RHEOLOGY OF MILK PRODUCTS

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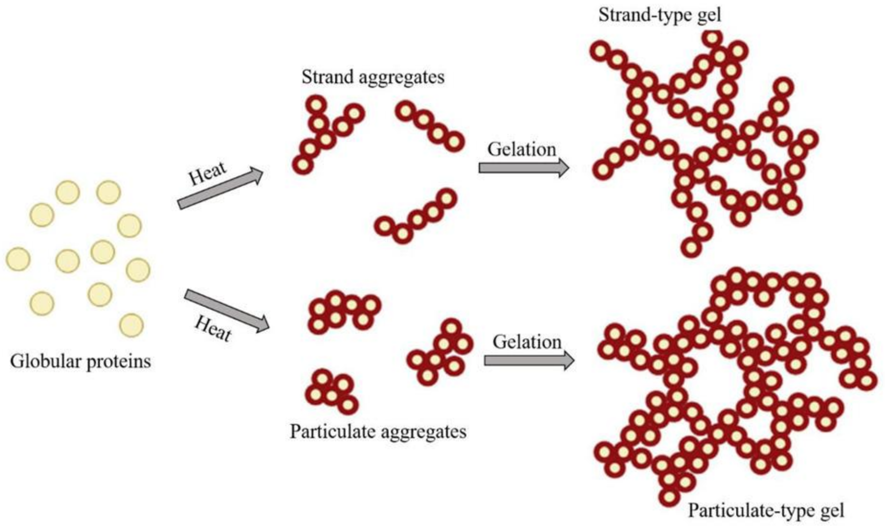
Objective of the Experiment

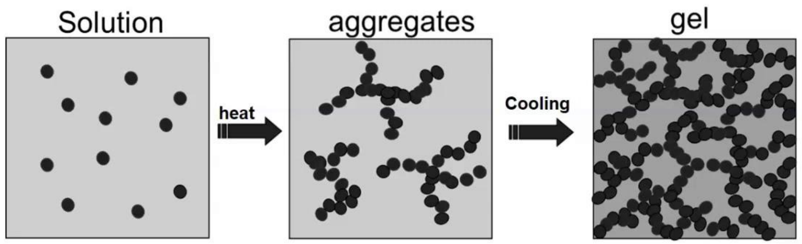
To determine whether curd exhibits gel-like behavior using frequency sweep test

To find **Glass Transition Temperature** of butter

INTRODUCTION:

- The way milk products like curd feel and taste depends on their scientific rheological properties.
- To make curd production, storage, and eating better, we need to understand its scientific rheology.
- Our objective is to Identify whether curd is a gel or not using a frequency sweep test.
- To achieve this objective, it's essential to understand the nature of gels, their properties, and how curd fits into this framework.





WHAT IS A GEL?

- When the particles aggregate to form a continuous network structure which extends throughout the available volume and immobilize the dispersion medium, the resulting semi-solid system is called a gel.
- Gels are semi-solid materials with a continuous solid-like structure and a significant liquid-like component.
- They exhibit both elastic (solid-like) and viscous (liquid-like) behavior.

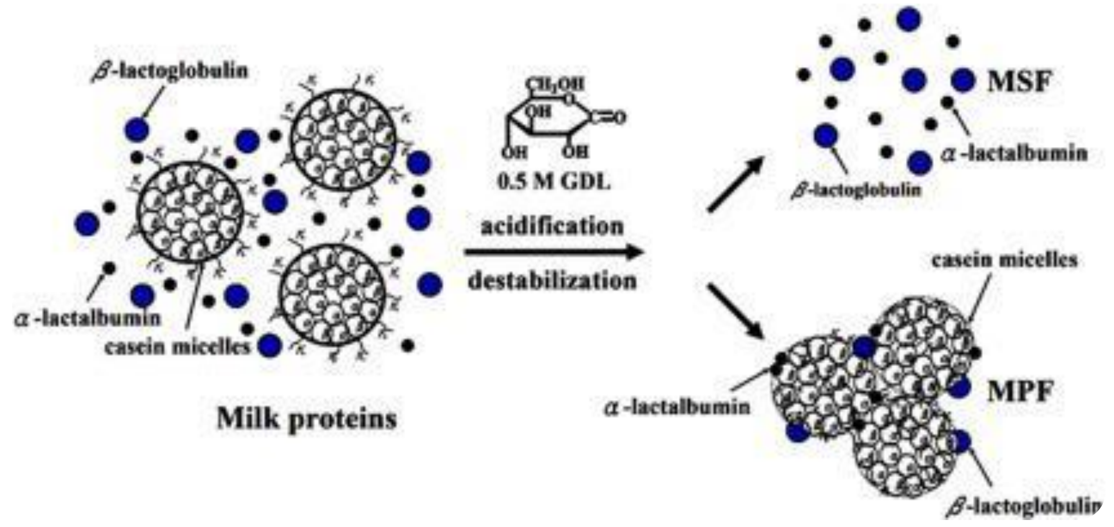
CURD AS A POTENTIAL GEL

- Curd is a dairy product formed through the coagulation of milk proteins, primarily casein.
- It has a complex structure with liquid (whey) trapped within a protein network.
- The protein network in curd might behave like a gel due to its semi-solid consistency and ability to regain shape after deformation.

Making of curd from milk is a chemical change.The bacteria Lactobacillus when added to milk converts it into curd.The bacteria breakdown the lactose in milk to lactic acid.This increases the acidity of milk due to which the milk protein casein coagulates as curd.This process is known as fermentation and requires a temperature of 35 - 40 degree Celcius.

The chemical reaction involved is:

$C_{12}H_{22}O_{11}$ (lactose) + H_2O (water) → 4 $CH_3CHOHCOOH$ (lactic acid)



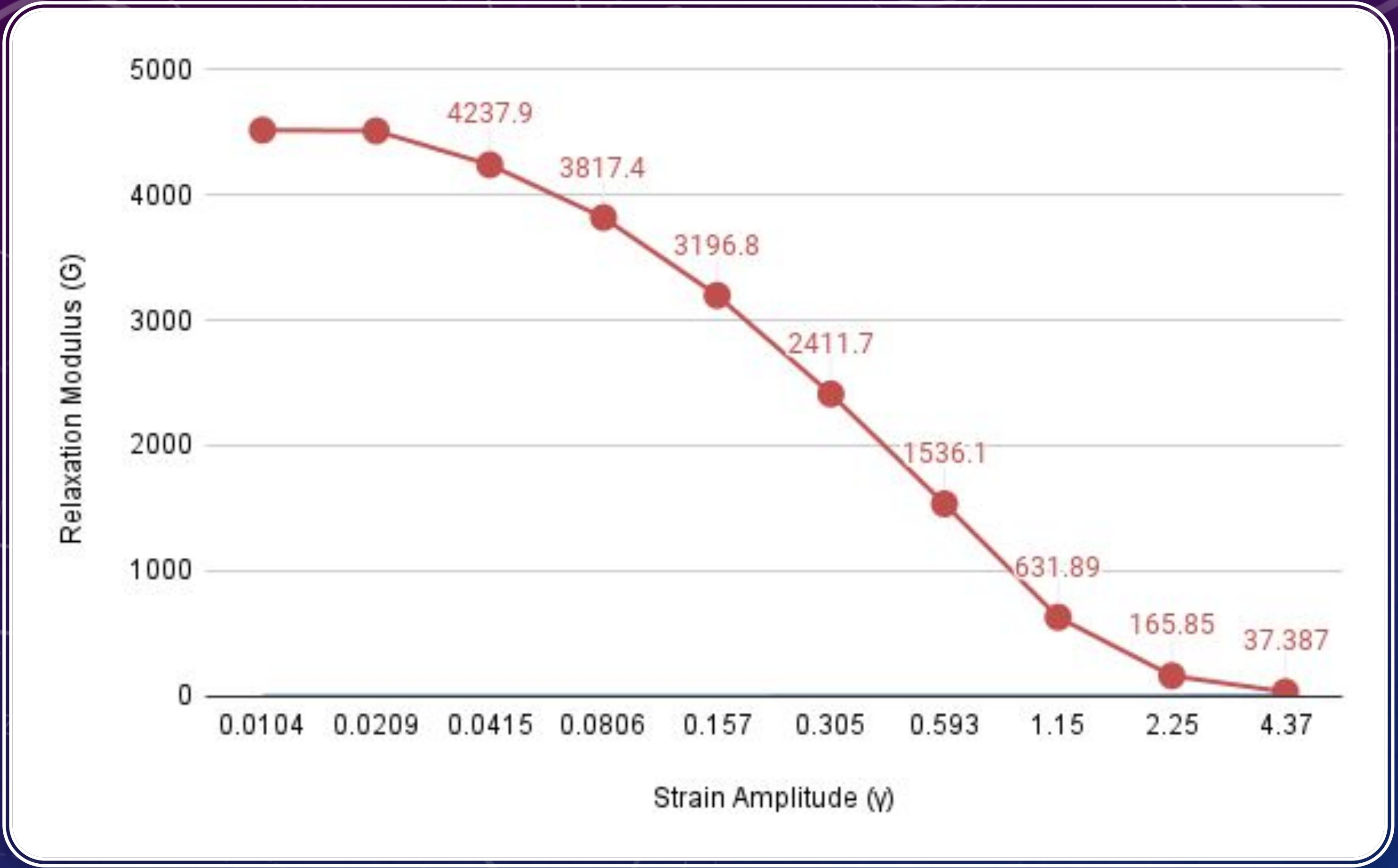
AMPLITUDE SWEEP TEST

- We conducted an amplitude sweep test to find the "linear regime" of curd.
- Linear Regime: This is the range of strain amplitudes (γ) where a material behaves linearly, i.e., stress is directly proportional to strain.
- Significance: Knowing the linear regime is essential for designing subsequent experiments, like the frequency sweep test, as it ensures accurate and predictable material behavior within this range.

AMPLITUDE SWEEP TEST – CURD (DATA) :

Point No.	Shear Strain	Shear Stress	Storage Modulus	Loss Modulus
Unit	[1]	[Pa]	[Pa]	[Pa]
1	0.0104	48.359	4514	1084.1
2	0.0209	96.874	4508	1095.2
3	0.0415	181.24	4237.9	1070.8
4	0.0806	318.55	3817.4	1027.4
5	0.157	522.85	3196.8	952.88
6	0.305	779.35	2411.7	844.69
7	0.593	1008.5	1536.1	726.41
8	1.15	975.4	631.89	560.39
9	2.25	797.64	165.85	313.83
10	4.37	627.35	37.387	138.52

AMPLITUDE SWEEP TEST – CURD (GRAPH)

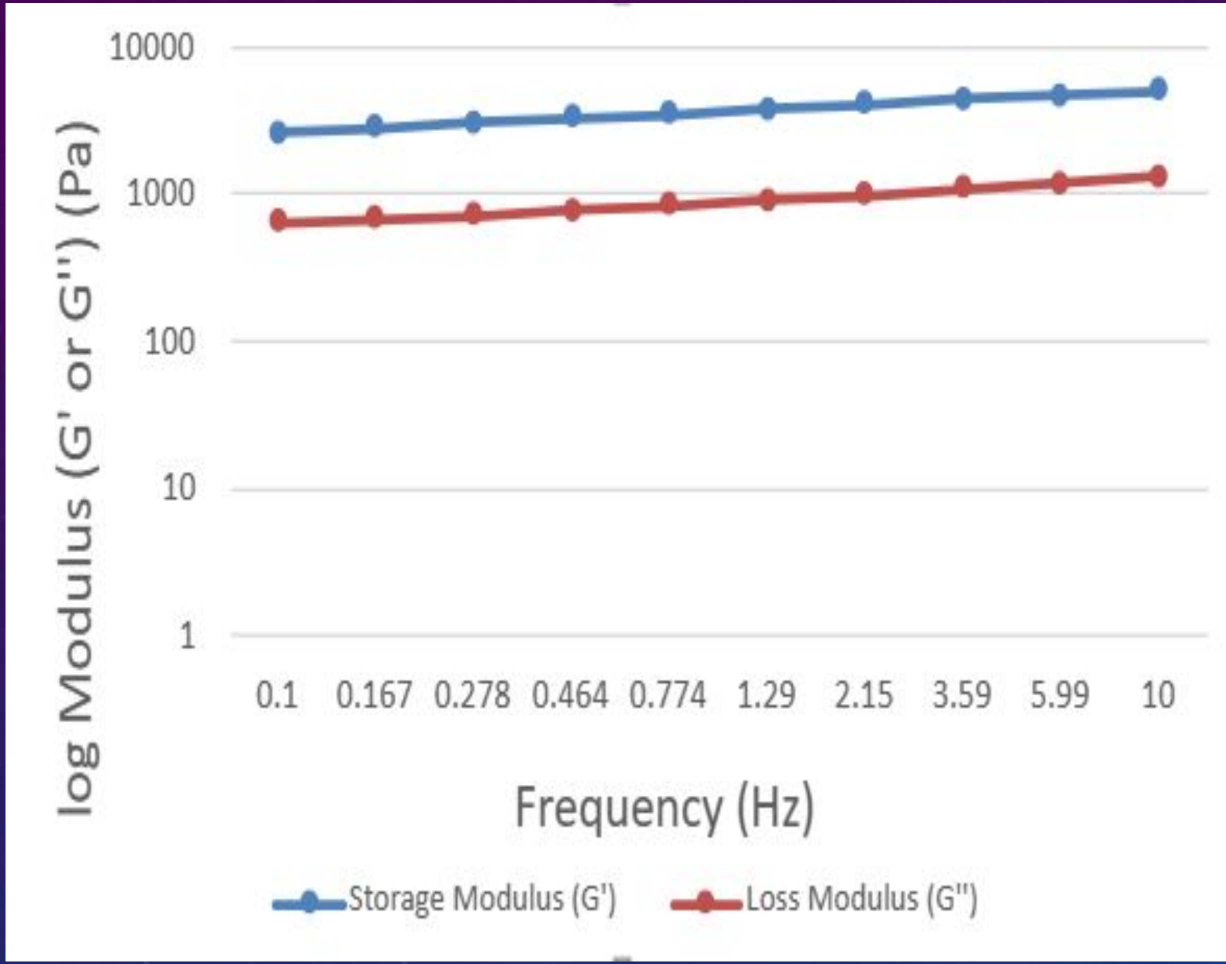


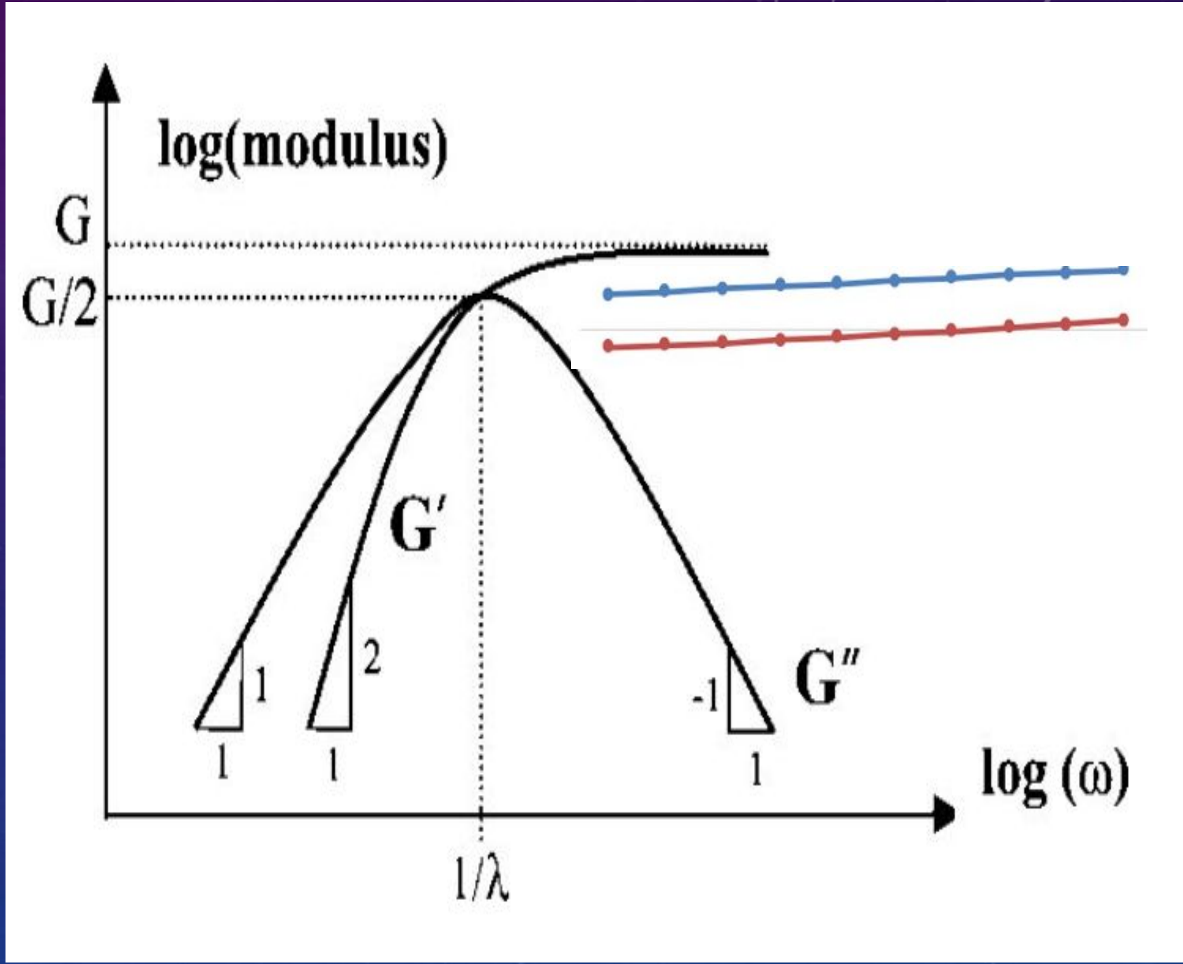
Frequency sweep test (Curd) (Data) :

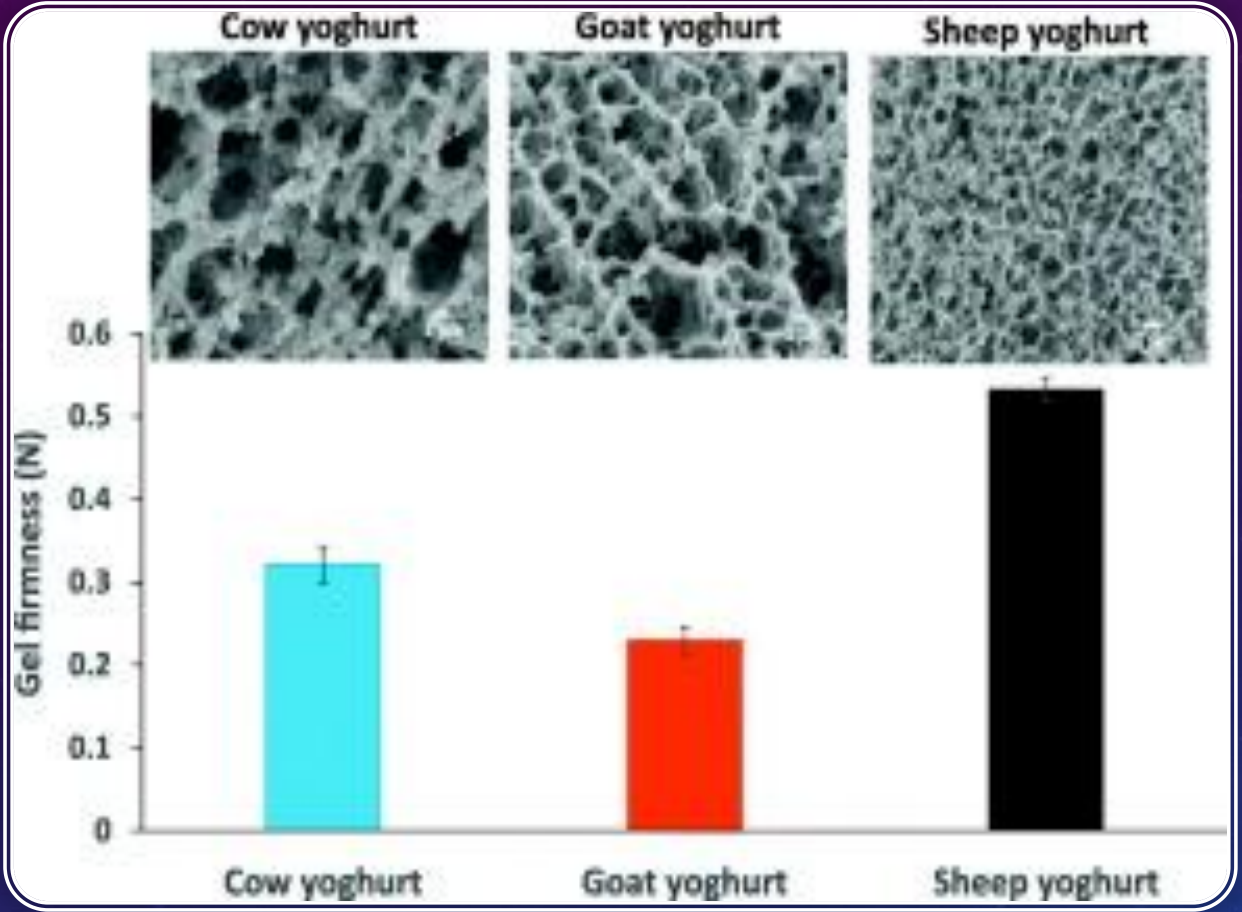
Curd Freq Sweep					
Point No.	Frequency	Storage Modulus	Loss Modulus	Shear Strain	Shear Stress
	[Hz]	[Pa]	[Pa]	[%]	[Pa]
1	0.1	2618.9	647.74	0.987	26.625
2	0.167	2829.2	679.97	1	29.108
3	0.278	3045.5	721.17	1	31.297
4	0.464	3273.8	774.01	1	33.64
5	0.774	3515	836.71	1	36.132
6	1.29	3779.3	910.71	1	38.876
7	2.15	4068	994.39	1	41.877
8	3.59	4381.3	1087.3	1	45.143
9	5.99	4719.2	1191	1	48.686
10	10	5079.5	1310.2	0.997	52.274

- Data points at every 6 cycle
- Amplitude is fixed
- Frequency is varied between the range – by Equal Percentage Increment
- Experiment within the linear regime of amplitude sweep test
- G' and G" data points observed

Frequency sweep test (Curd) (Graph) :





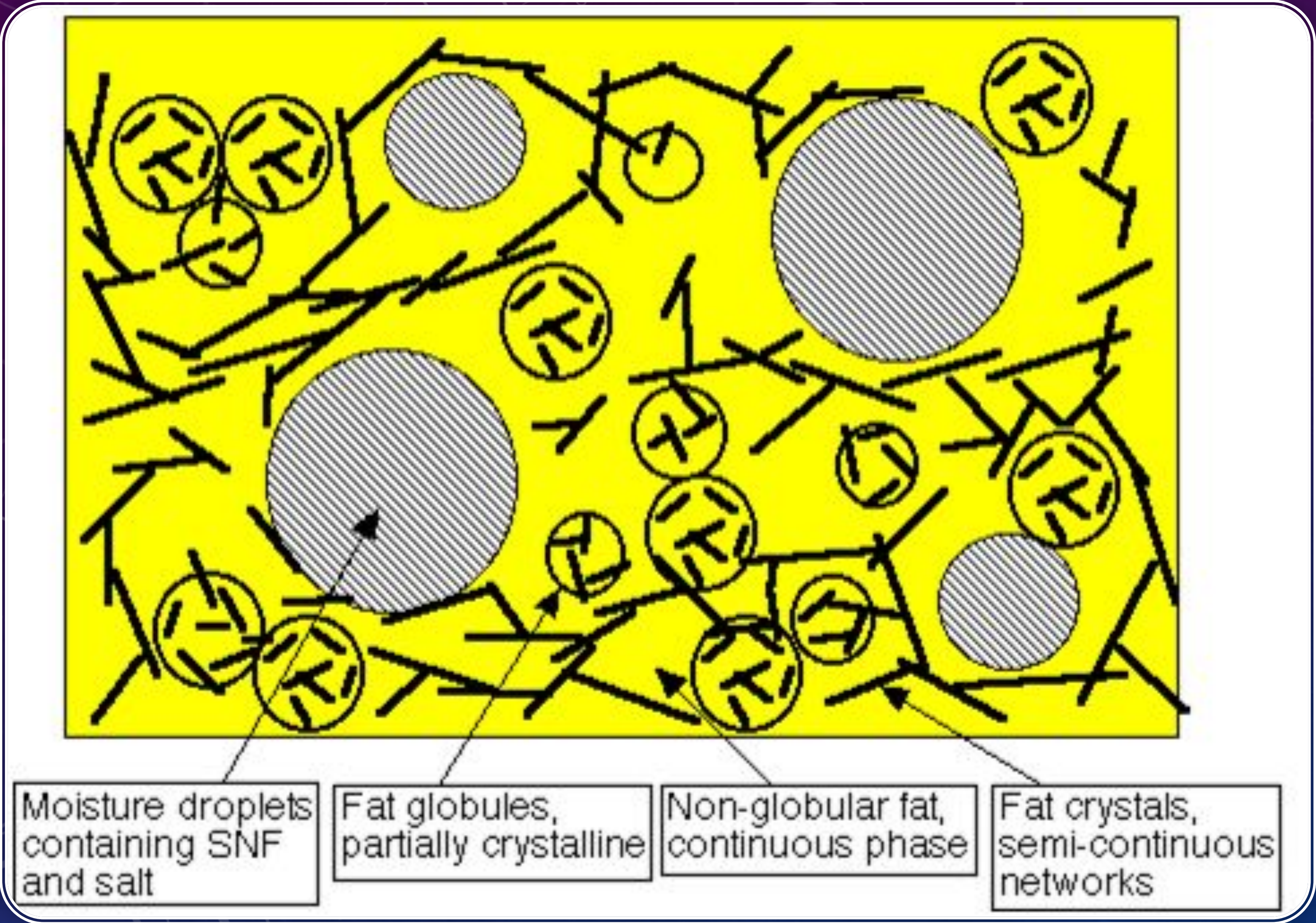


OBSERVATION AND CONCLUSION:

- Curd is a gel, non-liquid behavior
- G' and G" are not going to intersect any where
- It shows Non-Maxwellian behavior
- Virtually, Crossover point existed before the formation of curd
- For Gel, the relation of G' and G" is non-converging and G'>G" for all frequency
- All study done in the linear regime of Amplitude Sweep test

BUTTER – A COMPLEX SYSTEM

- Butter consists of mainly fats (80%), water (15-17%) and milk solids (2-3%).
- These components contribute to its unique properties and behavior.
- Butter can be described as the multi-phase system due to the presence of solid and liquid phases within its structure.
- Butter also contains an amorphous or non-crystalline phase, which plays an important role in determining the rheological behavior and glass transition temperature of butter.



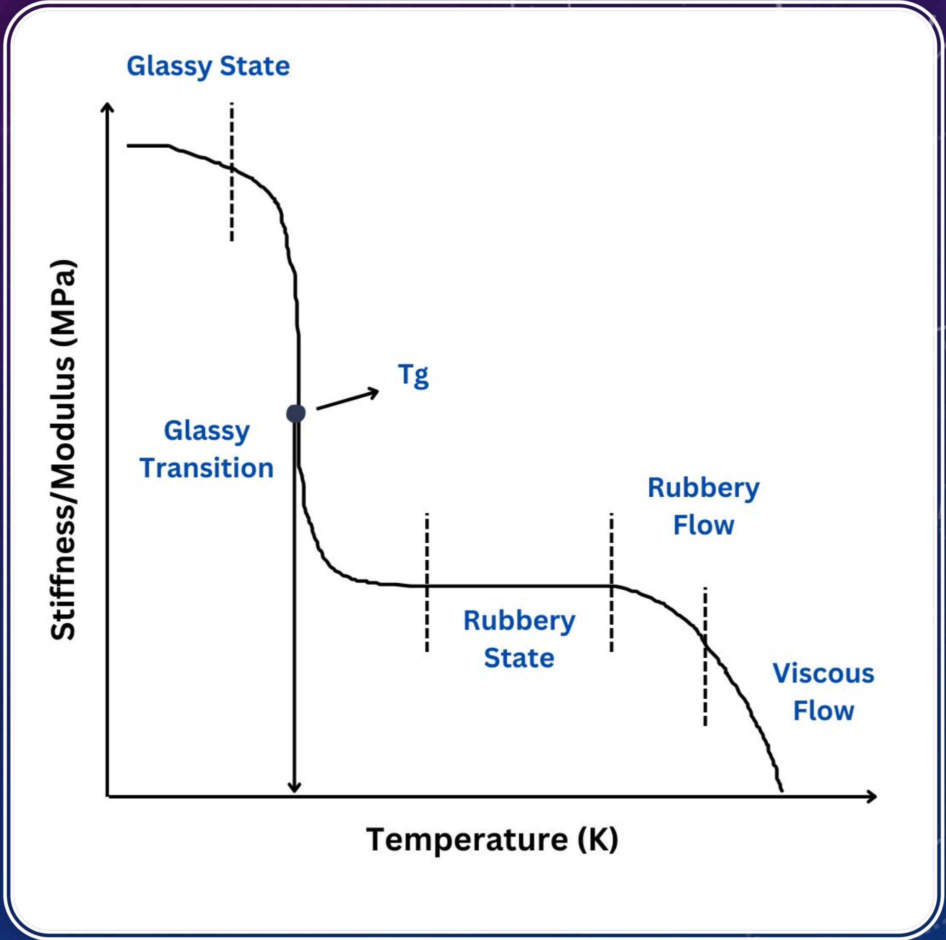
BUTTER STRUCTURE

COMPLEX RHEOLOGICAL BEHAVIOR OF BUTTER

- The rheological behaviour of butter is complex as its viscosity, texture, and flow properties are influenced by temperature, fat crystallization and shear rate.
- At higher temperatures, more fat is in the liquid phase, making butter softer and more spreadable.
- At lower temperatures, a higher percentage of fat is in the solid phase, leading to a firmer texture.
- As the temperature changes, the fat crystals within the butter undergo various transformations.
- The glass transition temperature is an important factor for understanding these temperature-dependent changes.

GLASS TRANSITION TEMPERATURE AND ITS RELEVANCY IN CONTEXT OF BUTTER

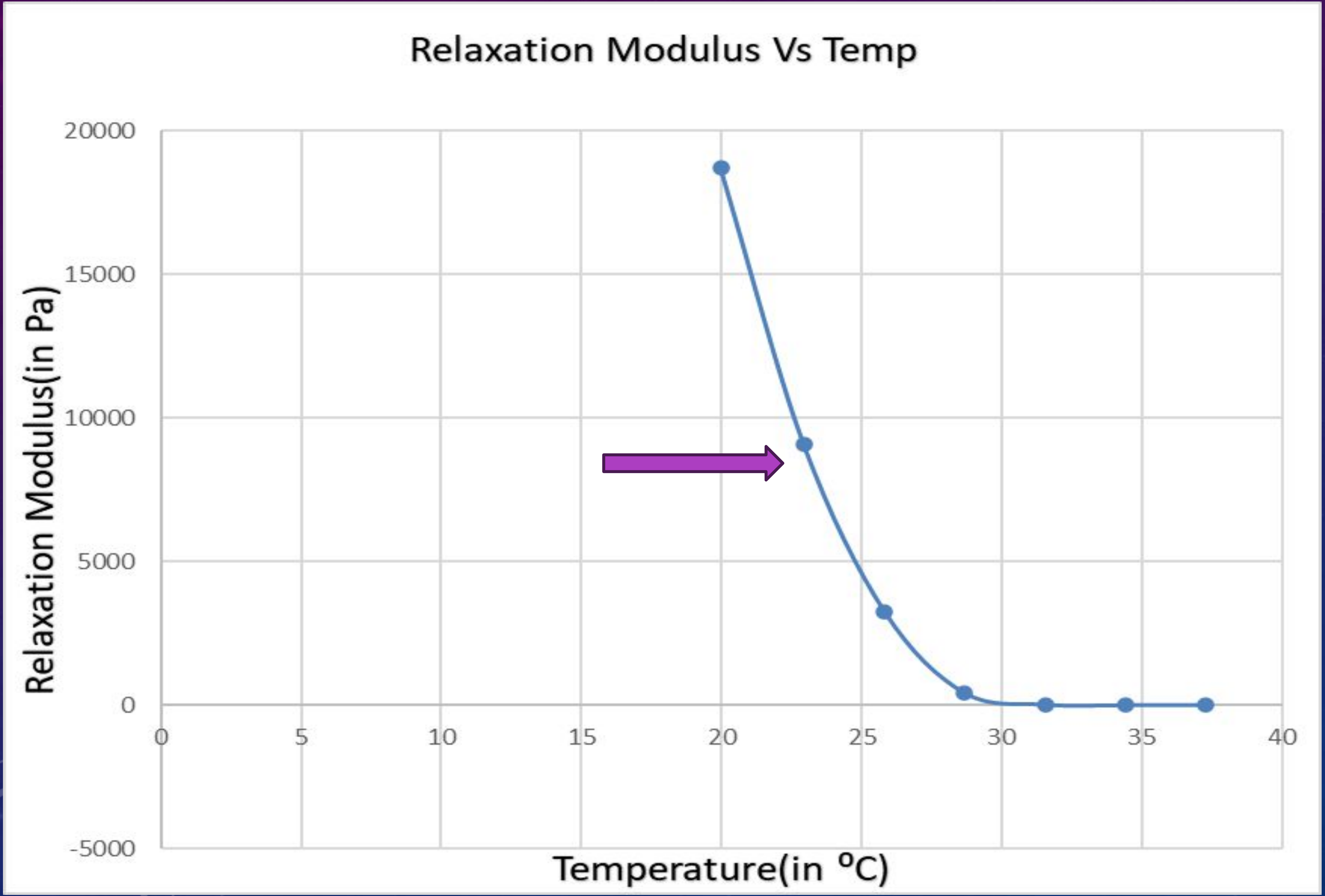
- The temperature at which a material undergoes transition from a solid like to liquid like behavior.
- Below Tg butter is in a rigid state and above Tg, it becomes more rubbery or viscous.
- Knowledge of Tg helps to prevent undesirable changes, such as oil separation or unwanted crystallization.
- The Tg of butter is crucial factor when selecting appropriate packaging materials and conditions.



Experimental Data of Butter

Point No.	Shear Strain	Shear Stress	Relaxation Modulus	Temperature
Unit	[1]	[Pa]	[Pa]	[C]
1	1	187.07	18700	19.98
2	1	90.999	9096.4	22.94
3	1	32.674	3266.1	25.83
4	1	4 4.3544	435.27	28.67
5	1	0.17566	17.56	31.54
6	1	-0.00692	-0.69149	34.4
7	1	0.001599	0.15982	37.26

Graph



Effect of Material Behavior

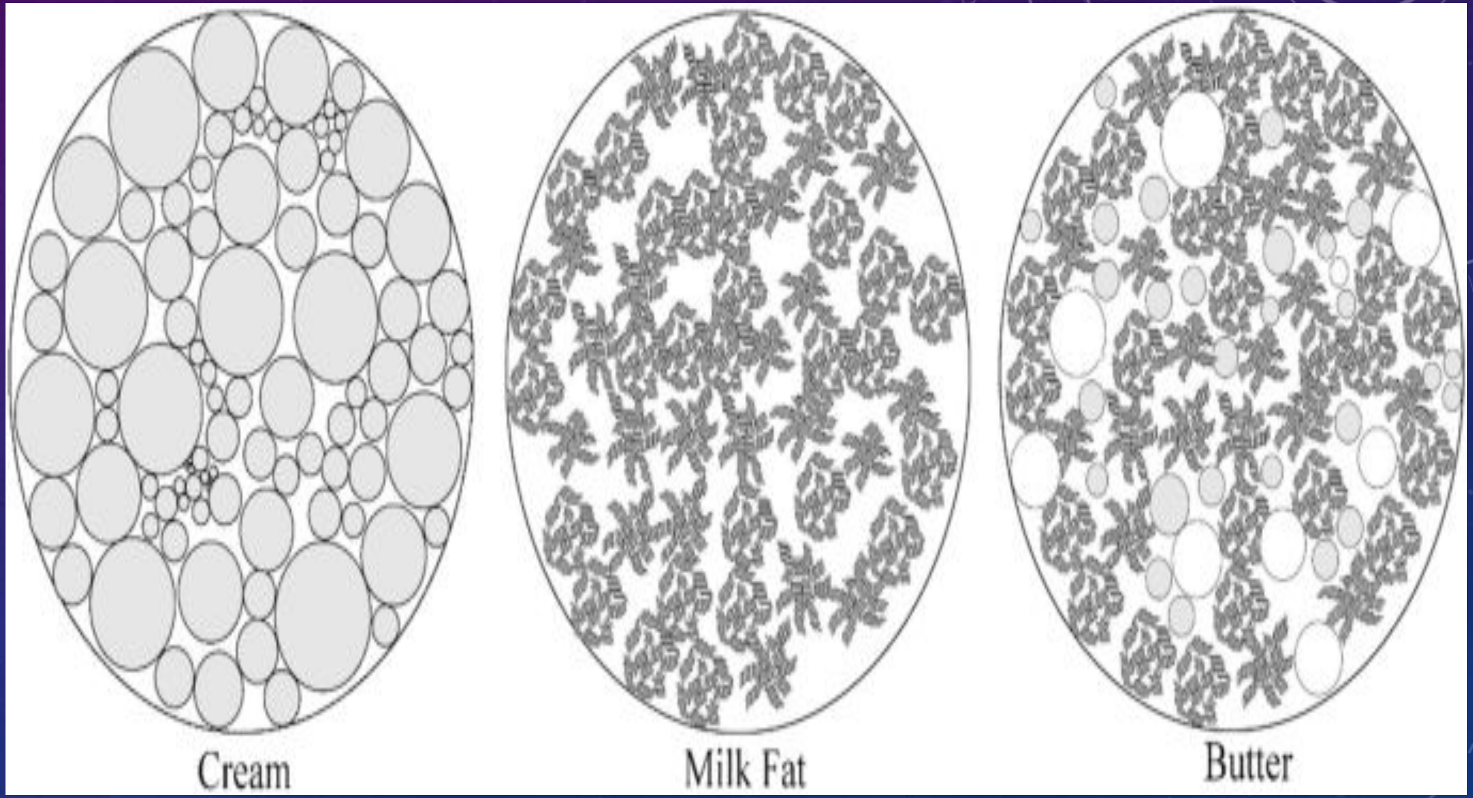
Glass Transition Temperature

1. Molecular weight
2. Cross links
3. Flexibility
4. Plasticizer
5. Intermolecular force

Practical Implications

Observation and Conclusion:

- Butter is a Multiphase System
- Glass Transition Temperature and its relevance
- Temperature Dependency of Relaxation Modulus

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