

Rheology of human saliva

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Abstract

Human saliva plays a fundamental role in oral health, digestion, and speech, and its rheological properties are crucial for understanding both physiological functions and pathological conditions. Saliva is a non-Newtonian fluid whose viscosity and viscoelastic behavior depend on its composition, which includes water, electrolytes, proteins (such as mucins), and enzymes. Rheological characteristics influence lubrication, bolus formation, taste perception, and mechanical protection of oral tissues. Variations in flow rate, pH, and protein concentration can significantly alter saliva's shear-thinning behavior and elasticity. Such changes are observed in conditions like xerostomia, Sjögren's syndrome, and after radiotherapy. Advanced rheometric techniques, including oscillatory shear tests and capillary rheometry, have been used to characterize saliva under physiological and pathological states. Understanding the rheology of human saliva can contribute to the development of diagnostic tools, artificial saliva formulations, and targeted therapies for oral and systemic diseases.

Keywords: Rheology, human, saliva

Introduction

Saliva is a complex biological fluid secreted by the major and minor salivary glands, essential for maintaining oral health, facilitating speech, and initiating digestion. Composed primarily of water ($\approx 99\%$), it also contains electrolytes, proteins, enzymes, and high-molecular weight glycoproteins such as mucins, which are key contributors to its rheological behavior. From a physical standpoint, saliva exhibits non-Newtonian shear-thinning properties, meaning its apparent viscosity decreases with increasing shear rate, a characteristic critical for lubrication and bolus formation during mastication^[1,5].

The rheology of saliva reflects both its composition and the dynamic conditions of the oral cavity. Flow rate, pH, ionic strength, and protein concentration can modulate viscosity and elasticity, influencing taste perception, mechanical protection of oral tissues, and antimicrobial defense. Alterations in saliva's viscoelastic properties are associated with pathological conditions such as xerostomia, Sjögren's syndrome, cystic fibrosis, and the side effects of radiotherapy.

Advances in rheological measurement techniques—such as oscillatory shear analysis, capillary rheometry, and microfluidic approaches—enable a more precise characterization of saliva under physiological and pathological conditions. Understanding saliva rheology not only deepens insight into oral biophysics but also supports the development of artificial saliva substitutes, diagnostic tools, and therapeutic strategies targeting salivary gland dysfunction^[6,12].

Material and methods

Sample Collection

Unstimulated whole saliva was collected from 20 healthy adult volunteers (10 males, 10 females; age range 20–35 years) with no history of systemic or oral disease and no medication intake in the previous three months. Participants refrained from eating, drinking, or performing oral hygiene procedures for at least 90 minutes before collection. Saliva

was collected between 9:00 and 11:00 a.m. to minimize circadian variation, following the passive drool method into sterile polypropylene tubes. Stimulated saliva samples were obtained from the same participants by chewing flavorless paraffin wax for 2 minutes. All samples were immediately placed on ice and processed within 30 minutes of collection.

Sample Preparation

Saliva was centrifuged at 4 °C for 10 minutes at $10,000 \times g$ to remove cellular debris and particulate matter. The supernatant was collected, and aliquots were stored at 4 °C for analysis within the same day to avoid rheological changes due to freezing.

Rheological Measurements

Rheological properties were assessed using a controlled-stress rheometer (e.g., Anton Paar MCR series) equipped with a cone-plate geometry (diameter: 50 mm, cone angle: 1°). The temperature was maintained at 37 °C using a Peltier plate to simulate physiological conditions.



Fig 1: Rheometer Anton Paar MCR

Results and discussion

Steady shear tests were conducted over a shear rate range of 0.1–1000 s⁻¹ to evaluate apparent viscosity and determine shear-thinning behavior.

Flow curves were fitted to the Carreau–Yasuda and power-law models to extract characteristic rheological parameters (zero-shear viscosity, consistency index, flow behavior index).

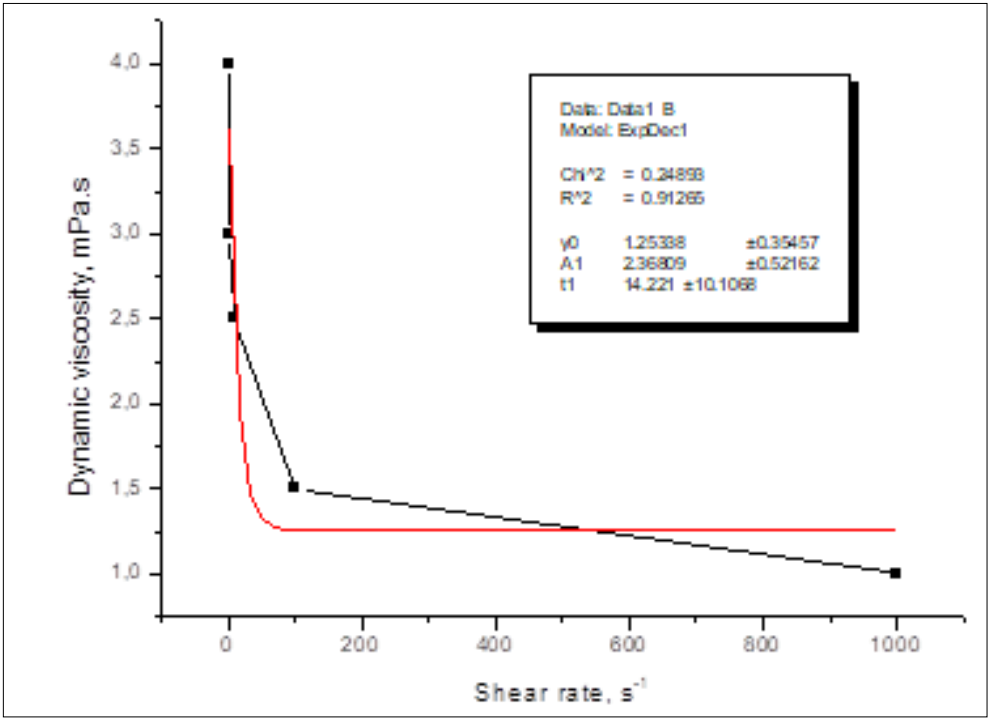


Fig 2: Dependence of dynamic viscosity on shear rate for human saliva (unstimulated)

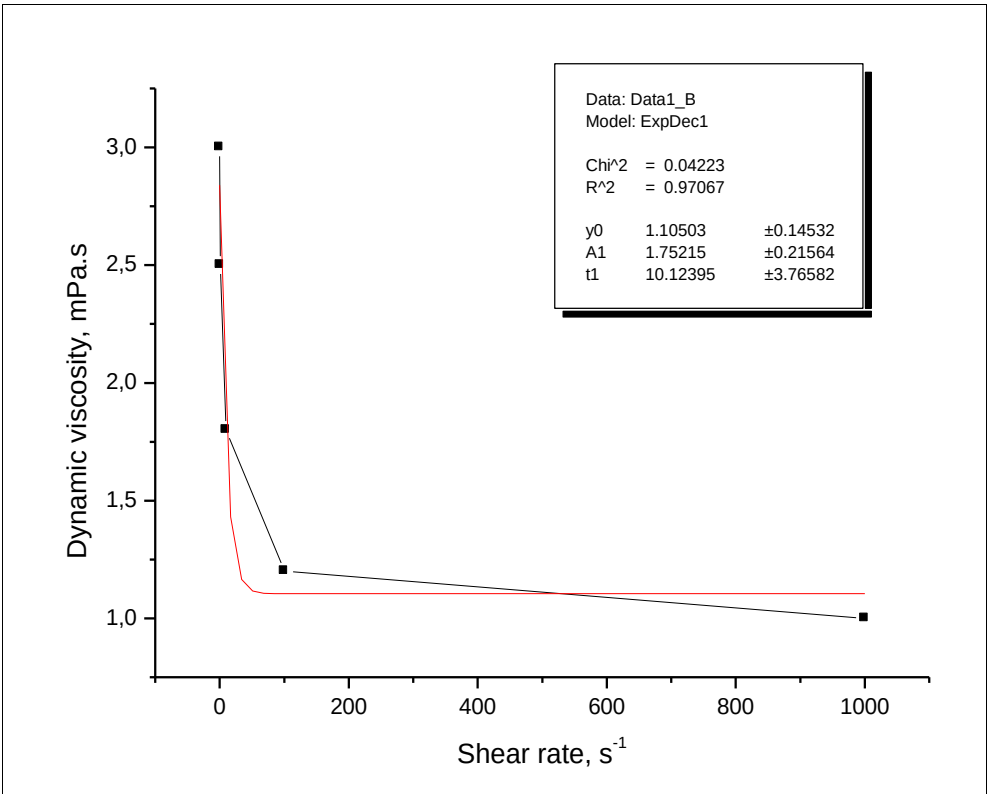


Fig 3: Dependence of dynamic viscosity on shear rate for human saliva (simulated)

Saliva is a shear-thinning fluid—viscosity decreases significantly as shear rate increases. Unstimulated saliva has a higher viscosity due to the higher concentration of mucins and proteins.

At very high shear rates (1000 s⁻¹), saliva approaches the viscosity of water (≈1 mPa•s). Individual differences can be large (±20–30%) depending on hydration, diet, and salivary gland health [13, 19].

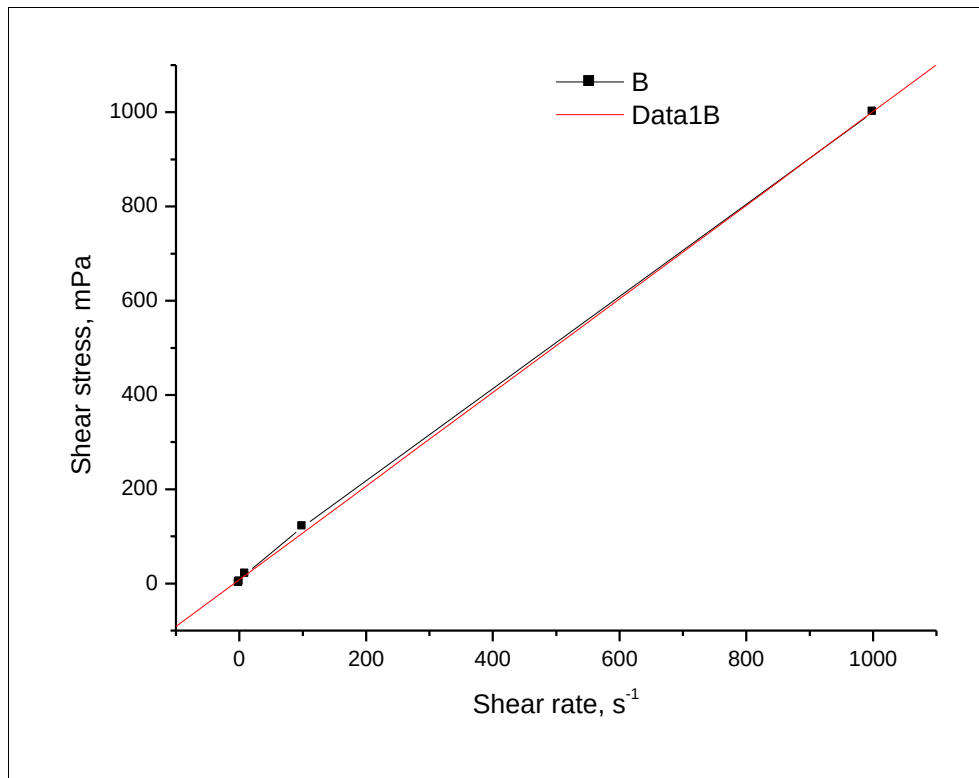


Fig 4: Shear stress dependence on shear rate for human saliva (unstimulated)

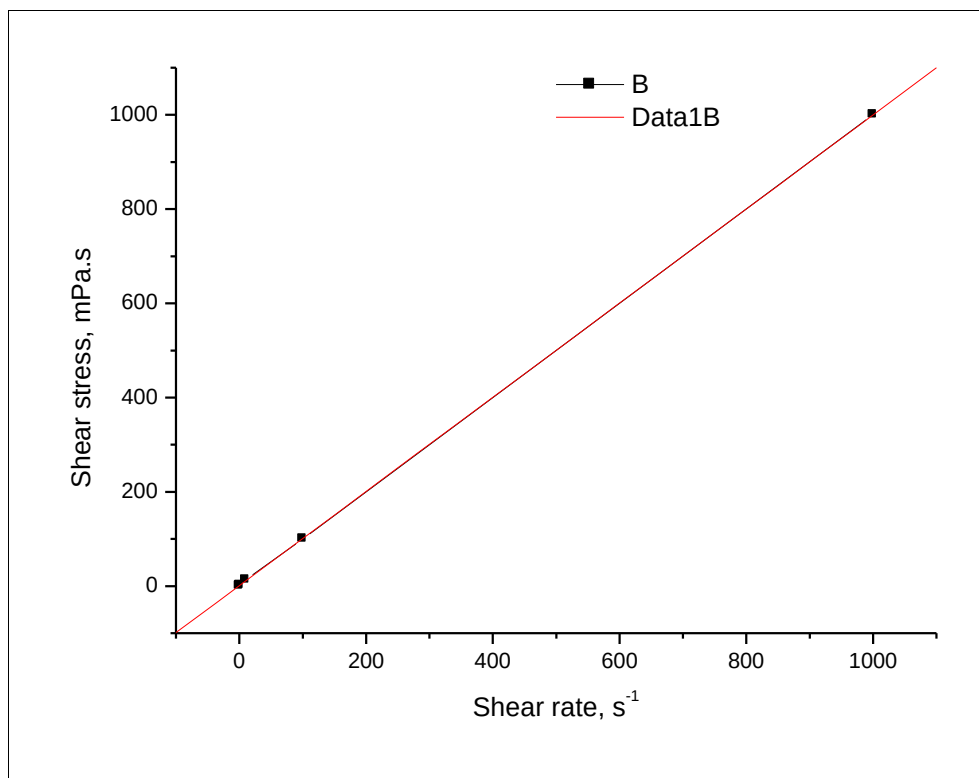


Fig 5: Shear stress dependence on shear rate for human saliva (simulated)

Conclusions

The rheological study of human saliva highlights the fact that it is a non-Newtonian shear-thinning fluid, whose properties depend on the chemical composition, especially on the concentration of mucins and proteins. The apparent viscosity decreases significantly with increasing shear rate, which facilitates physiological functions such as lubrication of oral structures, formation and transport of the food bolus, taste perception and mechanical protection of the mucosa.

Unstimulated saliva presents higher values of viscosity and elasticity compared to stimulated saliva, due to the higher concentration of macromolecular components. Rheological changes can be sensitive indicators of pathological conditions, such as xerostomia, Sjögren's syndrome or post-radiotherapy complications.

Detailed rheological characterization, using modern methods such as oscillatory rheometry and flow curve analysis, provides relevant information for differential

diagnosis, treatment monitoring and the development of artificial saliva formulations with properties as close as possible to physiological ones. In this context, saliva rheology is not only a topic of fundamental interest, but also a direction with major application potential in dentistry, internal medicine and the biomedical industry.

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