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Rheology Behavior of Biopolymer Gels

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ABSTRACT

Cellulose-based hydrogels and other polysaccharides find extensive use in diverse industrial applications, serving as effective thickeners and gelling agents. They contribute texture to food products, act as structural agents in toothpaste, and are notably utilized in pharmaceutical products. Despite their significant role, providing a molecular-level description of the processes governing their flow behavior remains a challenge. In this work, we employ rheological tests to investigate the flow characteristics of a cellulose-based biopolymer (CMC) and a polysaccharide (xanthan gum) with respect to polymer concentration, with a specific focus on the sol-gel transition. Of particular interest is the exploration of how rheological parameters within the constitutive law vary with concentration, emphasizing on apparent viscosity and yield stress.

Keywords: biopolymers, rheological characterization, constitutive law, xanthan gum, CMC.

1 Introduction

Xanthan gum is a polysaccharide synthesized by the bacterium 'Xanthomonas campestris'. This substance is primarily marketed in powder form, obtained by precipitating the polysaccharide present in the fermentation broth using a polar organic solvent. [1,2]. This gum dissolves readily in water, with solutions displaying a significant increase in viscosity at low concentrations and a notable shear-thinning behavior. Widely known for its applications as a food thickening agent and stabilizer, xanthan gum's rheological properties make it a valuable component in various industrial processes [2]. Carboxymethyl cellulose (CMC) is a cellulose ether polymer that is linear, anionic, and environmentally friendly, as it is biodegradable. CMC stands out as one of the most adaptable water-soluble hydrocolloids, showcasing various crucial characteristics including solubility, rheology, surface adsorption, and more. Within these features, viscosity and degree of substitution (DS) emerge as the pivotal attributes influencing CMC functionality. Importantly, both viscosity and DS can be fine-tuned during the processing stages [3]. Studying the rheological characteristics of solutions containing CMC and xanthan gum not only helps in understanding the polysaccharide structure but also aids in exploring their potential functionalities across a broad spectrum of engineering applications.

2 Experimental

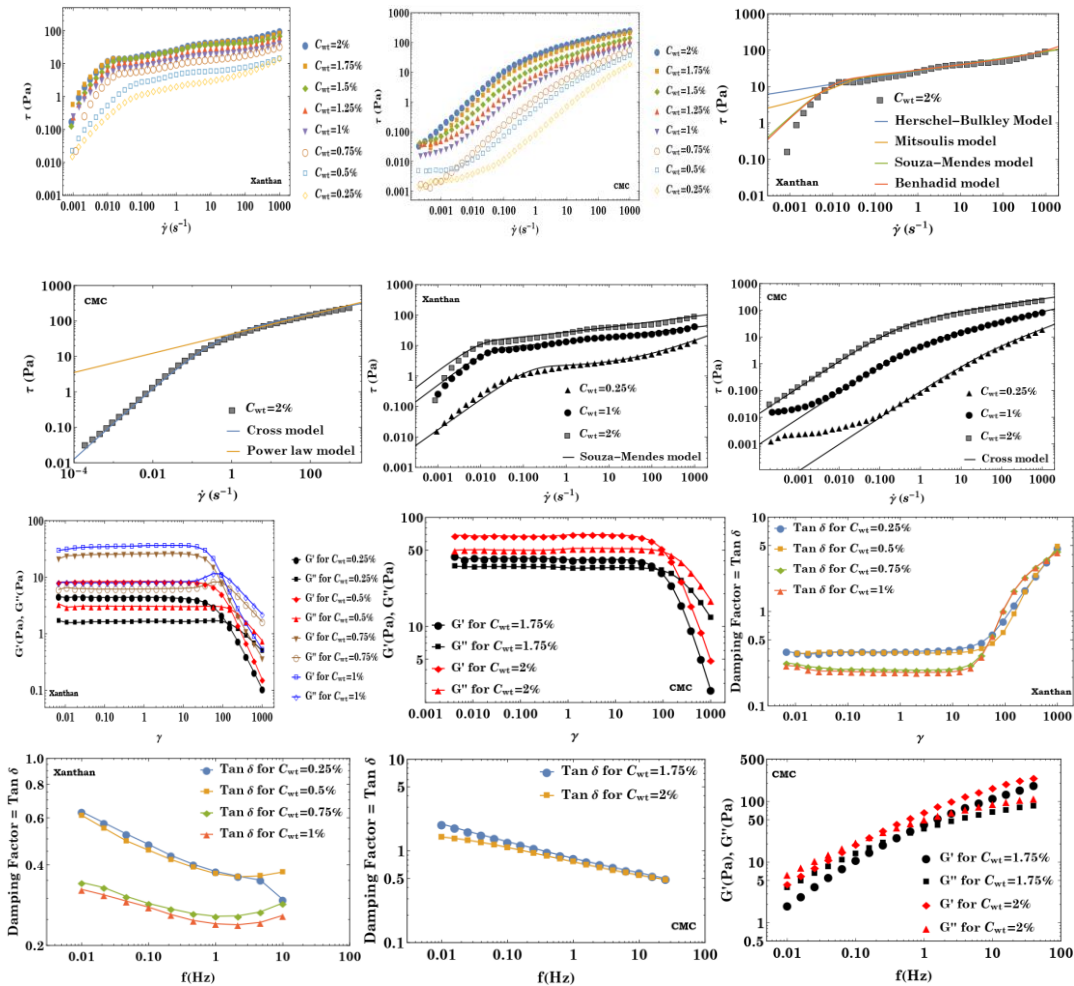
We carried out the rheological measurements using an Anton Paar MCR 302 rheometer of the cone-plane type and 60 mm in diameter. We carried out the rheological measurements using an Anton Paar MCR 302 rheometer of the cone-plane type and 60 mm in diameter. The characterization of the flow of the complex fluid prepared is done with a rotational rheometer. The device consists of a rotation axis connected to a motor which can be either at imposed speed or at imposed torque and a measuring cell. The cell is made up of a fixed part (stator) and a mobile part (rotor). Thus, the fluid to be studied is then confined in the space between the rotor and the stator commonly called gap or air gap.

3 Results and Discussion

We used the Cross viscosity model and the Souza-Mendes model, respectively, to fit the flow curves of the CMC and Xanthan solutions, which are given by



$$\tau(\dot{\gamma}) = \left(\eta_{\infty} + \frac{\eta_0 - \eta_{\infty}}{1 + \left(\frac{\dot{\gamma}}{\dot{\gamma}_c}\right)^n} \right) \dot{\gamma} \quad \tau(\dot{\gamma}) = (\tau_0 + k\dot{\gamma}^n) \left(1 - e^{-\frac{\eta_0}{\tau_0} \dot{\gamma}}\right)$$



4 Conclusions

The characterization protocol developed in this work made it possible to identify and choose the model that best suited the hydrogels used in this experimental study. Based on the graphical adjustment of the experimental points by the different models used; the choice fell on the Souza–Mendes model for Xanthan gum and on the Cross model for CMC. These models adequately translated the evolution of the non-Newtonian character of the biopolymers over a wide range of shear rates.

References

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