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Viscoelastic properties of tomato juice

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Abstract

Tomato is one of the most important vegetables for the food industry. Rheological characterization of tomato products is important for products, equipments and unit operations design and evaluation. It is necessary for process optimization and high quality products assurance. However, the works in literature present variable data, and some rheological characterization, as viscoelastic properties are still scarce. The present work has evaluated the viscoelastic properties of tomato juice, as well as the applicability of the Cox-Merz rule. The obtained data are potentially useful for future studies on food properties and process design.

1. Introduction

Tomato is one of the most important vegetables for the food industry. Its products consumption is large and widely included in human diet. The rheological characterization of tomato products is important not only for unit operations design, but for process optimization and high quality products assurance.

In fact, many works have been published regarding tomato products rheological characterization. However, data presented in literature are very variable [1] and concentrated only in steady state shear stress measurements. Many works just considered one-condition measurement (just apparent viscosity evaluation) or empiric methods evaluation (as the Bostwick consistometer). Moreover, it is important to notice that viscoelastic characterization of tomato products are very scarce [2,3].

The viscoelastic properties are important to understand and predict the physical-chemical stability of food dispersions, as fruit juices. The Cox-Merz rule states that the apparent viscosity ($n_a = \sigma / \gamma$) at a specific shear rate (γ) is equal to the complex viscosity (n^*) at a specific oscillatory frequency (ω) , when

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γ = ω (Equation 1; [4]). When its rule is valid, the rheological food properties can be determined by even oscillatory or steady-state shear experiments.

$$\eta_a(\gamma) = \eta*(\omega)\big|_{\gamma=\omega} \tag{1}$$

The present work has evaluated the viscoelastic properties of tomato juice, as well as the applicability of the Cox-Merz rule.

2. Materials & Methods

A commercial tomato juice was used for guaranty of standardization and repeatability [5]. Its soluble solids content were determined by using a refractometer, while its total solid content was measured by drying the samples in a vacuum oven at 70ºC (five replicates).

Rheological measurements were carried out in a Haake RS 80 rheometer with controlled stress (σ), using a Couette geometry (concentric cylinder; Haake Z40-DIN). The cup and bob radius ratio was 1.0847 (bob radius = 20.000 ± 0.004 mm). Temperature was maintained constant at 25ºC by using a water-bath (Phoenix ThermoHaake C25P) with deviation lower than ±0.3°C. The experiments were carried out in three replicates.

2.1. Steady-state shear behavior

The steady-state shear behaviour was evaluated for testing the Cox-Merz rule. Samples were sheared at 250 s^{-1} for 250 s, predetermined condition for elimination of product [5]. The shear stress data were then evaluated in the shear rate range of 0.01 s^{-1} to 10 s^{-1}.

2.2. Viscoelasticity properties

The rheological evaluation was carried out with new samples, with no mechanical history. Thus, samples were placed in the rheometer and kept at rest for 10 min before start shearing.

Oscillatory stress sweeps between 0.01 and 10 Pa were performed at a frequency of 1 Hz to determine the linear viscoelastic range. Then, frequency sweep measurements were carried out to at a fixed shear stress value within the linear viscoelastic range, in the range of 0.01 to 100 Hz. The storage modulus (G'), loss modulus (G'') and complex viscosity (n*) were thus obtained as function of frequency (ω).

3. Results & Discussion

The tomato juice soluble solids content were 5.4±0.2ºBrix, with 5.96±0.02% (w/w) of total solids (mean of five replicates ± standard deviation).

Figure 1 shows the oscillatory stress sweeps at 1 Hz for the tomato juice at 25ºC. Based on that, the shear stress of 0.1 Pa was selected for the oscillatory frequency sweeps (Figure 2), as it limits the product linear viscoelastic region.
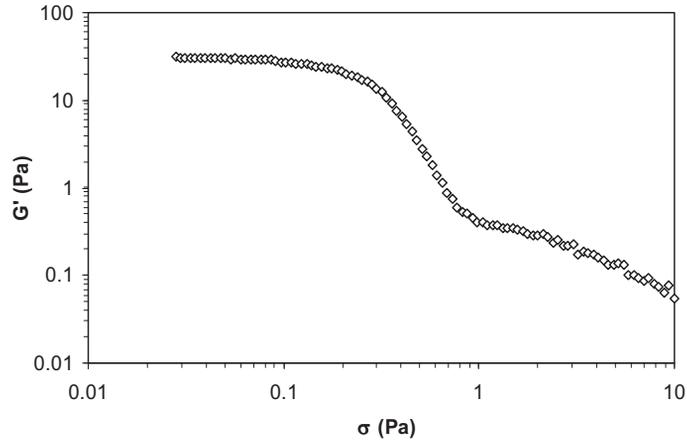
Fig. 1. Oscillatory stress sweeps at 1 Hz (25ºC).

As can be seen in Figure 2, tomato juice has shown low viscoelastic behaviour, as storage modulus (G') dependency of oscillatory frequency was very small. It is expected due to the low concentration of pulp in suspension.

Values of G' were always higher than those of G'', which indicates that tomato juice has dominant elastic properties rather than the viscous ones. Thus, the product can be classified as a weak gel [6]. Similar behaviour has been reported for other food products as açai pulp [7], jabuticaba pulp [8], umbu pulp [9], baby foods [10, 11] and tomato concentrates [12, 13, 14].

When the applicability of the Cox-Merz rule was evaluated, it was not possible to use it straight. It was necessary to use a shift factor (α; Equation 2), as on the evaluation of other food products [5].

$$\eta_a(\gamma) = \eta * (\alpha \cdot \omega)\big|_{\gamma=\omega} \qquad (2)$$

The shift factor for the modified Cox-Merz rule was 0.12 (Figure 3). This value is higher than those calculated by Rao and Cooley [15] for tomato paste (0.0029-0.029), but shown that the rheological properties of tomato juice can be determined by even oscillatory or steady-state shear experiments.
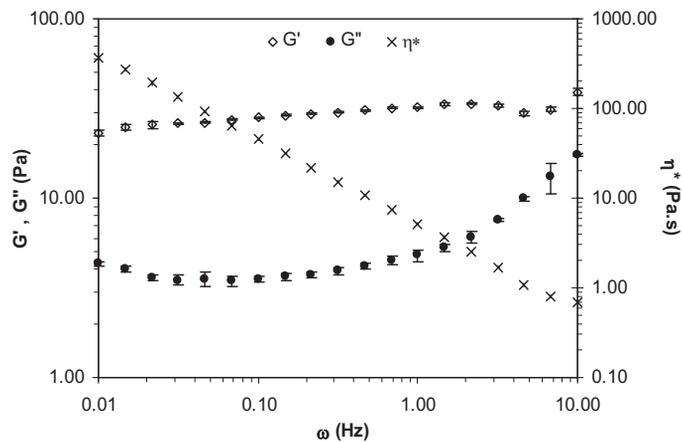

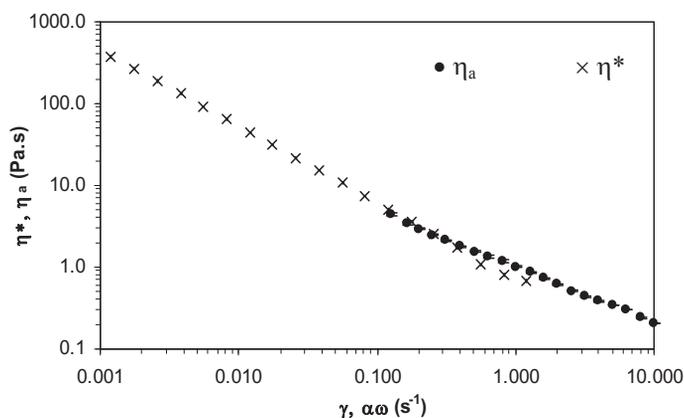Fig. 2. Oscillatory frequency sweeps at 0.1 Pa (25ºC).

Fig. 3. Apparent and complex viscosity as function of shear rate and oscillatory frequency: applicability of the Cox-Merz rule (α = 0.12; Equation 2) (25ºC)

4. Conclusion

The present work has evaluated the viscoelastic properties of tomato juice. Product has shown a weak gel behaviour, with storage modulus higher than loss modulus in the evaluated frequency. A modified Cox-Merz rule could describe the rheological properties of tomato juice. The obtained data are potentially useful for future studies on food properties and process design.

Acknowledgements

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