



Rheological behavior of animal feces

Ioana Stanciu*

Department of Physical Chemistry, University of Bucharest, Faculty of Chemistry, Bucharest, Romania

Abstract

The rheology of human feces is an important component in understanding intestinal function, defecation physiology, and the diagnosis of gastrointestinal diseases. Rheological properties, such as viscosity, elasticity, and plastic behavior, are influenced by factors such as water content, fiber composition, fat and gas content, and intestinal flora. Through experimental methods such as rotational rheometry, textural analysis, and numerical modeling, researchers can characterize the flow and deformation of feces, which provides useful data for the development of treatments for constipation, diarrhea, and other transit disorders. In addition, rheological characterization is also relevant in areas such as sanitary system design and forensic analysis. Studying fecal rheology thus contributes to a better understanding of digestive health and to the optimization of therapeutic and technological interventions.

Keywords: Rheology, human, feces

Introduction

Rheology, the study of the flow and deformation of matter, plays a critical role in understanding the physical behavior of complex biological materials. Among these, animal feces represent a particularly interesting and understudied class of soft matter. Composed of undigested food residues, microbial biomass, water, and metabolic waste products, feces exhibit a wide range of rheological properties depending on species, diet, hydration, and environmental conditions. Investigating the rheological behavior of animal feces is important not only for fundamental scientific knowledge but also for practical applications in agriculture, environmental management, veterinary science, and biomedical research.

Animal feces can be classified as a heterogeneous, multiphase system with characteristics of both solids and liquids. This duality places fecal matter within the category of viscoelastic materials, which display both viscous (fluid-like) and elastic (solid-like) responses when subjected to stress. The balance between these behaviors is influenced primarily by water content and the structural organization of particulate matter within the fecal matrix. For instance, feces with high moisture content tend to behave more like viscous fluids, exhibiting flow under relatively low stress, while drier feces exhibit more solid-like properties, resisting deformation until a critical stress threshold is reached.

One of the key rheological properties used to describe fecal matter is yield stress. Yield stress refers to the minimum stress required to initiate flow in a material. Many types of animal feces, particularly those with moderate to low water content, behave as yield-stress fluids. This means they can maintain their shape under small stresses but begin to flow when the applied stress exceeds a certain limit. This property is especially relevant in agricultural contexts, where the handling, transport, and spreading of manure depend on its ability to flow under mechanical forces.

Viscosity is another important parameter in the rheological characterization of feces. Unlike simple Newtonian fluids such as water, which have a constant viscosity regardless of the applied shear rate, fecal matter typically exhibits non-Newtonian behavior. Most animal feces are shear-thinning,

meaning their apparent viscosity decreases as the shear rate increases. This behavior arises from the breakdown of internal structures within the material, such as flocculated particles and microbial aggregates, under shear stress. Shear-thinning properties facilitate processes such as pumping and mixing, as the material becomes easier to handle when subjected to mechanical agitation.

The microstructure of feces plays a crucial role in determining its rheological behavior. Fecal matter contains a complex network of fibers, proteins, lipids, and microbial cells that interact to form a three-dimensional structure. This structure can trap water and create a gel-like consistency. The degree of connectivity and strength of this network influence both the elastic modulus and the viscosity of the material. Diet is a major factor affecting this microstructure; for example, high-fiber diets tend to produce feces with more pronounced structural networks, leading to higher yield stress and elasticity.

Different animal species produce feces with distinct rheological characteristics. Herbivores such as cows and horses typically produce feces with higher fiber content and greater structural integrity, resulting in more solid-like behavior. In contrast, carnivores often produce softer feces with higher protein and fat content, which can exhibit more fluid-like properties. Omnivores, including humans and pigs, produce feces with intermediate characteristics that can vary widely depending on dietary intake. These interspecies differences highlight the importance of considering biological and ecological factors when studying fecal rheology.

Environmental conditions also influence the rheological properties of feces. Temperature, for instance, can affect viscosity and microbial activity, leading to changes in structure over time. As feces age, microbial degradation can break down structural components, often resulting in a decrease in viscosity and yield stress. Similarly, water evaporation can lead to increased stiffness and reduced flowability. These time-dependent changes are particularly relevant for waste management systems, where fecal matter is stored, transported, or treated over extended periods.

Understanding the rheological behavior of animal feces has significant practical implications. In agriculture, optimizing the handling and application of manure can improve nutrient distribution and reduce environmental impacts such as runoff and greenhouse gas emissions. In wastewater treatment, knowledge of fecal rheology can enhance the design of pipelines, pumps, and treatment processes. In veterinary medicine, changes in fecal consistency can serve as indicators of animal health, aiding in the diagnosis of digestive disorders.

The rheological behavior of animal feces is governed by a complex interplay of physical, chemical, and biological factors. As a viscoelastic, non-Newtonian material, feces exhibit properties such as yield stress and shear-thinning that are critical for their handling and environmental interactions. Continued research in this field can provide valuable insights into both fundamental soft matter physics and practical challenges in waste management and animal health. [1, 5].

Materials and method

Biological materials

Faecal samples were collected from three species of domestic animals: cattle (*Bos taurus*), pigs (*Sus scrofa domestica*) and sheep (*Ovis aries*), from local farms located in Cluj County, Romania. The animals were fed with standardized rations for each species, without medication administration in the last 30 days before sampling. For each species, 10 individual samples were collected, immediately after defecation, using disposable gloves and sterile containers.

Sample handling and storage

Samples were transported in airtight containers, at controlled temperature (4 ± 1 °C), and analyzed within 6 hours of collection. Before measurements, the samples were homogenized for 2 minutes with a mechanical mixer (IKA RW 20 digital, Germany) to ensure uniformity. The moisture content was determined by drying 5 g of sample at 105°C for 24 h, according to ISO 6496:1999, and the value was used in the interpretation of rheological data.

Equipment and measurement conditions

The rheological tests were performed with a rotational rheometer (Anton Paar MCR 302, Austria) equipped with a cone-plate geometry (diameter 50 mm, angle 1°). The sample temperature during the tests was maintained at 37 ± 0.1 °C using an integrated Peltier system.

Experimental procedure

To determine the flow curves, a shear rate ramp between 0.1 and 100 s^{-1} was applied, with 20 logarithmic steps, both increasing and decreasing, each step having a stabilization time of 10 s. The apparent viscosity and shear stress were automatically recorded.

To analyze the viscoelastic behavior, amplitude oscillatory tests (0.01–100% strain, constant frequency 1 Hz) were performed to identify the linear response range, followed by frequency tests (0.1–10 Hz, fixed strain in the linear range).

Result and discussions

The feces of all three species exhibit pseudoplastic behavior (shear-thinning), characterized by a decrease in dynamic viscosity with increasing shear rate.

This phenomenon is determined by the disorganization of the network of solid particles and fibers that retain water at low shear rates.

Cattle showed the highest viscosity values at low shear rates, indicating a more rigid internal structure and more resistant to deformation.

For sheep, the initial viscosity values are close to those of cattle, but the decrease is faster with increasing shear rate, indicating a less stable network.

Pigs had the lowest viscosity values over the entire shear range, suggesting a more homogeneous structure and easier to disaggregate.

At s^{-1} , the viscosity values for all species converge, indicating that the structural differences between the samples become insignificant when the internal network is completely broken.

The results can be used to optimize technological processes involving pumping, mixing or mechanized transport of animal manure, by adapting the equipment to the rheological behavior specific to each species.

Figure 1 shows the dependence of dynamic viscosity on shear rate for cattle feces [6, 12].

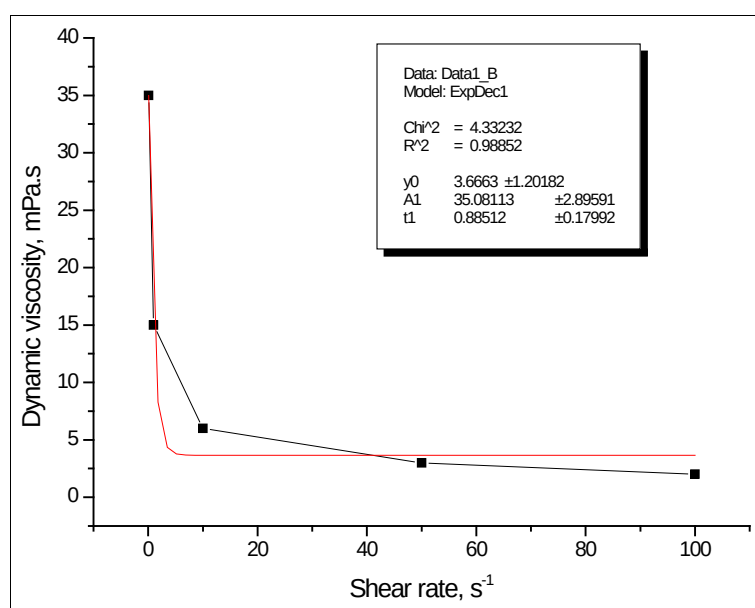


Fig 1: Dependence of dynamic viscosity on shear rate for cattle feces with 15-18% dry

Figure 2 shows the dependence of dynamic viscosity on shear rate for pig feces.

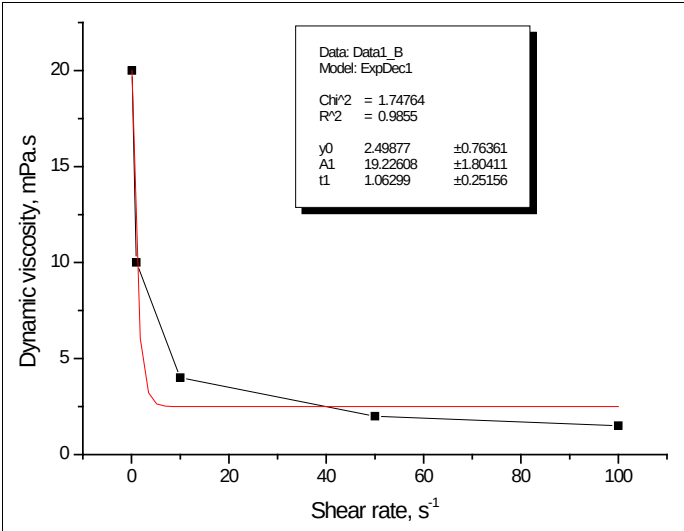


Fig 2: Dependence of dynamic viscosity on shear rate for pig feces.

Figure 3 shows the dependence of dynamic viscosity on shear rate for sheep feces.

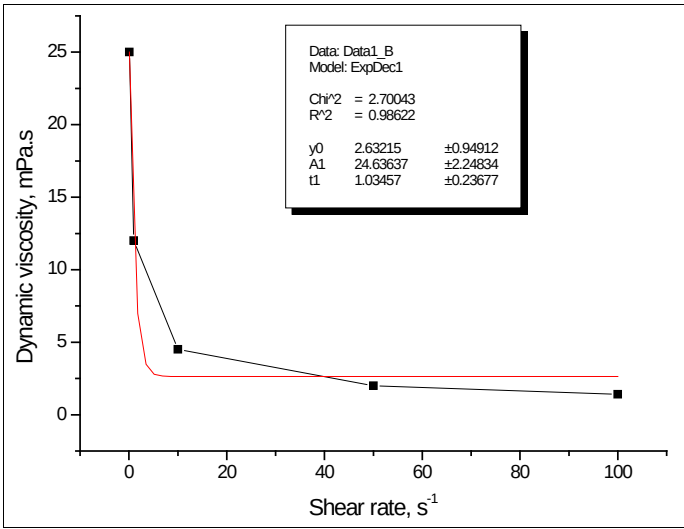


Fig 3: Dependence of dynamic viscosity on shear rate for sheep feces.

Figure 4 shows the dependence of shear rate on shear stress for cattle feces.

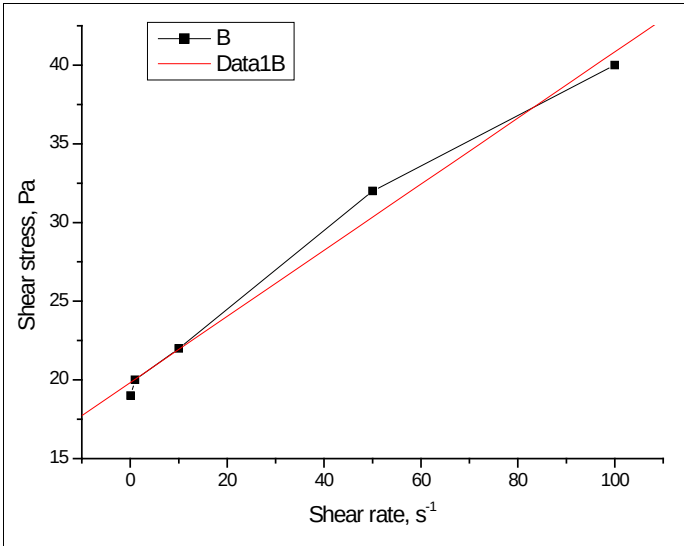


Fig 4: Shear rate versus shear stress for bovine feces.

Figure 5 shows the shear rate versus shear stress for porcine feces.

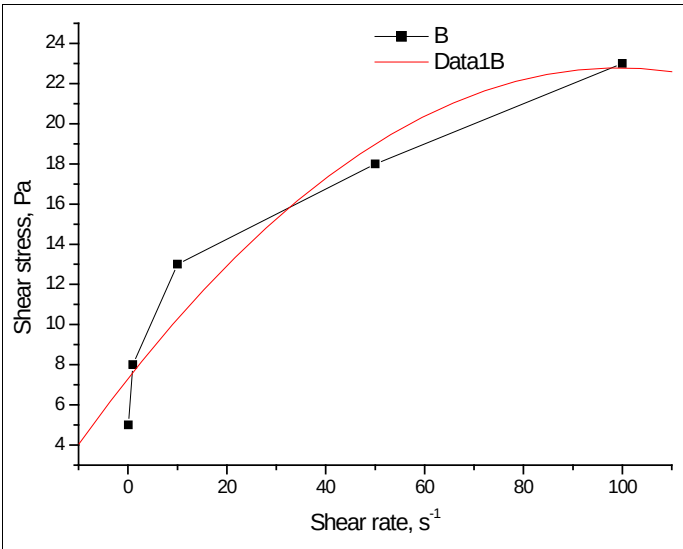


Fig 5: Shear rate versus shear stress for pig feces.

Figure 6 shows the shear rate versus shear stress for sheep feces.

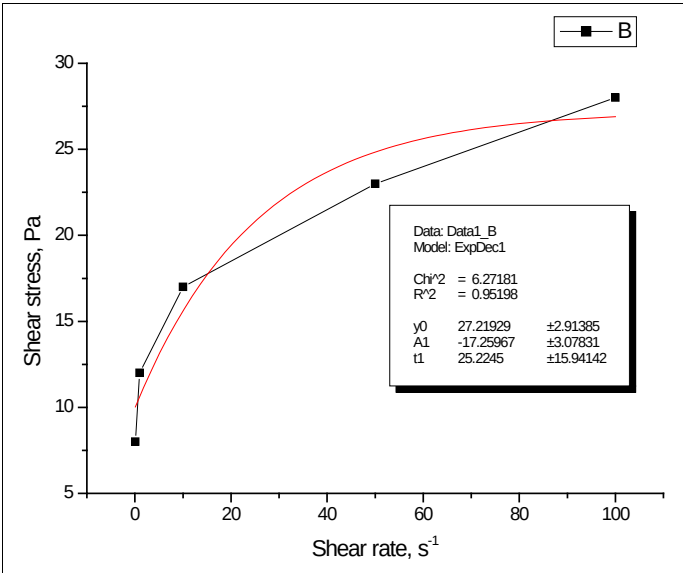


Fig 6: Shear rate dependence on shear stress for sheep feces.

Feces of all three species exhibit pseudoplastic behavior according to the Ostwald–de Waele model, which means that the shear rate increases faster than in a Newtonian fluid for the same increase in stress.

The parameter n is less than 1 in all cases, confirming the shear-thinning character.

Cattle require the highest values of shear stress to reach the same shear rate, indicating a high consistency and a resistant internal structure.

Sheep exhibit high initial stresses, close to cattle, but the increase in shear rate is more pronounced at moderate stress values, suggesting a more easily broken structure.

Pigs have the lowest stresses for the same level of shear rate, confirming a lower consistency and a less rigid internal structure.

At high stress values ($> 25\text{--}30\text{ kPa}$), the differences between species are significantly reduced, indicating that at intense shear the solid structure of the samples is completely disorganized.

These results are relevant for the design of pumping, mixing and transporting equipment for manure, where the energy required for movement depends directly on the specific relationship of each species ^[13, 19].

Conclusions

The study of human fecal rheology provides essential information for understanding the functioning of the digestive system and how different factors influence the defecation process. The mechanical properties of stool, such as viscosity, elasticity and flow tension, are strongly dependent on the chemical composition, water content and microbial structure. The analysis of these characteristics allows the identification and monitoring of intestinal transit disorders, thus supporting the diagnosis and treatment of gastrointestinal diseases.

Fecal rheology has an interdisciplinary character, with applications that go beyond the medical field, including public hygiene, sanitary engineering and the development of

food or pharmaceutical products with an impact on digestive health. By combining modern experimental methods with numerical modeling, personalized approaches can be created in the prevention and therapy of digestive problems.

Overall, the investigation of human fecal rheology not only improves the understanding of physiological processes, but also contributes to the optimization of clinical and technological interventions, demonstrating the relevance of this field in a scientific and practical context.

Reference

1. Subagio A, Morita N. Food Chemistry, 2003;81:97-102.
2. Dupont J, White PJ, Carpenter MP, Schaefer EJ, Meydani SN, Elson CE, *et al.* Journal of the American College of Nutrition, 1990;9(5):438-470.
3. Veljković VB, Biberdžić MO, Banković-Ilić IB, Djalović IG, Tasi MB, Nježić ZB, *et al.* Renewable and Sustainable Energy Reviews, 2018;91:531-548.
4. Beadle JB, Just DE, Morgan RE, Reiners RA. Journal of the American Oil Chemists' Society, 1965;42(2):90-95.
5. Strocchi A. Journal of Food Science, 1982;47(1):36-39.
6. Stanciu I. Rheological behaviour of biodegradable lubricant. Journal of Science and Arts, 2019;3(48):703-708.
7. Stanciu I. Rheological investigation of soybean oil from soya beans. Journal of Science and Arts, 2019;4(49):938-988.
8. Stanciu I. Modeling the temperature dependence of dynamic viscosity for rapeseed oil. Journal of Science and Arts, 2011;1:55-58.
9. Meneghetti SMP, Meneghetti MR, Wolf CR, Silva EC, Lima GE, Coimbra MDA, *et al.* Journal of the American Oil Chemists' Society, 2006;83(9):819-822.
10. Stanciu I. Journal of Science and Arts, 2018;18(2):453-458.
11. Sheibani A, Ghotbaddini-Bahraman NASER, Sadeghi FATEMEH. Oriental Journal of Chemistry, 2014;30(3):1205-1209.
12. Stanciu I. Some methods for determining the viscosity index of hydraulic oil. Indian Journal of Science & Technology, 2023;16(4):254-258.
13. Stanciu I. Rheological behavior of corn oil at different viscosity and shear rate. Oriental Journal of Chemistry, 2023;39(2):335-339.
14. Stanciu I. Rheological characteristics of corn oil used in biodegradable lubricant. Oriental Journal of Chemistry, 2023;39(3):592-595.
15. Stanciu I. Effect of temperature on rheology of corn (*Zea mays*) oil. Oriental Journal of Chemistry, 2023;39(4):1068-1070.
16. Stanciu I. Study Rheological Behavior of Rapeseed oils Compared to Mineral oil. Oriental Journal of Chemistry, 2021;37(1):247-249.
17. Stanciu I. Influence of Temperature on the Rheological Behavior of Orange Honey. Oriental Journal of Chemistry, 2021;37(2):440-443.
18. Ribot F, Toledano P, Sanchez C. Inorg Chim Acta, 1991;185(2):239-245.
19. Catterick J, Thornton P. Adv Inorg Chem and Radio Chem. H.J. Emeleus and A.G. Sharpe (eds.), 1977, 20.