Experimental Study on Rheology of Animal Fats

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Abstract: *In our days, there is a priority to diversify the sources of energy, in order to prevent the negative effects of human activity on the environment. One of the interestings solutions is to use the animal waste from the food industry. Turning animal fat into combustible would allow substituting it to oil in systems like boilers. But for using animal fat as energy in these systems, we should characterize it before by studying its rheological properties and especially the viscosity, in order to design the systems as well as possible. The purpose of the following study is to establish the main rheological properties of the pork fat, which is one of the most important waste source of animal fat from the food industry.*

Key Words: *Rheology, Rheometry, Non-Newtonian fluid, Biodegradable*

1. INTRODUCTION

The use of vegetable oils and animal fats as lubricants dates back to 1650 B.C. [1]. The discovery of petroleum oil in the late 1800s, however, resulted in replacement of vegetable oils and animal fats and, eventually, mineral oils became the primary base stock for lubricants due to their lower price and superior overall performance [2]. However, the use of vegetable oils and animal fats as lubricants continues, but mostly in specialty applications.

Early this century, environmental concerns have stimulated increased interest in biodegradable lubricants. Since vegetable oils and most esters are more biodegradable than mineral oils, worldwide attention on the biodegradability of lubricants has prompted many lubricant manufacturers to reconsider vegetable oils as base stocks [3-5].

Another application of animal fats is as liquid fuel in large-scale heating boilers. These fats were also used in mixtures with petroleum-based heating oils in this system. Other fuel applications for fats could include their use as fuels and fuel additives for diesel engines [6]. These agriculturally derived fuel products could provide reliable, renewable sources of meeting increasing demands for energy. Such fuels could also reduce dependence on foreign sources of petroleum, increasing international financial and energy security. Increased use of this biomass as a fuel would also have environmental benefits, as agricultural fats and oils are sulfur-free and exhibit much lower particulate matter and CO emissions than petroleum-based fuels [7]. Expanded use of these biomass-based fuels could provide developing countries with inexpensive and renewable energy from domestic sources. This study provides data necessary to help design systems in which pork fat can be used as liquid fuels. For this purpose, the main rheological properties of two different pork fats have been determined.

2. EXPERIMENTAL METHODOLOGY

In order to implement animal fat fuel systems on a large scale, it is necessary to determine the rheological behavior of these substances to guide the design of systems that will transport and utilize these oils. Since most animal fats exhibit high viscosity or solidification at normal working temperatures, it may be necessary to design systems with heating capabilities to insure the flow of the fuel.

These substances were selected to approximate the rheological behavior of defined commodities derived from common animal fats and food industry waste fats. It is well known that the animal fats have a low melting point, between 27°C and 40°C. The temperature of fat liquefaction depends on the area from which the pork fat is taken. From this point of view, two kinds of pork fat have been tested: Sample A – pork fat from the neck; Sample B – pork fat from the chest. The measure equipment for the tests was a cone and plate rotational viscometer "Brookfield Cap 2000+", as shown in Figure 1 [8]. Rotational viscometers use the idea that the torque required to turn an object in a fluid is a function of the viscosity of that fluid. The cone-plate systems are particularly suitable for determining the absolute viscosity of small samples. The resistance to rotation of the cone, caused by the presence of liquid sample between the cone and plate, produces a torque proportional to the shear stress in the liquid. The correct relative positioning of the cone and plate is obtained through a simple mechanical procedure without additional external gauge or instrument.

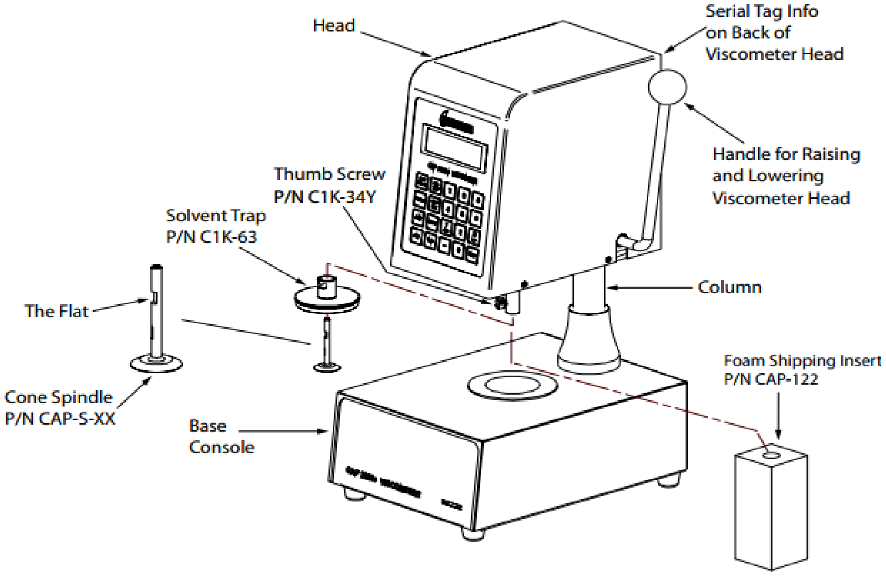

Fig. 1 Viscometer Brookfield Cap 2000+ [8]

Concerning the technical parameters of the viscometer, rotational speed selection ranges from 5 to 1000 RPM. Viscosity measurement ranges depend upon the cone spindle and the rotational speed (shear rate). Viscosity is selectively displayed in units of centipoise (cP), poise (P), or Pascal seconds (Pa•s). Temperature control of sample is possible between either 5°C (or 15°C below ambient, whichever is higher) and 75°C or 50°C and 235°C depending on viscometer model. The viscometer uses a CAPCALC32 software for complete control and data analysis.

Three different types of experimental tests were done:

1. *Shear stress tests*

These tests evaluate the performances of the pork fat against the shear stress. The test parameters are the following:

- two shear stress ranges (low and high shear stress ranges)
- two different constant temperatures corresponding to the semi rigid and liquid consistence

2. *Influence of time over the viscosity*

This test shows how the viscosity decreases with time against a constant shear stress. The parameters are the following:

- constant shear stress
- constant temperature

3. *Temperature performances*

These tests evaluate the viscosity variation of pork fat with its temperature. The parameters are the following:

- constant shear stress
- temperature range from 5°C to 40°C, which includes the transition between the semi-plastic consistence and the fluid one.

3. RESULTS

The first stage of the experiment was focus on the influence of the time on the measured rheological properties, which was the viscosity.

Figures 2 and 3 show the variation of the viscosity in time, for two sample of pork fat, at a constant shear rate.

This measurement was necessary for studying the thixotropy of the materials. If a thixotropic material is sheared at a constant rate after a period of rest, the structure will be progressively broken down and the apparent viscosity will decrease with time.

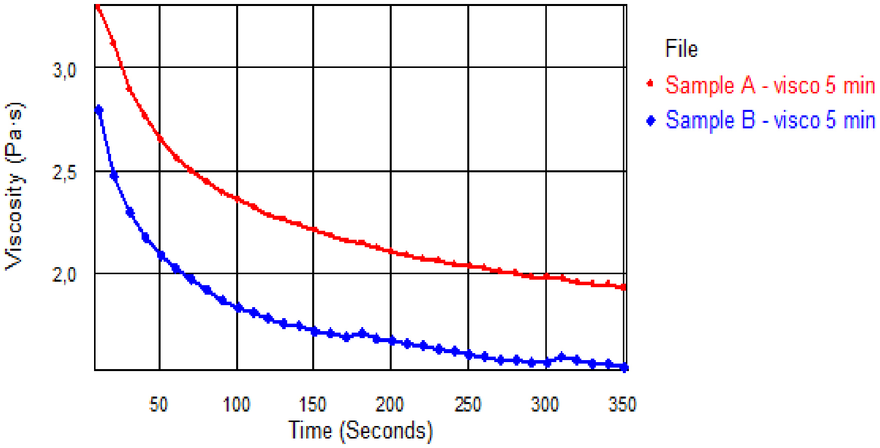

Fig. 2 Variation of the viscosity in time, at a constant shear rate (200 s^{-1}), constant temperature (20^{0}C) and during 5 min. testing time

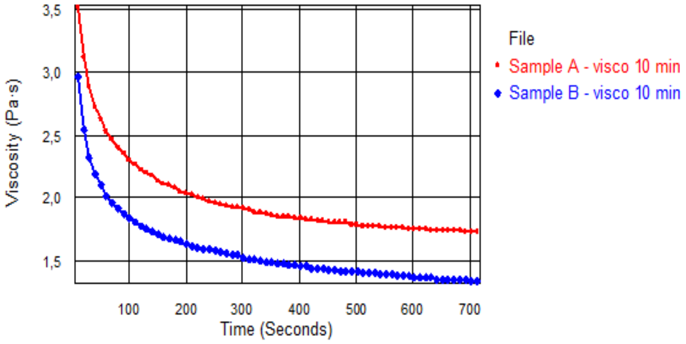

Fig. 3 Variation of the viscosity in time, at a constant shear rate (200 s^{-1}), constant temperature (20^0C) and during 12 min. testing time

It can be easily observed that the rate of breakdown of the structure during shearing at a given shear rate will depend on the number of linkages available for breaking and therefore must decrease with time. Another important observation is that viscosity depends on the body portion of the pork wherefrom it was collected (neck or chest).

This type of behavior leads to a kind of hysteresis loop of shear-stress plotted against rate of shear if the curve is plotted first for the rate of shear increasing at a constant rate and then for the rate of shear decreasing at a constant rate. This is illustrated in Figures 4 and 5, for the two samples of pork fat, at 20^0C, which clearly exhibit thixotropy. It is important to mention that at this temperature, the pork fat has a semi-plastic consistence.

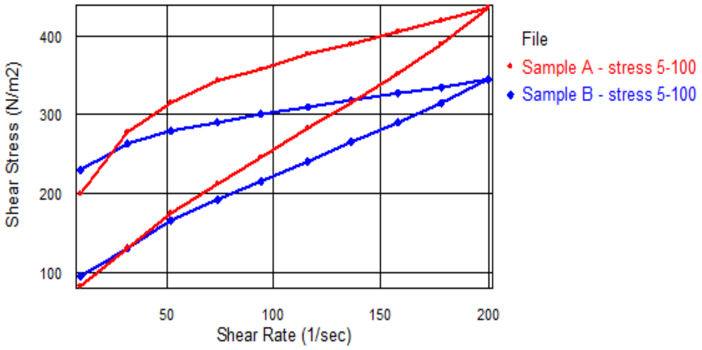

Fig. 4 Hysteresis loop for two pork fat samples, for low values of shear rate (50 s^{-1} - 200 s^{-1}), at constant temperature (20^0C)

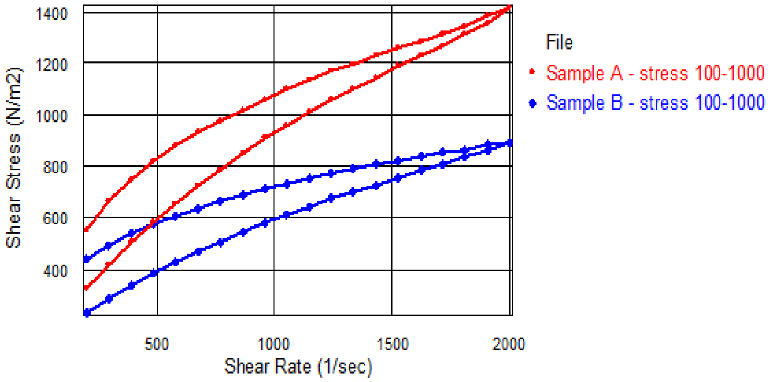

Fig. 5 Hysteresis loop for two pork fat samples, for high values of shear rate (100 s^{-1} - 2000 s^{-1}), at constant temperature (20^0C)

In order to observe the transition of the pork fat between the semi-plastic consistence and the fluid one, a few thermal tests were made.

The main parameter measured was the variation of the viscosity with temperature, correlated with pictures of the pork fat during the test.

Figure 6 presents the results obtained for viscosity, for both samples A and B. It can be observed that the differences between the two samples are more important at low temperature.

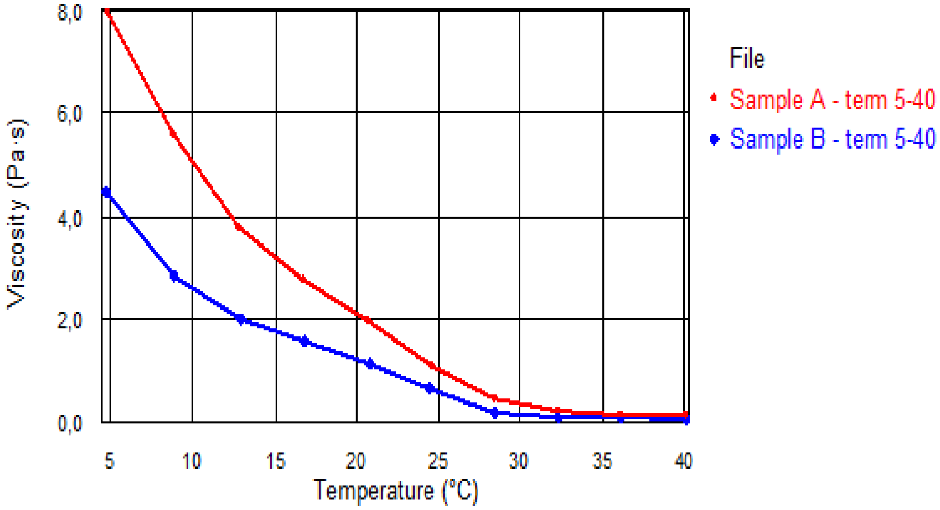

Fig. 6 Variation of viscosity with temperature, at a constant shear rate (200 s^{-1})

Also, the transition domain, between semi-plastic and fluid behavior, is emphasized for a range of temperatures between 25^0C … 35^0C (Figures 7 and 8).

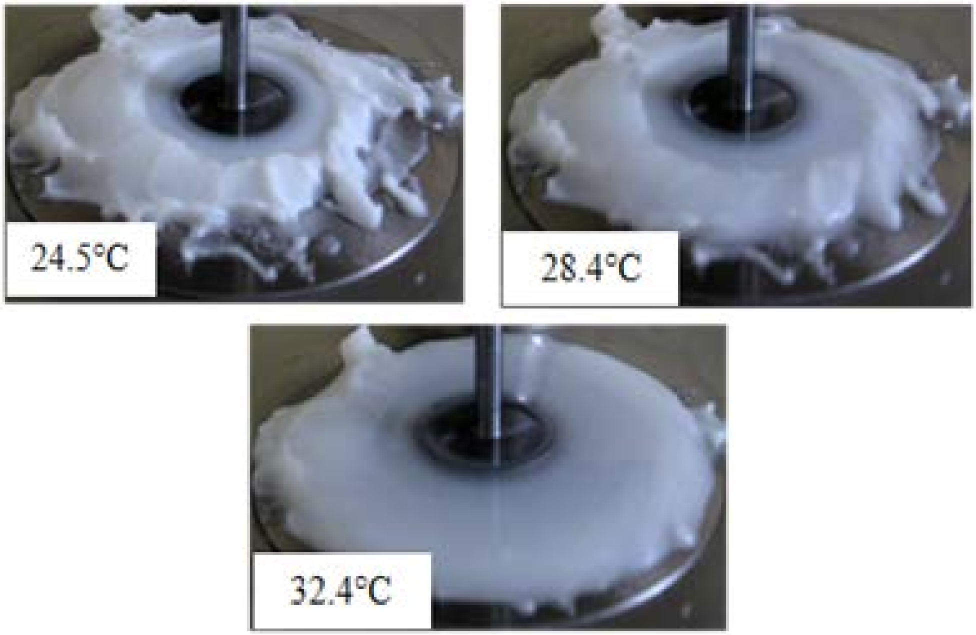

Fig. 7 Pictures for the transition domain (semi-plastic to fluid) for pork fat sample A

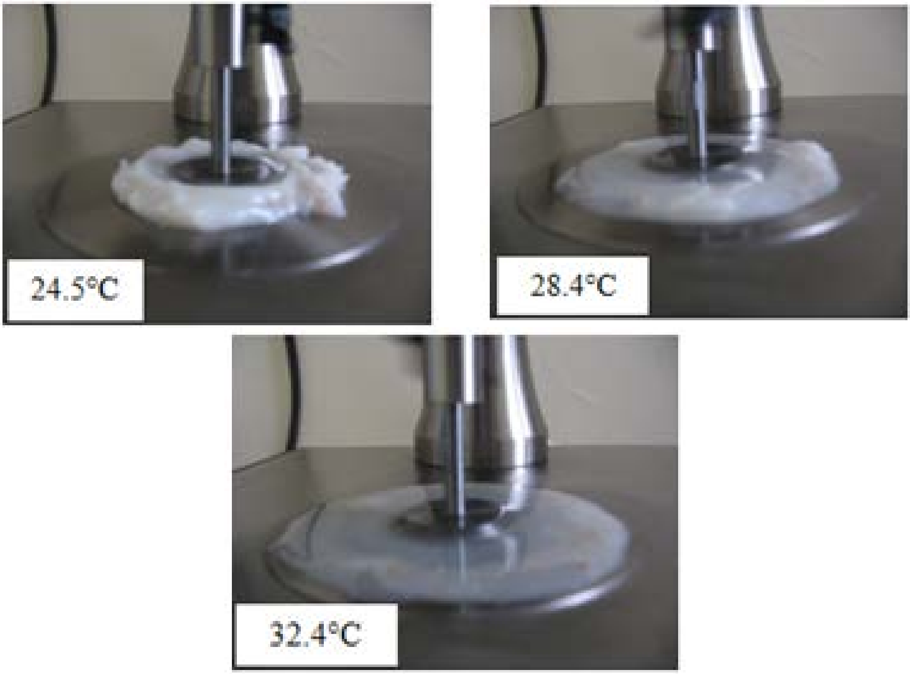

Fig. 8 Pictures for the transition domain (semi-plastic to fluid) for pork fat sample B

4. DISCUSSIONS

The rheological models for the two pork fats were obtained using the rheometer software (Capcalc V3.0) and they are centralized in Table 1. The rheological models assumed for the lubricants were:

- the Bingham model:

$$\tau = \tau_0 + \eta\dot{\gamma} \tag{1}$$

- the Herschel-Bulkley model:

$$\tau = \tau_0 + m\dot{\gamma}^n \tag{2}$$

where: τ - shear stress, η - viscosity, *m* - consistency index, *n* - flow index, τ_0 - yield stress, $\dot{\gamma}$ - shear rate

Table 1: The pork fats rheological parameters

Pork fat	Bingham model			Herschel-Bulkley model			
	η, Pa·s	τ_0, Pa	Corr. coeff.	m, Pa·s^n	τ_0, Pa	n	Corr. coeff.
Sample A	0.507	451	90.54%	51.2	94	0.443	80.22%
Sample B	0.297	335	87.90%	23.4	50	0.471	85.21%

It can be observed that the best fitted rheological model is the Bingham model, for both samples. The corresponding regression curves are presented in Figures 9 and 10.

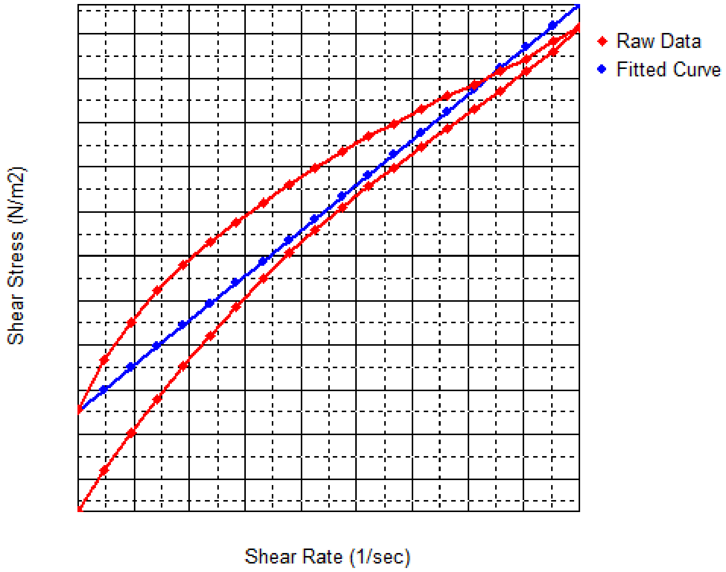

Fig. 9 Regression curve for sample A

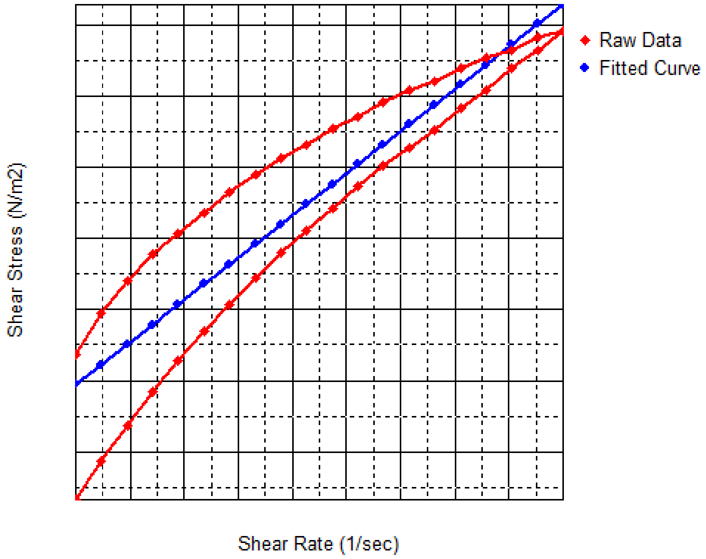

Fig. 10 Regression curve for sample B

5. CONCLUSIONS

1. The rheological properties of pork fats depend on the body portion of the pork wherefrom they were collected;
2. The pork fat has an important thixotropic behavior, due to the breakdown of the structure during shearing at a given rate;
3. The transition domain, between semi-plastic and fluid behavior, is emphasized for a range of temperatures between 25^0C and 35^0C;
4. The aspect of the pork fat, in its fluid state, depends on the portion of the pork's body from which it was collected.

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