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Fundamental Rheological Investigation of Snail Secretion Filtrate in Well-Defined Shear Flow Fields

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ABSTRACT

In this work, preliminary rheological investigation has been made in several well-defined shear flow fields in order to systematically characterize the viscoelastic properties of snail secretion filtrate which is used as a base material in cosmetic cream and lotion formulations

INTRODUCTION

Snail is a common name that can be used for most soft-bodied animals of the molluscan class Gastropods which have a flattened foot with coiled shell in the adult stage[1,2]. Snail is able to move forward rapidly or smoothly on the surface (even wall and ceiling) through the secreted viscous mucus, which acts as an effective adhesive due to its viscoelasticity[3]. It can also help injury healing by regenerating damaged cells, full organs and their skin when damaged by predators or accidents[4].

It is generally believed that the basic structure of snail secretion filtrate is a complex biological compound consisting of glycoproteins and mucopolysaccharides with antioxidants[5].

These days, it is a popular raw material used for the production of many cosmetics such as anti-aging, wrinkles, scars, adult acne, stretch marks, age stops, shampoos, and soaps[6].

Therefore, knowledge of the rheological properties of snail secretion filtrate becomes an important key to improve processing efficiency as well as to develop consumer-acceptable final products. Especially, it is used as a great part of ingredients in a wide variety of cosmetic cream and lotion formulations. Consequently, the quality of the creams and lotions are strongly dependent on the properties of snail secretion filtrate.

The main objective of this research is to systematically investigate the fundamental rheological properties of snail secretion filtrate using a rotational rheometry system in several well-defined shear flow fields including steady and oscillatory flow conditions.

EXPERIMENTAL SECTION

Snail secretion filtrate selected in this research was extracted from the species *Helix pomatia (Escargot)* in France. The steady shear and the dynamic viscoelastic properties of snail secretion filtrate have been measured using a strain-controlled rheometer [Advanced Rheometric Expansion System (ARES), Rheometric Scientific, Piscataway, NJ, USA] equipped with a parallel-plate fixture with a radius of 12.5 mm and a gap size of 0.5 mm. All rheological measurements were performed at a fixed temperature of 20 ℃ over a wide range of shear rates, angular frequencies and strain

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amplitudes.

In all measurements, a fresh sample was used and rested for 10 min after loading to allow material relaxation and temperature equilibration.

The steady shear flow properties were measured over a wide range of shear rates from 0.1 to 1000 1/s with a logarithmically increasing scale. In order to interpret the relationship between the viscoelastic behavior and the microstructure of snail secretion filtrate, frequency-sweep tests in small amplitude oscillatory shear flow fields were nextly performed over an angular frequency range from 0.025 to 100 rad/s with a logarithmically increasing scale at a fixed strain amplitude of 10 %. In addition, strain-sweep tests were carried out over a strain amplitude range from 0.25 to 1000 % with a logarithmically increasing scale at several fixed angular frequencies of 0.1, 0.25, 0.5, 1, 2.5, 5, 10, 25 and 50 rad/s in order not only to find out the linear viscoelastic region but also to investigate a nonlinear viscoelastic behavior in large amplitude oscillatory shear flow fields. Finally, sinusoidal shear strains of $\gamma(t) = \gamma_0 \sin \omega t$ at several strain amplitudes of 100, 200, 400, 600, 800, 1000 and 1200 % with a constant angular frequency of 1 rad/s were imposed to snail secretion filtrate.

RESULTS AND DISCUSSION

Fig.1 shows the shear rate dependence of the shear stress and steady shear viscosity for snail secretion filtrate. The shear stress tends to decrease as a decrease in shear rate. While the Newtonian viscosity region is not observed at low shear rates the steady shear viscosity exhibits a non-Newtonian shear-thinning behavior as an increase in shear rate.

Fig. 2 (a) shows the strain dependence of the storage modulus, G'(γ_0), at fixed angular frequencies of 0.1, 0.25, 0.5, 1, 2.5, 5, 10, 25 and 50 rad/s for snail secretion filtrate. The storage modulus is gradually increased as an

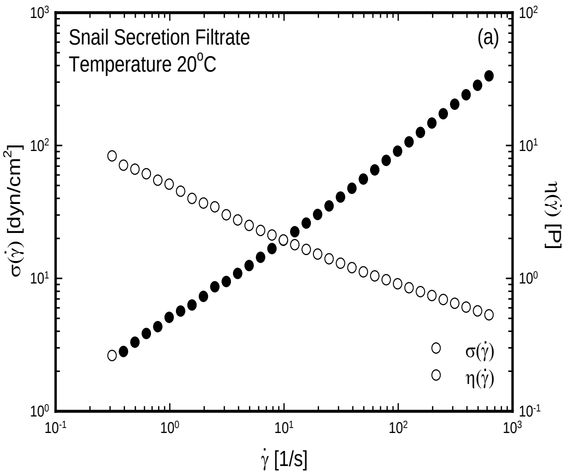

Figure 1. Shear stress and steady shear viscosity versus shear rate for snail secretion filtrate.

increase angular frequency over a whole range of strain amplitude tested.

At several angular frequencies (ω = 10, 25 and 50 rad/s), a linear behavior is observed within a certain strain amplitude range (γ_0 < 20 %) in which the storage modulus exhibits a constant value regardless of strain amplitude.

However, at relatively lower angular frequencies (ω = 0.1, 0.25, 0.5 and 1 rad/s), the storage modulus is slightly decreased up to a certain strain amplitude ($\gamma_0 \approx$ 20 %). After then, a sharp decrease in storage modulus is observed with increasing strain amplitude, indicating a marked strain-thinning feature.

An interesting finding to be noted is that, at several applied angular frequencies of 2.5, 5, 10, 25 and 50 rad/s, a nonlinear behaviour occurs at strain amplitude range larger than 10 % where the storage modulus is first increased up to a certain strain amplitude ($\gamma_0 \approx$ 100 %), beyond which followed by a sharp decrease in storage modulus with increasing strain amplitude, indicating a strain-overshoot behavior.

Fig. 2 (b) represents the strain dependence of the loss modulus, G"(γ_0), at fixed angular frequencies of 0.1, 0.25, 0.5, 1, 2.5, 5, 10, 25 and 50 rad/s for snail secretion filtrate.

Likewise the storage modulus [Fig. 2 (a)], the loss modulus is also progressively increased as an increase in angular frequency over a whole range of strain amplitudes measured. In addition, a linear region is observed at strain amplitude range smaller than 10 % within which the loss modulus exhibits a constant value regardless of strain amplitude. However, an exceptional nonlinear behavior takes place at strain amplitude larger than 10 % where the loss modulus is first increased up to a certain strain amplitude ($\gamma_0 \approx 90 \sim 200$ %), beyond which followed by a decrease in loss modulus with increasing strain amplitude, indicating a strain-overshoot phenomenon.

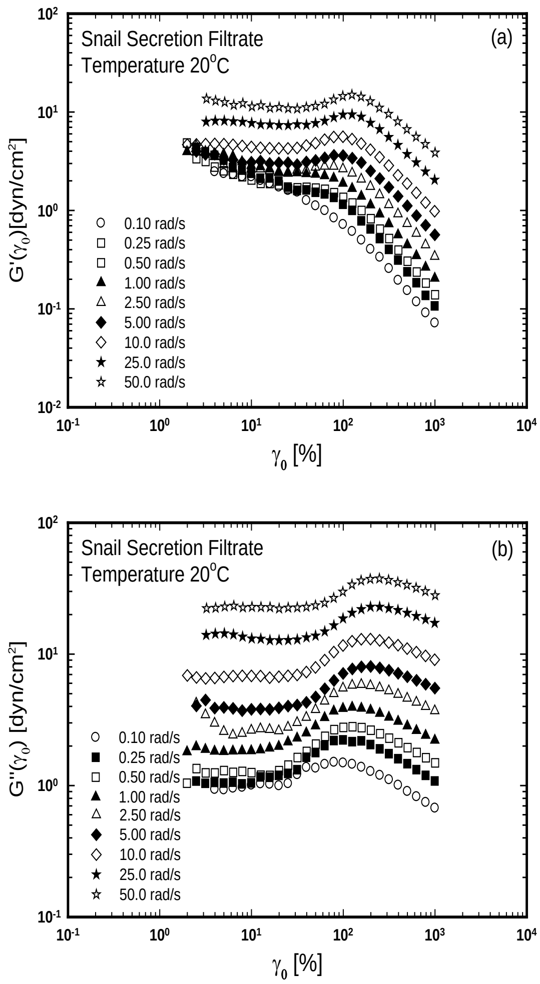

Figure 2. (a) Storage modulus and (b) loss modulus as a function of strain amplitude for snail secretion filtrate with different angular frequencies.

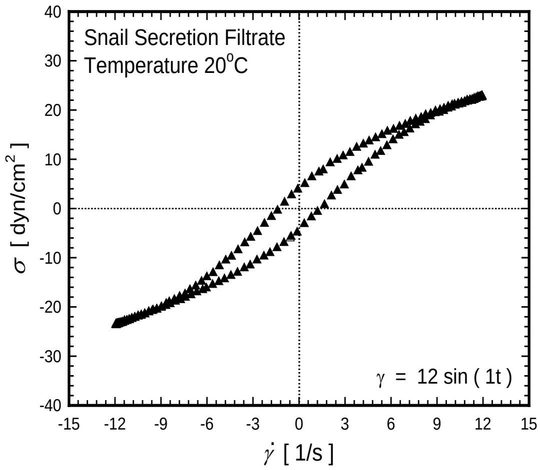

Figure 3. Lissajous curve for snail secretion filtrate at strain amplitude amplitude of 1200 %.

Fig. 3 demonstrates the Lissajous curve obtained from the relation between stress and strain rate for snail secretion filtrate. When very large strain amplitude (γ_0 = 1200 %) was imposed, a 'S' shaped curve is obtained, representing a nonlinear viscoelastic behavior.

Fig. 4 displays the Fourier spectrum obtained from the FFT of the experimental stress response for snail secretion filtrate. The Fourier spectrum consists of the first and several higher harmonic terms from the first-harmonic at angular frequency of 1 rad/s to the third-harmonic (or the fifth-harmonic)

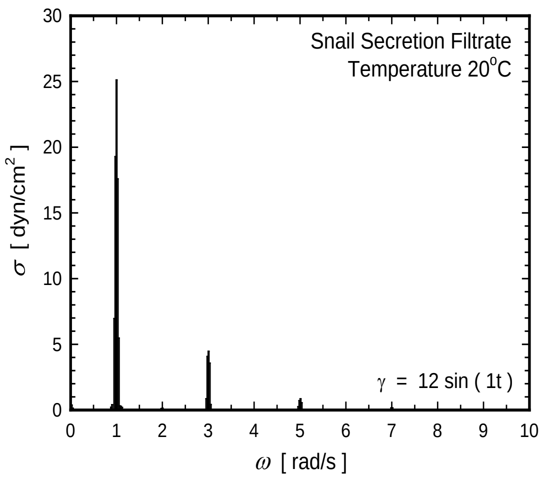

Figure **4.** Fourier spectrum of nonsinusodal response for snail secretion filtrate.

at angular frequency of 3 rad/s (or 5 rad/s). Therefore, the effects of higher harmonic terms should be considered to interpret a nonlinear viscoelastic behavior for snail secretion filtrate.

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