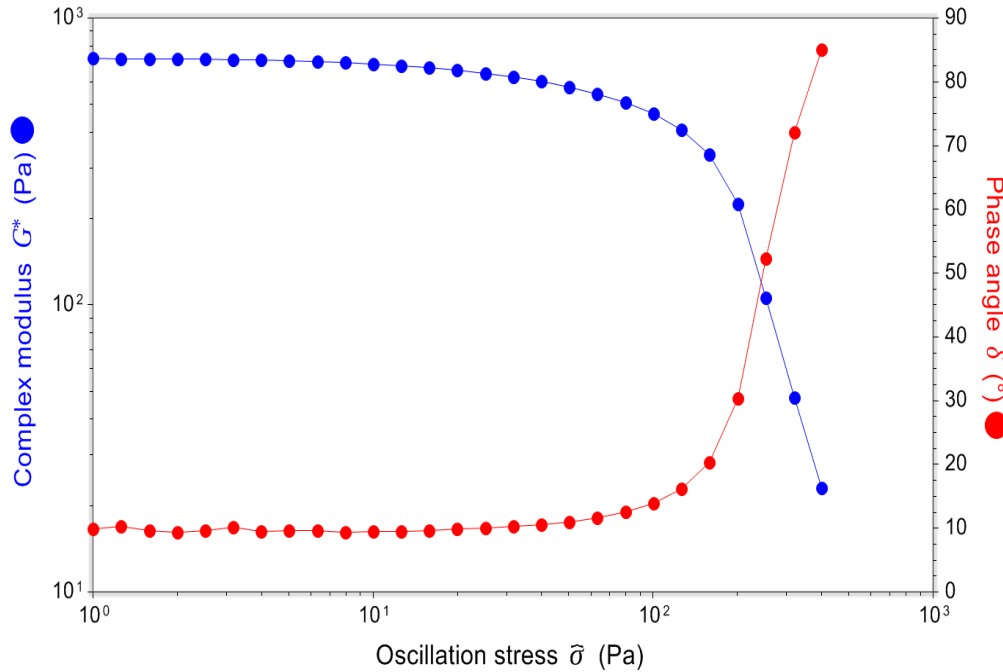
3-dimensional network interactions, for example generate an elastic response.



Stress and strain are in phase when structure is present. Rise in phase angle reveals yielding.



# Quantification

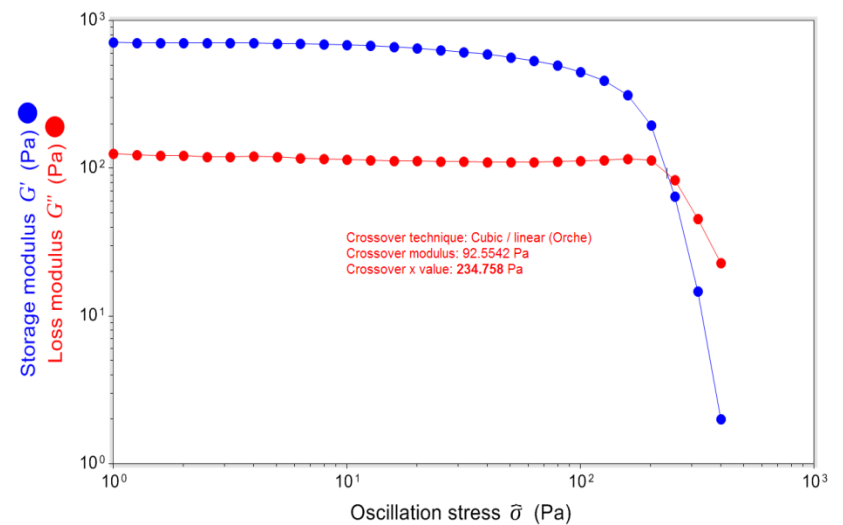
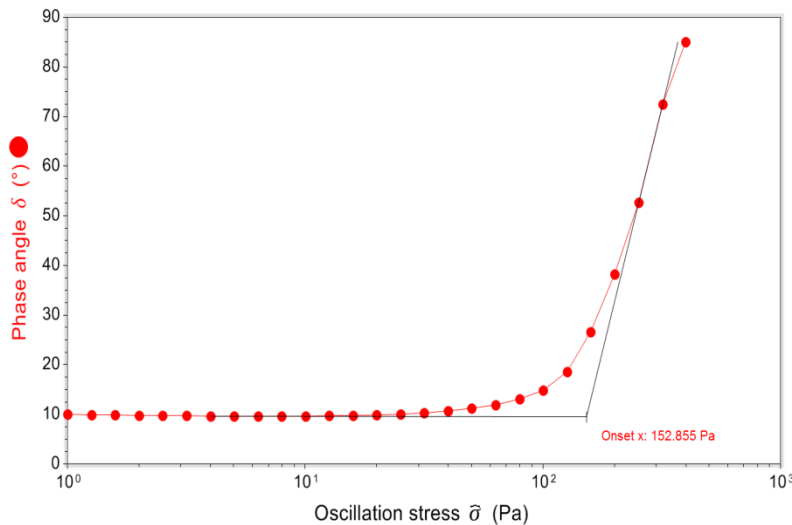


## Plateau Values

- Complex Modulus
- Phase Angle

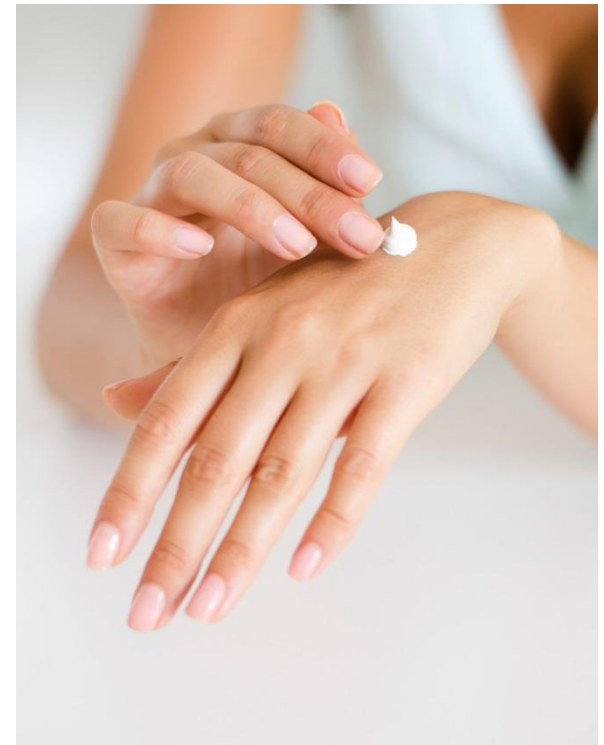
## Yield Stress

- Onset Point
- Modulus Crossover

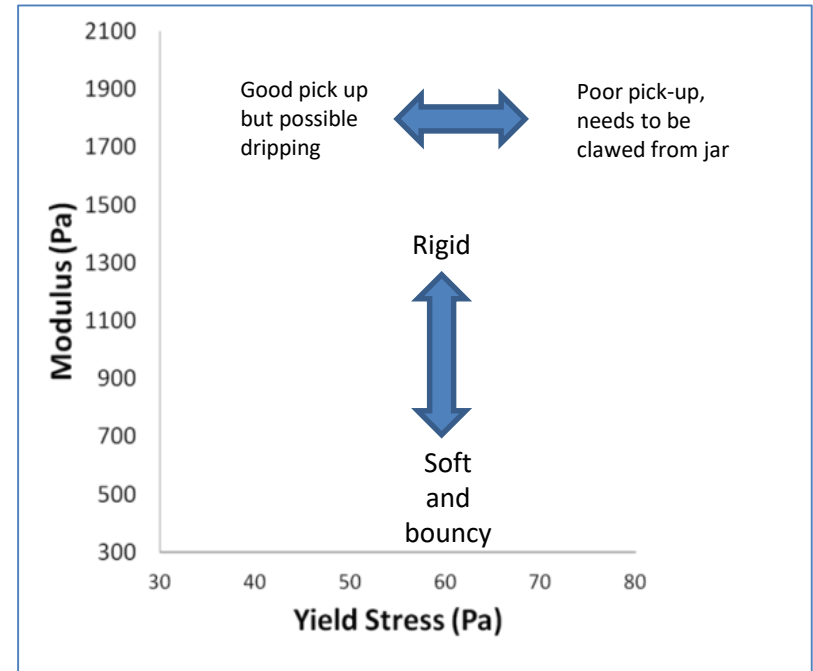
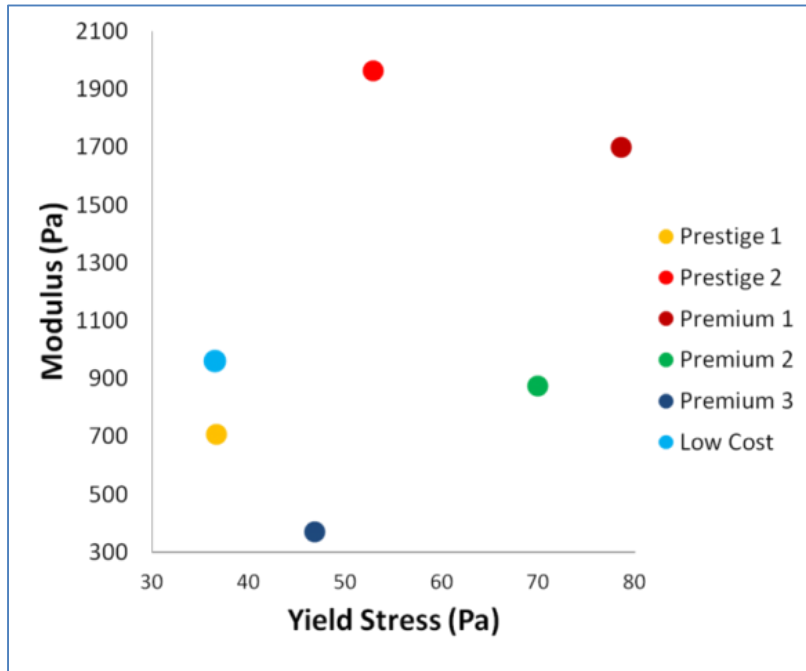


# Topical Products

- Benchmark based on focus
  - First Touch / Pickup
  - Spreadability
  - Force of extrusion
  - Suspension stability
  - Pumpability / processing

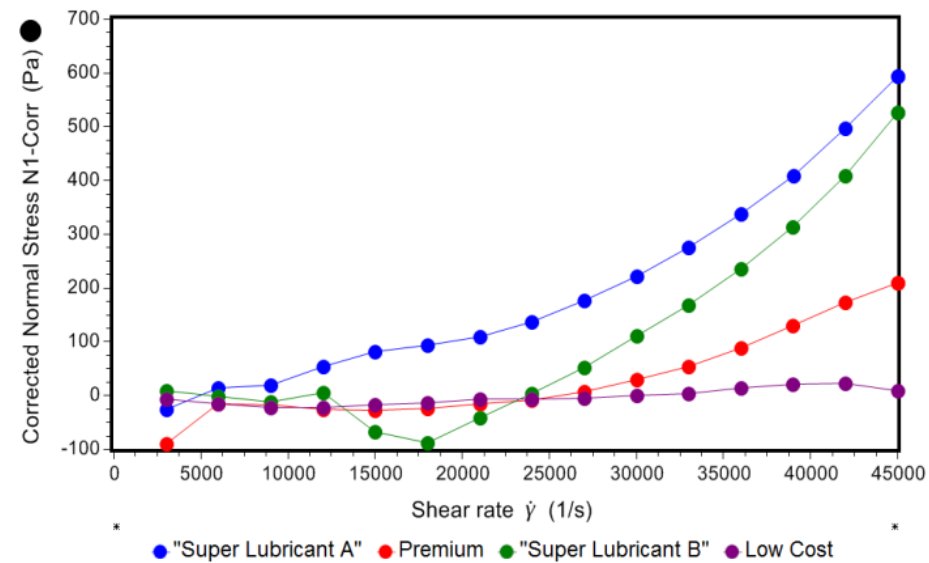
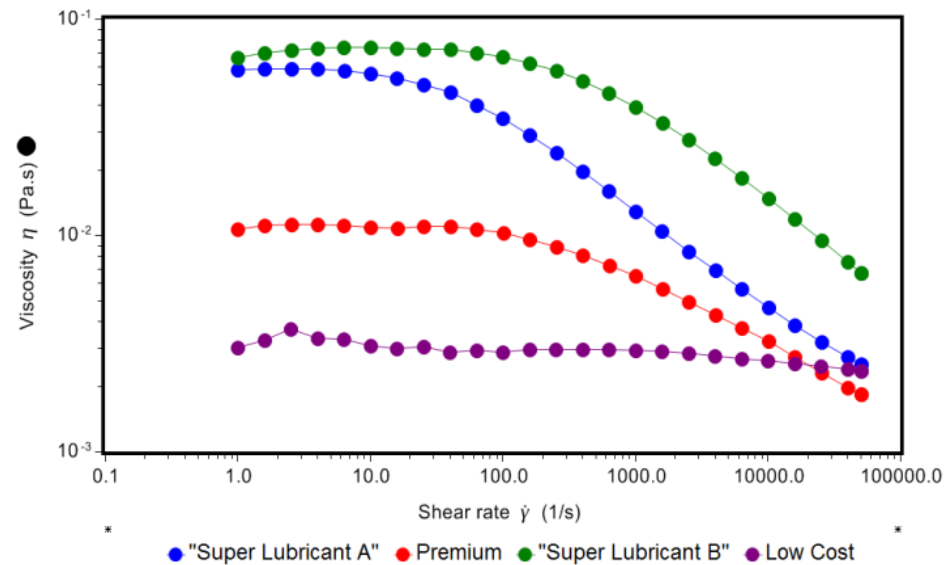


# Appearance, first touch and pick up of skincare



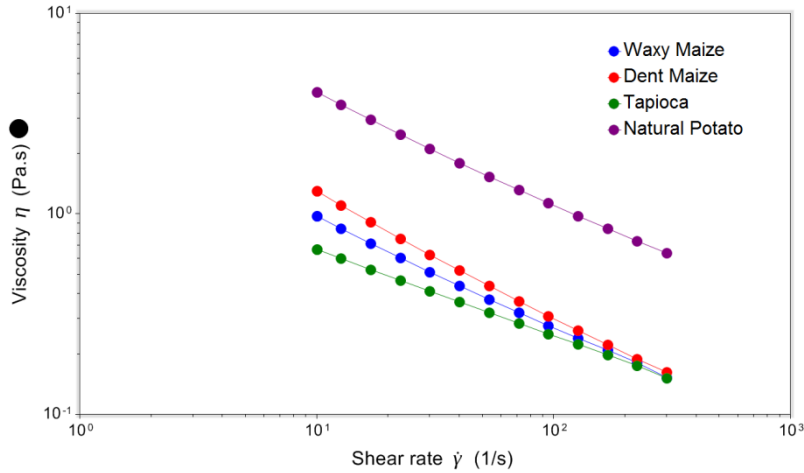
# Eye drop viscosity profiling

- Maximizing ocular residence time
- Minimizing blink resistance
- Formation of a lubricating film maintaining separation of eyelid and cornea

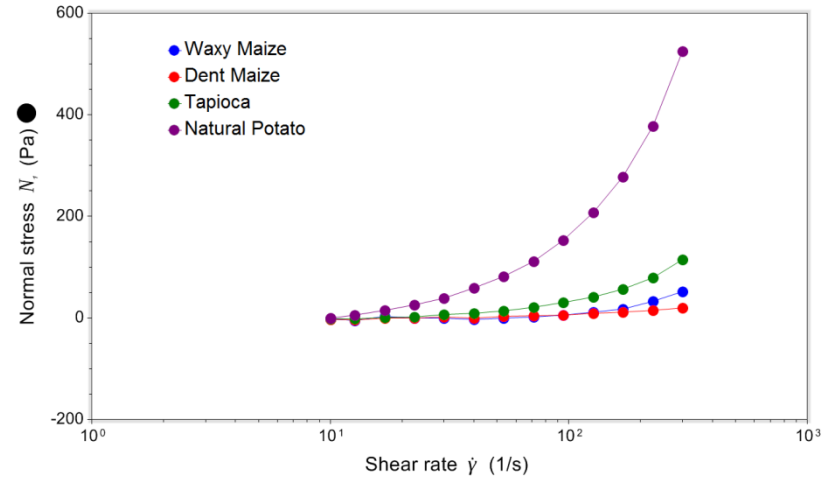


# Rheology of gelatinized starch gels

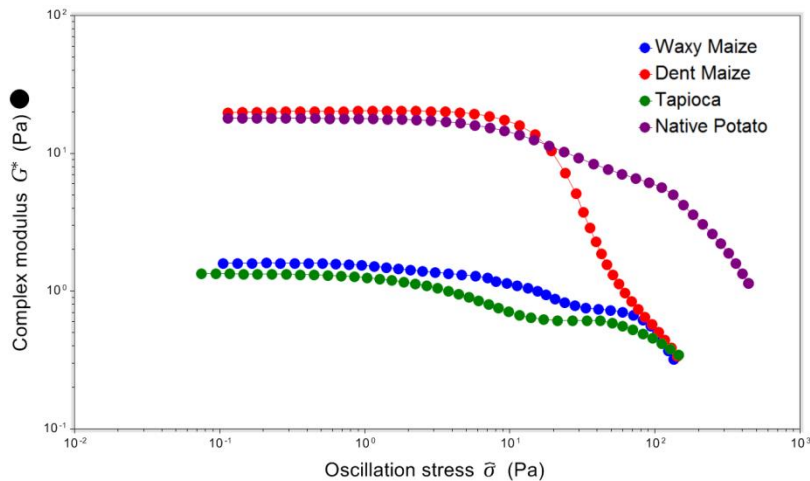
All 5% w/v, gelatinized then measured at 60°C. Rheology profiling reveals the wide variation on textures.



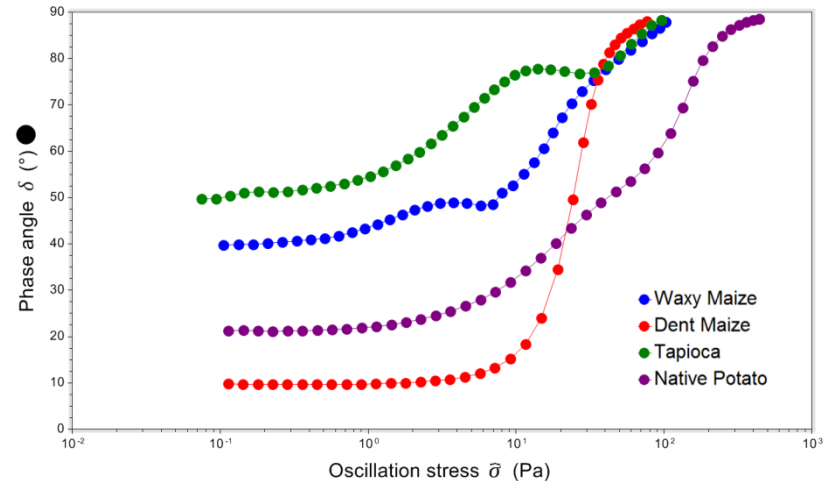
Viscosity/ shear rate profile



Normal stress under shear



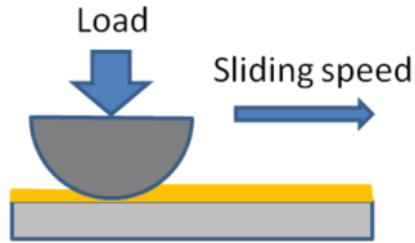
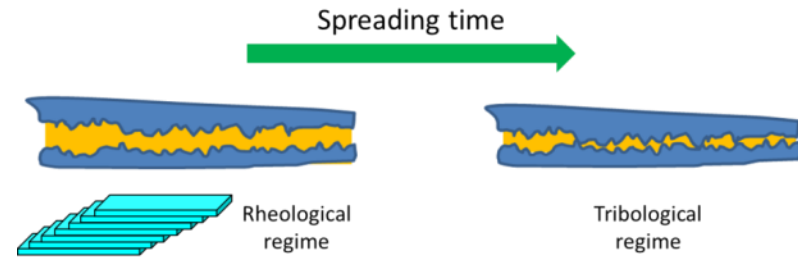
Complex modulus / shear stress for rigidity and yield stress



Phase angle / shear stress for structure and yield stress

# Topical Products: Friction and lubrication

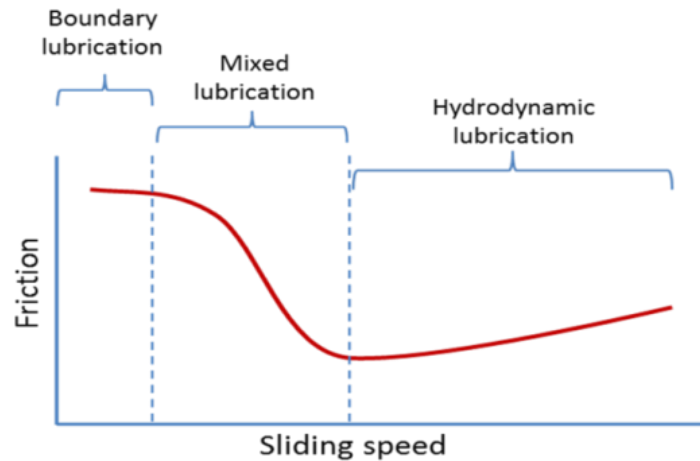
In the later stages of application surfaces come into close contact. Asperities (surface peaks and troughs) interact and a tribological regime is approached.



$$\text{Coefficient of friction} = \frac{\text{Sliding force}}{\text{Load}}$$



Boundary lubrication feels intimate, with surfaces in close contact.



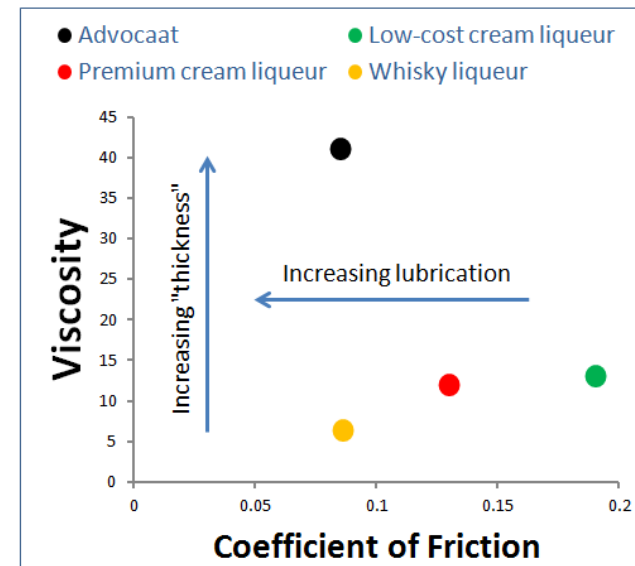
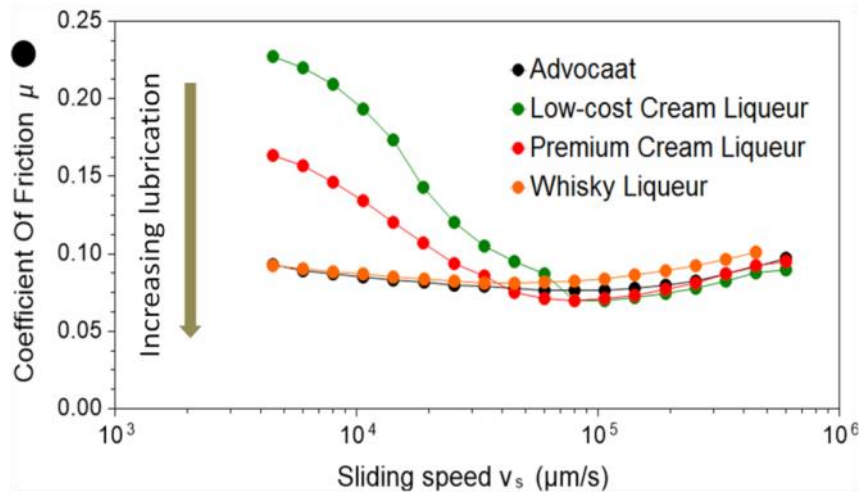
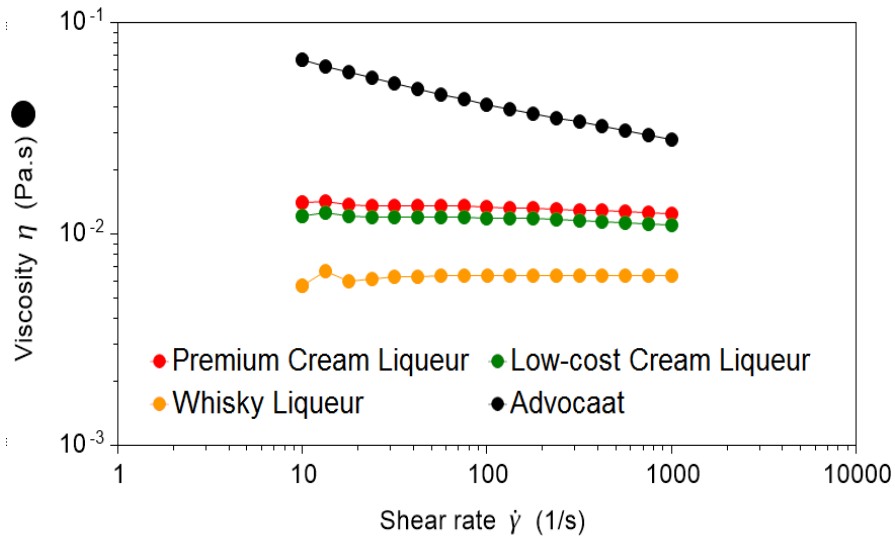
A consequence of hydrodynamic lubrication

Extensional resistance can promote fluid-film lubrication



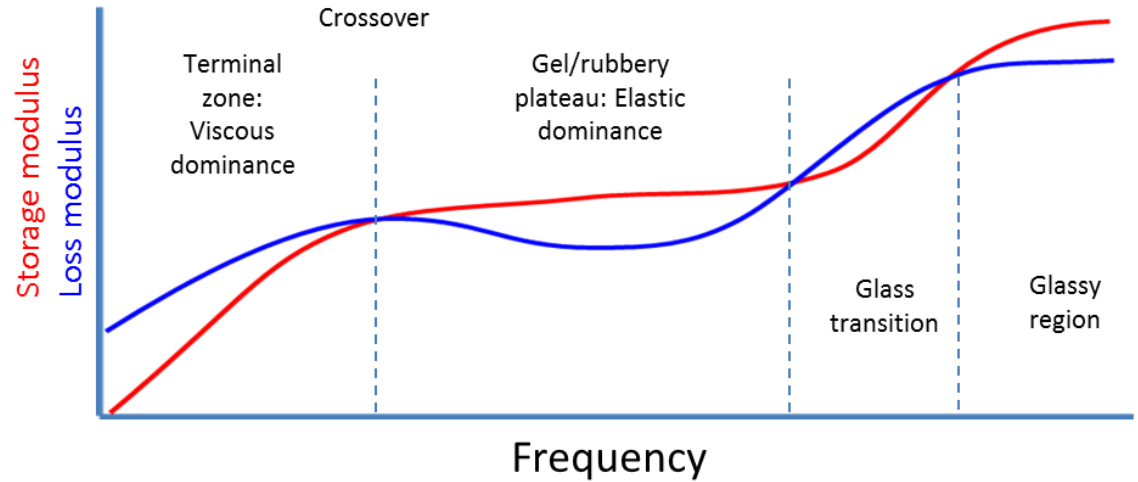
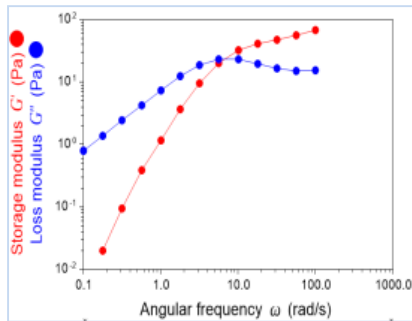


# Tribology and rheology profiling of liqueurs

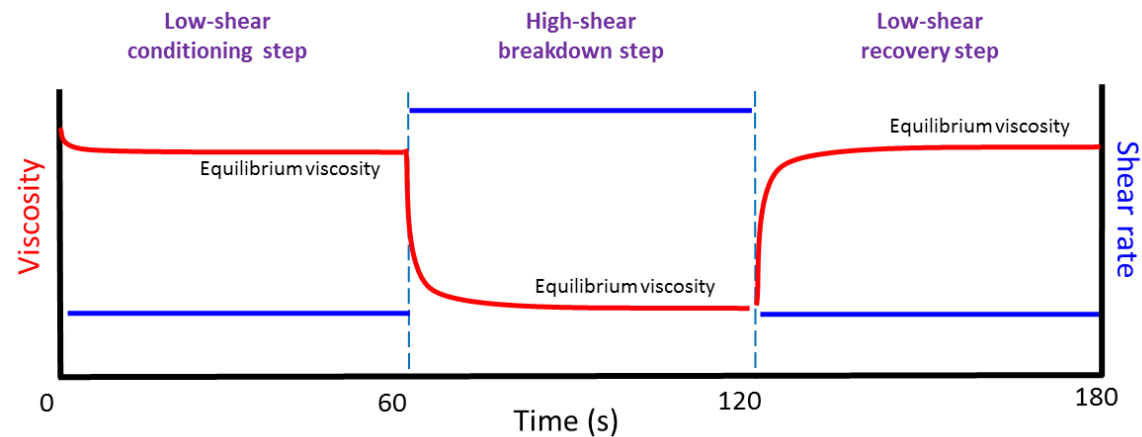


# Further Rheological Analysis

## Oscillation Frequency Sweeps



## Analysis of Thixotropic Properties



# Other Areas of Import

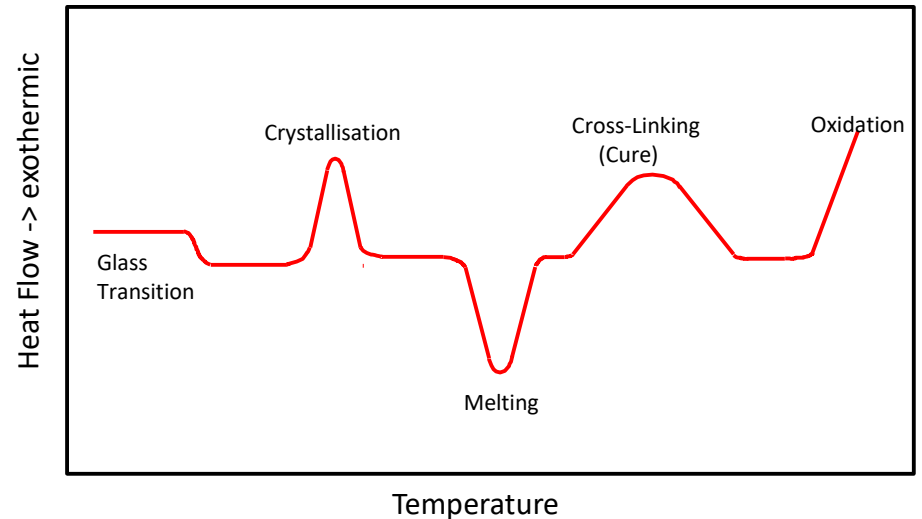
- **Surface tension**

- Sessile and pendant drop methods for exploring interface properties



- **DSC**

- Transitions measured include Glass transition ( $T_g$ ), melting, crystallization, curing and cure kinetics, oxidation and heat capacity



# Summary

- When attempting to benchmark a sample it is important to question the relevance of any measurement.
  - What differentiates these products?
  - Does the viscosity impact on the performance? What shear rates will be applied during use?
  - Is there a structure present within the sample?
- The tests relevant for benchmarking are heavily dependent on the **samples** of interest but also the **reason** for the benchmarking.

# Thank you for your time

