INFLUENCE OF TEMPERATURE ON THE VISCOSITY OF ANDIROBA OIL COMPARED TO ALTERNATIVE AND CONVENTIONAL SOURCES

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ABSTRACT

Andiroba oil has properties of great interest to the food, pharmaceutical and cosmetic industries. Therefore, this study aims to evaluate the effect of temperature on the viscosity of andiroba oil compared to vegetable oils from conventional sources (sunflower and soybean) and alternative (baru). The flow curves of the vegetable oils were obtained from 20 °C to 80 °C and the Arrhenius model was fitted to the experimental data. The oils showed Newtonian behavior throughout the temperature range. The viscosity of the andiroba oil varied from 76.94 mPa.s to 10.79 mPa.s at 20 °C to 80 °C, respectively. Andiroba oil showed activation energy (Ea) close to baru oil and higher than conventional oils. The information about the temperature dependence on the rheological properties of andiroba oil may be useful in the development of new products and several applications in the food industry.

Keywords: viscosity, vegetable oils, rheological properties.

INTRODUCTION

The rheological properties of vegetable oils provide important information about appearance, texture, and quality, which can define their final application. In addition, viscosity is one of the rheological properties of fluids needed to optimize and design industrial processes, especially in the food, chemical, and pharmaceutical industries (1). Viscosity is defined as the fluid's resistance to flow, and therefore, more viscous fluids require more energy to move from one place to another (2).

The flow activation energy is an important property and is directly related to the effect of viscosity against temperature changes in fluids, where higher values of activation energy indicate that viscosity is more sensitive to these thermal changes (3,4).

The influence of temperature on the viscosity (μ) of fluids is described by the Arrhenius-type equation (2,5), which is expressed in terms of absolute temperature (T), a universal constant of ideal gases (R), activation energy (Ea), and fitting parameter (A):

$$\mu = A\,exp\left(\frac{Ea}{RT}\right) \qquad \text{(Equation 1)}$$

The oil extracted from the andiroba seed (*Carapas guianensi*) has interesting properties for nutritional, medicinal, pharmaceutical, and cosmetic purposes, in addition to potential use in the food sector, especially by consumers who have shown to be increasingly concerned about a healthier and sustainable lifestyle (6,7). Thus, the study of the rheological behavior of andiroba oil and other vegetable oils, subjected to thermal changes, is essential to define its final application.

OBJECTIVE

To evaluate the influence of temperature on the viscosity of refined andiroba oil and compare it with other refined vegetable oils from alternative (baru) and conventional (sunflower and soy) sources.

MATERIALS AND METHODS

Materials

The refined andiroba and baru oils were purchased from Mundo dos Óleos (Brasília-DF), and the soybean and sunflower oils were obtained from local commerce in the city of Viçosa-MG.

Rheological Properties

The evaluation of the rheological properties was determined using a dynamic oscillatory rheometer HAAKE MARS (Modular Advanced Rheometer System, Thermo Electron Corp., Germany), equipped with a thermostatic bath (Phoenix 2C30P, Thermo Electron Corp., Germany) with a temperature range from 20 °C to 80 °C, using a coaxial cylinder sensor (DG41). The flow curves of the vegetable oils were obtained by applying a strain rate ranging from 0.01 to 200 s^{-1} for 120 s. Newton's model was fitted to the experimental data:

$$\tau = \mu\gamma \quad \text{(Equation 2)}$$

Where τ is the shear stress (Pa); μ is the absolute viscosity (Pa.s), and γ is the shear rate (s^{-1}).

The Arrhenius-type equation (Eq. 1) was used to model the dependence of the viscosity of vegetable oils as a function of temperature (2).

RESULT AND DISCUSSION

The viscosity values for andiroba, baru, sunflower, and soybean oils, measured over a temperature range of 20°C to 80°C, are shown in Table 1. As the temperature increased, there was a decrease in viscosity for all oils. The same result was found in the literature for different oils from conventional plant sources, such as soybean, sunflower, corn, cotton, canola, and oils from alternative sources, such as mustard, grape seed, and jojoba (1,8-13). This result is expected because the behavior of the fluid is altered by temperature due to the reduction of the intermolecular force, which reduces viscosity and consequently facilitates its flow (9). The relationship between viscosity and temperature for andiroba and baru oils was not found in the literature.

The effect of temperature on viscosity was described using the Arrhenius model. The values of activation energy (Ea), the adjustment parameter (A), and the determination coefficient (R^2) are presented in Table 2. The coefficients of determination were greater than 99% for all oils, indicating that the Arrhenius model adequately describes the relationship between viscosity and temperature for these vegetable oils.

The highest A results were presented for soybean and sunflower, 1600 mPa.s x 10^{-6} and 1560 mPa.s x 10^{-6}, respectively. In the literature, values of 1593 mPa.s x 10^{-6} for soybean and 1511 mPa.s x 10^{-6} for sunflower have been found (8). However, no results were found for andiroba and baru oils.

The Ea values for andiroba (28.12 $kJ.mol^{-1}$) and baru (27.68 $kJ.mol^{-1}$) (values not found in the literature for comparative purposes) were higher than those for sunflower (25.67 $kJ.mol^{-1}$) and soybean (25.63 $kJ.mol^{-1}$). The Ea values for conventional oils were similar to those found by Brock et al. (8), where the Ea for sunflower oil was 25.72 $kJ.mol^{-1}$ and for soybean oil was 25.62 $kJ.mol^{-1}$. Ea values for some oils from alternative plant sources have been reported, and among the values similar to andiroba oil are peanut oil 29.69 $kJ.mol^{-1}$ (14), rice oil (27.49 $kJ.mol^{-1}$) (3), and flaxseed oil (27.80 $kJ.mol^{-1}$) (15). According to Steffe (2), high activation energies indicate that small temperature changes are required to rapidly change viscosity. Thus, the results suggest that andiroba oil has a higher sensitivity to viscosity change with increasing temperature compared to conventional soybean and sunflower oils.

Table 1. The viscosity of andiroba, baru, sunflower, and soybean oils as a function of temperature.

Temperature (°C)	Viscosity (mPa.s)			
	Andiroba	**Baru**	**Sunflower**	**Soybean**
20	76.94	81.90	61.52	61.96
25	61.54	65.80	50.72	50.33
30	49.94	53.40	41.81	41.60
35	41.11	44.00	34.77	34.72
40	34.06	36.65	29.12	29.31
45	28.54	30.92	24.97	24.99
50	24.18	26.31	21.42	21.47
55	20.75	22.54	18.59	18.65
60	17.93	19.53	16.54	16.27
65	15.61	17.48	14.45	14.66
70	13.70	14.95	12.98	12.70
75	12.14	13.21	11.46	11.33
80	10.79	11.74	10.21	10.32

Table 2. Activation energy values (Ea) and constant A obtained by the Arrhenius equation for vegetable oils.

Oil	A (mPa.s) × 10^{-6}	Ea ($kJ.mol^{-1}$)	R^2 (%)
Andiroba	710	28.12	99.78
Baru	910	27.68	99.80
Soybean	1600	25,63	99,77

Sunflower	1560	25,67	99,77

R^2: coefficient of determination.

CONCLUSION

The study of the influence of temperature on the viscosity of andiroba oil showed that this oil undergoes greater changes in its flow behavior than conventional oils (soybean and sunflower), but is similar to baru oil and other alternative vegetable sources. Understanding this property is important for industrial process control and product development and engineering design. Due to the lack of data in the literature about this rheological property of oils from alternative vegetable sources, especially andiroba, this study is of great relevance to the food industry.

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