

# Food Rheology

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## ABSTRACT

Food rheology is the scientific study of the rheological properties of food, that is, the consistency and flow of food under tightly specified conditions. It is the science of how food materials flow or deform under applied forces, covering both liquids (like sauces) and semi-solids/soft solids (like gelled desserts or dough). It relates mechanical behavior (such as flow, viscosity, elasticity, yield stress) to food structure and composition. Food rheology is crucial in processing and engineering, quality control, product development and sensory quality, and nutrition and health applications. It is very important in product design, manufacturing, and nutrition applications. This paper presents an introduction to food rheology and its importance to man.

**KEYWORDS:** *Food rheology, viscosity, yield stress, elasticity, plasticity, flow behavior index, thixotropy, texture, shelf life, sensory properties.*

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## INTRODUCTION

The term “rheology” is from the Greek word *rheos* which means to flow. It is applicable to all materials and was founded by two scientists, Professors Marcus Reiner and Eugene Bingham. The Greek philosopher Heraclitus described rheology as “Panta rei” – everything flows [1].

Food rheology is the study of the rheological properties of food, that is, the consistency and flow of food under tightly specified conditions [2]. Food rheology can also be simply defined as the science that studies the flow, deformation, and texture of food materials. It is also considered as the study of the deformation and flow of food materials under various forces, such as shear, compression, and tension. The consistency or the rheological properties of food, or degree of fluidity, and other mechanical properties are important in understanding how long food can be stored, how stable it will remain, and in determining food texture, as shown in Figures 1 and 2.

The study of food rheology entails unique factors that are beyond the understanding of the basic rheological dynamics of the flow and deformation of matter. Food classification can be based on its rheological

state – such as a solid, gel, liquid, or emulsion – each with associated rheological behaviors, and measurable rheological properties [3, 4], as shown in Figure 3. These properties are known to affect the design of food processing plants, as well as shelf life and other important factors, which include sensory properties that appeal to consumers.

## HISTORY

The historical overview of food rheology is as outlined below:

### 1. Origins of Rheology (General Science)

Before food rheology existed as a specialized area or field, the broader science of rheology developed:

- The term “rheology” was coined by Eugene C. Bingham in 1929 and Markus Reiner. The term was from the Greek *rhein* (“to flow”), inspired by Heraclitus’s idea that “*everything flows*” [5].
- Rheology as a discipline studies deformation and flow of materials (fluids and soft solids), bridging classical fluid mechanics and solid mechanics. Early contributions date back much earlier (e.g., Newton’s viscosity law, Hooke’s elasticity), but rheology as a distinct field dates to the early 20<sup>th</sup>

century with formal definitions and societies forming through the 1920s-1940s [5].

## 2. Emergence of Food Rheology

**Early Mentions (Informal Practice):** Before the emergence of scientific study, humans have practically engaged with food rheology for millennia – for example in ancient Egyptian bakers judged dough consistency by feel [4].

**Formal Scientific Development (20<sup>th</sup> Century)**

➤ 1960-1970s:

Systematic food rheology research began in earnest. Early academic articles surveyed rheology and its applications in food research by the 1970s, linking rheological behavior to food structure and processing [6].

➤ 1980s-1990s:

The field expanded with specialized conferences and symposia – e.g., 1<sup>st</sup> International Symposium on Food Rheology and Structure (Zurich, 1997) – this brought experts together to discuss rheology in food processing and texture [7].

➤ 1990s:

Tutorial reviews such as *Food texture and Rheology* (1992) helped formalize food rheology as an academic discipline, integrating texture science and mechanical measurements [8].

**Modern Era (2000s-Present)**

➤ **Comprehensive Texts:** In this case, books like *Advances in Food Rheology and Its Applications*, and chapters in food engineering handbooks expanded the technical basis of the field and its relevance to industry [9].

➤ **Integration with Sensory Science:** Research now connects rheological measurements with *oral processing* and *consumer perceptions* (e.g., tribology studies combined with rheology [10].

➤ **Technological Advances:** Rheological instruments have evolved from simple viscometers to automated rheometers capable of small and large amplitude oscillatory measurements, giving detailed insights into food microstructure and viscoelastic behavior [10], as shown in Figure 4.

## IMPORT OF FOOD RHEOLOGY

Food rheology is very important as it is central to:

➤ **Processing efficiency and manufacturing:** The design of pumping, mixing, and heat transfer operations depends on rheological properties. That is, the designing of pumps, pipes, mixers, and heat exchangers requires knowing how food flows within equipment. Helps to improve handling, pumping, and packaging [11, 12].

➤ **Product development:** Rheology informs ingredient functionality, texture design, consistency, and mouthfeel [13].

➤ **Texture and Sensory quality:** consumer perception of food (mouthfeel, creaminess, spreadability) is largely determined by rheological properties like viscosity and elasticity. It enhances sensory experience and satisfaction leading to consumer acceptance [4], as shown in Figure 5.

➤ **Quality Control and Stability:** Rheological measurements help ensure consistent product quality during storage and transport [14].

➤ **Shelf Life:** This predicts and extends product stability (i. e. product's usable life)– which is the ability of a food product to maintain its desired physical, chemical, microbiological, and sensory characteristics over time, under specified storage conditions [15].

## CORE CONCEPTS IN FOOD RHEOLOGY

1. Stress, Strain, and Deformation

➤ Stress is force per unit area applied to a food material. The two types of stress are: Shear stress and Normal stress.

➤ Strain is the change in shape or resulting deformation due to stress and is dimensionless.

➤ Rheology quantifies their relationship under defined conditions [16, 17].

2. Viscosity

Viscosity is the resistance of a fluid to flow and is defined as: shear stress/shear rate.

Its importance in food is that:

➤ It determines thickness, mouthfeel, and processability

➤ It influences pumping, mixing, and swallowing [18, 19].

3. Shear Rate

Shear rate represents the rate of deformation during flow. However, high shear rates occur during [20]:

➤ Mixing

➤ Chewing

➤ Extrusion

4. Newtonian and Non-Newtonian Flow

**Newtonian Behavior:** Viscosity is constant regardless of the shear rate.

**Non-Newtonian Behavior:** In this case, viscosity varies with shear rate (very common in foods).

Types: The two types are:

A. Shear-thinning (pseudoplastic) – sauces, yogurt

B. Shear-thickening (dilatant) – starch suspensions [21, 22].

## 5. Yield Stress

Yield stress is the minimum stress that is required for a material to start flowing.

Below yield stress 'n solid-like

Above yield stress 'n liquid-like

Food examples: mayonnaise, ketchup, tomato paste [16, 17, 23].

## 6. Elasticity

Elasticity is the ability of a food material to recover its original shape after deformation.

This is very common in: Gels, Cheese, and Bread crumb [24, 25].

## 7. Viscoelasticity

Most foods are known to exhibit viscoelastic behavior, combining:

- Elastic response (energy storage)
- Viscous response (energy dissipation)

Viscoelasticity is measured by:

- Storage modulus ( $G'$ )
- Loss modulus ( $G''$ ) [26, 27].

## 8. Time-Dependent Rheological Behavior

**Thixotropy:** Thixotropy is a property of certain fluids (non-Newtonian fluids) that become thinner (less viscous) when shaken, stirred, or stressed (sheared) and then gradually thicken back up to their original state when left to rest, such as ketchup or paint. It's a time-dependent behavior where the material's internal structure breaks down under force, allowing flow, and reforms when the force is removed, providing stability. In other words, viscosity decreases with time under constant shear and recovers when shear stops.

**Rheopexy:** In this case, viscosity increases with time under shear (rare in foods) [21, 23, 28, 29].

## 9. Creep and Recovery

**Creep:** This is deformation under constant stress.

**Recovery:** This is shape recovery after stress removal. These are used to assess: Structural strength, and Long-term stability [18, 30].

## 10. Temperature Dependence

Rheological properties change significantly with temperature:

- Higher temperature 'n lower viscosity
- Phase transitions affect texture (melting, gelation) [31].

## 11. Structure-Rheology Relationship

Rheological behavior reflects food microstructure, including:

- Protein networks
- Starch granules
- Fat droplets

Structural changes during processing is known to alter rheology [32, 33].

## 12. Psychorheology

Psychorheology links rheology measurements to sensory perception (creaminess, firmness, smoothness) [34, 35].

## Challenges in Food Rheology

Food rheology is faced by several challenges that impact food product development and processing, some of which include [21, 36-39]:

1. Complexity of Food Systems: Generally speaking, foods are complex, multi-component systems with varying structures and interactions.
2. Non-Newtonian Behavior: Many foods are known to exhibit non-Newtonian flow, which makes rheological characterization complex.
3. Time-Dependent Behavior: Foods can exhibit thixotropy, rheopexy, or other time-dependent changes, as shown in Figure 6.
4. Temperature and Moisture Effects: Rheological properties can be highly sensitive to temperature and moisture changes.
5. Scale-up and Translation: Lab-scale rheology data may not translate directly to industrial processes.

Some specific challenges have to do with:

1. Modeling and Simulation: This has to do with developing accurate rheological models for complex foods.
2. Instrumentation Limitations: This is with respect to measuring rheological properties of fragile or heterogeneous foods.
3. Sensory Correlation: This is linking rheological data to sensory perception.

## Addressing/Solutions to Challenges to Food Rheology

Addressing the challenges in food rheology involves a combination of advanced techniques, modeling, and understanding of food systems. Some of the solutions would include [21, 36-42]:

1. Advanced Rheological Techniques: This is by the use of dynamic rheometry, texture profiling, and other sophisticated methods to characterize complex food behaviors.
2. Modeling and Simulation: By employing computational models (e. g., finite element analysis) to predict rheological behavior and scale-up processes.
3. Ingredient Modification: Tailoring ingredients (e.g., starches, hydrocolloids) to achieve desired rheological properties.
4. Process Optimization: By adjusting processing conditions (e. g., temperature, shear) to manage rheological changes.

5. Sensory-Rheology Correlation: Linking rheological data to sensory attributes using techniques like descriptive analysis.

#### Addressing some specific challenges such as:

- Non-Newtonian Behavior: Make use of models like power-law or Herschel-Bulkley to describe flow behavior.
- Time-Dependent Behavior: Employ thixotropy tests or dynamic rheometry to capture changes.
- Scale-Up: Use pilot-scale testing and modeling to predict industrial-scale behavior.

#### CONCLUSION

Most foods are known to exhibit complex, non-Newtonian and viscoelastic behavior, arising from their multiphase nature (emulsions, foams, suspensions, gels). These properties are strongly influenced by factors such as temperature, shear rate, time, moisture content, and ingredient interactions – which enables scientists and engineers to predict and control food performance under real processing and consumption conditions. Food rheology also plays a critical role in product quality and consumer acceptance. Directly related to rheological parameters are textural attributes like creaminess, firmness, spreadability, chewiness, and pourability. Also, from the technological angle, rheology is indispensable in process design and optimization. Food rheology is a cornerstone of food science and engineering, integrating structure-property-function relationships across the food chain. Its application enhances product quality, processing efficiency, and consumer satisfaction, thereby making it an essential tool for advancing both traditional and emerging food systems. More information on food rheology can be found in the books in [43-47] and the following related journals:

Journal of Food Science (JFS)- Wiley.  
 Food Hydrocolloids – Elsevier.  
 Food Research International – Elsevier.  
 Journal of Texture Studies – Wiley.  
 Rheological Acta – Springer.  
 Food Science and Technology  
 Journal of Food Engineering  
 International Journal of Food Science & Technology  
 LWT – Food Science and Technology  
 Food Chemistry  
 Journal of Rheology  
 Soft Matter

#### REFERENCES

- [1] S. Pallavi, “Food rheology,” <https://www.slideshare.net/food-rheology>
- [2] B. M. McKenna and J. G. Lyng (2003), *Texture in food: Introduction to food rheology and its measurement*, pp. 2-3.
- [3] M. A. Rao (2007), *Rheology of fluid and semisolid foods: Principles and applications*, Springer, p. 1.
- [4] “Food rheology,” Wikipedia, the free encyclopedia, <https://www.en.wikipedia.org/food-rheology>
- [5] “Rheology,” Wikipedia, the free encyclopedia, <https://www.en.wikipedia.org/rheology>
- [6] G. W. White, “Rheology in food research,” *International Journal of Food Science and Technology*, vol. 5, no. 1, March 1970, pp. 1-32.
- [7] B. Wolf and E. J. Windhab (ed.), “Food rheology and structure I,” *Proceedings of the 1<sup>st</sup> International Symposium on Food Rheology and Structure*, March 16-21, 1997, Zurich, Switzerland.
- [8] R. P. Borwankar, “Food texture and rheology: A tutorial review,” <https://www.sciencedirect.com/food-texture-and-rheology-a-tutorial-review>
- [9] J. Ahmed (ed.), P. Ptaszek and S. Basu, “Chapter 1 – Food rheology: Scientific development and importance to food industry,” In: *Advances in Food Rheology and Its Applications*, (PDF), Elsevier, September 2016, pp. 1-4. <https://www.researchgate.net/food-rheology-scientific-development-and-importance-to-food-industry>
- [10] J. Ahmed, “Advances in rheological measurements of food products,” *Current Opinion in Food Science*, vol. 23, October 2018, pp. 127-132.
- [11] M. A. Rao, “Food rheology and texture,” *Food Engineering*, vol. II.
- [12] L. Day & M. Golding, “Food rheology,” <https://www.sciencedirect.com/food-rheology>
- [13] K. Shanmugam, “Food rheology: An introduction and fundamental concepts,” *Scientific and Social Research*, vol. 6, no. 6, 2024. <https://www.ojs.bbwpublisher.com>
- [14] P. Bose (July 15, 2021), “Why rheology is important in food technology,” <https://www.azom.com/why-rheology-is-important-in-food-technology>
- [15] Food Research International -Stability and Shelf Life.
- [16] H. A. Barnes, J. F. Hutton & K. Walters (1989), *An introduction to rheology*, Elsevier.

- [17] M. A. Rao (2007), "Rheology of fluid foods," *Journal of Textual Studies*, vol. 38, pp. 1-28.
- [18] J. F. Steffe (1996), *Rheological methods in food process engineering*.
- [19] J. McClements (2007), *Understanding and controlling the microstructure of complex foods*. Woodhead.
- [20] M. A. Rao et al. (2014), *Engineering properties of foods*. CRC Press.
- [21] M. A. Rao (2014), *Rheology of fluids, semisolid, and solid foods*.
- [22] G. Schramm (2006), *A practical approach to rheology and rheometry*, Thermo Fisher.
- [23] H. A. Barnes (1999), "The yield stress – a review," *Journal of Non-Newtonian Fluid Mechanics*, vol. 81, pp. 133-178.
- [24] J. D. Ferry (1980), *Viscoelastic properties of polymers*. Wiley.
- [25] Dickinson (2011), "Food structure and rheology," *Journal of Food Engineering*, vol. 107, pp. 1-9.
- [26] M. A. Rao & J. F. Steffe (1992), *Viscoelastic properties of foods*. Elsevier.
- [27] T. G. Mezger (2020), *The rheology handbook*. Vincentz Network.
- [28] "Thixotropy," <https://www.britannica.com/thixotropy>
- [29] "Rheopecty," Wikipedia, the free encyclopedia, <https://en.wikipedia.org/rheopecty>
- [30] M. H. (2011), "Small-strain dynamic rheology of food protein networks," *Journal of Agricultural and Food Chemistry*, vol. 59, pp. 1481-1486.
- [31] M. A. Rao & A. K. Datta (2006), "Heat transfer and rheology in food processing," *Food Technology*, vol. 60, pp. 58-64.
- [32] J. M. Aguilera & D. W. Stanley (1999), *Microstructural principles of food processing and engineering*. Springer.
- [33] D. J. McClements (2015), *Food emulsions: Principles, practices, and techniques*. CRC Press.
- [34] A. S. Szczesniak (1963), "Classification of textural characteristics," *Journal of Food Science*, vol. 28, pp. 385-389.
- [35] S. Szczesniak (2002), "Texture is a sensory property," *Food Quality and Preference*, vol. 13, pp. 215-225.
- [36] J. F. Steffe (1996), "Food rheology: Principles and applications."
- [37] M. C. Bourne (2002), "Food texture and viscosity."
- [38] *Journal of Food Science: Rheology and Texture Challenges*.
- [39] *Food Research International: Advances in Food Rheology*.
- [40] *Journal of Food Engineering: Rheology in Food Processing*.
- [41] *Food Hydrocolloids: Rheology of Food Systems*.
- [42] *Advances in Food Rheology – Food Research International*.
- [43] T. Ian Norton, F. Spyropoulos & P. Cox, "Practical food rheology: An interpretive approach."
- [44] Ton van Vliet, "Rheology and fracture mechanics of foods."
- [45] J. Ahmed & S. Basu (eds.), "Advances in food rheology and its applications." (2<sup>nd</sup> Ed.)
- [46] H. S. Joyner (ed.), "Rheology of semisolid foods."
- [47] R. K. Gupta & M. Padmanabhan, "Polymer and food rheology: Volume 1."



**Figure 1. Food rheology**

**Source:**

[https://en.wikipedia.org/wiki/Food\\_rheology](https://en.wikipedia.org/wiki/Food_rheology)



**Figure 2. Food preservation**

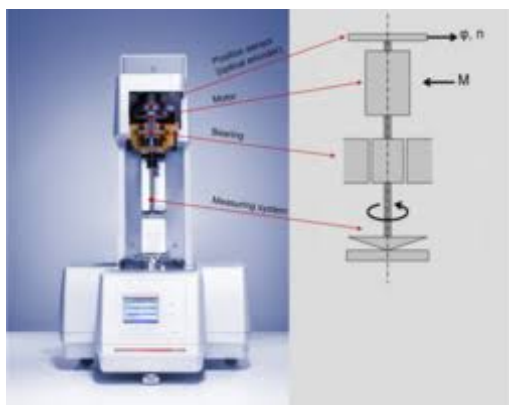
**Source:**

[https://en.wikipedia.org/wiki/Food\\_preservation](https://en.wikipedia.org/wiki/Food_preservation)



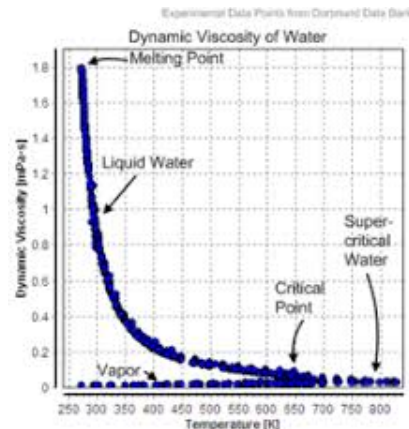
**Figure 3. Food**

Source: <https://en.wikipedia.org/wiki/Food>



**Figure 4. Rheometer**

Source: <https://en.wikipedia.org/wiki/Rheometer>



**Figure 5. List of viscosities**

Sources:

[https://en.wikipedia.org/wiki/List\\_of\\_viscosities](https://en.wikipedia.org/wiki/List_of_viscosities)



**Figure 6. Thixotropy**

Source: <https://en.wikipedia.org/wiki/Thixotropy>

