The Soft Matter Kitchen: Exploring Viscoelasticity through Dairy Products

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Society of Rheology (SoR)

- Founded December 19, 1929
- "We aim to expand the knowledge and practice of rheology through education, partnership and collaboration with associated fields, industries, and organizations, as well as to disseminate to diverse communities what rheology is, and how it impacts humanity and the world."

- https://www.rheology.org/sor/

What is Rheology?

- Study of the flow of matter
- Focuses heavily on **non**-Newtonian fluids
- Has applications in materials sciences, industry practices, engineering, pharmaceuticals, etc.

Newton's Law of Viscosity:

$$\tau = \eta\dot{\gamma}$$

Stress = viscosity constant × rate of deformation


SOFT MATTER
KITCHEN

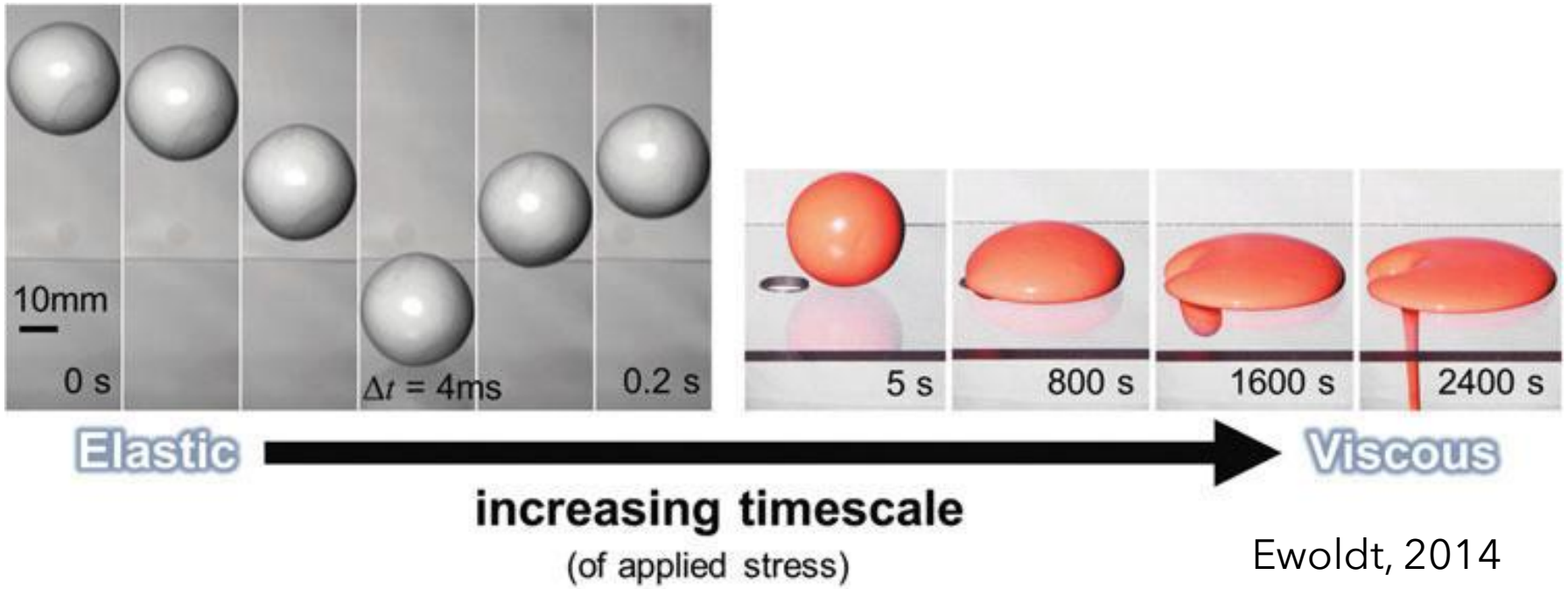
Soft Matter Kitchen

Created by Arif Nelson

Dedicated to making Rheology accessible and understandable through food

Includes variety of recipes and material analysis

https://www.arif.zone/home/kitchen



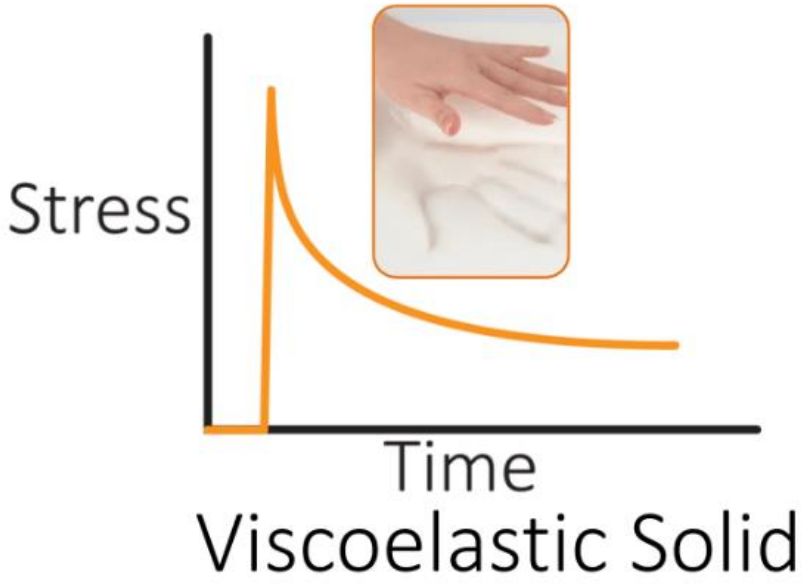
Ewoldt, 2014

Viscoelasticity

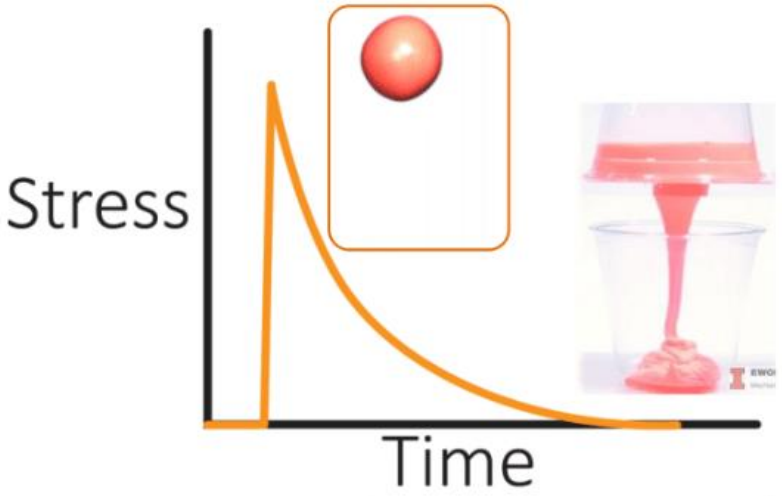
- Property that describes materials exhibiting both solid and fluid-like behavior
- Timescale-dependent: Both the rate at which force is applied and the duration of the force being applied matter

Timescale Dependance

- Built up stresses will relax over time
- Shorter timescale results in more solid-like behavior
- Longer timescale results in fluid-like behavior



Viscoelastic Solid



Viscoelastic Liquid

Protorheological Demonstrations to Analyze Timescale Behavior

Hossain et al. Journal of Rheology Accepted

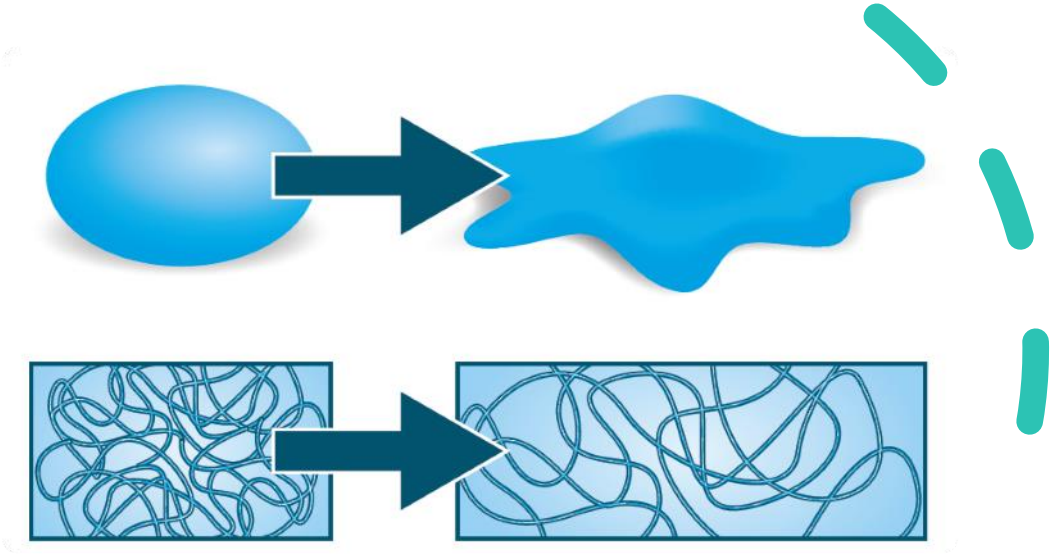
Edible Silly Putty

Beam Displacement Test

Bounce Test

Edible Silly Putty

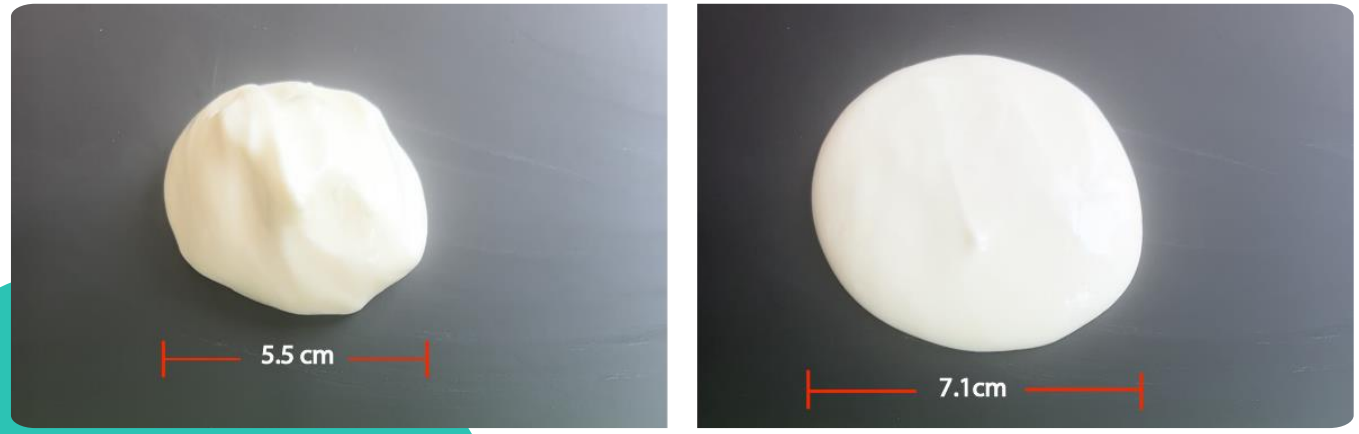
- Cornstarch and Yogurt
  - Ratio depends on thickness of yogurt
- Excellent example of Timescale Dependance
  - Try pulling apart both fast and slow and observe
- Demonstrates Creep



Creep

- Applying a constant force results in increase in deformation over time
  - Shown by letting silly putty expand over time due to gravitational force
- Example of longer timescale behavior

Edible Silly Putty Before and After Resting for 3 minutes
1 tbsp yogurt : 2.5 tbsp cornstarch



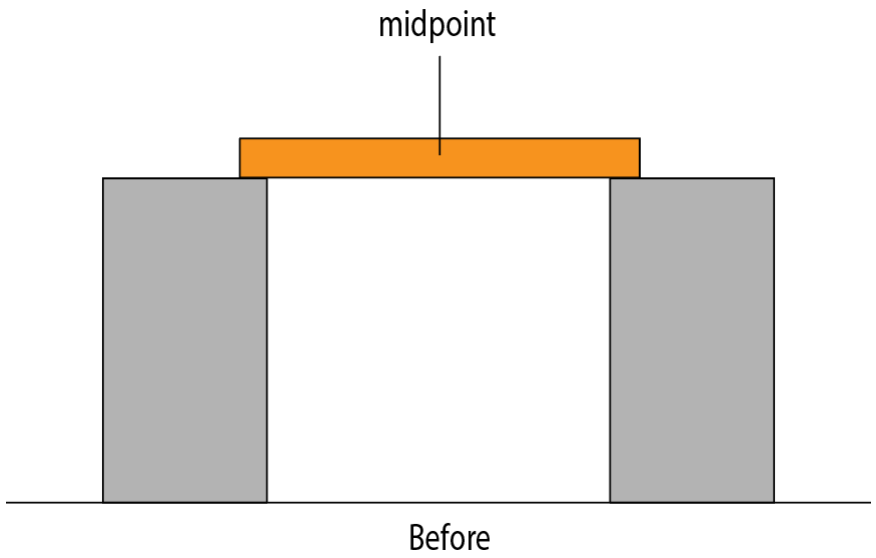
Cheese!

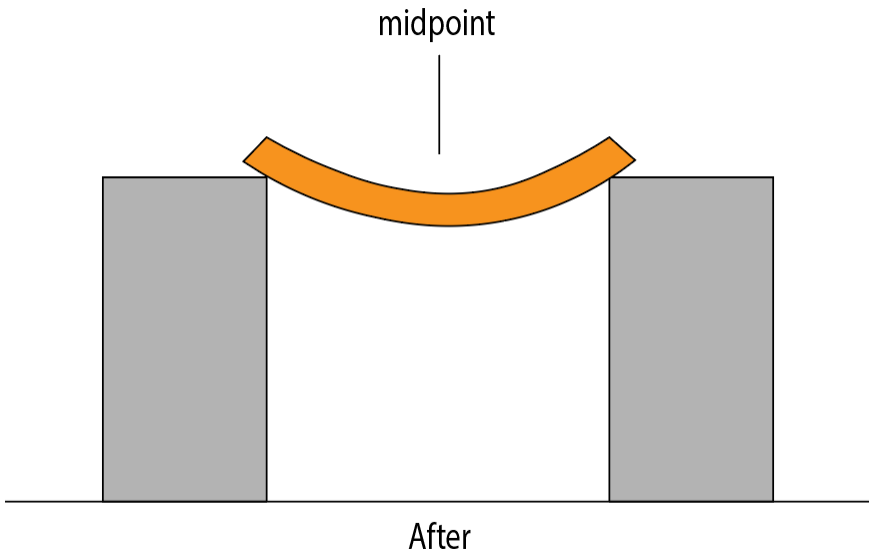
- Regular Cheddar
- Cashew-Based Cheddar
- Potato-Based Substitute
  - Potato
  - Seasonings
  - Almond Milk
  - Vegetable Oil
  - Lemon Juice

Beam Displacement Test

$y(t) = 0 \rightarrow$ Perfect Solid
$y(t) > 0 \rightarrow$ Viscoelastic

- Place slice of cheese between two support beams
- Measure displacement of midpoint [y(t)] over time (5 minutes)
- Example of longer timescale behavior



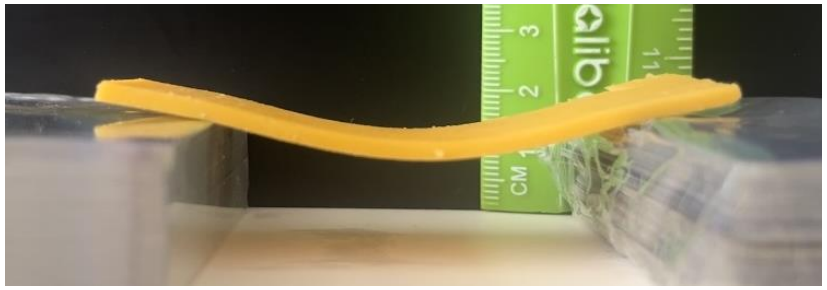


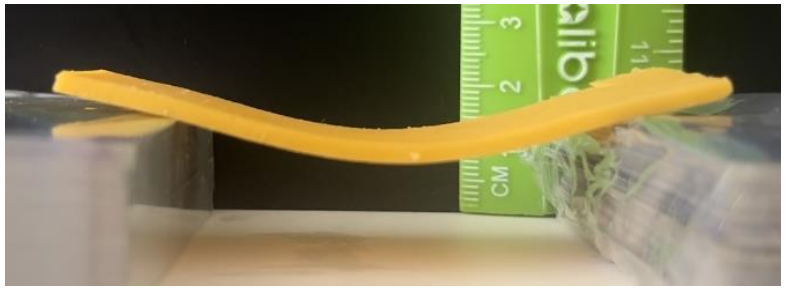
0 minutes

5 minutes

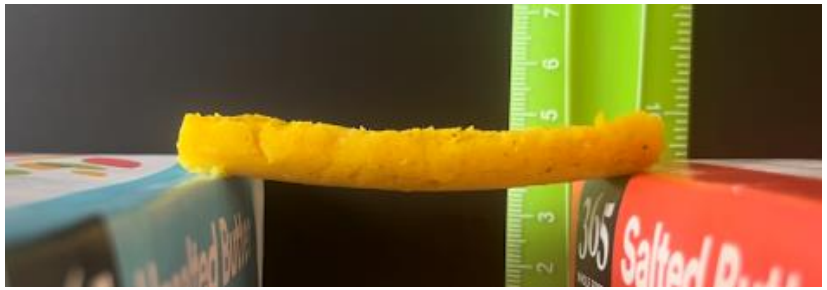
Regular

Cashew-Based



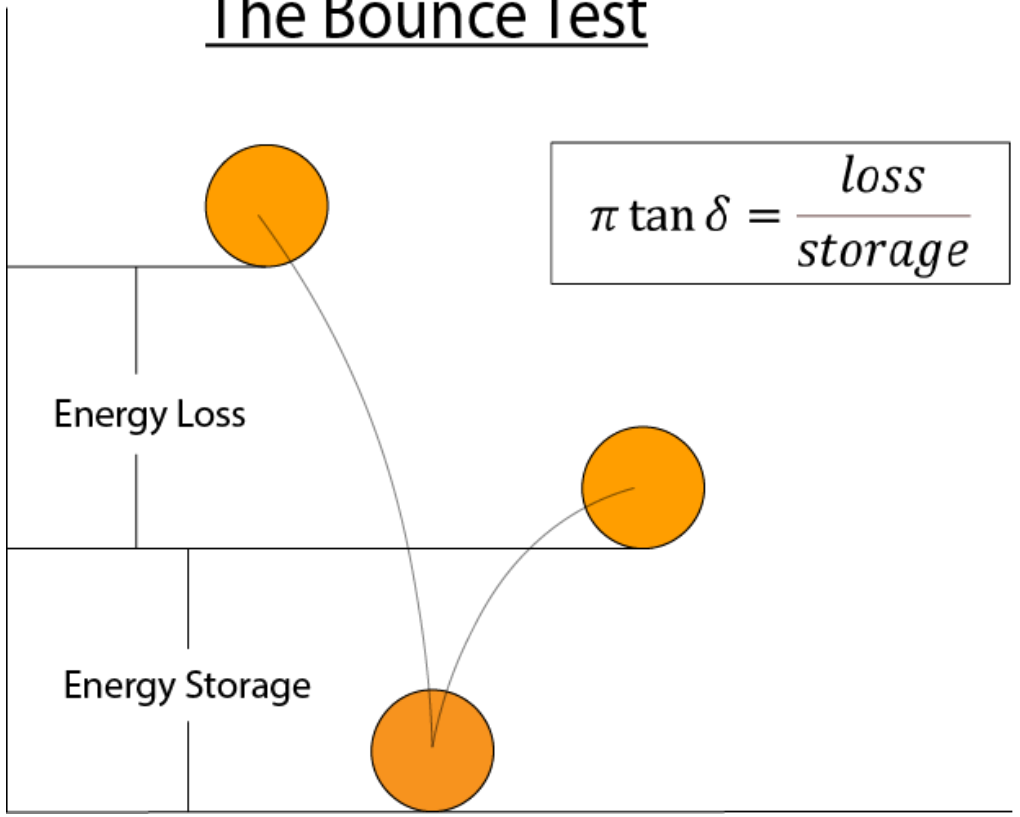


Potato-Based

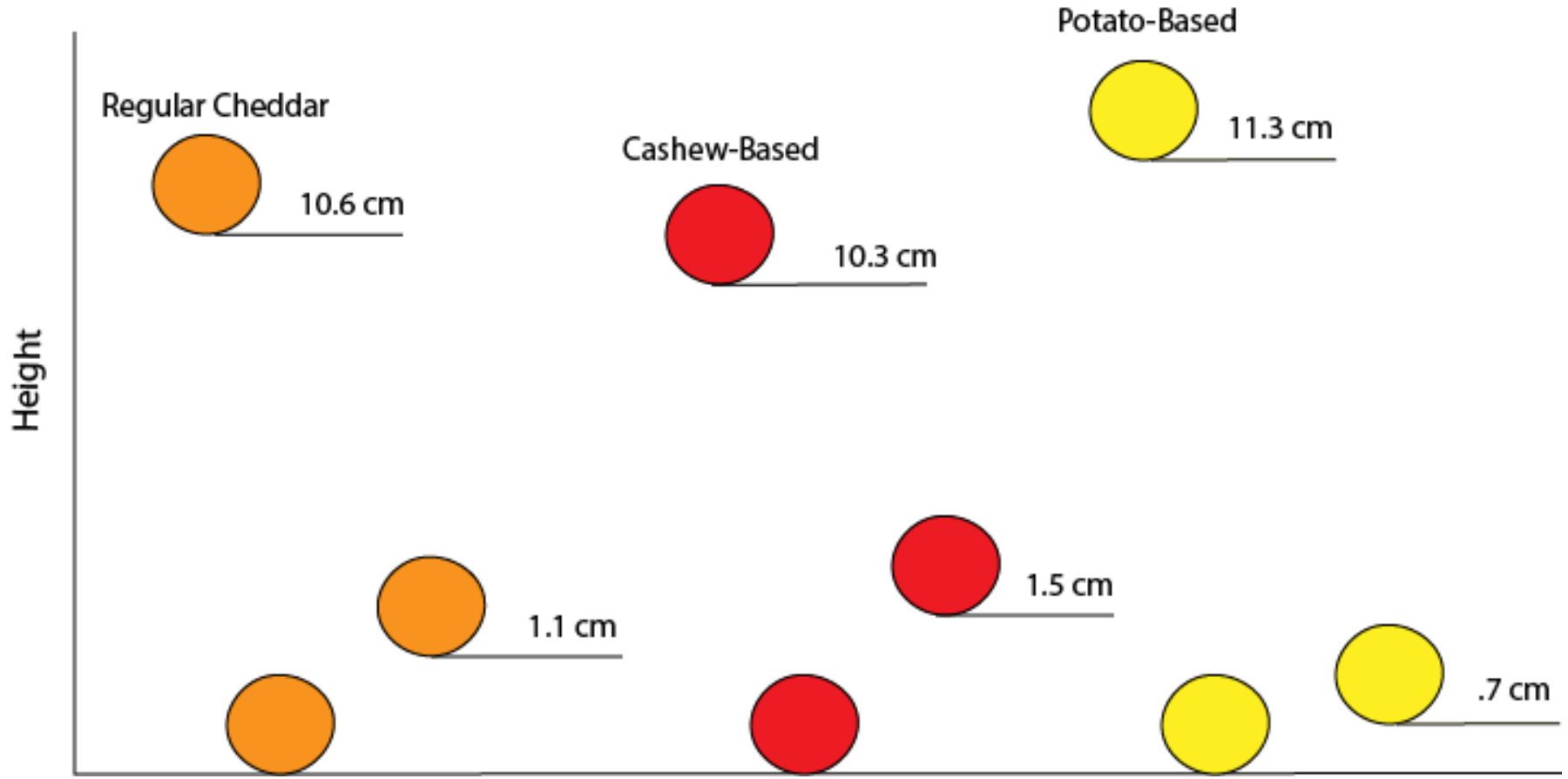


Bounce Test

- Uses drop and rebound bounce height to solve for $\tan\delta$
- Output value tells us where material lies on range of viscoelasticity
  - If $\tan\delta \sim 0 \rightarrow$ elastic solid
  - If $\tan\delta \sim \infty \rightarrow$ liquid

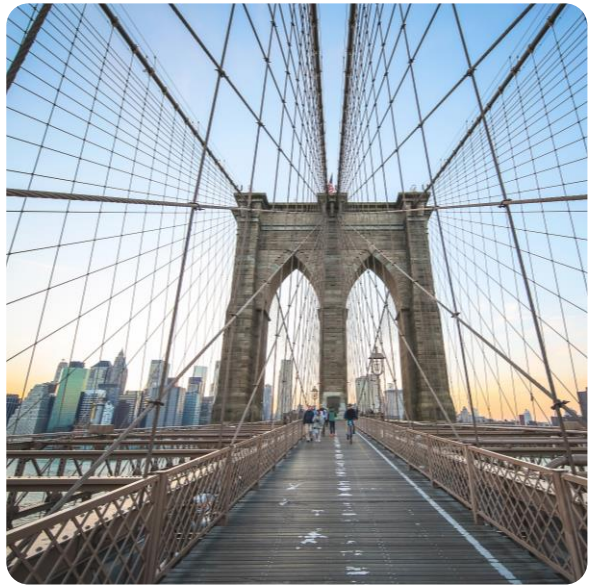


Drop and Rebound Bounce Height of 3 Cheeses



1. Cashew-Based → $\tan\delta = .885$
2. Regular Cheddar → $\tan\delta = .721$
3. Potato-Based → $\tan\delta = .613$

$\tan\delta \sim 0 \rightarrow$ elastic solid
$\tan\delta \sim \infty \rightarrow$ liquid



Final Thoughts and Takeaways

- Rheology has a variety of applications across many different fields
- At-home demonstrations / analysis methods encourage understanding of Rheology and Viscoelastic concepts
- Dairy-Free Cheese substitutes are not worth the hassle and will stink up your kitchen

SINGAPORE INSTITUTE OF TECHNOLOGY

Arif Nelson

SOFT MATTER KITCHEN

Thank you to all those that have supported me throughout my time as the SoR / Soft Matter Kitchen Intern including my mentor, Arif Nelson, as well as **Brad Conrad**, Mikayla Cleaver, Kayla Stephens, and everyone involved in creating and continuing the SPS Internship program!