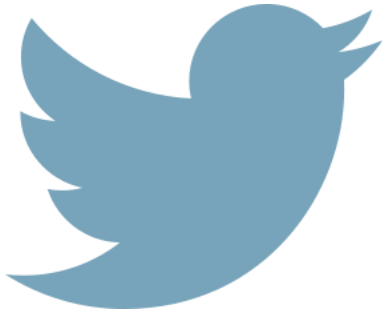
See you on Social Media

FACEBOOK

www.facebook.com/rheosense



TWITTER

www.twitter.com/rheosense

LINKEDIN

www.linkedin.com/company/rheosense

RheoSense
Simply Precise®

Broadening Horizons: 5 Fields where viscosity is key

Zachary Imam
Stacey Elliott
28 April 2021

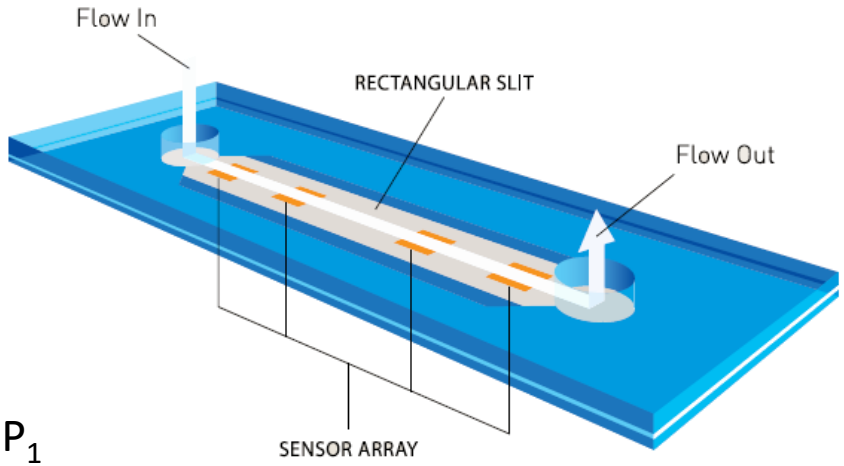
Overview

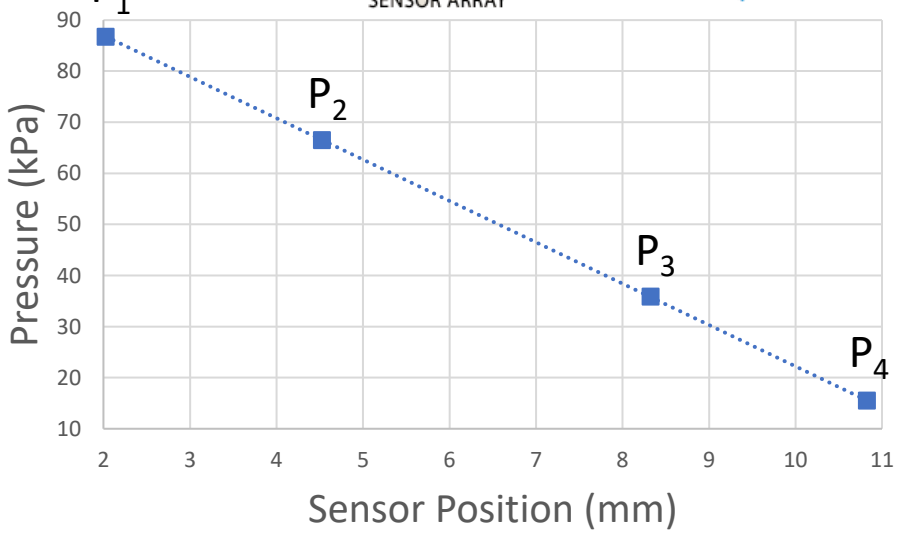
- Viscosity and VROC® review

1. Industrial polymers – rheology modifiers
2. Food/beverage
3. Personal care
4. Cell culture media – low viscosity Newtonian fluids
5. Cannabis – high viscosity oils

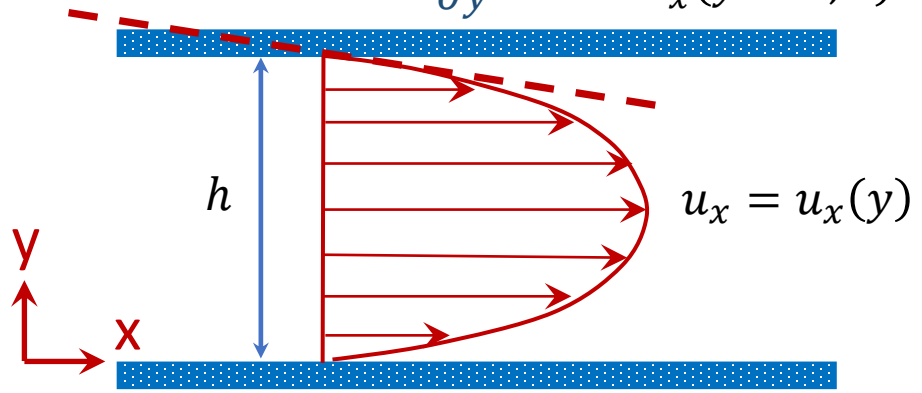
VROC® – Viscometer/Rheometer-on-a-Chip

Microfluidics and MEMS





$$\dot{\gamma} = \frac{\partial u_x}{\partial y} \qquad u_x(y = 0, h) = 0$$

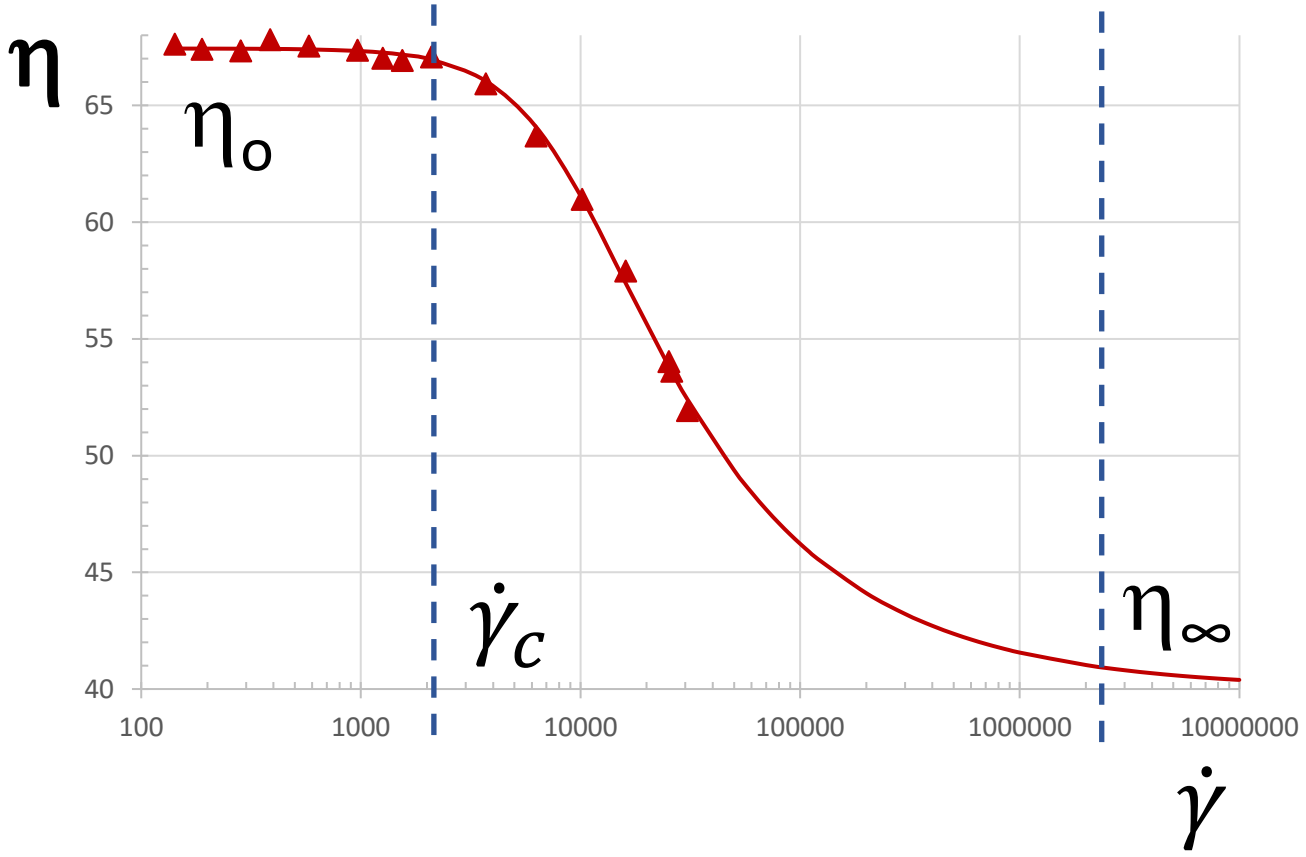


$$\eta \equiv \frac{shear\ stress}{shear\ rate} = \frac{\sigma}{\dot{\gamma}_w} \qquad \dot{\gamma}_w = \frac{6Q}{wh^2}$$

$$\sigma = -\frac{\Delta P}{\Delta L}\frac{wh}{2(w+h)}$$

Where $Q = volumetric\ flow\ rate$
$w = flow\ channel\ width$
$h = flow\ channel\ height\ or\ depth$
$\Delta P = pressure\ drop$
$\Delta L = length\ of\ flow\ path$

Industrial Polymers – Rheology Modifiers

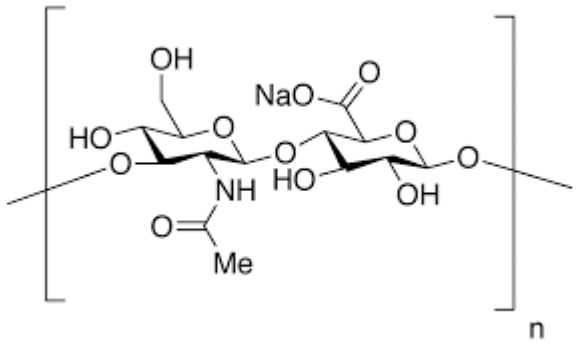


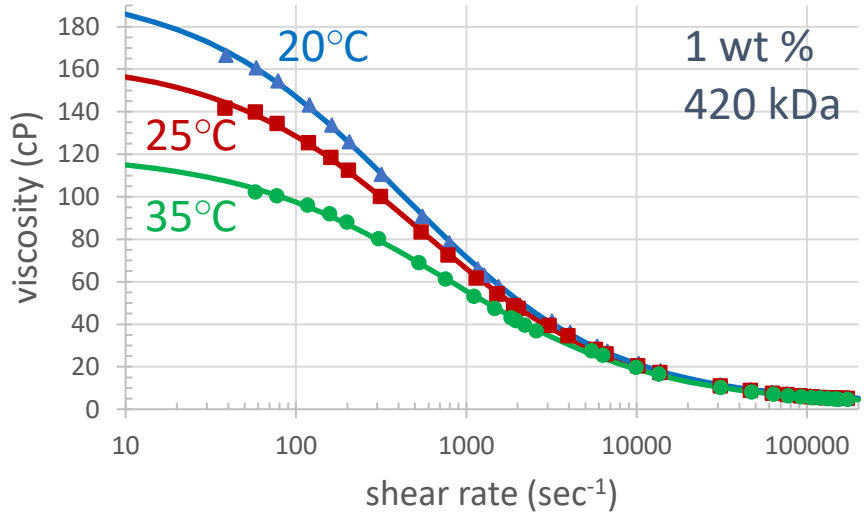
- "Thickeners", "viscosity modifiers"
- Control entire viscosity profile
  - Low shear plateau
  - High shear plateau
  - Onset of shear thinning
  - Range of shear thinning
  - Thixotropy
- Can be sensitive to environment
  - pH
  - Ionic strength
  - Solvent quality
  - Temperature

Rheology Modifiers

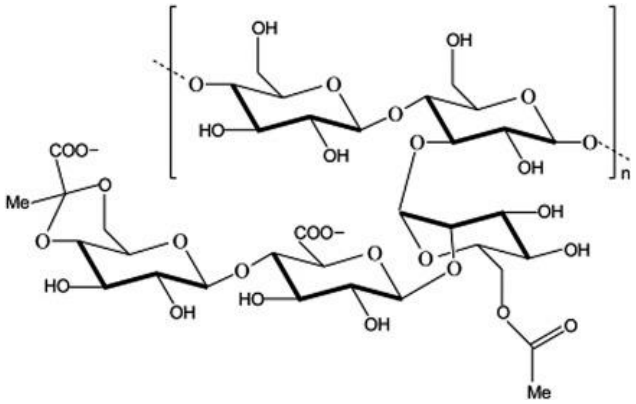
Food and Personal Care

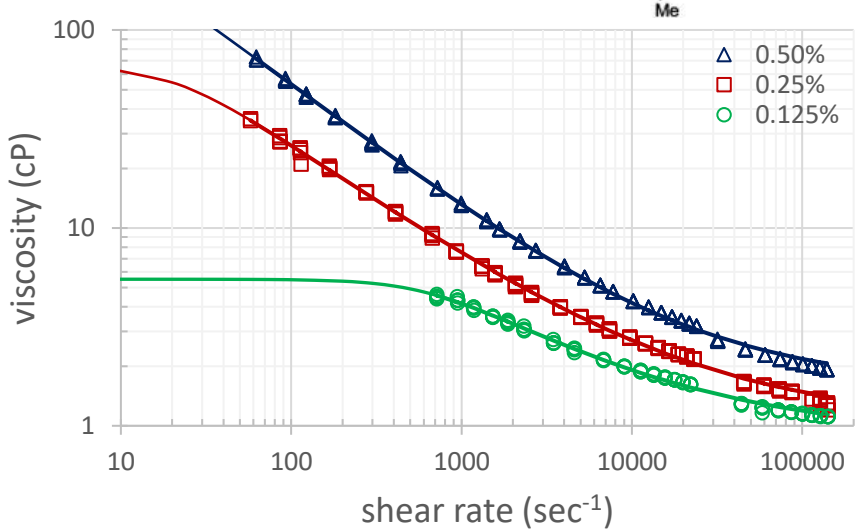
hyaluronic acid (sodium hyaluronate)





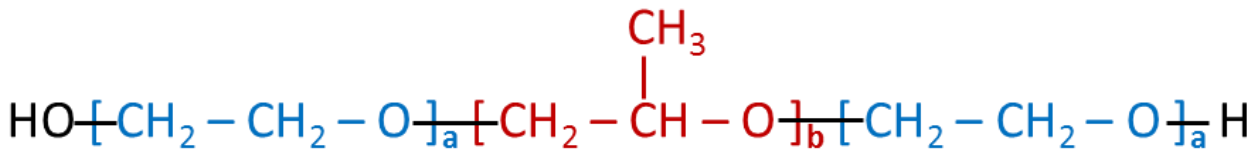
xanthan gum

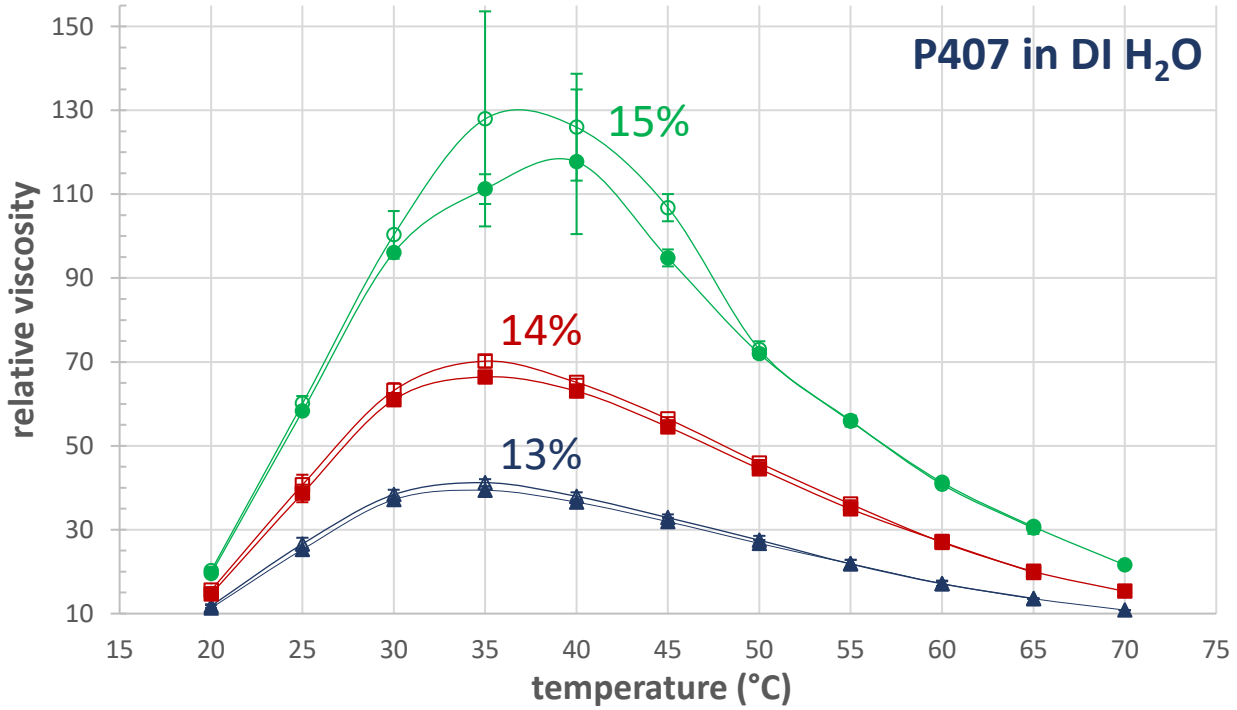




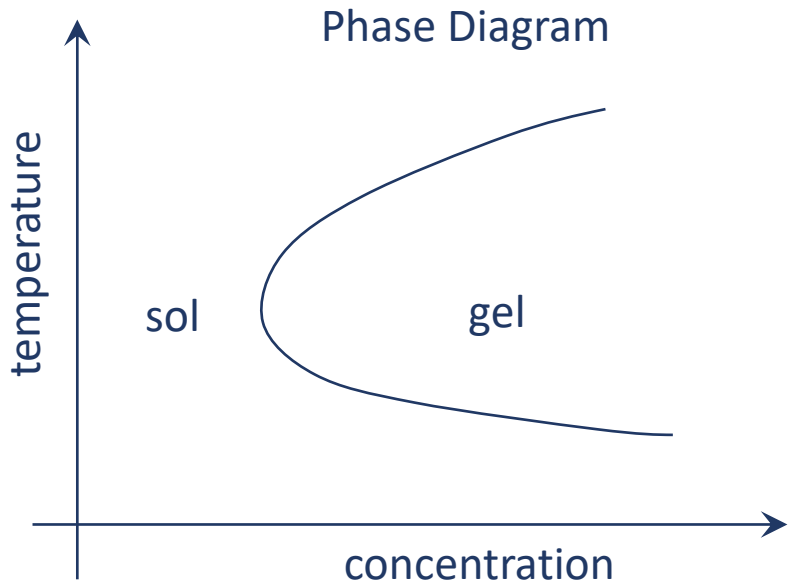
Rheology Modifiers

Thermo-Responsive
Self Assembling Polymer



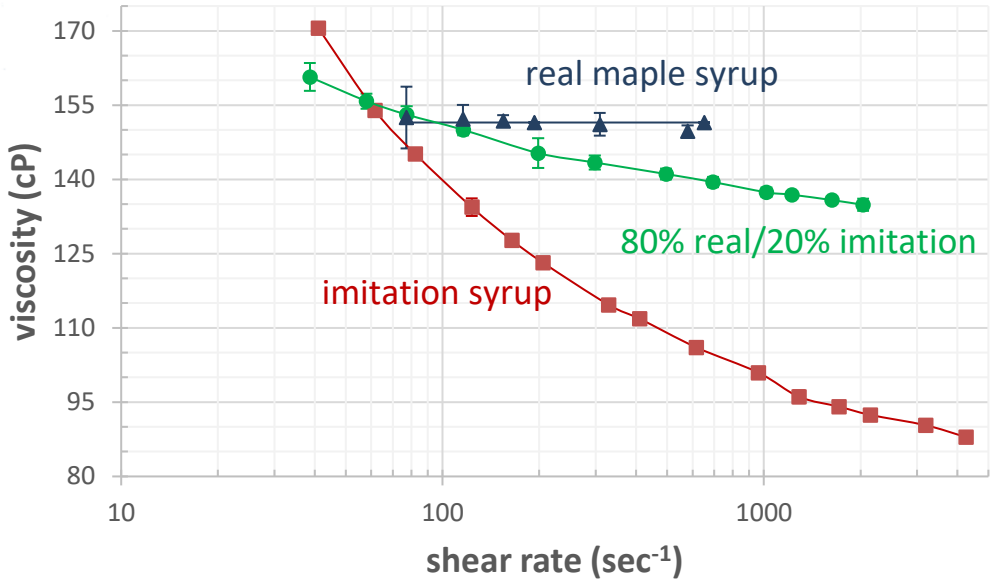


Poloxamer	a	b	MW	a/b
188	80	27	7680 – 9510	3
407	101	56	9840 – 14600	1.8



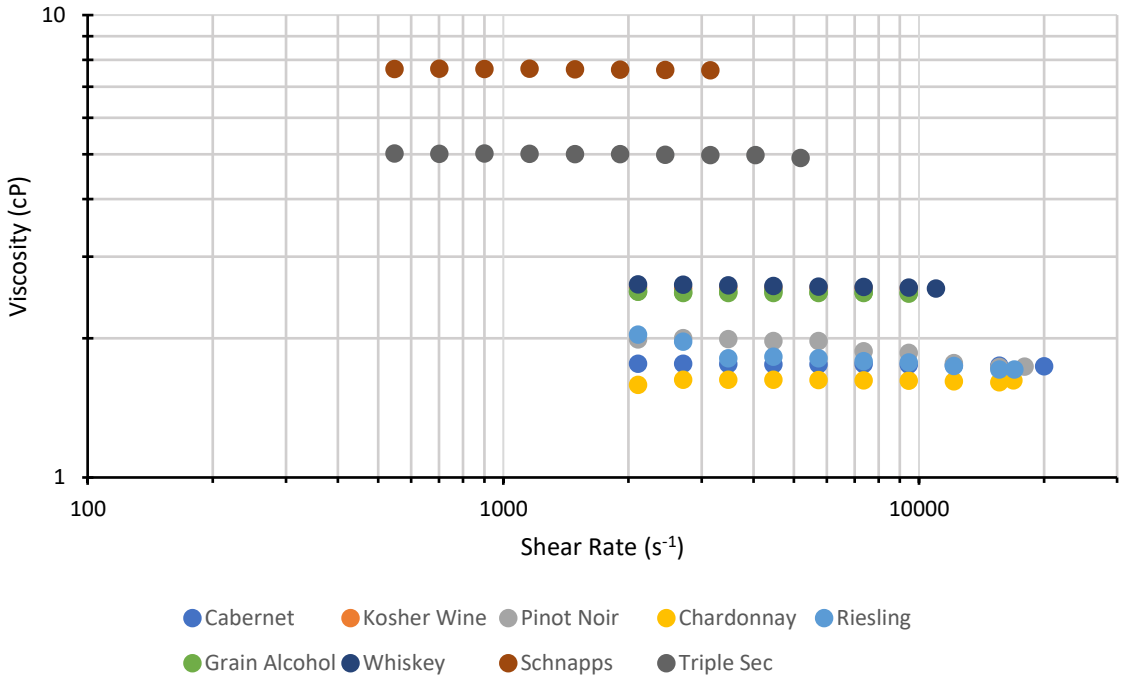
Food/Beverage Industry

Syrups



- Real maple syrup
  - Newtonian
  - Primarily sucrose/water
- Imitation syrup
  - Non-Newtonian
  - Xanthan gum

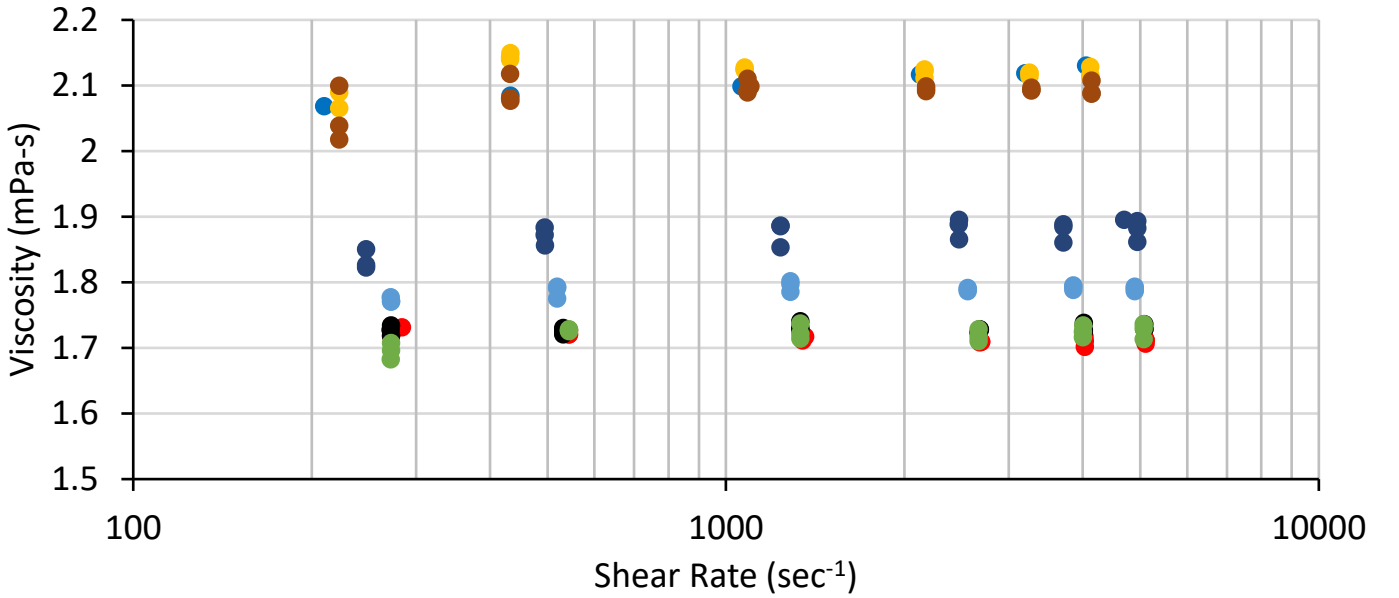
Alcoholic beverages

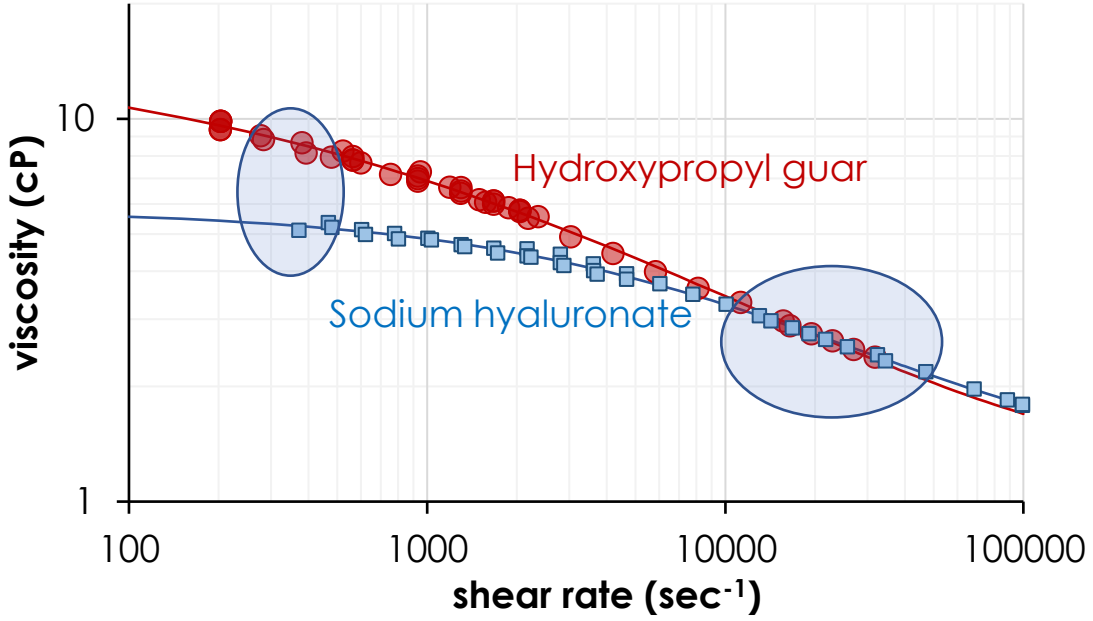


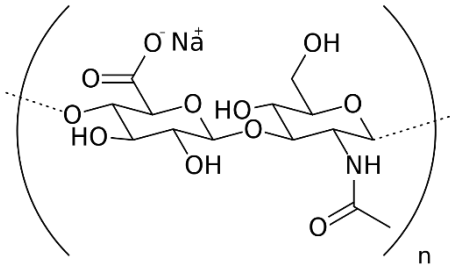
- Newtonian
  - Alcohol
  - Water
  - Sugars
  - Flavorings

Personal Care Products- It's all in the ingredients

- Cologne modified with alcohol
- Different ingredients yield different rheological behavior







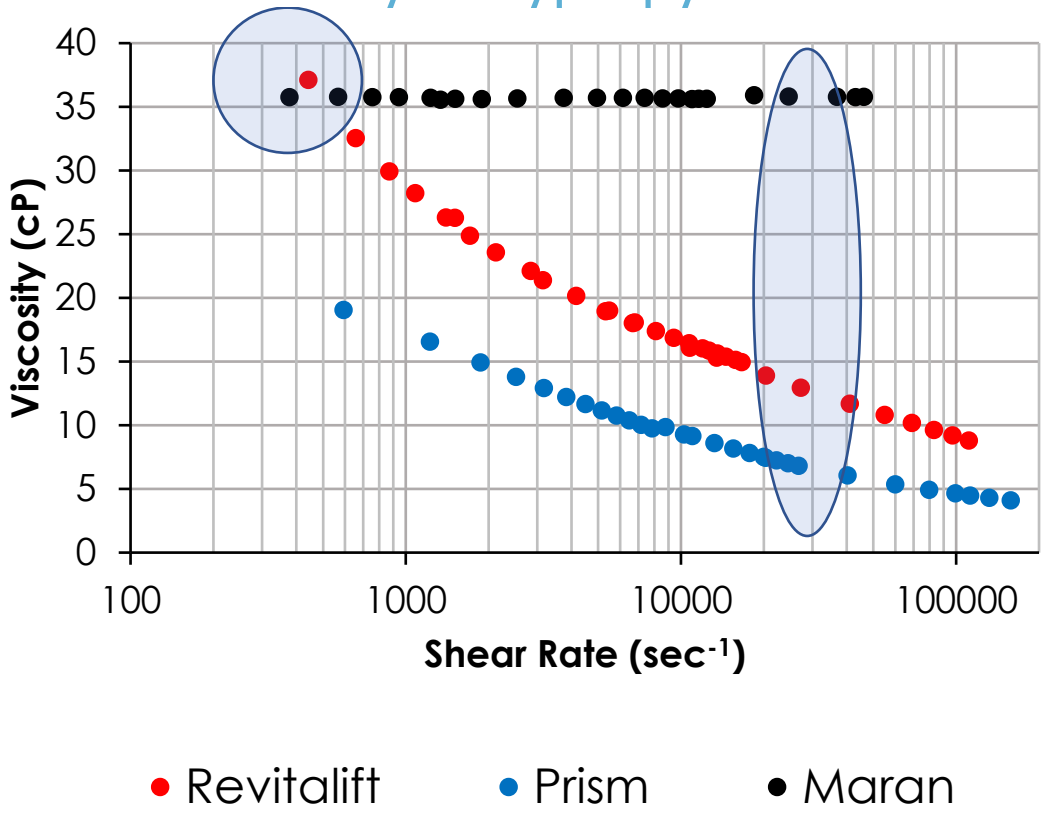
Sodium hyaluronate

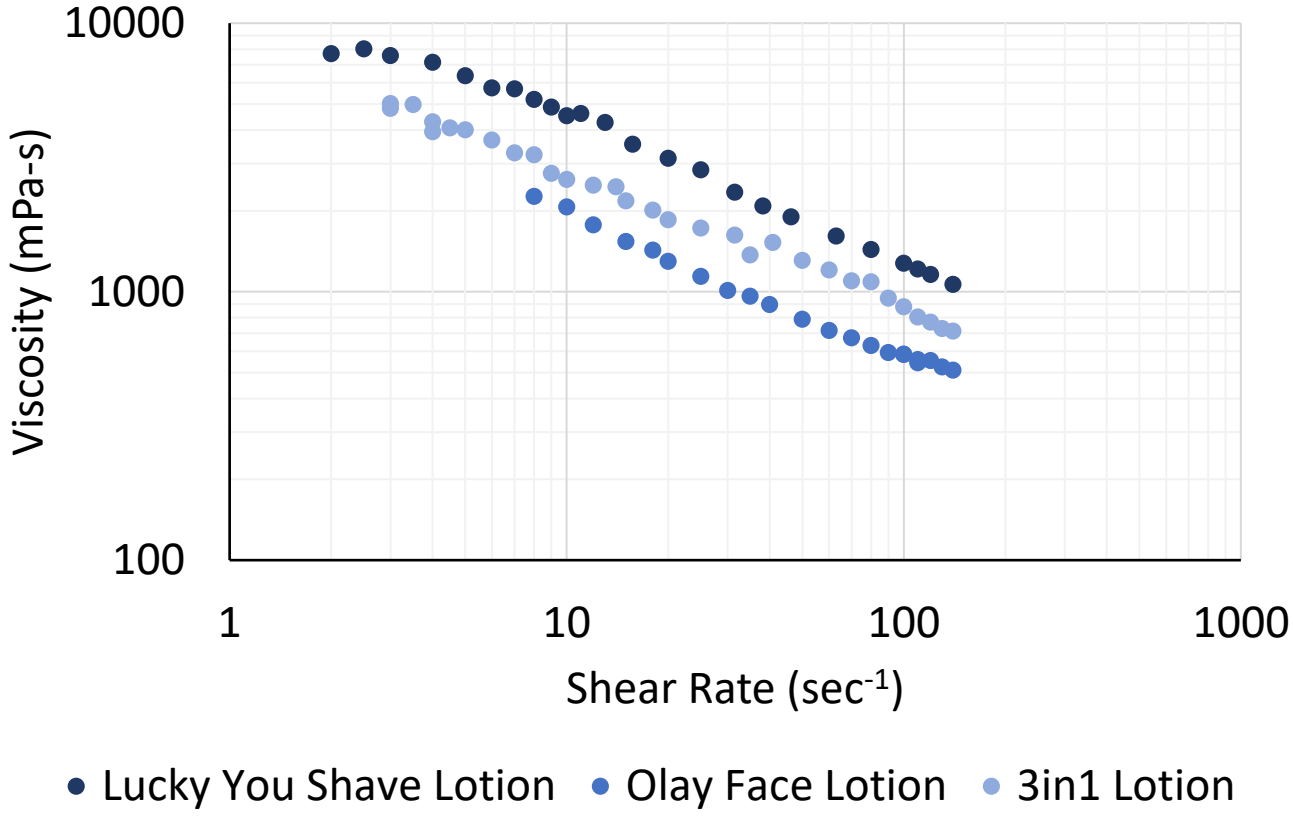
Personal Care Products-Viscosity Modifiers

- Hyaluronic Acid
- Xanthan Gum
- Hydroxypropyl Guar

- Paraffin
- Xanthan Gum
- Stearyl Alcohol

- Dimethiconol
- PDMS
- Cetyl Alcohol





Cell Culture Media – Differentiating Low Viscosity Fluids

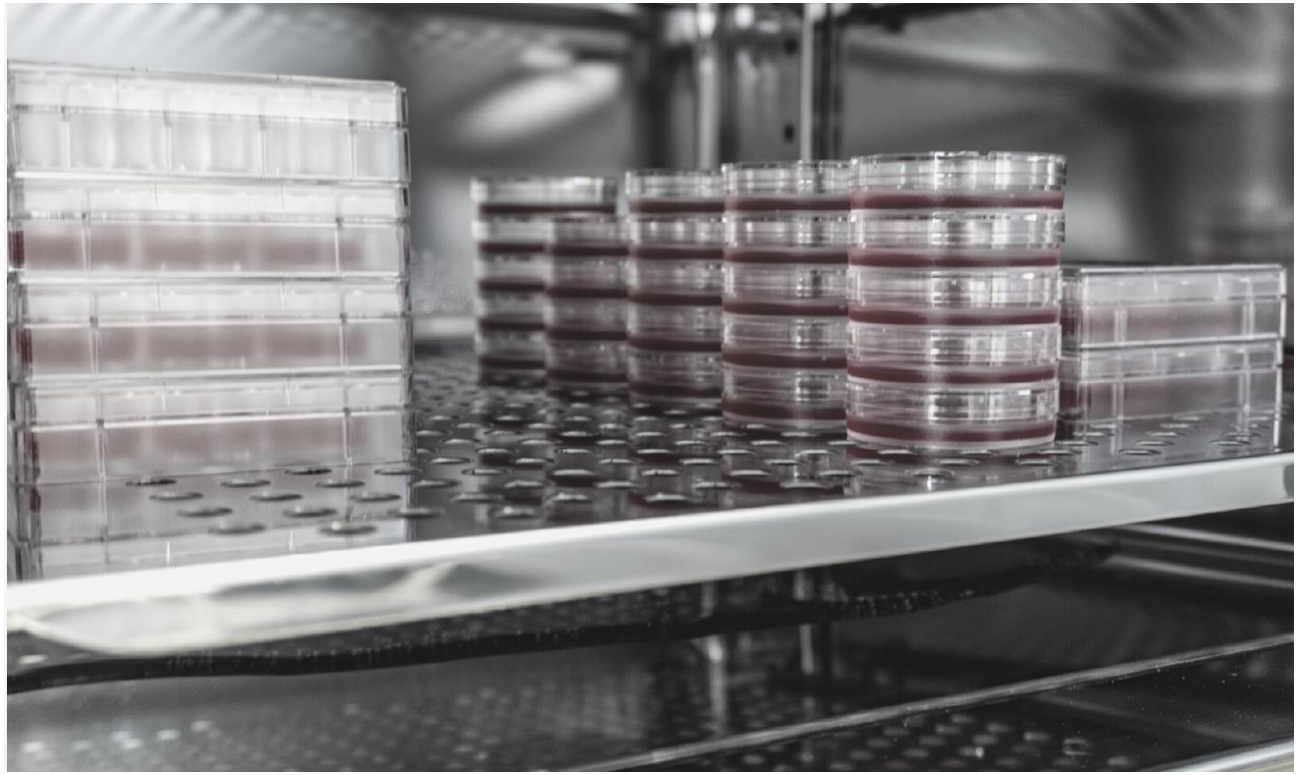
Cell culture media is vital for the biotechnology industry

Required For:

- Cell Growth
- Proliferation
- Differentiation

Fields:

- Basic Scientific Studies
  - Cellular Processes
  - Stem Cells
- Drug Development
- Regenerative Medicine
- Lab Grown Meat
- Organ-on-a-Chip



Cell Culture Media – Differentiating Low Viscosity Fluids

Cell culture is specific for each cell type and application

Two Types of Media:

- Natural Media
  - Serum
- Synthetic Media

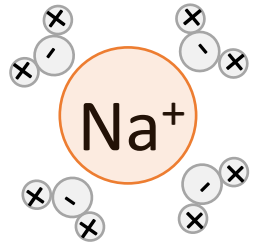
Commonly Used Media:

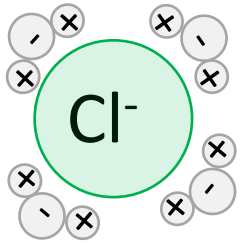
- Eagle's Minimal Essential Media (EMEM)
- Dulbecco's Modified Eagle Media (DMEM)-More common
- Ham's or F12 Media
- Grace's Media

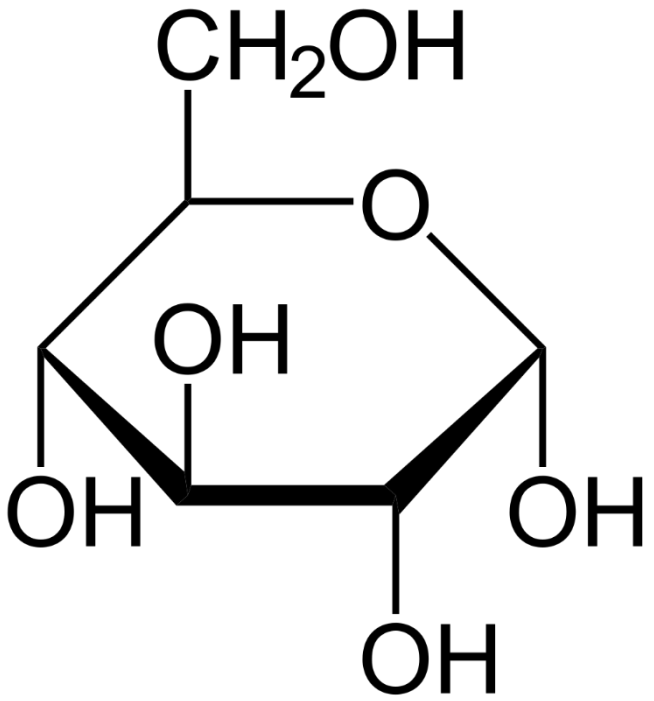
Cell Culture Media – Differentiating Low Viscosity Fluids

Cell Culture Media Components

- Dextrose
  - 5 – 25 mM
- Amino Acids
  - < 1 mM (Highest Concentrations)
- Salts
  - 110-130 mM NaCl
  - 14 – 44 mM Sodium Bicarbonate
- Vitamins
  - < 0.1 mM (Highest Concentrations)

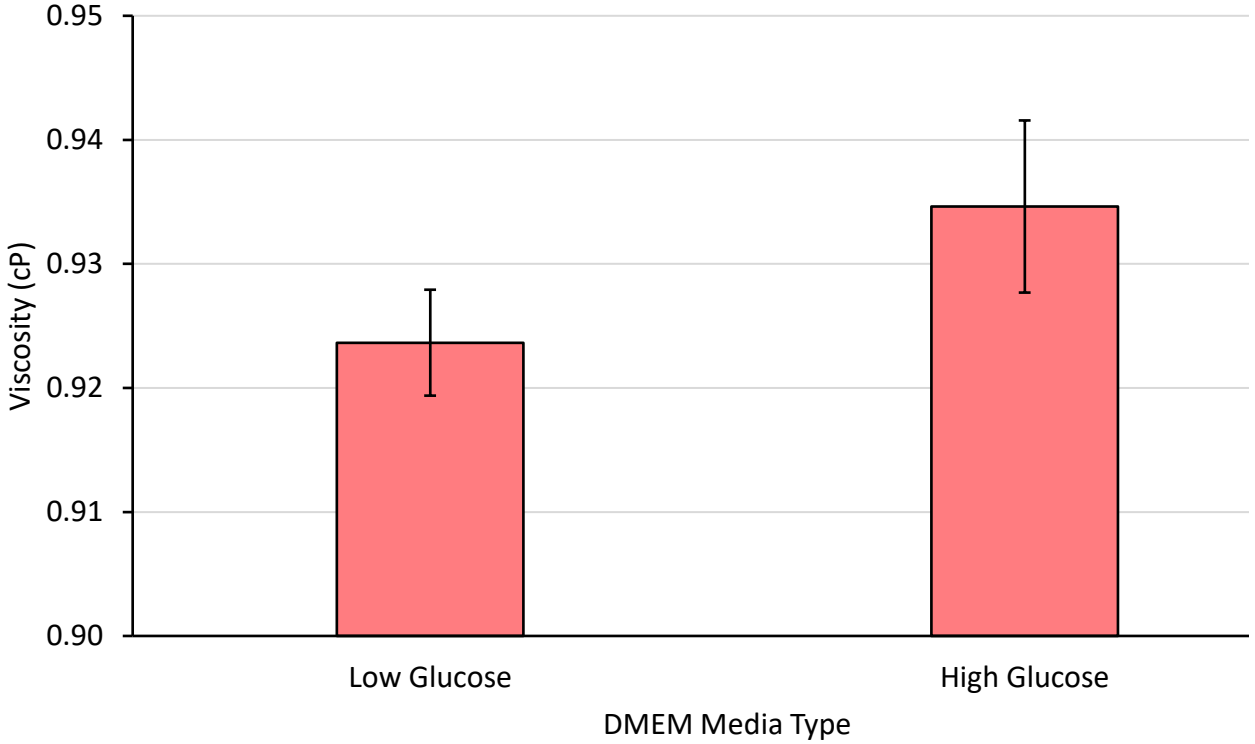


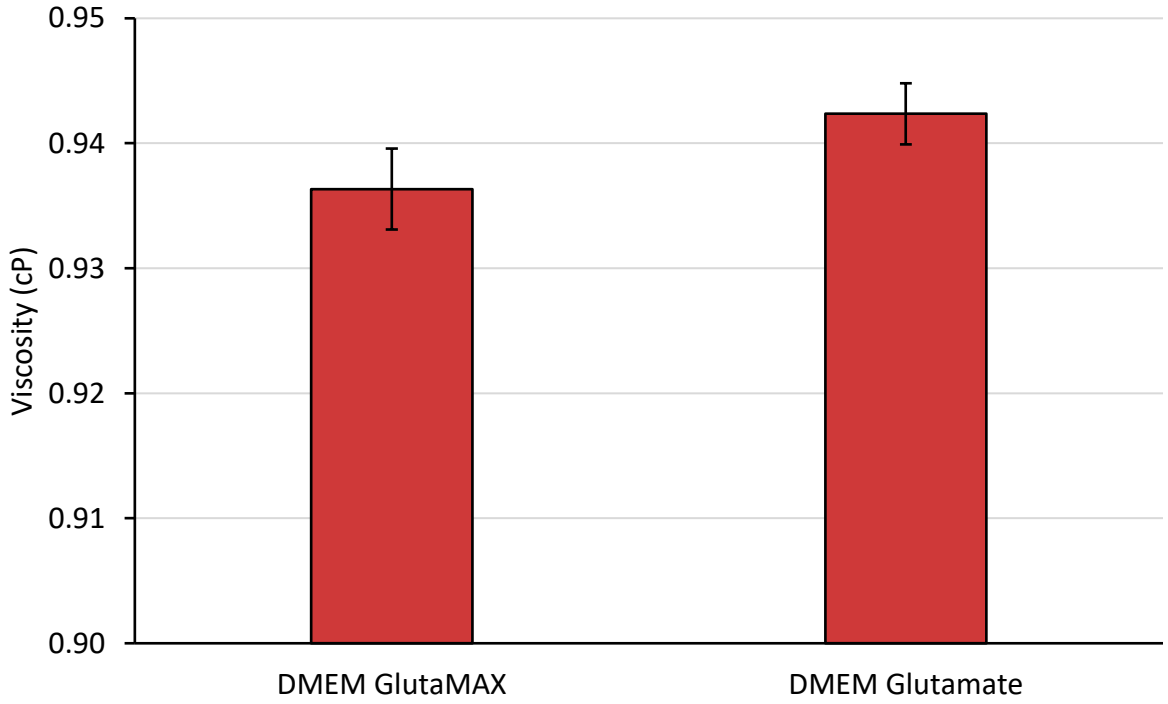




Thermofisher

Cell Culture Media – Dubecco's Modified Eagle Media (DMEM)

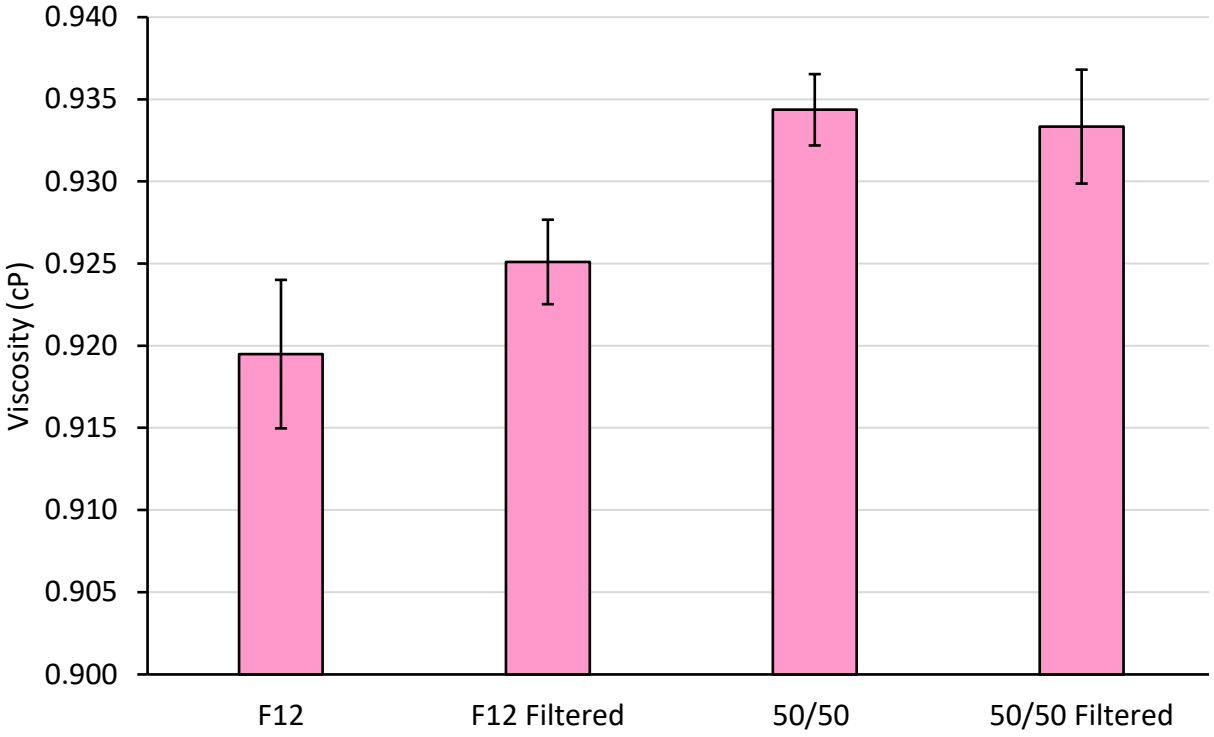


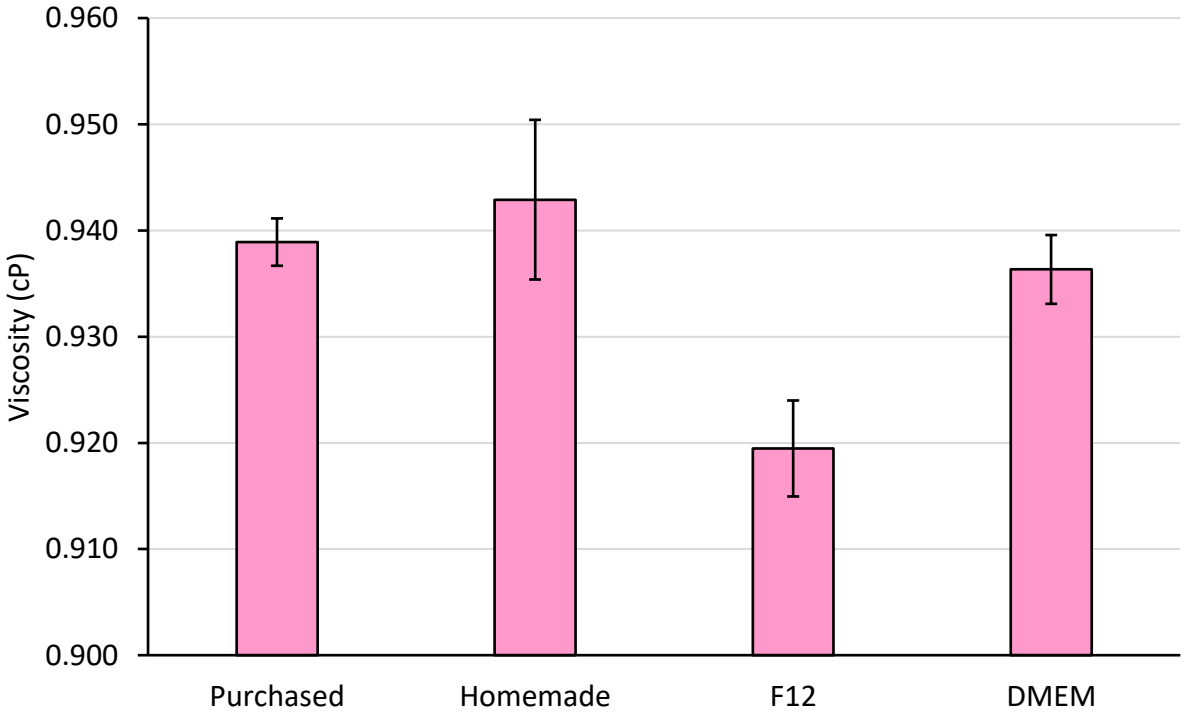


	Average (cP)	Standard Deviation
Low Glucose	0.924	0.004
High Glucose	0.935	0.007

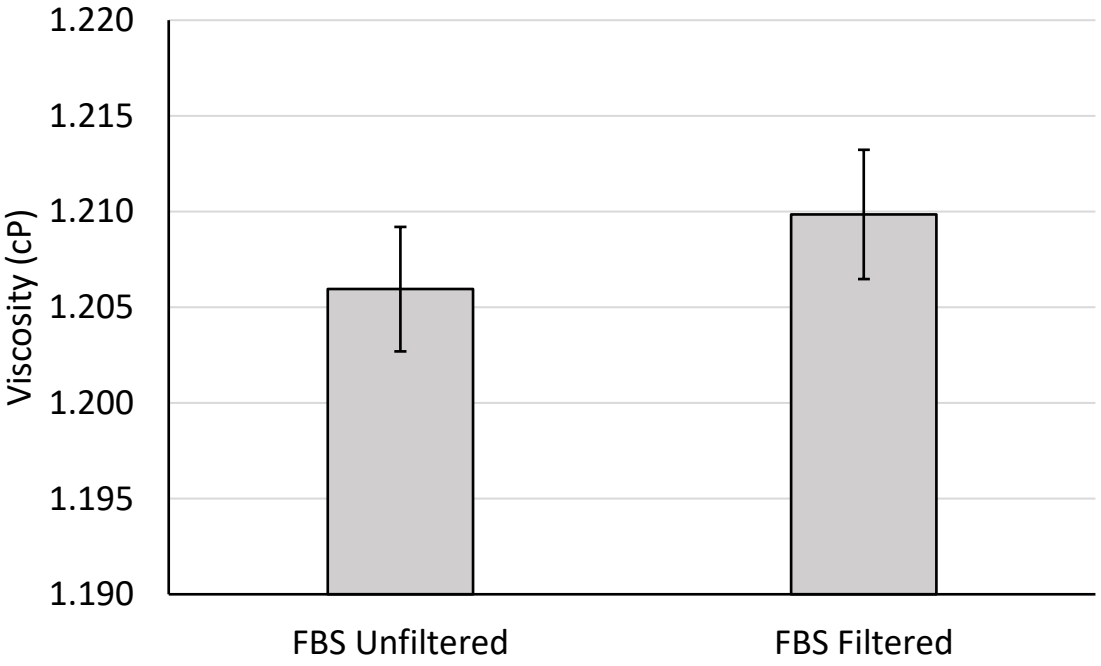
	Average (cP)	Standard Deviation
DMEM GlutaMAX	0.936	0.003
DMEM Glutamate	0.942	0.002

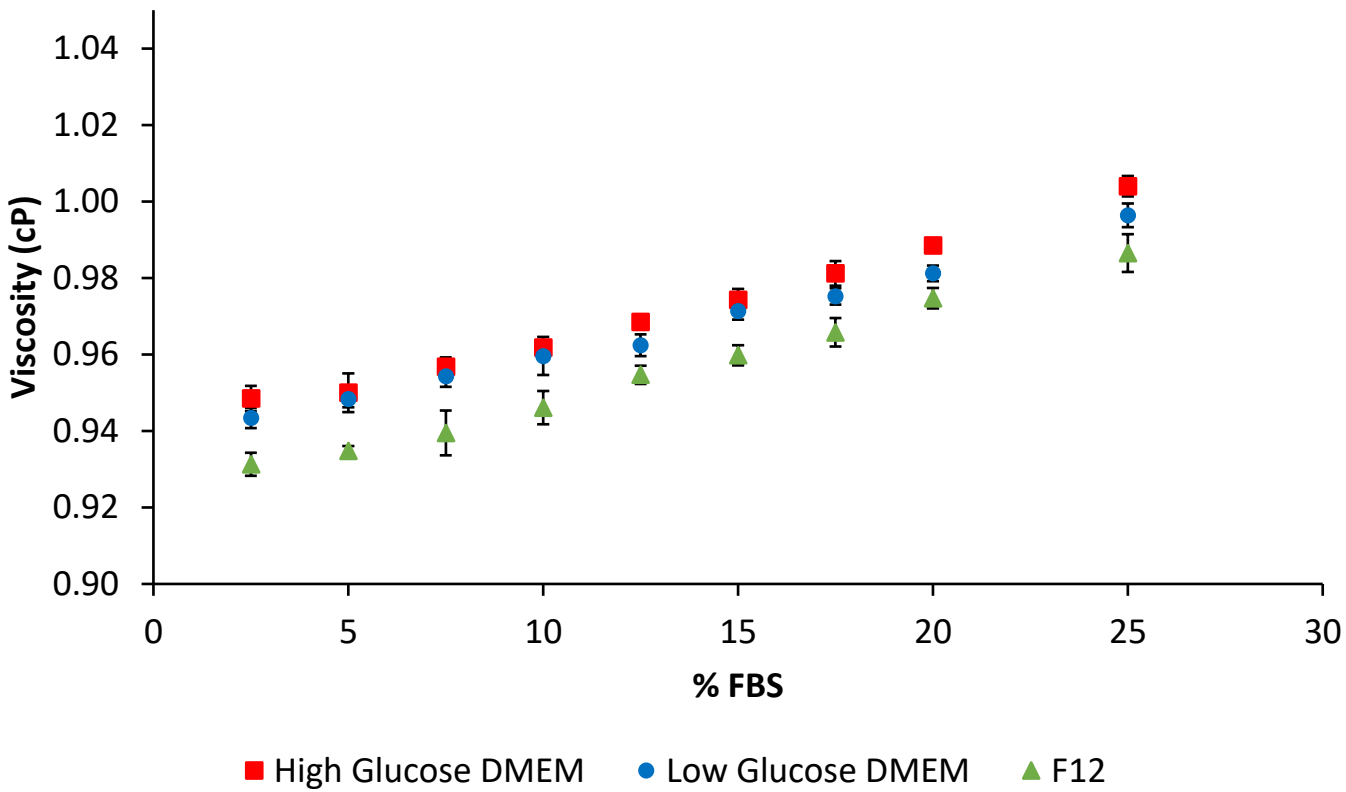
Cell Culture Media – F12



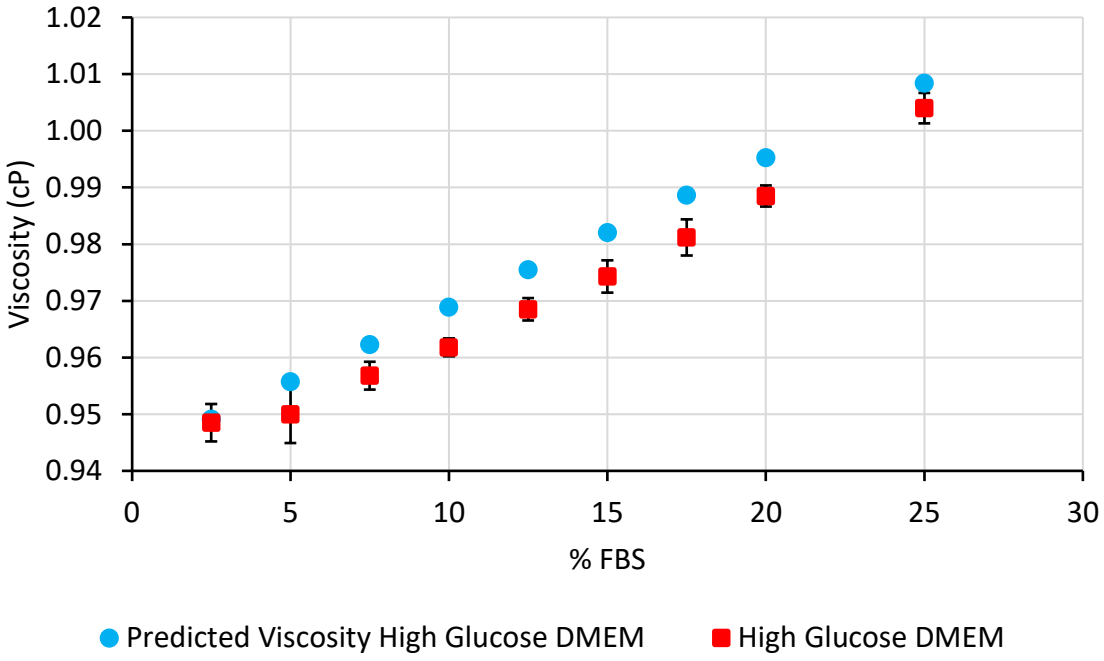


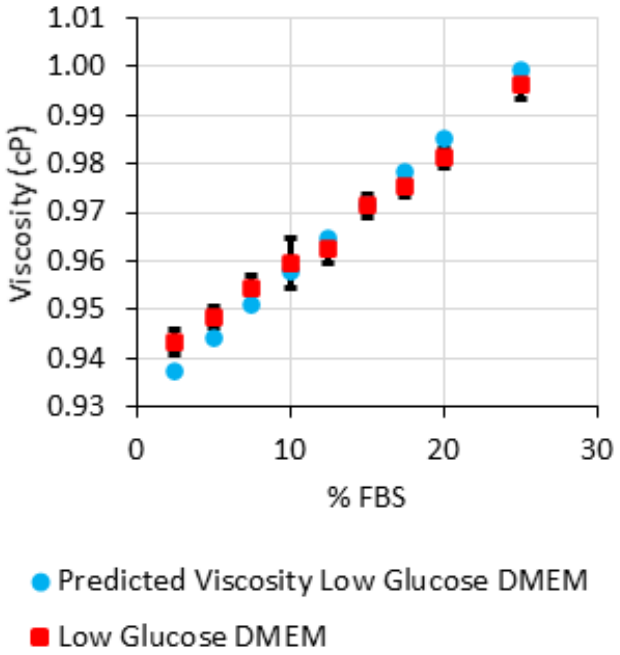
Cell Culture Media – Fetal Bovine Serum

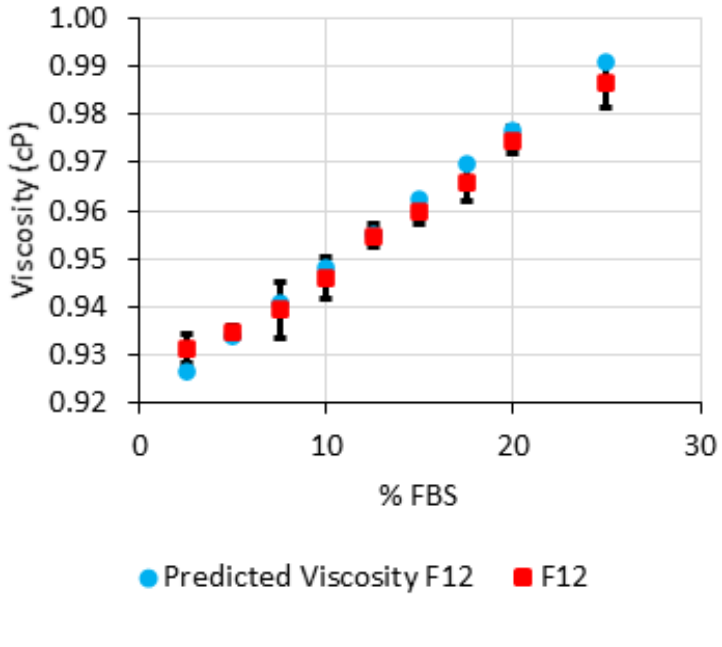




Cell Culture Media – Fetal Bovine Serum







$$\eta_{predicted} = \%\ media * \overline{\eta_{media}} + \%\ FBS * \overline{\eta_{FBS}}$$

Cell Culture Media – Conclusions

- There are small differences between the F12 and DMEM media formulations that can be detected by VROC

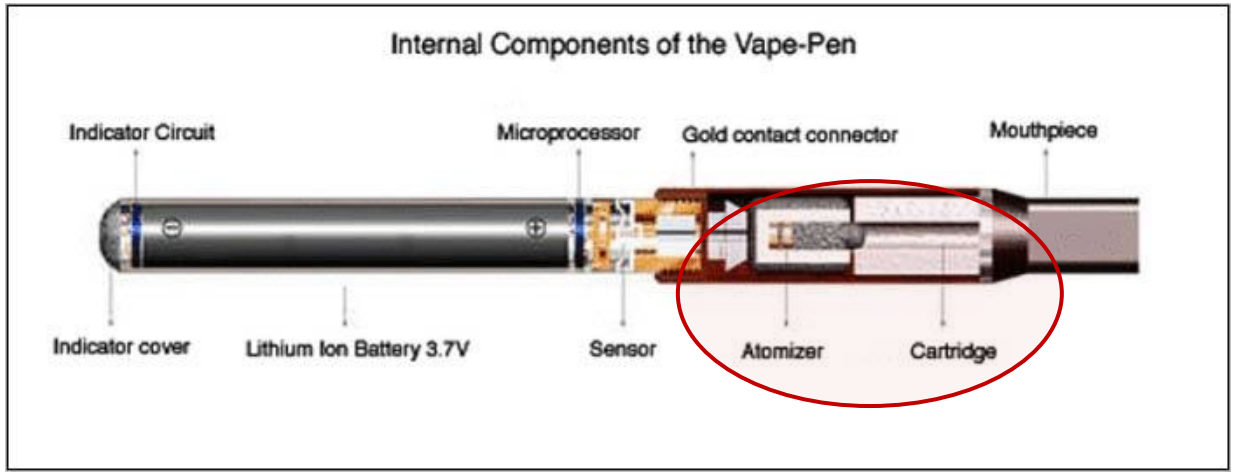
- Dextrose (Glucose) is the likely the primary contributor to these differences.
  - Amino Acid, Salt, and vitamin are too low in molecular weight
  - Also are formulated at similar concentrations between all media types

- Viscosity differences trend with increasing glucose concentration
  - Low Glucose DMEM = 5 mM
  - F12 = 10 mM
  - F12/DMEM = 17.5 mM
  - High Glucose DMEM = 25 mM

- FBS and glucose interact at some level.

Cannabis Oils

High viscosity
Temperature sensitive

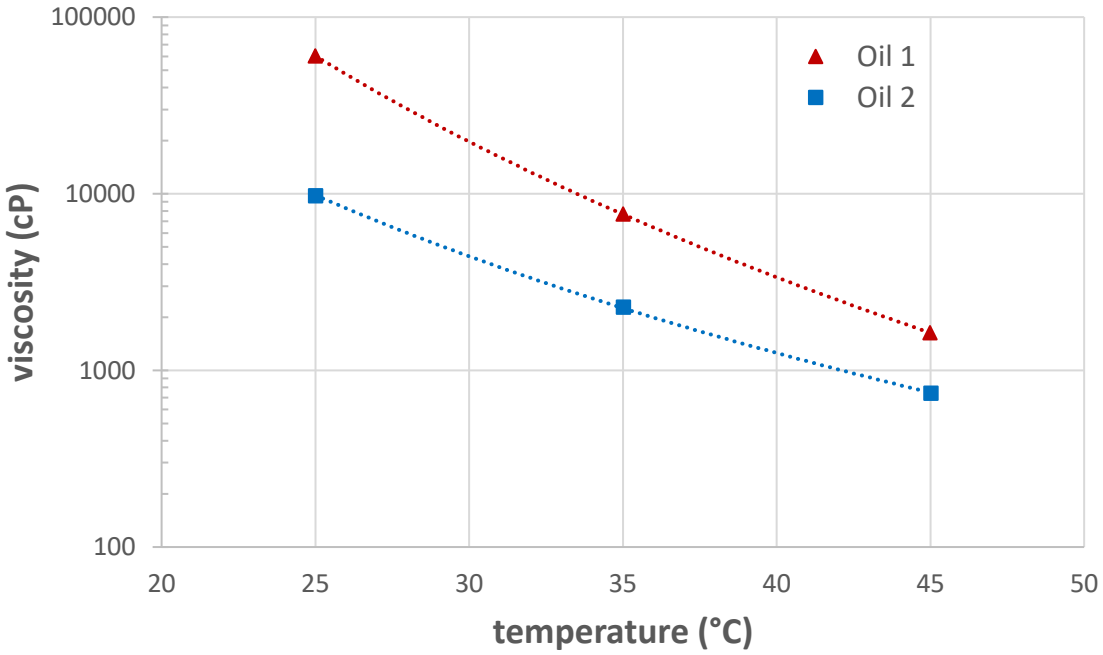


- Viscosity too low – flood the heating element
- Viscosity too high – clog cartridge or burn
- Variable formulation components – broad range of viscosities
- Temperature dependence relevant
  - Heating element in atomizer
  - Extreme use or storage conditions

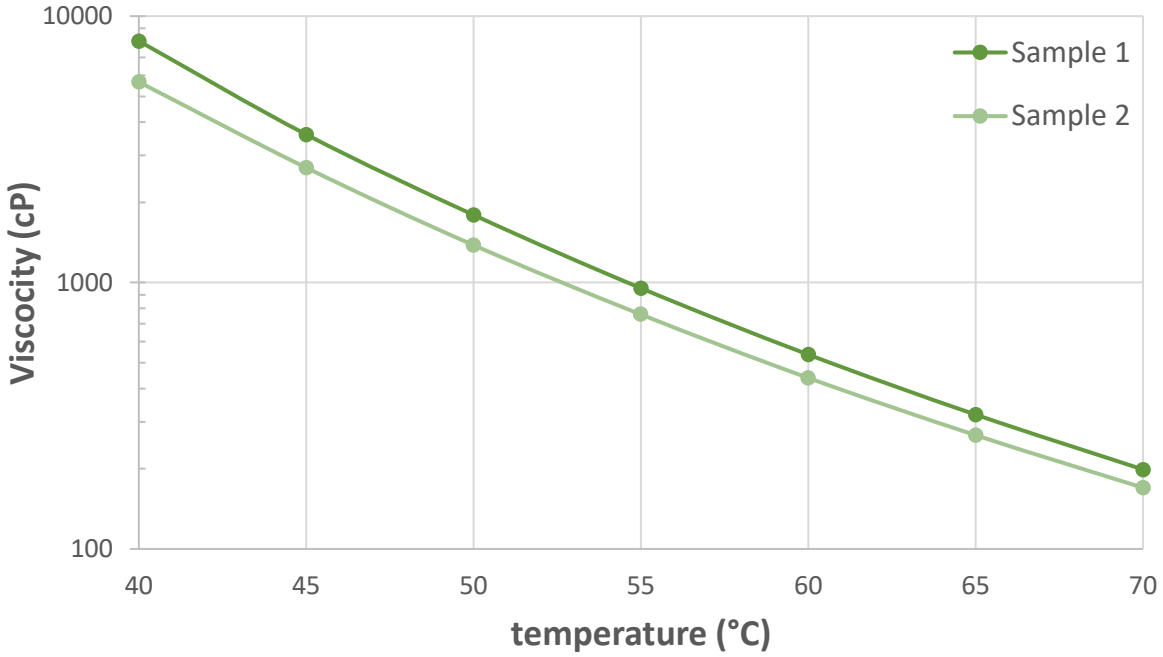
Cannabis Oils

Temperature Dependence

mVROC®

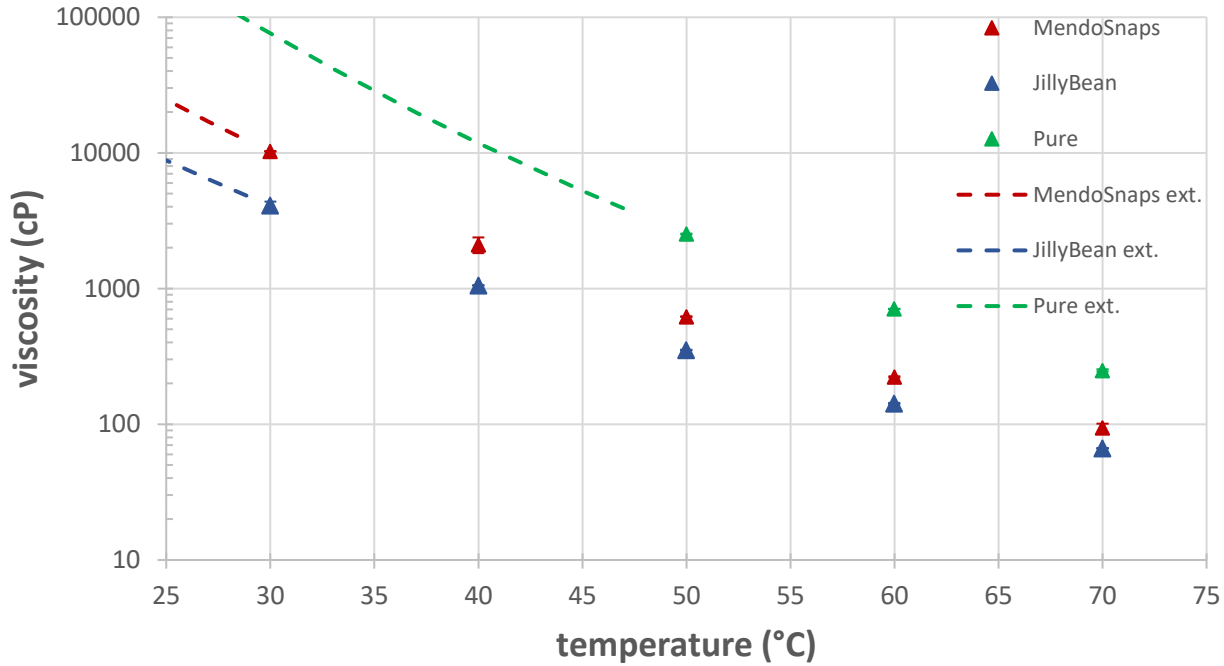


VROC® initium



Cannabis Oils

Composition Dependence



Product Name	Ingredients	Intended Use
Pure INDICA	Cannabis oil, natural terpenes (THC 91.8%, CBD 1.1%)	Dabbing, eating, smoking
Raw Garden Mendo Snaps	Whole flower terpenes, cannabis oil (THC 79.50%, CBD 0.32%)	Vape cartridge
KINGPEN JILLY BEAN	Cannabis oil (THC 82.88%, CBD 0.20%)	Vape cartridge

RheoSense
Simply Precise®

Thank You!

Dr. Zachary Imam
Research Scientist
RheoSense, Inc.
zimam@RheoSense.com
+1 (925) 866-3801 ext. 1013

Dr. Stacey Elliott
Principal Scientist
RheoSense, Inc.
Selliott@RheoSense.com
+1 (925) 866-3801 ext. 1013

Grace Baek
Marketing & Sales
RheoSense, Inc.
GraceB@RheoSense.com
+1 (925)-866-3801 ext. 1013

Eden Reid
Senior Marketing Associate
RheoSense, Inc.
EReid@RheoSense.com
+1 (925)-866-3801 ext. 1013