ual: london college of fashion

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Comparative evaluation of a range of natural gums as rheological modifiers in cosmetic emulsions

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MSc Cosmetic Science

http://www.arts.ac.uk/fashion/courses/integrated-masters/msc-cosmetic-science/

Semisolid Cosmetic Products

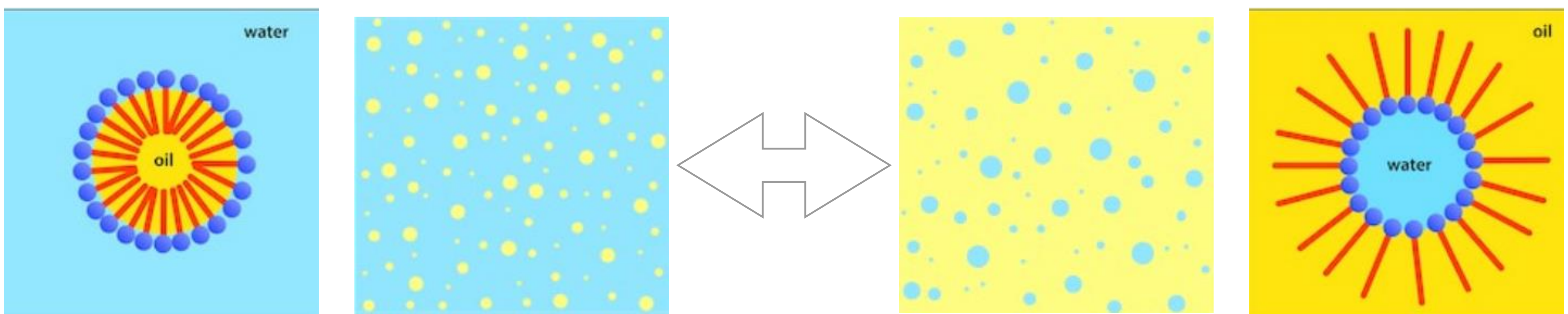
Semisolid products are available in a variety of:

- Types
- Functions
- Benefits

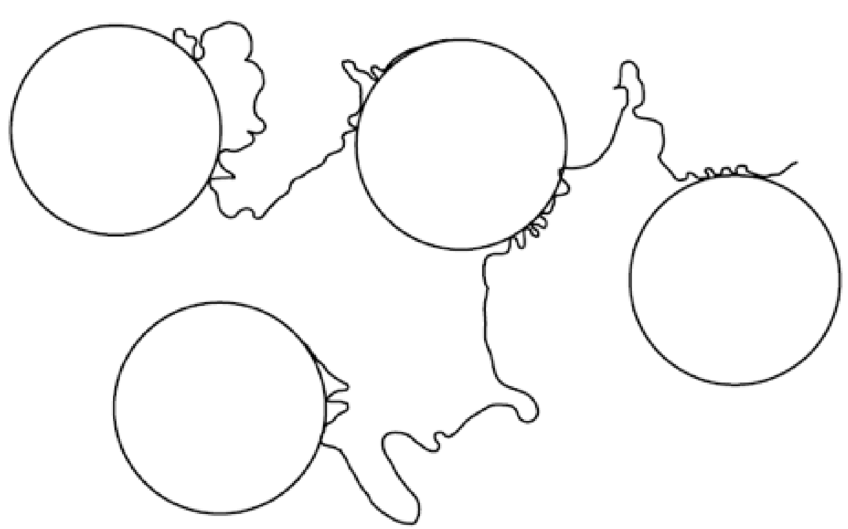
Many of their functions are dependent on **rheology**, e.g. scooping, pouring, spreading and pumping out of a container.

Emulsions

Emulsions are widely used in cosmetics due to their versatility in terms of function and customisation, and for their overall benefits.



Modified **rheology**



Enhanced **stability**

Rheology Modifiers

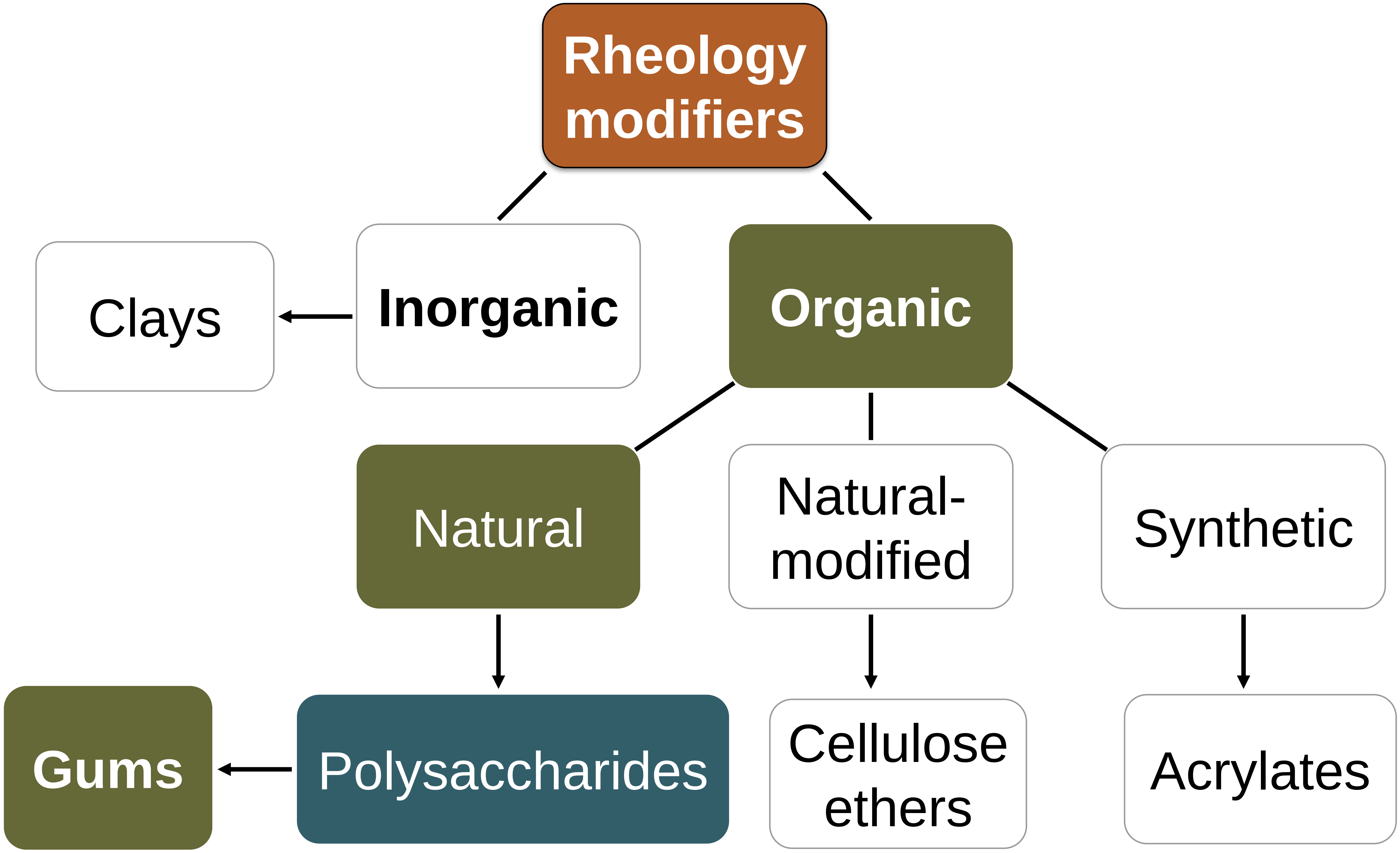
Rheology modifiers

Commonly denoted ‘thickeners’, but they affect product parameters besides viscosity, e.g. stickiness, spreadability and stringiness.

affect

- Skin delivery
- Sensorial profile
- User experience
- Product aesthetics
- Stability
- Quality

Rheology Modifiers



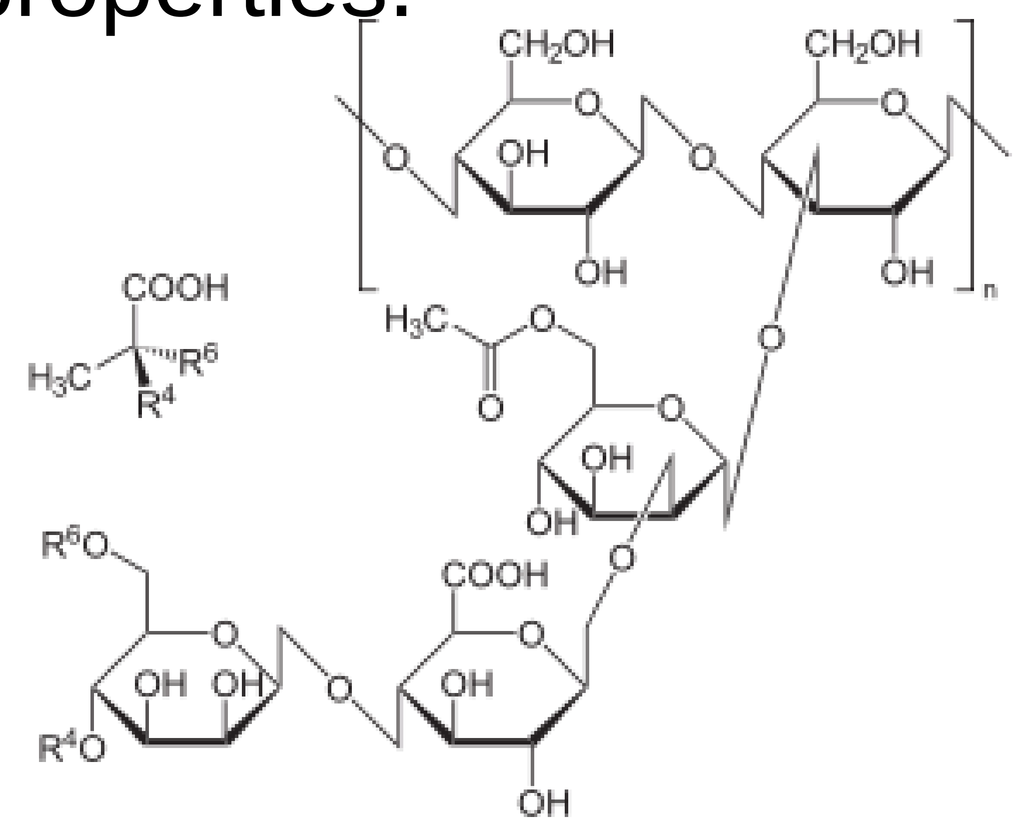
Focusing on Gums

- Goswami and Naik (2014):
  - Gums are derived from readily-available, renewable plant or bacterial-based sources.
  - They are biodegradable.
- Feleke and Melaku (2011):
  - The production of most gums is a farmer-based industry, providing income to farmers and potentially in remote regions of the world.

Materials

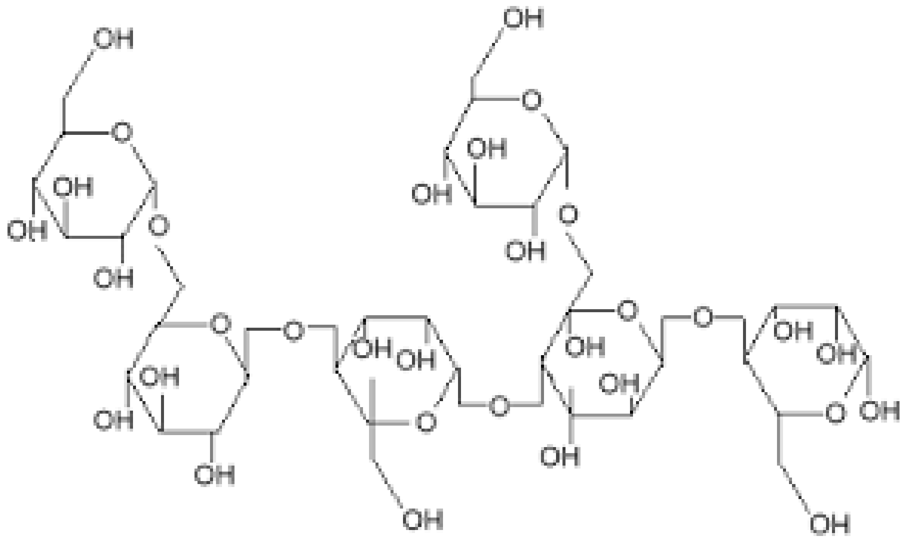
Xanthan Gum

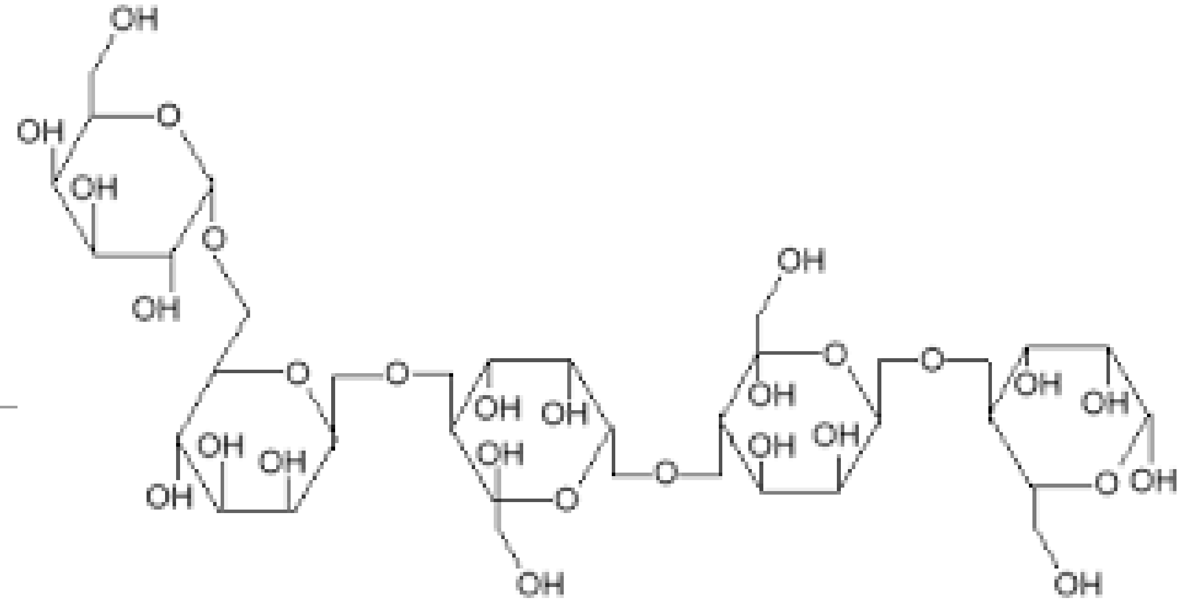
- Produced by *Xanthomonas campestris* bacteria.
- Anionic, helical polysaccharide widely reported in the literature.
- Dehydroxanthan Gum is a modified version that gels up quickly in a range of temperatures.
  - Used widely for its film-forming properties.



Guar Gum

- Non-ionic galactomannan.
- Cold soluble due to its high galactose content.
- Obtained from the beans of *Cyamopsis tetragonoloba.*
- Gresta et al., (2014):
  - The Guar tree tolerates droughts and saline soils well.
  - Guar Gum is a low-emission crop.

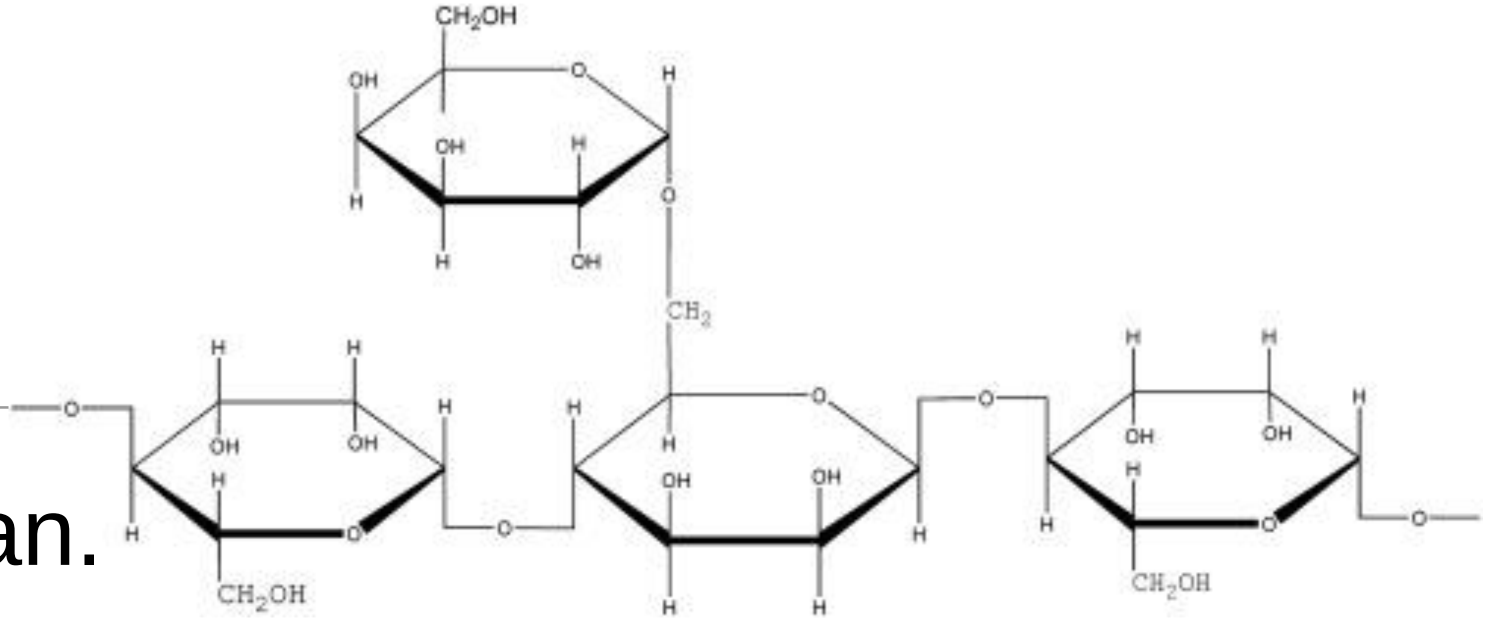




Locust Bean Gum

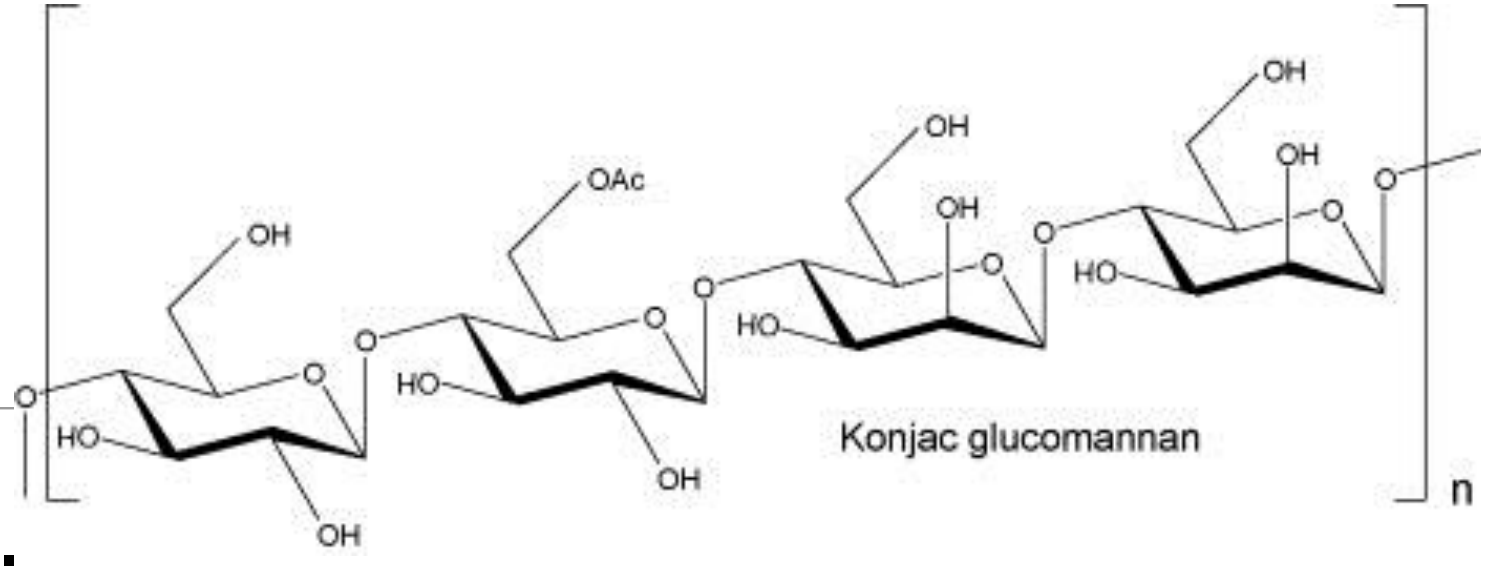
- Non-ionic galactomannan.
- Obtained from the beans of *Ceratonia siliqua*, a.k.a. carob tree, native to the Mediterranean.
- Used mainly in food products, it is a common chocolate replacement.

Tara Gum



- Non-ionic galactomannan.
- Wu et al., 2015:
  - Extracted via grinding seed endosperms of *Caesalpinia spinosa*, a tree with a short growth cycle native to South American countries.
- Used mainly in food products.

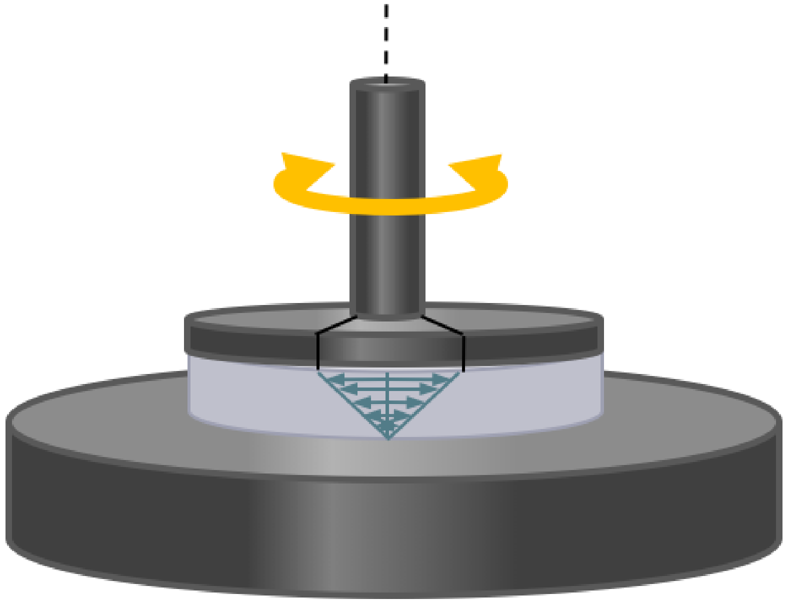
Konjac Root Extract



- Non-ionic glucomannan.
- Obtained from the roots of *Amorphophallus rivieri* K.
- Native to Southeast Asian countries.
- Used mainly in food products.

Methods

Rheological Evaluation

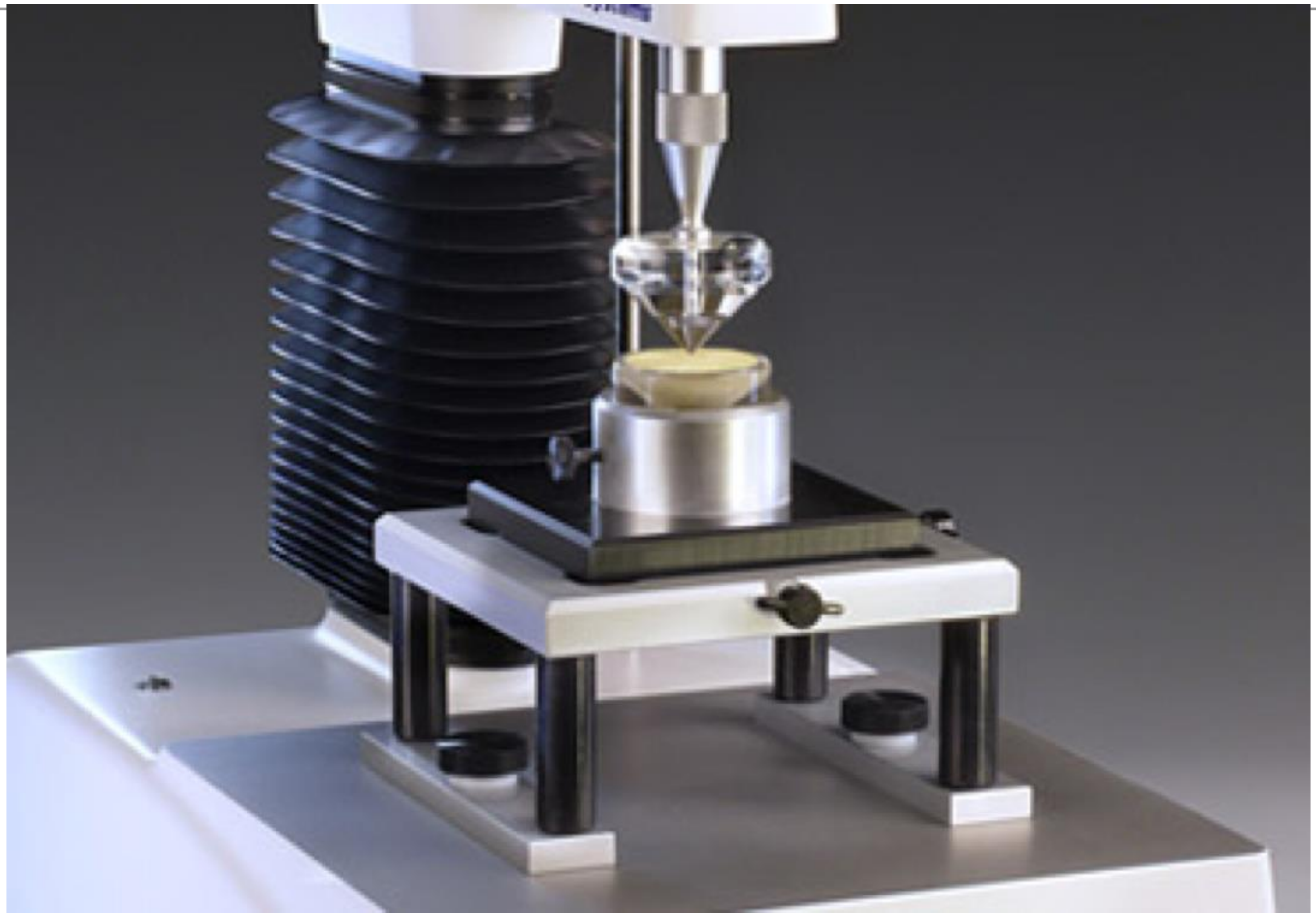


Rheological Evaluation

- RheoStress™ RS75 oscillatory rheometer (Haake™, Germany) with parallel plates (⌀ = 35 mm; 0.5 mm gap), at 22 ± 0.5 °C.
- RheoWin™ Analysis Software version 4.41 (Thermo Fisher Scientific, USA).

Shear Rate Sweep	Time-Dependent Viscosity	Oscillatory Stress Sweep
• 250 – 10 s^{-1} • 20 steps, 300 s • Viscosity curves	• 3-step method • Sequence of shear rates, 1 min each: • 10, 250 and 10 s^{-1} • Calculated viscosity recovery (%)	• 1 - 2000 Pa • 1 Hz, constant • G* (rigidity) • δ (elastic response)

Texture Analysis

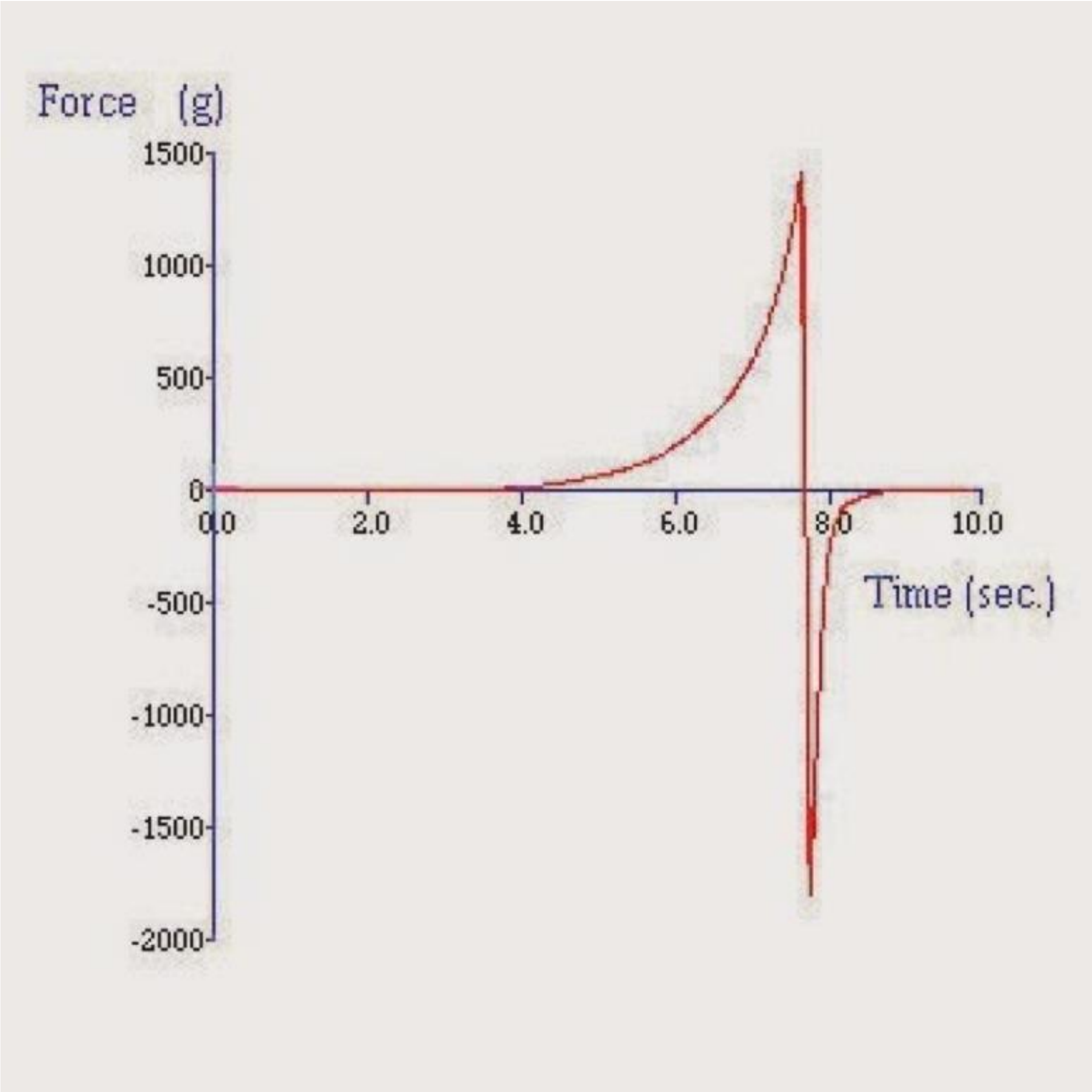


Texture Analysis

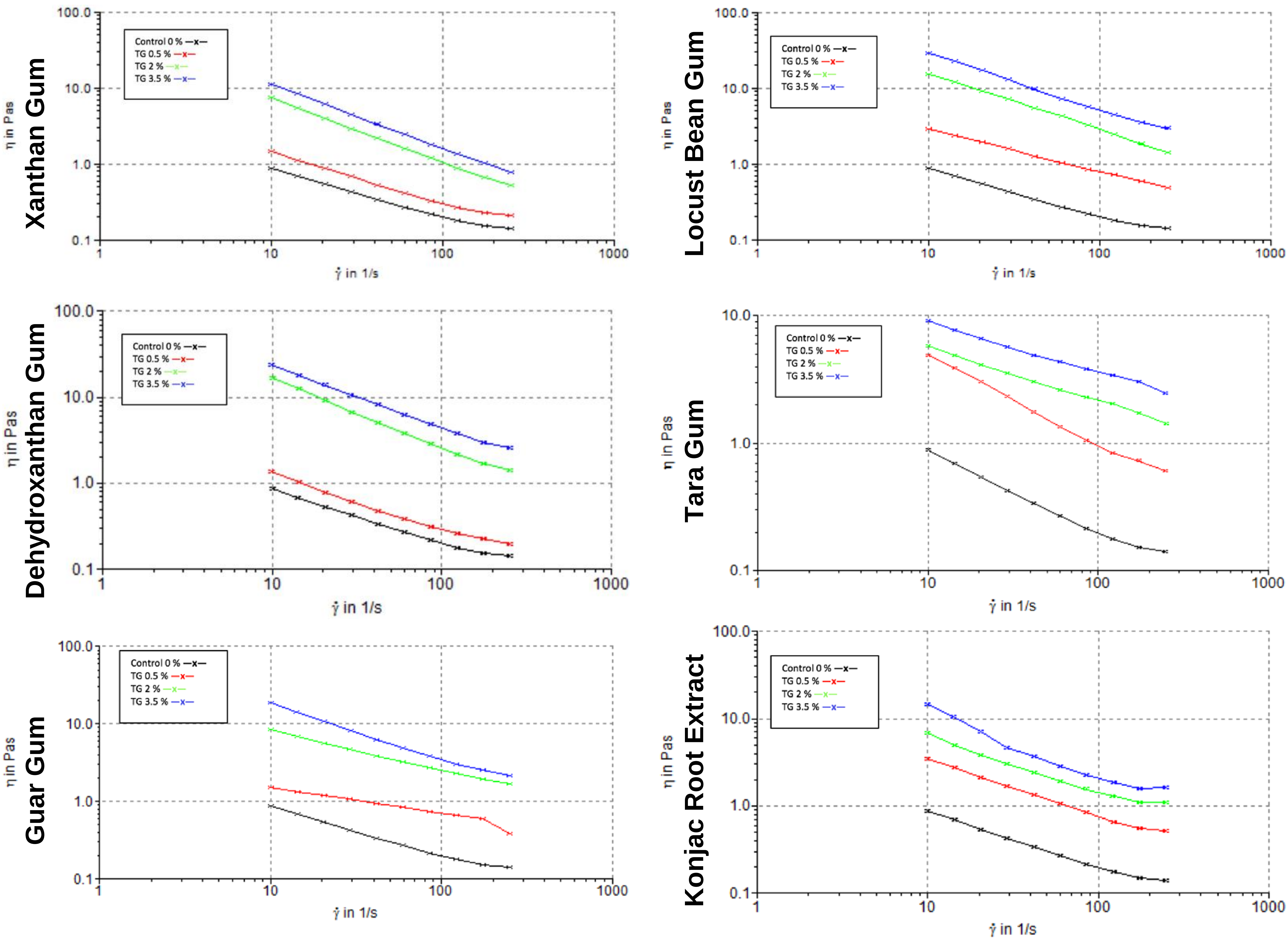
- TA.XT™Plus texture analyser (Stable Micro Systems, UK) with a TTC spreadability rig, by immersion/de-immersion of the convex cone into the sample.
- Exponent Software Version 6:1.11 (Stable Micro Systems, UK)

Firmness	Work of Shear	Stickiness	Work of Adhesion
• Maximum force used to spread the sample • Hardness	• Force required to deform the sample to the specified distance	• Maximum force used to detach the cone from the sample • Adhesiveness	• Force required to separate the sample from the cone to return to its starting position

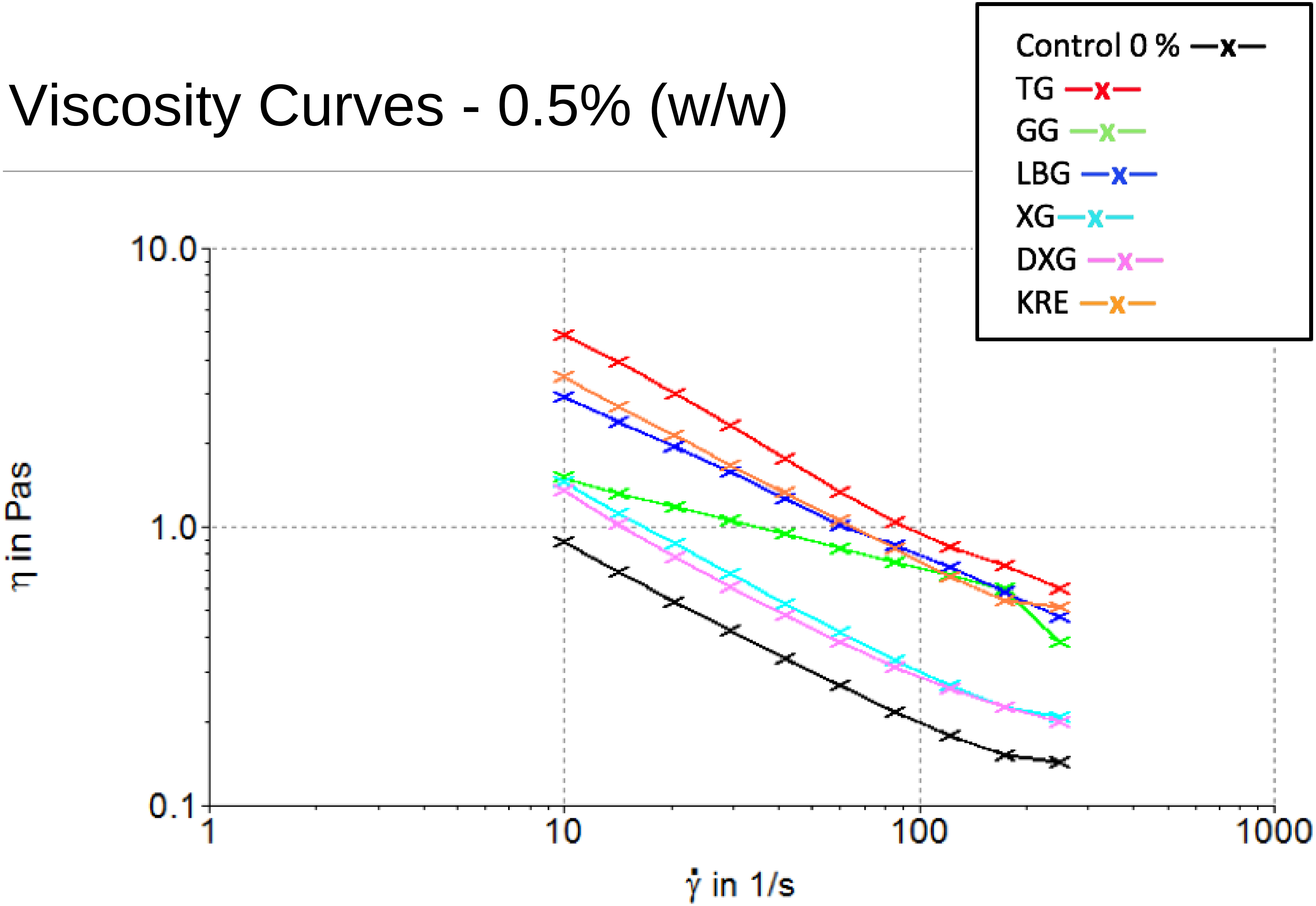
Texture Analysis: Spreadability and Stickiness



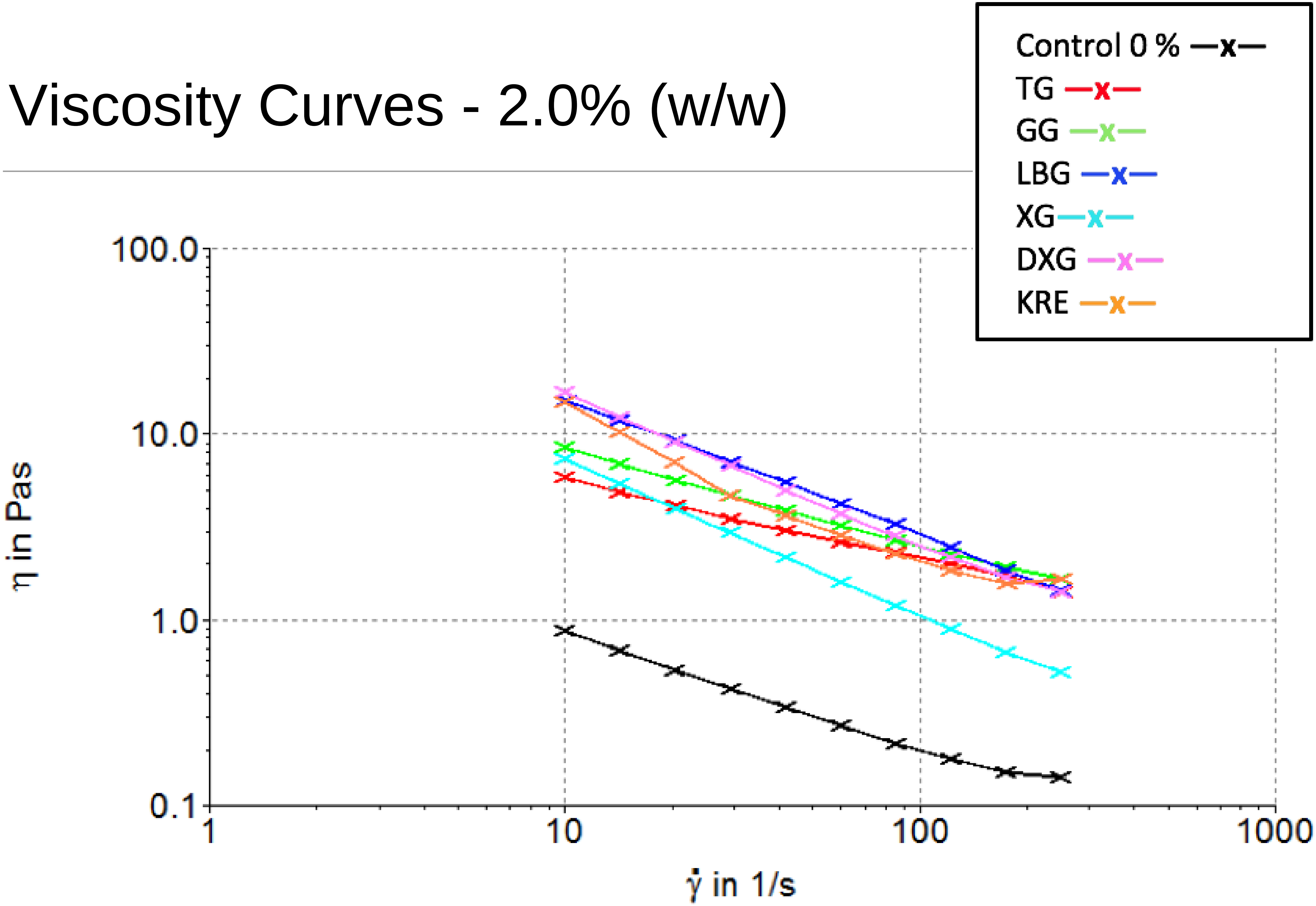
Results: Shear Rate Sweep


Xanthan Gum
Locust Bean Gum
Dehydroxanthan Gum
Tara Gum
Guar Gum
Konjac Root Extract
Control 0 %
TG 0.5 %
TG 2 %
TG 3.5 %
η in Pas
γ̇ in 1/s
100.0
10.0
1.0
0.1
1
10
100
1000

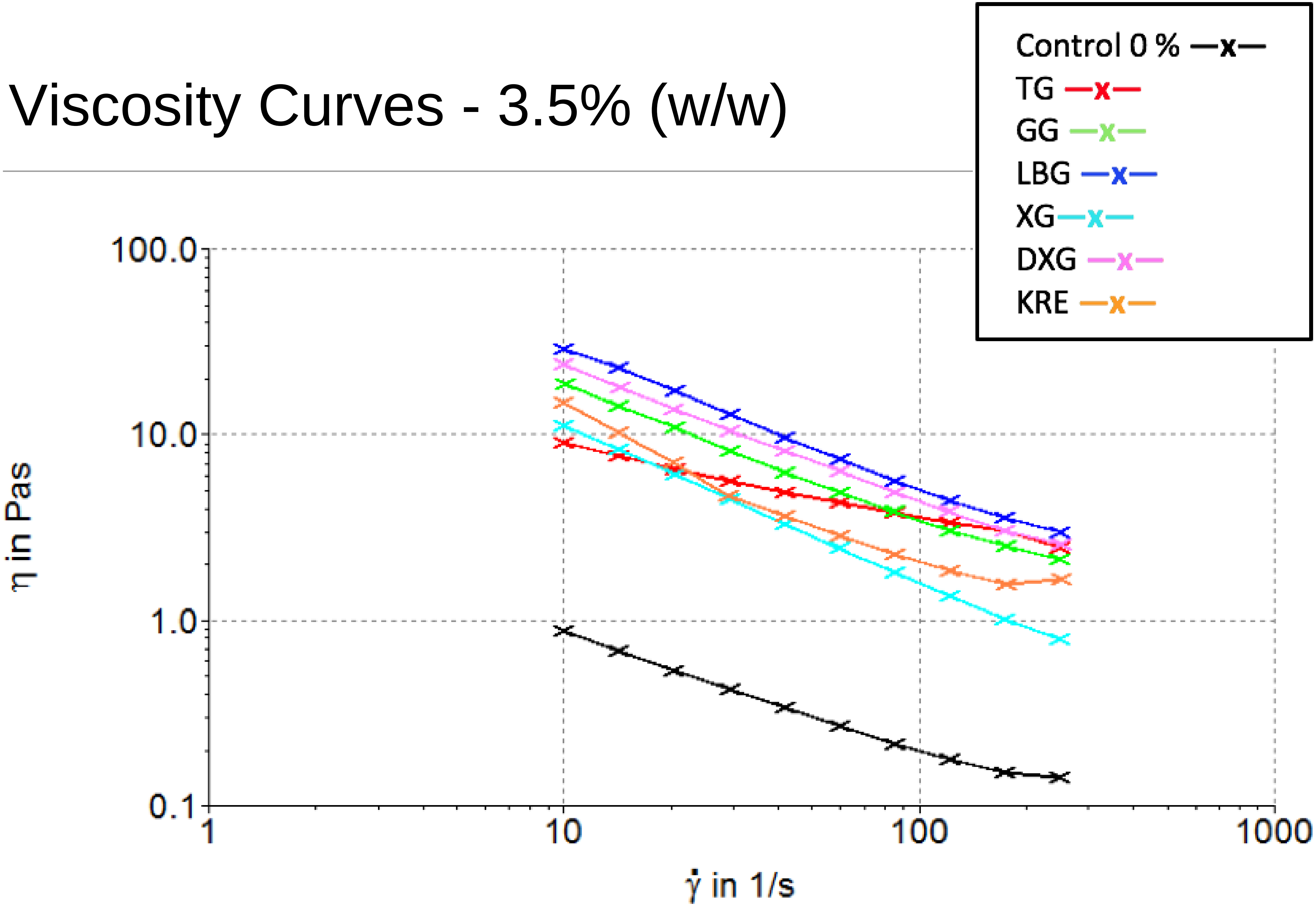
Viscosity Curves - 0.5% (w/w)



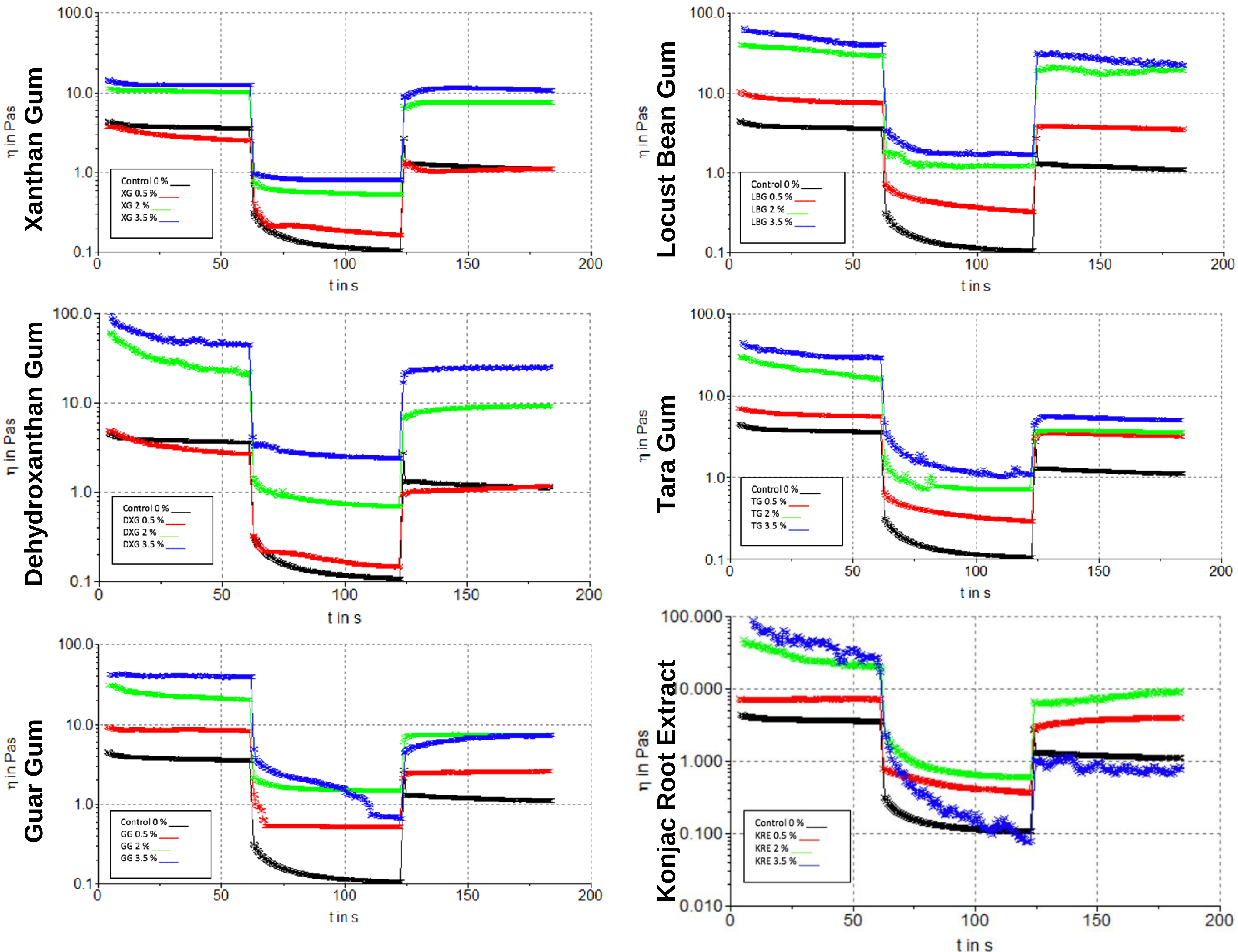
Viscosity Curves - 2.0% (w/w)



Viscosity Curves - 3.5% (w/w)



Results: 3-Step Thixotropy


Xanthan Gum
η in Pas
t in s
Control 0 %
XG 0.5 %
XG 2 %
XG 3.5 %
Locust Bean Gum
η in Pas
t in s
Control 0 %
LBG 0.5 %
LBG 2 %
LBG 3.5 %
Dehydroxanthan Gum
η in Pas
t in s
Control 0 %
DXG 0.5 %
DXG 2 %
DXG 3.5 %
Tara Gum
η in Pas
t in s
Control 0 %
TG 0.5 %
TG 2 %
TG 3.5 %
Guar Gum
η in Pas
t in s
Control 0 %
GG 0.5 %
GG 2 %
GG 3.5 %
Konjac Root Extract
η in Pas
t in s
Control 0 %
KRE 0.5 %
KRE 2 %
KRE 3.5 %
100.0
10.0
1.0
0.1
100.000
1.000
0.100
0.010
0
50
100
150
200

Viscosity Recovery

Concentration	0.5% (w/w)	2.0 % (w/w)	3.5% (w/w)
Xanthan Gum	**43.7 %**	**75.9 %**	**85.5 %**
Dehydroxanthan Gum	**43.2 %**	**42.9 %**	**55.6 %**
Guar Gum	**31.1 %**	**35.8 %**	**18.4 %**
Locust Bean Gum	**47.1 %**	**67.1 %**	**56.4 %**
Tara Gum	**57.4 %**	**22.1 %**	**17.2 %**
Konjac Root Extract	**55.4 %**	**45.2 %**	**3.0 %**
Control		**30.92%**	

Continuous Flow Rheology - Key Points

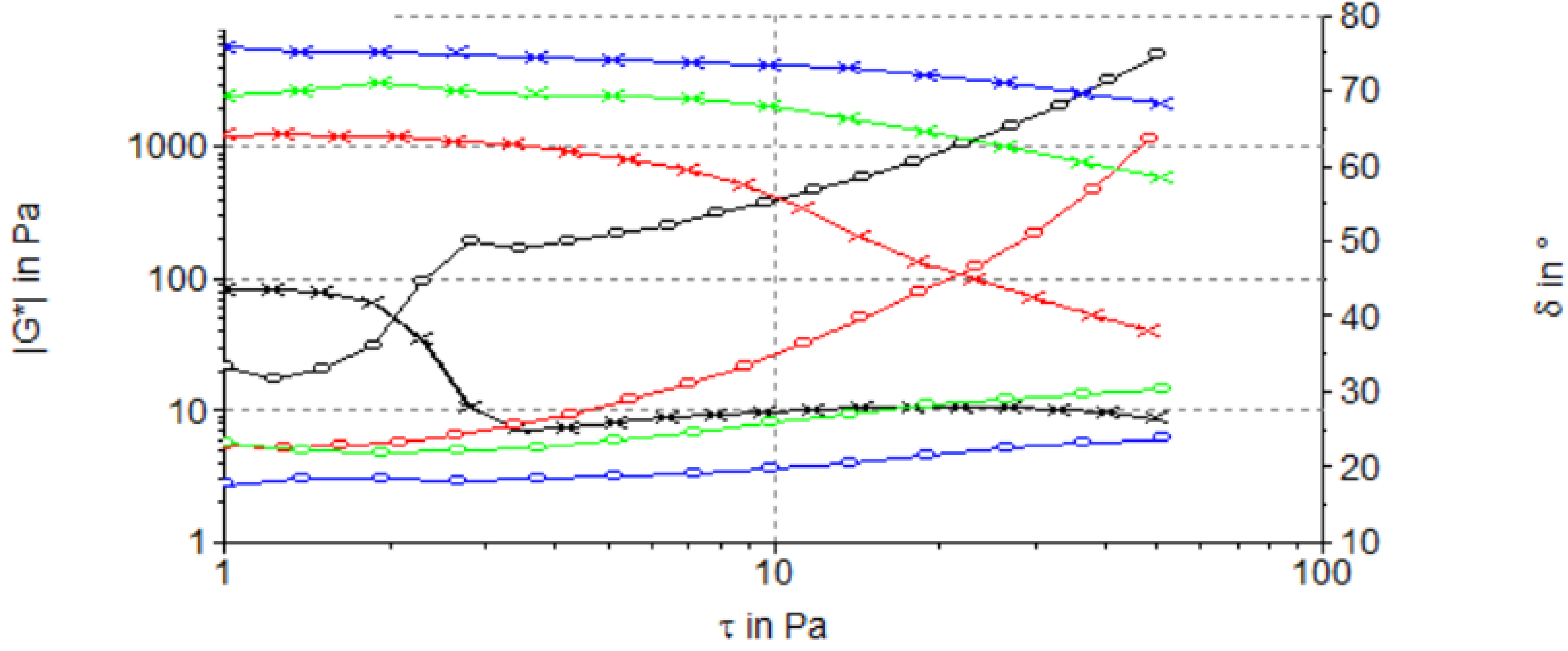
- All gums show a shear-thinning behaviour.
- For all gums, viscosity increases with increasing gum concentration.
    - The increase in viscosity is not consistent for all gums.
    - XG is the least resistant to shear forces.
    - The increase in viscosity is more drastic at lower gum concentrations.
- XG and DXG recover viscosity quicker with increasing concentration.
- All other gums recover viscosity slower with increasing concentration.

Results: Oscillatory Stress Sweep and Yield Stress

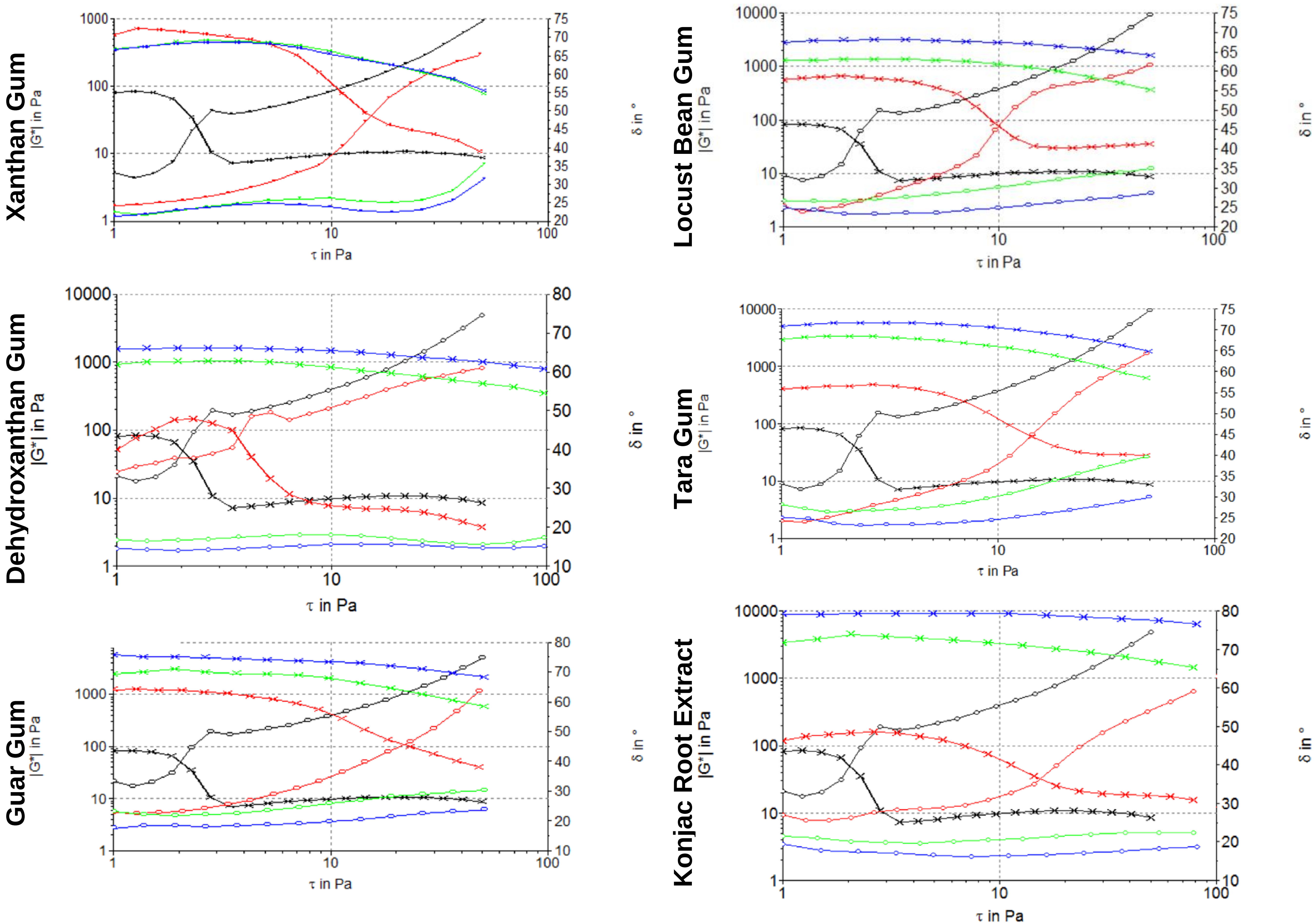
Oscillatory Stress Sweep Results

G* - rigidity; how hard/soft?

Yield stress - how strong?



δ - elasticity; how solid/liquid?


Xanthan Gum
|G*| in Pa
δ in °
τ in Pa
Locust Bean Gum
|G*| in Pa
δ in °
τ in Pa
Dehydroxanthan Gum
|G*| in Pa
δ in °
τ in Pa
Tara Gum
|G*| in Pa
δ in °
τ in Pa
Guar Gum
|G*| in Pa
δ in °
τ in Pa
Konjac Root Extract
|G*| in Pa
δ in °
τ in Pa

Yield Stress

Sample	Concentration (% w/w)	Yield Stress (Pa)
Control	0.0	**1.67**
Xanthan Gum	0.5	**3.85**
	2.0	**4.62**
	3.5	**4.62**
Dehydroxanthan Gum	0.5	**2.52**
	2.0	**12.32**
	3.5	**17.09**
Guar Gum	0.5	**4.91**
	2.0	**17.09**
	3.5	**32.87**

Yield Stress

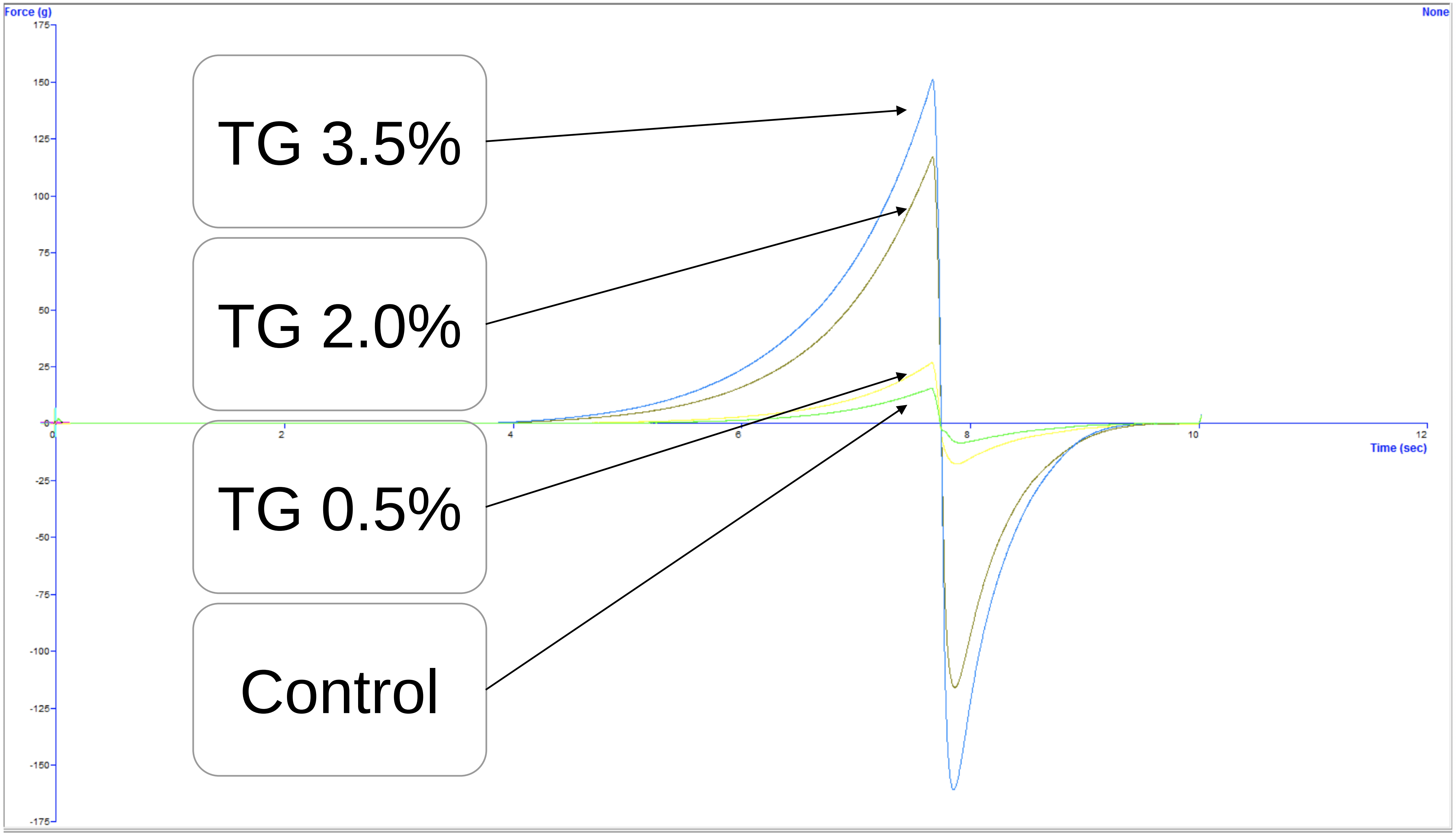
Sample	Concentration (% w/w)	Yield Stress (Pa)
Control	0.0	**1.67**
Locust Bean Gum	0.5	**3.80**
	2.0	**12.32**
	3.5	**32.81**
Tara Gum	0.5	**3.85**
	2.0	**6.26**
	3.5	**14.63**
Konjac Root Extract	0.5	**3.85**
	2.0	**7.97**
	3.5	**14.81**

Oscillatory Rheology - Key Points

- For all gums, with increasing gum concentration:
  - Emulsion rigidity increases;
  - Emulsion elasticity increases;
  - Emulsion yield stress increases.

Texture Analysis - Spreadability and Stickiness

Texture Analysis Results: Example



Texture Analysis

Sample	[%]	Firmness (g)	Work of Shear (g.s)	Stickiness (g)	Work of Adhesion (g.s)
Control	0.0	15.69	5.19	-8.86	-6.45
XG	0.5	**10.27**	**0.68**	**-6.24**	**-5.18**
	2.0	**35.49**	**24.25**	**-16.96**	**-13.88**
	3.5	**48.11**	**33.54**	**-18.49**	**-20.37**
DXG	0.5	**7.29**	**5.65**	**-2.68**	**-3.21**
	2.0	**159.65**	**122.08**	**-37.51**	**-39.44**
	3.5	**258.16**	**216.71**	**-70.95**	**-69.38**
GG	0.5	**24.60**	**12.80**	**-17.03**	**-11.51**
	2.0	**111.58**	**93.50**	**-74.87**	**-46.05**
	3.5	**174.67**	**167.71**	**-127.44**	**-65.15**

Texture Analysis

Sample	[%]	Firmness (g)	Work of Shear (g.s)	Stickiness (g)	Work of Adhesion (g.s)
Control	0.0	15.69	5.19	-8.86	-6.45
LBG	0.5	**30.00**	**16.70**	**-20.28**	**-13.81**
	2.0	**79.37**	**58.58**	**-65.48**	**-36.79**
	3.5	**94.05**	**71.66**	**-86.67**	**-43.99**
TG	0.5	**26.91**	**14.15**	**-18.13**	**-12.41**
	2.0	**117.19**	**97.73**	**-116.3**	**-62.39**
	3.5	**151.20**	**134.59**	**-161.12**	**-80.72**
KRE	0.5	**28.13**	**14.79**	**-11.87**	**-11.73**
	2.0	**156.72**	**139.15**	**-59.16**	**-29.88**
	3.5	**375.31**	**381.47**	**-98.11**	**-41.32**

Conclusions

- All gums are suitable for use in O/W emulsions.
- All gums affect an emulsion's structure in similar manner:
  - Shear-thinning behaviour, at varying degrees;
  - Alter the system's thixotropy, depending on the gum;
  - Increase the emulsion's yield stress.
- At low concentrations, increase spreadability and reduce stickiness by using XG or DXG at low concentration.
- Decrease spreadability and increase stickiness with GG, LBG, TG and KRE.

Future Work

- Relate rheological changes to sensorial properties.
- Explore how natural gums perform in combination with other rheological modifiers.
- Compare the rheological properties of synthetic polymers to those of natural gums in order to explore the former's replacement for the purpose of sustainability.