Rheological Modelling of the Effects of Sucrose Adulterant on Nigerian Honey

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ABSTRACT

Rheology has been applied as sensitive tool for material characterisation since flow behaviour correlates closely with composition, molecular weight and molecular weight distribution. Pure honey was serially diluted with different percentages of sucrose: 10%, 50%, 70% and 90% and each were analysed rheologically at two different temperatures. Pure honey exhibits thixotropic time dependent rheological behaviour, while the behaviour of sucrose tends towards Newtonian. The addition of adulterant to honey drags the viscosity of the resulting fluid towards Newtonian. The rheological curve fitting was done using the Power Law and Carreau-Yasuda models. The results show that the Carreau-Yasuda model fitted better the rheology of pure honey samples. Conversely, the rheology of sucrose solution was predicted better with Power Law model.

Keywords: Rheology, honey, Carreau-Yasuda model, Power Law model, sucrose adulteration.

Introduction

Honey is a natural product from the nectar-sucking bees *(Apis Mellifera)*. All fluids, including honey, flow when subjected to stress. The dynamics of the fluids responds to the input stress is studied in rheology. Through rheology, insight on how flow behaviour correlates with properties such as composition, molecular weight and molecular weight distribution is understood (Bakier, 2007).

A good understanding of rheology is essential for understanding many processes in food engineering, chemical engineering and other areas of research. All materials are made up of molecules, and the same molecular motions and interactions are responsible for rheology (Bird *et al.,* 2002).

There are different varieties of honey bees and all produce honey which properties may vary depending on the nectar source and climatic conditions, but since all honeys are produced by bees there must be something that may be common for all honeys made by bees and that is the essence of this rheological study (Anidiobu, 2009). This study seeks to establish rheological baseline behaviour for honey.

The rheological characterisation of polymers and polymers in dilute solutions are well established to characterize honey since honey contains some oligomers. It has been reported that honey contains as high as 11% melzitose which is an oligomer (Sopade *et al.,* 2004; Rao and Steffe, 1992; Rao, 1977 and 2005). This 11% percent concentration of melzitose in honey is very high, as polymers as low as 2% concentration in solution exhibits non-Newtonian behaviours (De Laney and Reilly, 2000 and Sunthar, 2008).

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Some authors have previously tried in the past to rheologically characterize honey using the rheological properties. Bera *et al.,* (2008) studied some physicochemical and rheological properties of irradiated honey. James *et al*. (2009) worked on physical characterisation of some honey samples from North-Central Nigeria. Also DaCosta and Pereira (2012) undertook the rheological analysis of honey and propolis mixtures.

The objective of this work is to characterize, rheologically, pure honey, adulterated honey and imitation honey at different temperatures to obtain the baseline behaviour.

Theoretical background

Power Law Model (Turian and Bird, 1963):

$$\tau = \eta\gamma^n \qquad (1)$$

Where, η is the consistency coefficient or dynamic viscosity (cp or mPa.s)

τ is the shear stress of the fluids (D/cm^2 or N/m^2) n is the power law index (Dimensionless)

Put $\tau = \eta\gamma$ which is equation (2) into equation (1) with η in the equation (1) changing to η_o

$$\eta\gamma = \eta_o\gamma^n$$

Making η the subject,

$$\eta = \eta_o\gamma^{n-1} \qquad (3)$$

Taking the natural logarithm of equation (3)

$$\ln\eta = \ln\ \eta_o + (n-1)\ln\gamma \qquad (4)$$

A plot of $\ln\eta$ against $\ln\gamma$ will give a straight line graph with slope and intercept $(n-1)$ and $\ln_o$ respectively.

The intrinsic viscosity or zero shear viscosity η_o has a direct relationship with the molecular weight of the fluid in Mark-Houwink equation (Rao, 1997):

$$\eta_o = K'Ma \qquad (5)$$

Where M is the molecular weight of the fluid.

K' and a are Mark-Houwink constants for a given temperature for a given polymer-solvent system.

a is generally in the range of 0.5 to 0.8 (Launay *et al.,* 1986).

Putting equation (5) into equation (3):

$$\eta = K'M^a\gamma^{n-1} \qquad (6)$$

$$\ln\eta = \ln(K'M^a) + (n-1)\ln\gamma \qquad (7)$$

The implication of Equation (7) is that from a log - log plot of viscosity and shear rate, the intercept of the graph on the vertical axis will contain some information on the molecular weight of honey.

Carreau-Yasuda Model (Yasuda, 1979):

$$\eta(\dot{\gamma}) = \eta_\infty + (\eta_o - \eta_\infty)\left[1 + (\dot{\gamma}\lambda)^a\right]^{\frac{n-1}{a}} \qquad (8)$$

This empirical model has five adjustable parameters, α, λ, n, η_o and η_∞.

This model describes non-Newtonian time dependent flow viscosities at zero (η_o) and infinite (η_∞) shear rates, and with no yield stress. The parameter λ is the viscous relaxation time that defines the location of the transition from shear-thickening to shear-thinning behaviour, where 1/λ is the critical shear rate at which viscosity begins to decrease. The power-law slope is (n − 1). The value of n changes with the composition of the fluid. The parameter "α" is dimensionless parameter (sometimes called "the Yasuda constant" since it is a parameter added to Carreau equation by Yasuda, (1979)) which describes the transition region between η_o and the power-law region and it is inversely related to the breath of the zone.

The model fitting was carried out with the method of Morrison (1999). She used the "Solver" Add-on in Microsoft Excel.