# Introduction to Rheology of Agricultural Produce

Rheology studies deformation and flow of matter.

It is crucial in agriculture and food science.

Rheological properties affect texture, quality, and acceptance.

Applications include fruit firmness and dough elasticity assessment.

Unit V

# Fundamental Concepts: Force & Deformation

## Force

External influence causing shape or motion change, measured in Newton (N).

## Deformation

Change in size or shape due to force, measured in millimeters or inches.

## Types

- Elastic
- Plastic
- Viscous

# Stress and Strain: Quantifying Internal Responses

### Stress

Force per unit area inside material, units: Pascal or psi.

### Strain

Ratio of deformation to original size, dimensionless.

### Relation

Stress equals modulus times strain (Stress = Modulus × Strain).

# Elastic Behavior: Recovering Original Shape

## Elasticity

Material returns to original shape after force removal.

Example: Hooke's Law explains proportional stress and strain.

## Agricultural Example

- Underripe peach shows elastic behavior in texture tests.
- Elastic modulus measures stiffness in produce.

**Hooke's Law** states that:
**"The force (F) needed to extend or compress a spring by some distance (x) is proportional to that distance."**

- ❖ The amount a material stretches (or compresses) is directly proportional to the force applied, as long as the material is within its **elastic limit**.
- ❖ If you double the force, the stretch doubles (linear relationship).
- ❖ This law only holds **within the elastic limit** — beyond that, the material deforms permanently (plastic deformation).
- ❖ It explains **elastic behavior** of materials like springs, rubber bands, or even agricultural produce (e.g., slight pressing of an apple).

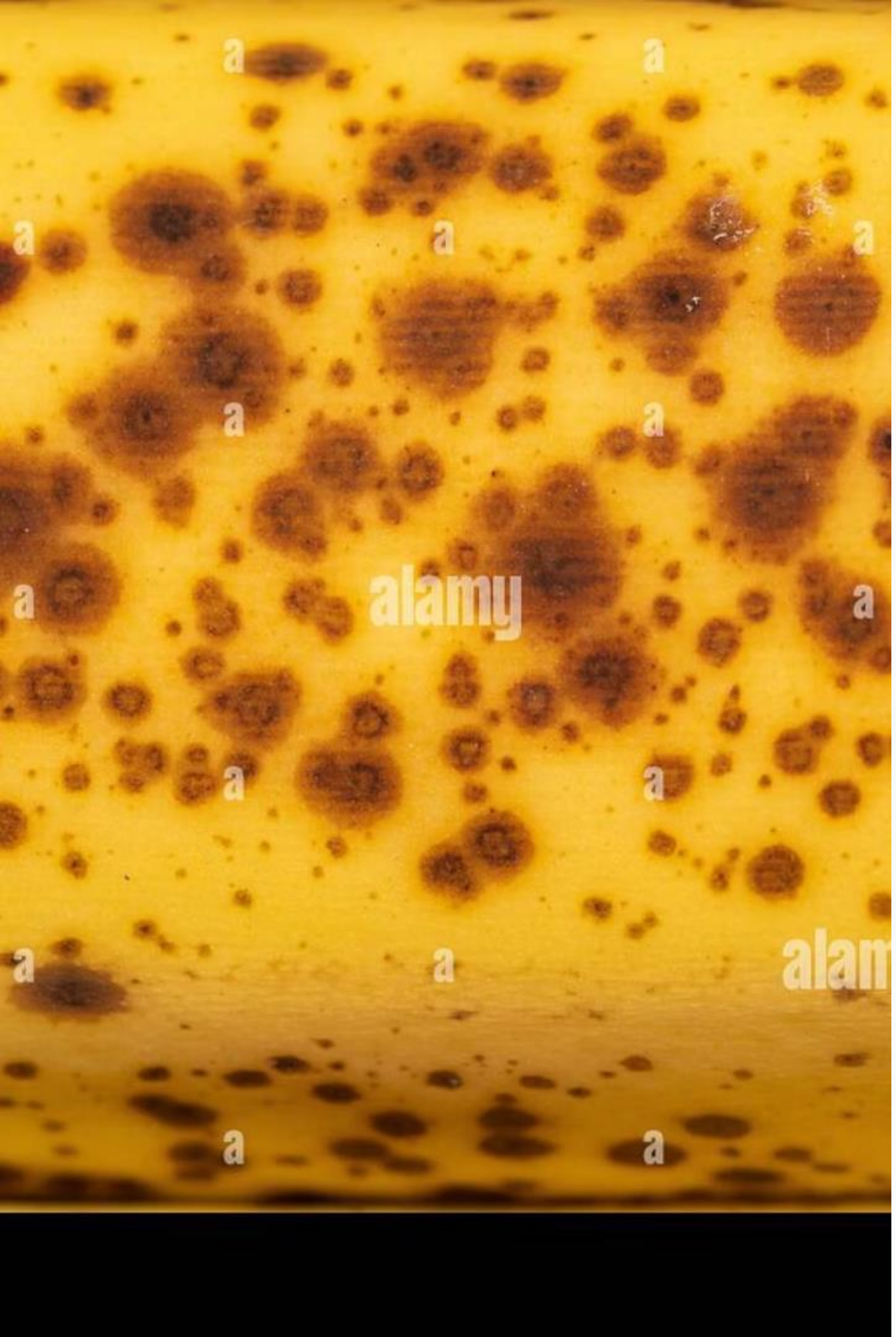
**Mathematical Formula:**

$$F = k \times x$$

Where:

- $F$ = Force applied (Newtons, N)
- $k$ = Spring constant (N/m) — a measure of stiffness
- $x$ = Displacement (meters, m) — how much the object stretches or compresses

- When a **fruit** like an apple is slightly pressed, the initial resistance follows **Hooke's Law** — deformation is proportional to applied force.
- It helps in designing **handling equipment** that applies safe levels of force without damaging delicate produce.




# Plastic Behavior: Permanent Deformation

1

## Plasticity

Permanent shape change after force is removed.

2

## Yield Point

Marks transition from elastic to plastic behavior.

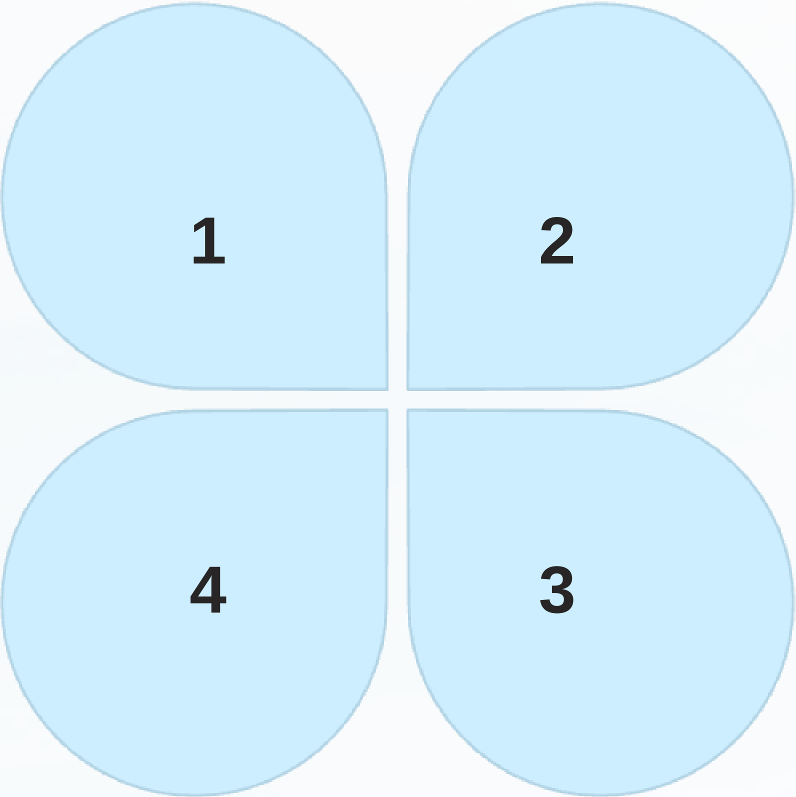
3

## Energy Dissipation

Energy lost as heat or structural changes.

Bruised ripe bananas demonstrate plastic deformation in produce.

# Viscous Behavior: Resistance to Flow




### Viscosity

Resistance to flow under shear stress, unit Pa·s.

### Newtonian Fluids

Constant viscosity; example: water.

### Non-Newtonian Fluids

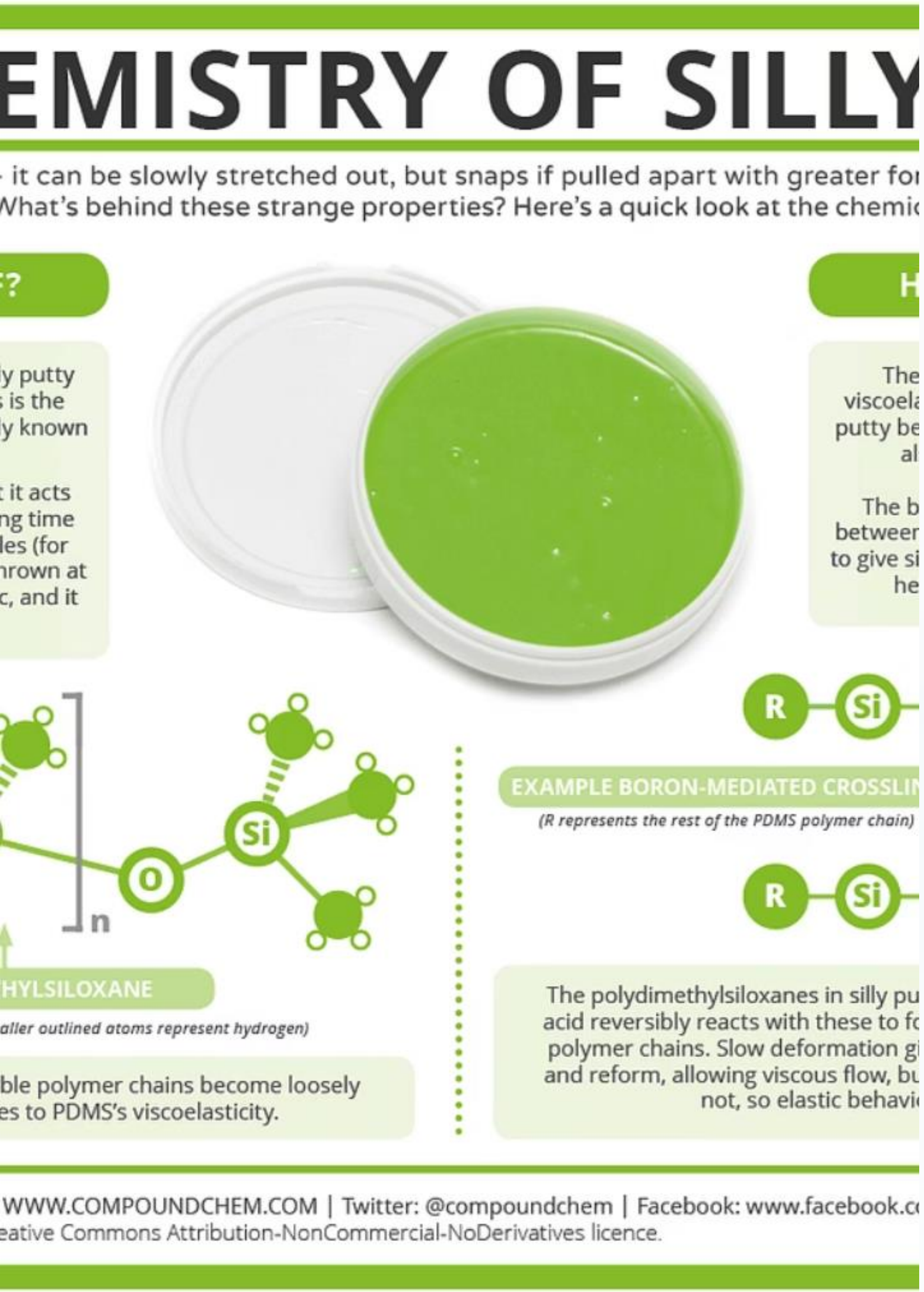
Viscosity varies with shear rate; example: honey.

### Agricultural Example

Tomato sauce becomes less viscous when stirred.

The **Shear Rate** is the rate at which **adjacent layers** of a fluid or soft material **move relative to each other**.
In simple words:
→ **How quickly** one layer of material slides over another layer.
It measures **the change in velocity** between layers **per unit distance**.

## Shear stress: the specific sum of forces that impose a deformation on a material in a plane parallel to the direction of the stress




# Viscoelasticity: Combined Properties

1. **Viscoelasticity**

   Materials exhibit both elastic and viscous responses.

2. **Creep**

   Deformation increases under constant stress over time.

3. **Stress Relaxation**

   Stress decreases under constant strain over time.

Apple sauce combines starch elasticity and water viscosity.

**Types of Non-Newtonian Behavior in Agri-Produce:**

- **Shear-Thinning (Pseudoplastic)**:
  *Viscosity decreases* with stirring.
  *Example*: Tomato ketchup, fruit purees.

- **Shear-Thickening (Dilatant)**:
  *Viscosity increases* with stirring.
  *Example*: Some starch-water slurries.

- **Bingham Plastic Behavior**:
  Requires a minimum force to flow.
  *Example*: Mayonnaise, mashed potatoes.

- **Thixotropic Behavior**:
  Viscosity *decreases over time* under constant stress.
  *Example*: Yogurt becoming runny when stirred.

# Applications in Agricultural Produce

### Texture Analysis

Measures firmness, crispness, chewiness of produce.

### Shelf Life Prediction

Monitors rheological changes during storage.

### Process Optimization

Controls mixing, pumping, and packaging processes.

### Quality Control

Ensures consistent product characteristics.

# Rheology in Food Processing

### Raw Material Testing

Evaluate produce texture before processing.

### Product Formulation

Adjust ingredients for desired viscosity and elasticity.

### Processing Control

Manage shear rates and stress during production.

### Final Product Assessment

Ensure product meets rheological standards for consumer appeal.


# Key Takeaways & Future Directions

### Understanding Rheology

Critical for optimizing produce quality and processing.

### Combined Properties

Elastic, plastic, and viscous behaviors influence texture.

### Future Trends

Advanced rheological tools to improve shelf life and texture.

Investing in rheology helps deliver superior agricultural products to consumers.

# Worksheet and Case study

**1. Tomato (Fruit - Semi-solid)**

- **Rheological Behavior**: Soft tissue, **elastic-plastic** behavior.
- **Impact on Handling**:
  - Tomatoes are highly sensitive to compressive force.
  - *Excessive force* during mechanical harvesting or packaging causes **plastic deformation** (permanent bruising).
- **Impact on Processing**:
  - Tomato puree exhibits **shear-thinning** (pseudoplastic) behavior — it flows easily under processing equipment like pulpers and homogenizers.
  - Understanding its viscosity profile is essential for designing **pumping and filling systems** in ketchup production.

**Banana (Fruit - Solid when raw, viscous paste when mashed)**

**Rheological Behavior**: Initially **elastic**, becomes **viscous** after processing.

**Impact on Handling**:

Green bananas are tougher and can tolerate some mechanical force.

Ripened bananas bruise easily due to **loss of elasticity** and onset of **plasticity**.

**Impact on Processing**:

In mashed form (banana puree), behaves as a **highly viscous, non-Newtonian** material.

Needs specific **mixers and dispensers** adapted for thick pastes.