ABE 304
Bioprocess Engineering Laboratory

RHEOLOGICAL PROPERTIES OF BIOLOGICAL FLUIDS

Introduction and Scope

Rheological properties of biomaterials are necessary for accurate performance in industrial food and biological processing. Viscosity is a measure of how much resistance a fluid will have to motion. Knowledge of rheological properties enables prediction of fluid behavior in a variety of processes from pressure losses in piping systems to film heat transfer coefficients in evaporation systems. Many fluids encountered by biological engineers are non-Newtonian and often exhibit very high viscosities. This lab will focus on comparing different types of fluids using a rotational viscometer and the implications of viscosity on performance.

Experimental

For these experiments, you will be gathering data from a digital viscometer (Brookfield). The rotational rheometer is used in research and development for biomaterials and provides accurate information on viscosity. The Brookfield DVE viscometer will measure fluid viscosity at given shear rate. Material properties determined by this instrument may be considered fundamental properties of the sample. Refer to your pre-lab for more information about viscometry and the equations that relate your recorded data to the viscoelastic properties of your materials.

Procedure

1. You will measure the viscosity of four known samples: hair conditioner, liquid yoghurt, 85% glycerol, and corn starch 55% w/w in 85% w/w glycerol. You will also measure the viscosity of your fermentation products, both with and without cells present.
2. The TA will power up the viscometer before the class and the default viscosity unit is cP.
3. From the default screen shown on the equipment, press the SPINDLE arrow keys to scroll through the list of available spindles until the correct spindle number is shown on the display. **Tip:** The different spindle code will affect the full-scale range value of the equipment, so you should make sure the spindle you chosen is match the code shown on the display.

Table 1: Spindle selection according to type of fluid and spindle viscosity ranges.

Spindle	Viscosity range / cP	Code	Fluid
LV 1	15 – 20 000	61	Glycerol 85% w/w, xanthan gum
LV 2C	50 – 100 000	66	Liquid yoghurt, Corn starch 55% w/w in glycerol
LV 3C	200 – 400 000	67	Hair conditioner

4. Pour 200 mL of the test liquid into the 250 mL beaker.
5. Immerse the spindle in the fluid up to the mark with care, to avoid the formation of air bubbles. CAUTION: Make sure that the spindle is centered and does not touch the bottom or the walls of the sample container.
6. Select the lowest speed (rpm) available with the SET SPEED key and start the viscometer.
7. Wait until the reading stable and record the viscosity value (cP or mPa s) displayed.
    a. Change the RPM from 0.3-100 by pressing the SPEED up/down arrow key. The viscometer will rotate the spindle at the selected speed when the MOTOR ON/OFF key is pressed once.

   b. Write down the RPM and read the viscosity displayed on the screen when it stables at reasonable range.

8. Repeat steps 6−8 for the remaining speeds, in increasing order.

   Tips: I. when the torque % readings exceed 100% the screen will display "EEEE" for both viscosity and torque %, this data can not be used. You need either reduce the speed or use a smaller size spindle.

   II. when the torque % readings below 10.0% the screen will display both torque % and viscosity with flashing unit, this data can not be used. You need either increase the speed or use a larger size spindle.

   III. when the torque % readings is negative, viscosity will be displayed as "____", this data can not be used.

9. After the highest speed is attained, repeat the viscosity measurements, in decreasing order.

   NOTE: You will need three replicates of each fluid tested for accurate statistical analysis.

10. Clean the beaker and spindle after you test each liquid.
11. Repeat the procedure for all the liquid samples.

Data Analysis

1. Covert the experimental rotational speeds (rpm) to shear rate,γ, (s^{-1}) and the experimental viscosity values (cP) to SI unit (Pa·s). Note that 1 s^{-1} = 60 min^{-1} and 1 cP = 1 mPa·s = 0.001 Pa·s.
2. From the experimental viscosity values obtained, calculate the shear stress (τ) at each shear rate (γ) using Equation 1.

$$\mu = \frac{\tau}{\gamma} \qquad (1)$$

   Some fluids will exhibit a yield stress, τ_0, before flow is initiated. Determine and report the yield stress as needed.
3. Plot μ versus γ and τ versus γ for each test fluid. Note: For time-dependent non-Newtonian fluids plot the values for both increasing and decreasing shear rates in the same graph.
4. Classify the rheological behavior of the fluids based on the experimental flow curves and calculate the appropriate rheological parameters by applying the Power Law model. Use the Excel option Power fit to add a trend line and obtain a best fit for your data.
5. Present pertinent plots to show the flow behavior of each fluid tested. Comment on any time-dependent fluids. How will the time-dependence affect fluid flow?
   a. Include a table listing each sample, the power law parameters (n, K) – with standard deviations included – and the classification of each fluid.
6. How does the presence of cells influence the flow behavior of the fermentation product?
7. Comment on how each of these fluids would influence friction in the flow experimental apparatus and how the viscosity of the fluid would affect the heat transfer in a stirred vessel. Use of prior experimental data will be needed to support claims.

References

Doran, P. M. (2013). *Bioprocess Engineering Principles*. Academic Press.