Relationship Between Temperature and Dynamic Viscosity in Vegetable Oil

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Abstract

The association between dynamic viscosity and temperature for vegetable oils is thoroughly examined in this paper, with a special emphasis on coconut oil. The investigation includes several shear rates ranging from 3 to 120 s^{-1} and a broad temperature range of 40 to 100 $^{\circ C}$. Using the HV1 viscosity sensor and a Haake Viscotester VT 550, experimental measurements were made. Using a Haake Viscotester VT 550 with the HV_1 viscosity sensor and shear speeds ranging from 3 to 120 s^{-1}, the tests were carried out. The parameters η_0, A, and B for various shear rates were calculated by fitting the data. Strong agreement between the experimental data and the fitted model is shown by the obtained correlation coefficients, which constantly show values near to unity. The viscosity-temperature connection for coconut oil showed a high degree of precision and dependability, with the lowest correlation coefficient, measured at a shear rate of 17.87 s-1, being 0.9615. These results advance knowledge of the behaviour of vegetable oil's viscosity across a range of temperature circumstances and may be useful for lubricant formulation, biofuel production, and a number of other sectors.

Key words – Temperature, Viscosity, Vegetable Oil

Introduction

In order to comprehend the flow behaviour and rheological characteristics of fluids, it is essential to grasp the relationship between dynamic viscosity and temperature. The viscosity-temperature connection is a key factor in defining the processing conditions, product stability, and quality of different food items in the area of food science and engineering. Understanding how viscosity changes with temperature is crucial since vegetable oils, in particular, are often utilized in the food business as cooking oils, ingredients, and additives.

Due to its distinct makeup and wide range of uses, coconut oil has become one of the most popular vegetable oils. Coconut oil is renowned for having a high percentage of saturated fat and for having a unique blend of fatty acids, both of which contribute to its unique physicochemical features. Understanding how coconut oil's viscosity changes with temperature will help us better understands its processing properties, storage stability, and uses in a variety of culinary compositions.

This research aims to clarify the relationship between dynamic viscosity and temperature in coconut oil. Finding the mathematical link that explains how viscosity changes when temperature varies within a given range is the aim of the study. Using experimental findings and techniques for data fitting, the researchers aim to develop an accurate model that captures the relationship between viscosity and temperature in coconut oil.

The HV1 viscosity sensor, which is installed on the Haake Viscotester VT 550 utilized in the study, enables precise and consistent viscosity measurements across a wide temperature range. The researchers will look at samples of coconut oil at different temperatures and shear rates in order to completely comprehend the dynamic viscosity behavior and its link to temperature.

The results of this research have applicability in a variety of industries, such as food manufacturing, where controlling the viscosity of coconut oil is crucial for achieving the texture, stability, and sensory characteristics that customers seek in food products. The findings may potentially have an influence on industries that significantly rely on viscosity-temperature relationships for efficient and efficient product performance, such as biofuel production and lubricant formulation.

By illuminating the relationship between viscosity and temperature in coconut oil, this work contributes to the body of information about the rheological features of vegetable oils. In a number of applications, it also offers helpful insights for improving processing conditions and elevating product quality.

Several previous studies have investigated the influence of temperature on the dynamic viscosity of vegetable oil. These studies have put forth different formulas, including two-constant, three-constant, and multi-constant equations, to describe the temperature dependence of dynamic viscosity. Simple two-constant formulas have been proposed to elucidate the relationship between temperature and dynamic viscosity.

$$\eta = Ae^{B/T} \quad (1)$$

$$\eta = CT^{D} \quad (2)$$

Where A and B are constants, T is the temperature in Kelivn, and η is the dynamic viscosity in cP.

Three-constant formulations were used to express the dynamic viscosity as a function of temperature.

$$\text{In } \eta = A + B/T + C/T^2 \quad (3)$$

$$\text{In } \eta = A + B/T + CT \quad (4)$$

Where T is the temperature in Kelvin and η is the dynamic viscosity in Pa. The constants A, B, C, and D

The following equations serve as their representation.

$$\text{In } \eta = A + B/T + CT + DT^2 \quad (5)$$

$$\text{In } \eta = A + BT + CT^2 + DT^3 \quad (6)$$

η stands for the dynamic viscosity in Pa and in cP, respectively, in equations (6) and (7). T is the Kelvin unit of temperature. The A, B, C, and D are constants

The primary goal of this article is to determine the correlation between temperature and dynamic viscosity for coconut oil. By analysing experimental data and employing curve fitting techniques, the researchers identified a mathematical relationship (equation 7) that describes the dependency of dynamic viscosity on temperature across all the shear speeds at which the oil was investigated.

Methodology

The coconut oil examined in this study was sourced from Tamil Nadu, India. The research focused on investigating the behaviour of coconut oil across a range of temperatures from 40 to 1000 °C and shear rates from 3 to 120 s^{-1}. The experimental measurements were conducted using a Haake Viscotester VT 550 equipped with the HV1 viscosity sensor. The temperature accuracy was within ± 0.1 °C.

Results and discussion

Figures 1–6 demonstrate a clear exponential decrease in the dynamic viscosity of the oil with increasing temperature, observed across the range of shear rates investigated in this study.

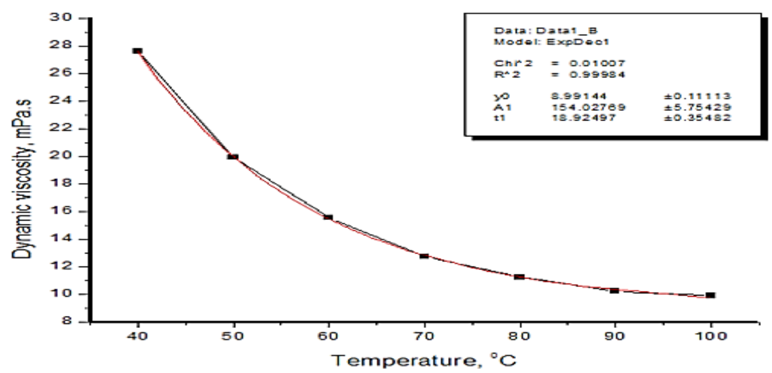

Fig. no. 1) Temperature and dynamic viscosity dependence

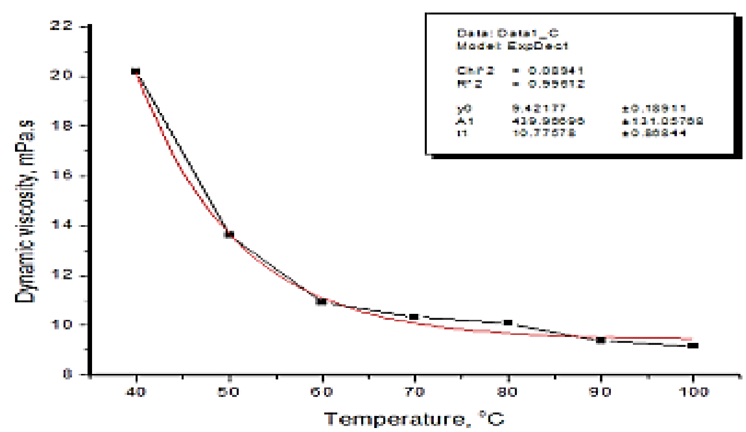

Fig.2) Investigation of Dynamic Viscosity's Temperature Dependence at a Shear Rate of $6s^{-1}$

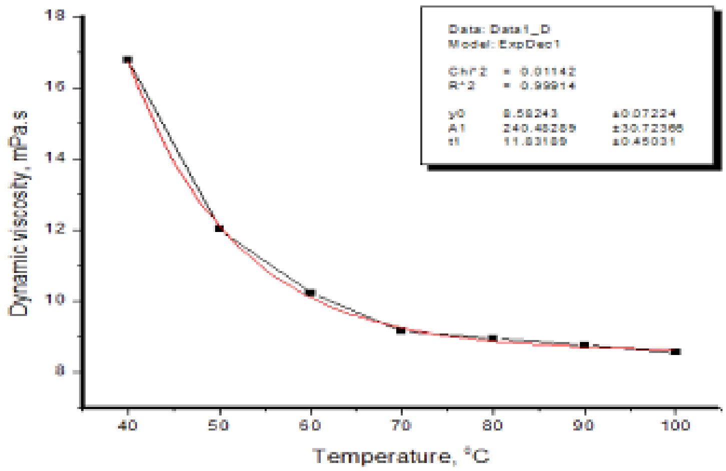

Fig.3) Investigation of Viscosity's Temperature Dependence at a Shear Rate of 17.87s^{-1}

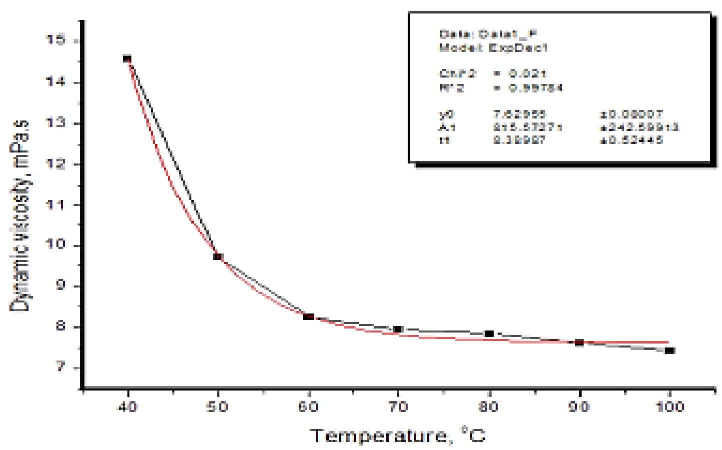

Fig.4) Investigation of Viscosity's Temperature Dependence at a Shear Rate of 30 s^{-1}

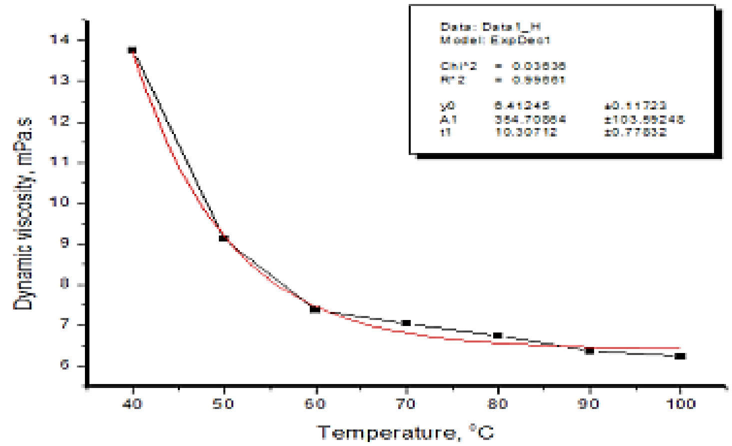

Fig. 5) Investigation of Viscosity's Temperature Dependence at a Shear Rate of 80 s^{-1}

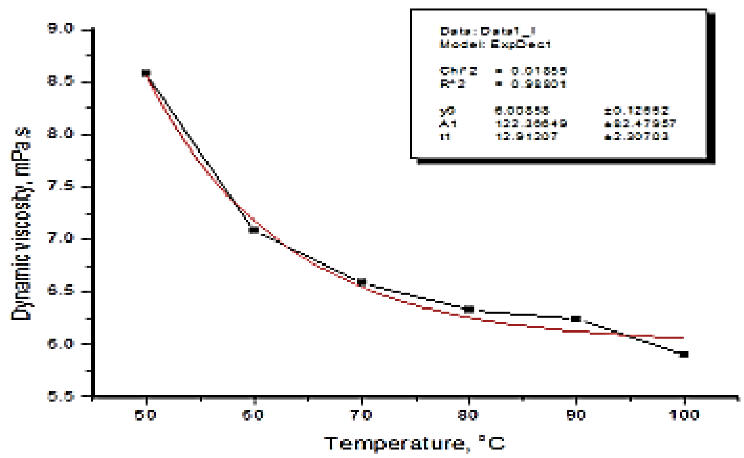

Fig. 6) Investigation of Viscosity's Temperature Dependence at a Shear Rate of 120 s^{-1}

The constants for coconut oil were established through the utilization of the software Origin 6.0. Equation (7), formulated in the subsequent manner, elucidates the exponential relationship between dynamic viscosity and temperature:

$$\eta = \eta_0 + A e^{-t/B} \quad (7)$$

The constants η_0 and B are considered as variables, where η_0 remains constant while B varies with shear rate. The values of the parameters A, B, and η_0 are influenced by the specific operating conditions, the type of oil, and the shear rates applied. The values of the constants η_0, B, and the correlation coefficients are presented in Table 1.

Table 1. The shear rate, along with the parameters A and B as determined by equation (7), and the correlation coefficient R^2, represent numerical values that characterize the properties of coconut oil.

Rate of value shear, S^{-1}	η_0	Parameter values		Value correlation coefficient,
		A	B	R^2
3.3	8.9812	153.1473	18.9844	0.9999
6	8.9799	172.7209	14.7205	0.9807
10.6	8.0799	95.1123	16.9476	0.9725
17.87	7.5877	80.5137	17.0566	0.9615
30	7.2580	131.8048	13.9522	0.9695
52.95	6.6084	149.8882	13.3417	0.9842
80	6.1921	156.7318	13.2341	0.9909
120	6.1180	1107.9796	8.6595	0.9888

As the shear rate increases, the value of h0 decreases, with a relatively smaller reduction observed at higher shear rates, ranging between 6.6084 and 6.1180. At a shear rate of 120 s-1, parameter A exhibits a maximum value of 1107.9796 and a minimum value of 80.5137. Parameter B, on the other hand, has a minimum value of 8.6595 at the highest shear rate and decreases as the shear rate increases.

The coefficients of correlation for the data closely approach unity, indicating strong relationships between the variables. The lowest correlation coefficient value of 0.9615 is observed at a shear rate of 17.87 $s^{-1.}$

Conclusion

This article focuses on the investigation of coconut oil at a wide range of temperatures, spanning from 40 to 1000 degrees Celsius. Through careful analysis at various shear speeds, ranging from 3.3 s^{-1} to 120 s^{-1}, we have established a clear exponential relationship, denoted as equation (7) that describes the impact of dynamic temperature viscosity. Notably, the correlation coefficients obtained from our analysis demonstrate a remarkable proximity to unity, indicating strong associations between the variables. It is worth mentioning that among the different shear rates examined, the lowest correlation coefficient value (0.9615) was observed at a shear rate of 17.87s^{-1}. These findings significantly contribute to our understanding of the complex behaviour of coconut oil under varying conditions.

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