Application Note: Measuring Infant Milk Viscosity with *micro*VISC

Viscosity is a key component in the analysis of human milk and infant formulas. Research has shown that viscosity is the most important rheological property to determine the ease of swallowing, especially among preterm infants suffering from dysphagia.[1] Milk with too high a viscosity, however, can hinder breastfeeding and induce milk duct clogging.[2] The effects of different additives on formulation viscosity are a topic of ongoing research and have various clinical relevance.

The *micro*VISC viscometer from RheoSense provides a simple, portable, fast, and accurate method of viscosity measurement. Milk and infant formula viscosity can vary over time. *micro*VISC enables on-the-spot measurements with little preparation and small sample volume to help ensure that formulations are correct. A typical cone-and-plate viscometer can require 5-20 ml of sample for viscosity measurement; a major hindrance when dealing with limited samples like human milk. With *micro*VISC, 400 µl of sample is enough for multiple measurements! In addition, *micro*VISC pipettes can be sterilized to avoid sample contamination in clinical environments.

The *micro*VISC TC temperature controller provides *micro*VISC users with the capability to accurately measure viscosity from 18 °C to 50 °C. In the following experiment it is used to measure viscosity at 25 °C and at 37 °C.

Instruments:

*Fig. 1: micro*VISC *(left) and micro*VISC *loaded into micro*VISC TC *(right)*

Samples:

- Lucerne brand skim milk and whole milk (3.25% fat)
- Generic brands of low fat milk (1% fat) and reduced fat milk (2% fat)
- Enfamil Premium infant formula
- Nutramigen infant formula

Test Conditions:

- Temperatures: 25 °C and 37 °C
- Volume used: 100 µl or less of sample per measurement
- Shear rates (1/s): 1,000-9,000
- Infant formulas tested within 30 minutes of mixing.

Experiments:

- Two types of bovine milk (with 0% and 3.25% fat content) are tested and compared at 37 °C, and three types (0%, 1%, 2% fat) are compared at 25 °C.
- Two types of infant formula; Enfamil and Nutramigen, are tested within 30 minutes of mixing to analyze the effect of the added thickeners.

Both the Enfamil and Nutramigen infant formulas are mixed according to manufacturer's instructions.

Each sample is loaded into the *micro*VISC, and allowed to rest for 3 minutes in order to reach thermal stability. One 400 µl pipette of each sample is used, and runs are performed at varying shear rates. Shear rates are chosen to achieve a wide dynamic range while maintaining high accuracy. Below is a graph of the 37 °C data.

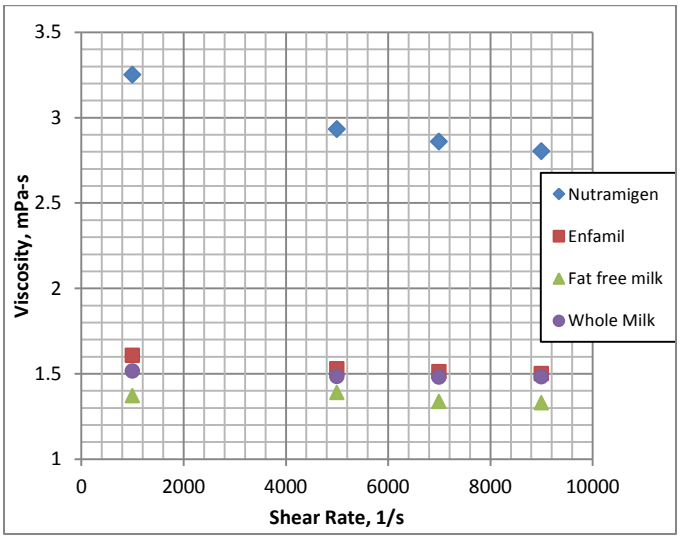

Fig. 2: Viscosity versus shear rate plot of milk and infant formula samples at 37°C

As can be seen from the graph above, *micro*VISC can detect a change in viscosity as a function of a 3.25% increase in fatty content of milk. In addition, Nutramigen

exhibits significantly shear-thinning* behavior, and Enfamil exhibits slightly shear-thinning behavior.

The table below shows the average viscosity of each of the three lower viscosity samples at 37 °C:

Sample	Average Viscosity, mPa-s
Fat free milk	1.36
Whole milk (3.25%)	1.49
Enfamil	1.54

Table 1: Averaged viscosity values of samples at 37 °C

The whole milk viscosity is 9.8% greater than that of skim milk, and the Enfamil is an additional 3.3% more viscous than the whole milk.

Several milk samples, including the skim milk used at 37 °C, are tested at 25 °C. Below is the averaged data for these samples:

Sample	Average Viscosity, mPa-s
Fat free milk	1.61
Low fat milk (1%)	1.95
Reduced fat milk (2%)	1.90

Table 2: Averaged viscosity values of milk samples at 25 °C

Other than fat concentration, the variation between samples can also be attributed to different manufacturers for the milks tested. There is, however, a very notable difference between the skim milk and the other two, mirroring what is seen at 37 °C.

Using *micro*VISC and *micro*VISC TC, it is now possible to analyze both shear and temperature dependence of formulation viscosity outside of a laboratory environment!

Conclusions:

- Viscosity is an important property in neonatal infant nutrition.
- 400 µl of sample is sufficient to determine viscosity and analyze shear dependence of a milk sample using *micro*VISC.
- System is able to reliably measure a difference between milks with different levels of fat content, and to detect a shear rate dependence in two different infant formulations.
- With its small footprint and sample requirement, *micro*VISC is an ideal and indispensible tool for researchers to study the rheological properties of human milk and other clinic samples.

Full Data at 37C:

Sample ID	Shear Rate, 1/s	Viscosity, mPa-s
Fat free milk	9001	1.33
	7000	1.34
	5000	1.39
	1000	1.37
Whole milk	9000	1.48
	6999	1.48
	5000	1.48
	1000	1.52
Nutramigen	8999	2.80
	6999	2.86
	5000	2.93
	1000	3.25
Enfamil	9000	1.50
	6999	1.51
	5000	1.53
	1000	1.61

Table 3: Full table of viscosity data collected at 37 °C

References:

1. Almeida MBdMd., Almeida JAGd., Moreira MEL., Novak FR. "Adequacy of human milk viscosity to respond to infants with dysphagia: experimental study". *Journal of Applied Oral Science* (2011) 19:554-9
2. Cichero J., Nicholson T., Dodrill P. "Liquid Barium is not Representative of Infant Formula: Characterization of Rheological and Material Properties". *Dysphagia* (2011) 26:264-271

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***Shear-thinning fluids have a viscosity that is inversely related to the shear rate applied. This behavior is caused by changes in solute molecular structure under shear stress, and can be commonly found in solutions with high molecular weights.*