Rheology of model dough formulations

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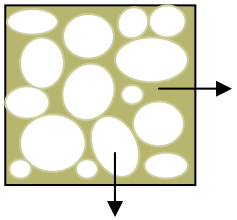
Outline

- Introduction
- Motivation and Approach
- Materials and methods
- Strain Rate Frequency Superposition
- Extensional rheology
- Conclusions

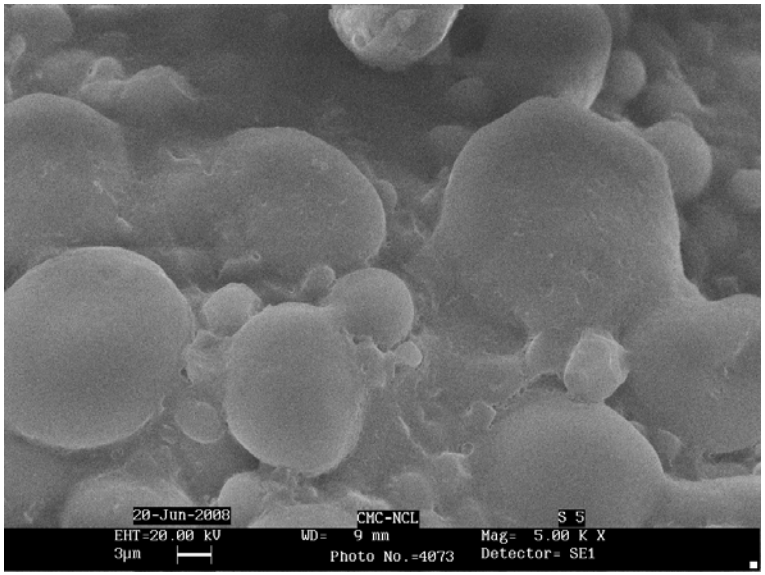
What is dough?

Dry Basis (flour)	
Components	Approx wt%
Starch	85
Gluten	10
Fat, Minerals	5
Wet basis (dough-50/50 water/flour)	
Components	Approx vol%
Starch + water	70%
Matrix (gluten+water)	30%



Gluten + interstitial water

Swollen starch particles



Motivation and Approach

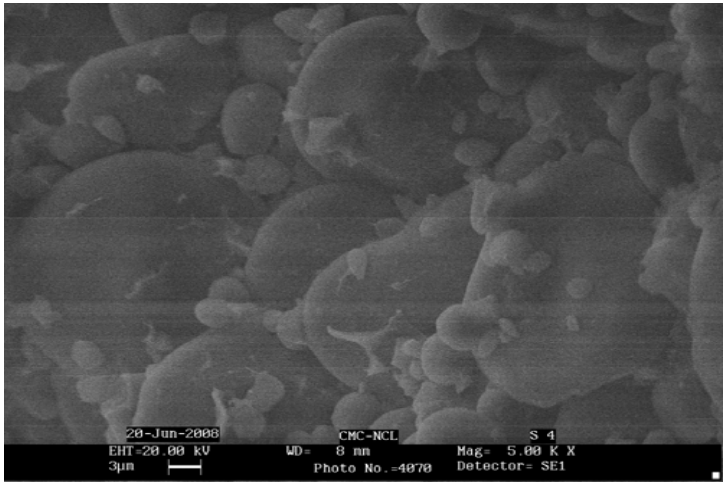
The rheology of dough should have contributions from interparticle friction (like soft solids) and also from the viscoelastic gluten. **The motivation of this study is to decipher these two contributions**

Classical oscillatory rheology, SRFS and extensional rheology was used to probe soft material characteristics of the following:

- Aq starch dispersion (~70 wt%)
- Saturated gluten
- Starch + gluten (90/10, 75/25, 50/50, dry basis)

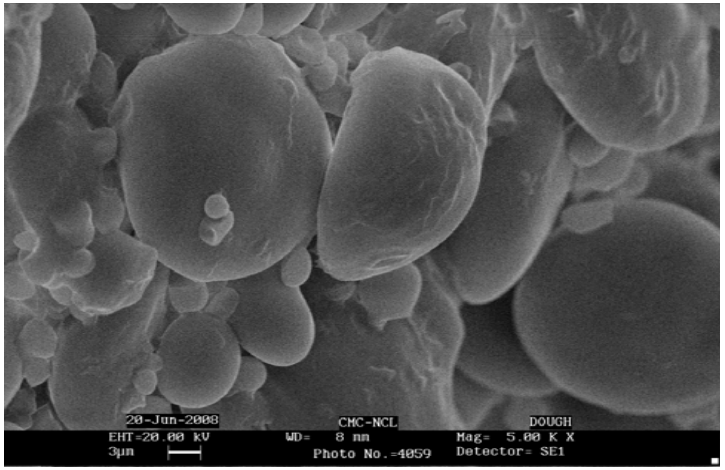
Model dough compounds

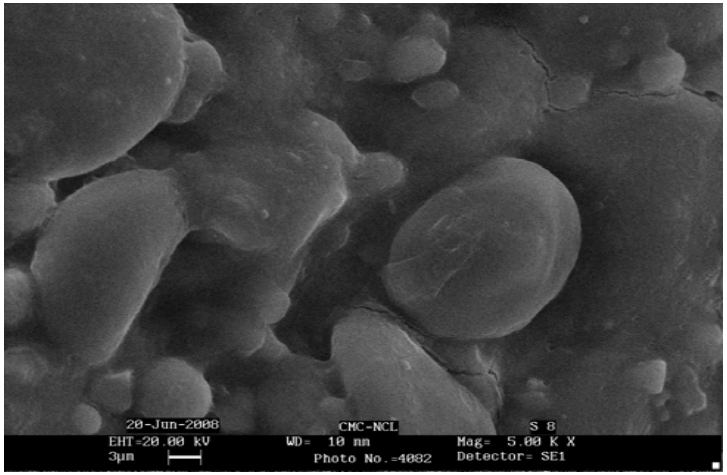
Model doughs	Gluten % (dry basis)	Gluten volume fraction	Starch volume fraction	Water volume fraction	Mid-line Peak Value %
SG0	0	0	52.9	47.1	30.9
SG10	10	5.9	47.6	46.	31.9
SG20	20	11.7	42.3	45.9	36.9
SG40	40	23.5	31.8	44.7	71.8
SG60	60	35.3	21.2	43.5	
SG100	100	58.8	0	41.2	



Starch

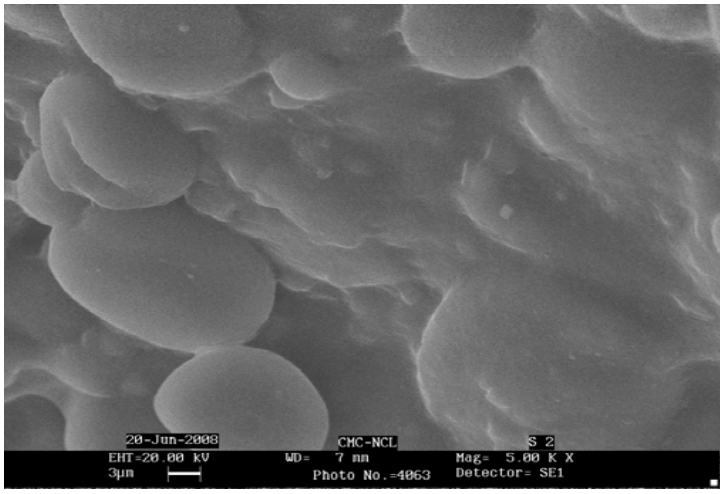
SG 10

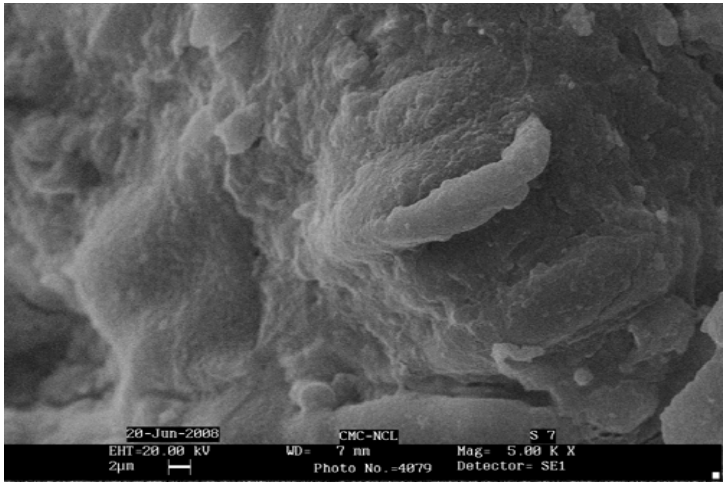




SG 30

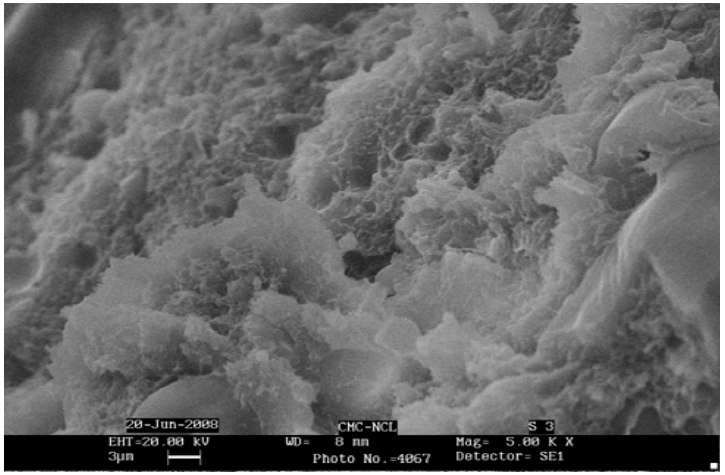
SG 40





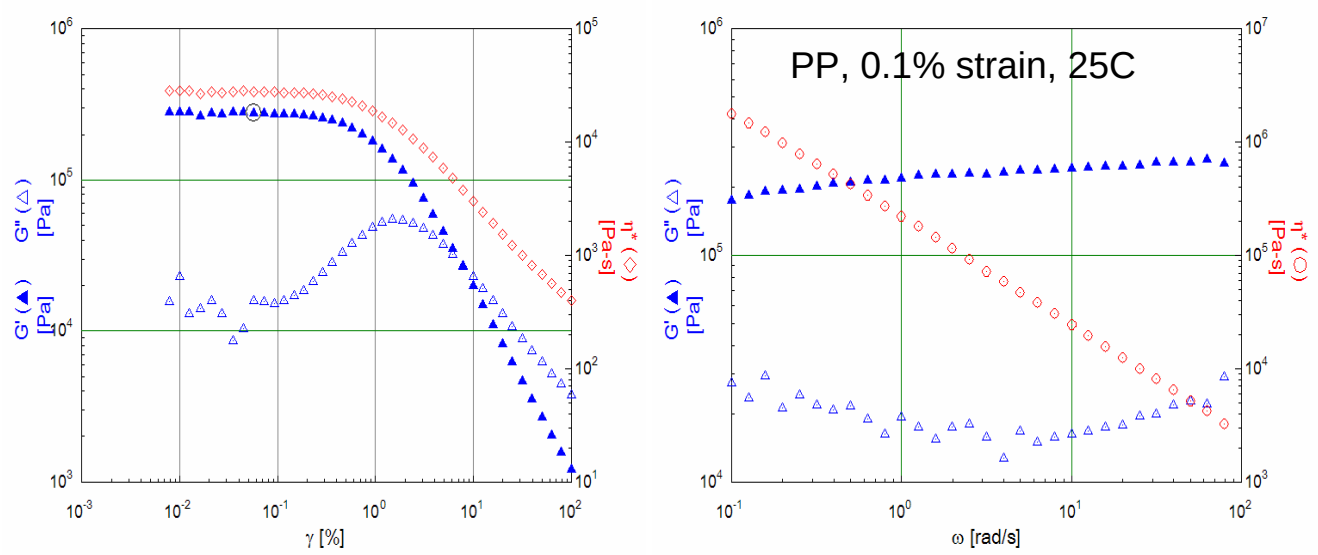
SG 60

Gluten



Strain rate frequency sweep (SRFS)

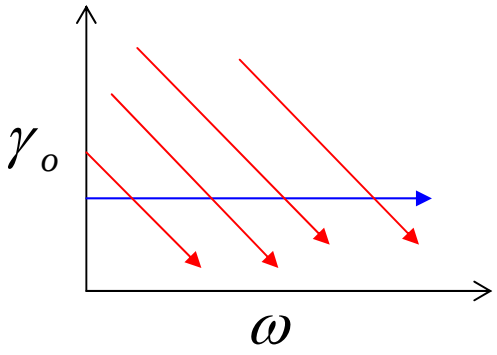
SG0



Strain sweep

Frequency sweep

To probe $\tau(\dot{\gamma})$ directly, perform FS keeping strain rate amplitude $\omega\gamma_o = \text{constant}$



$$\frac{1}{\tau(\gamma)} = \frac{1}{\tau_o} + k\gamma^n$$

[1]Hans M. Wyss, Kunimasa Miyazaki, Johan Mattson, Zhibing Hu, David Reichman and David Weitz

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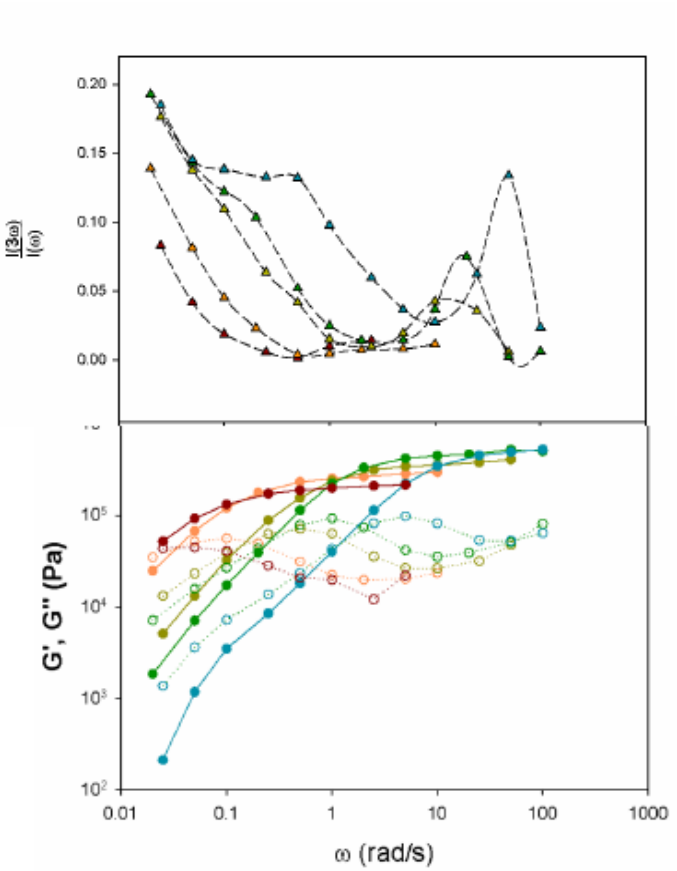
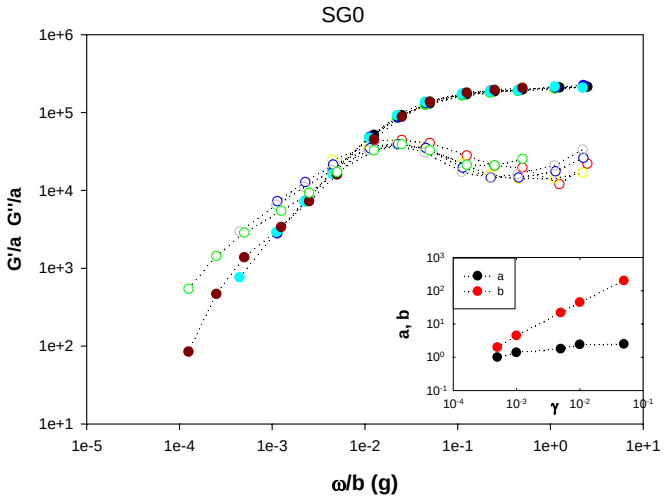
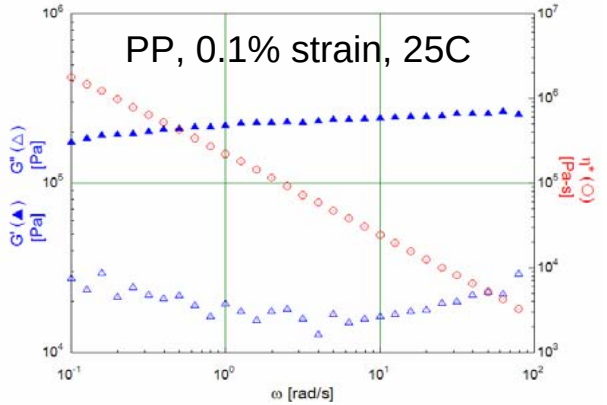
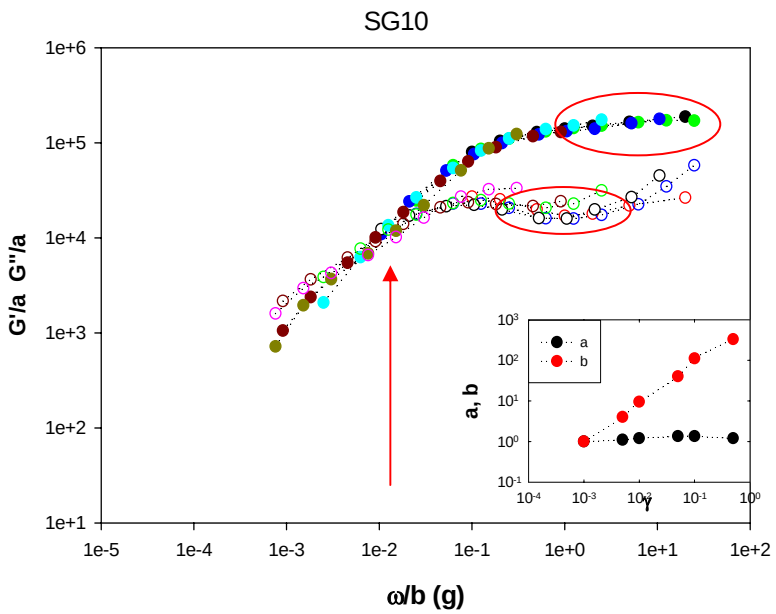
SRFS – Starch

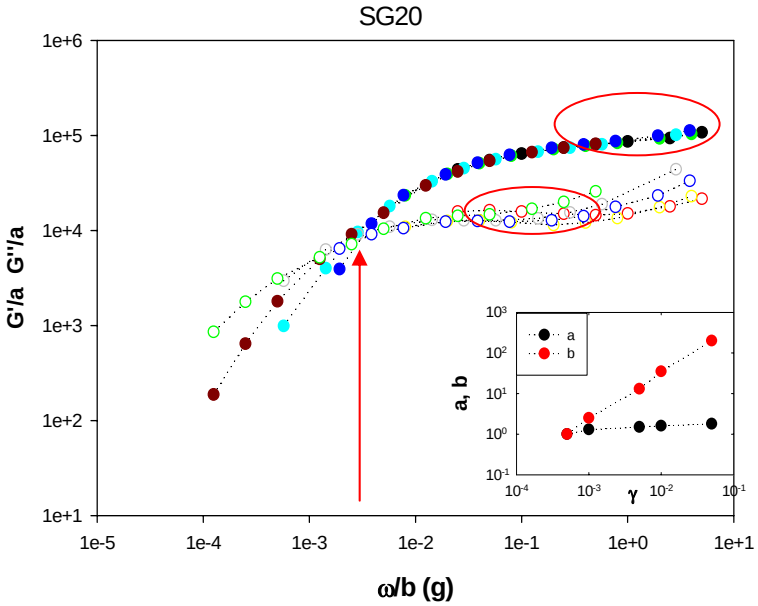

I(3ω)/I(ω)
G', G'' (Pa)
ω (rad/s)

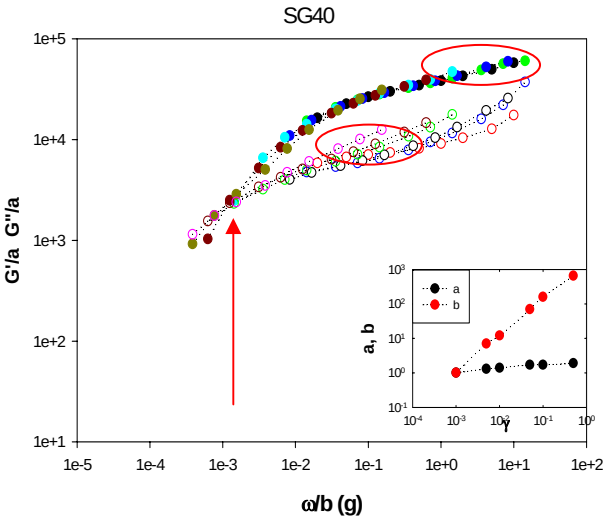

SG0
G'/a G''/a
ω/b (g)
a, b
γ
a
b

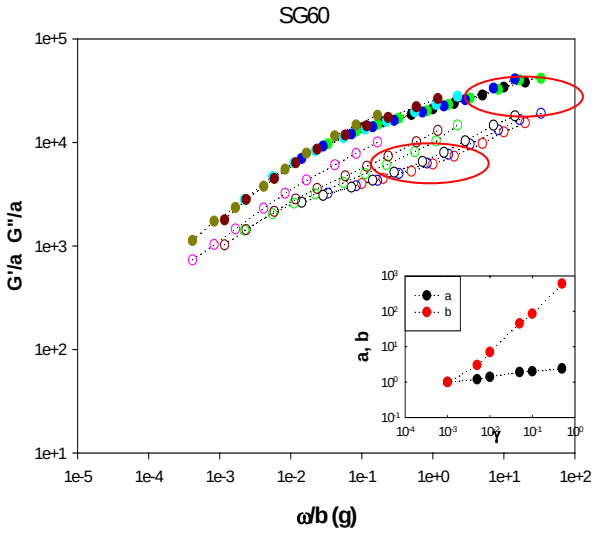

PP, 0.1% strain, 25C
G' (▲) [Pa]
G'' (△) [Pa]
η* (○) [Pa-s]
ω [rad/s]

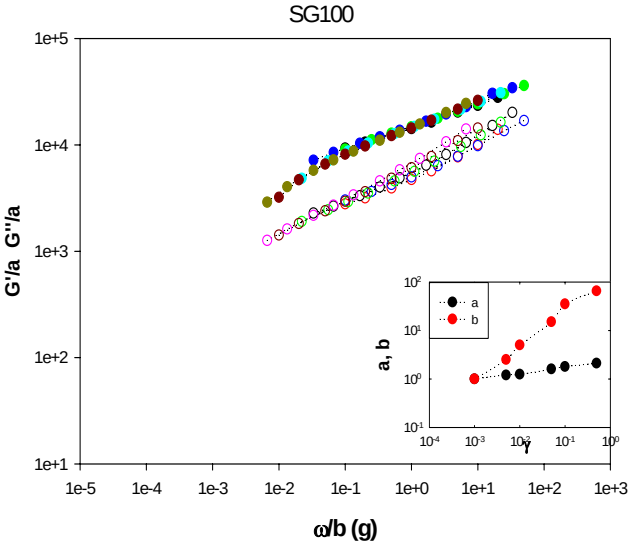
SRFS – model dough



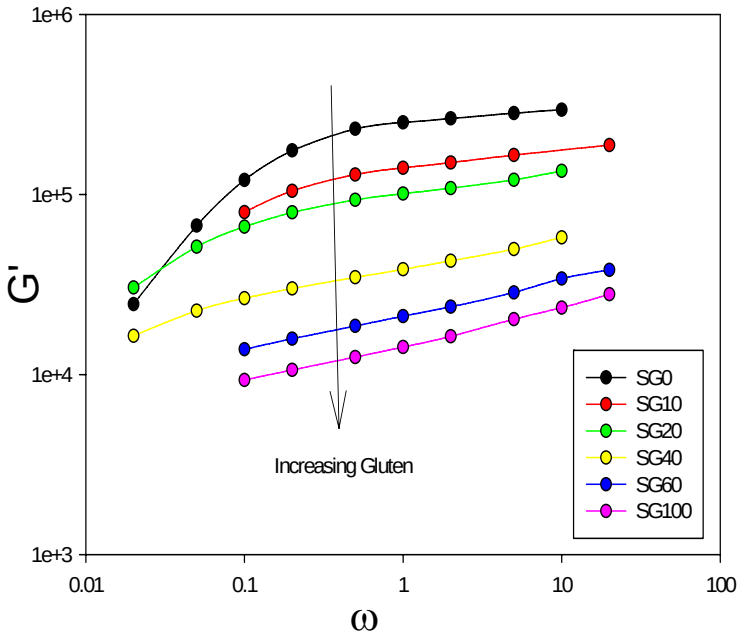


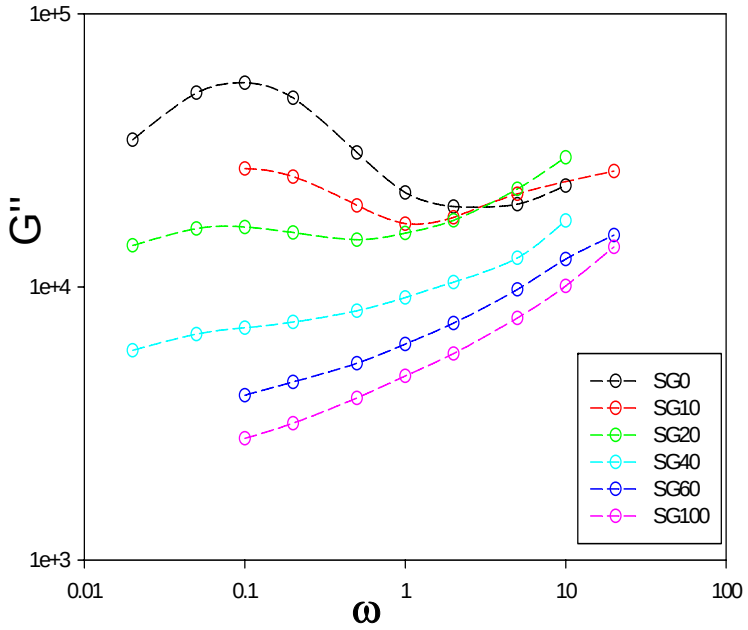




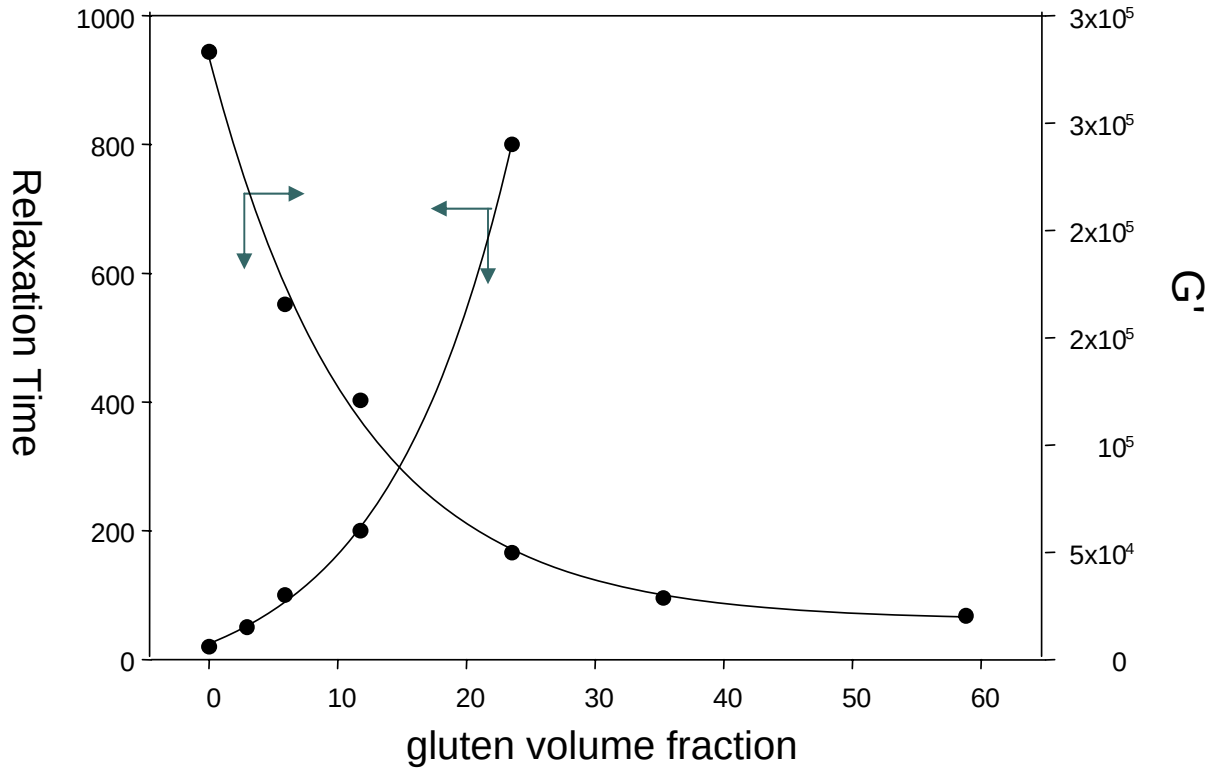


Frequency sweep

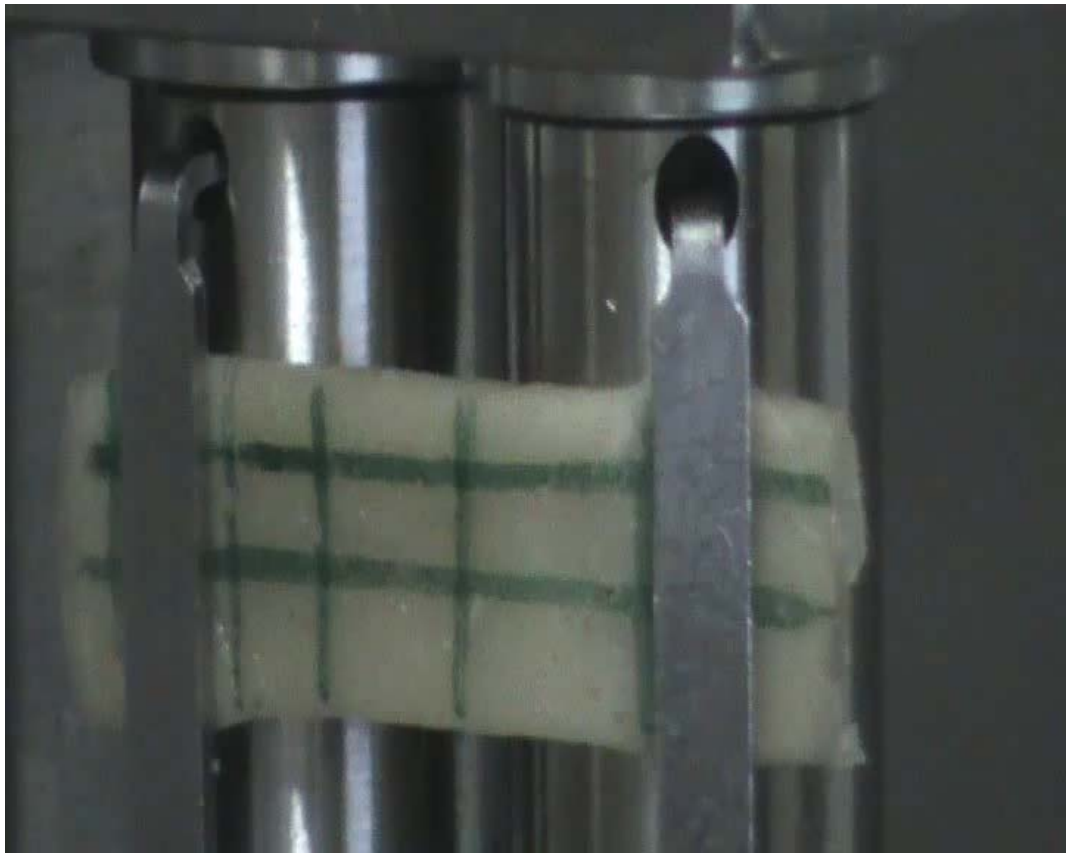




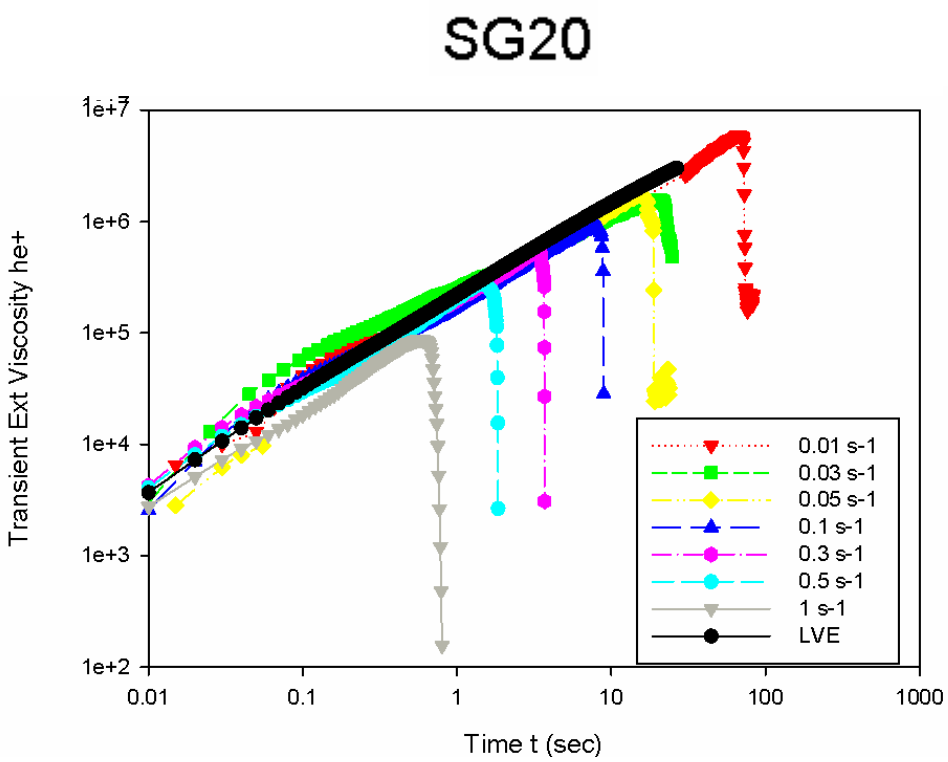
Relaxation time and Modulus

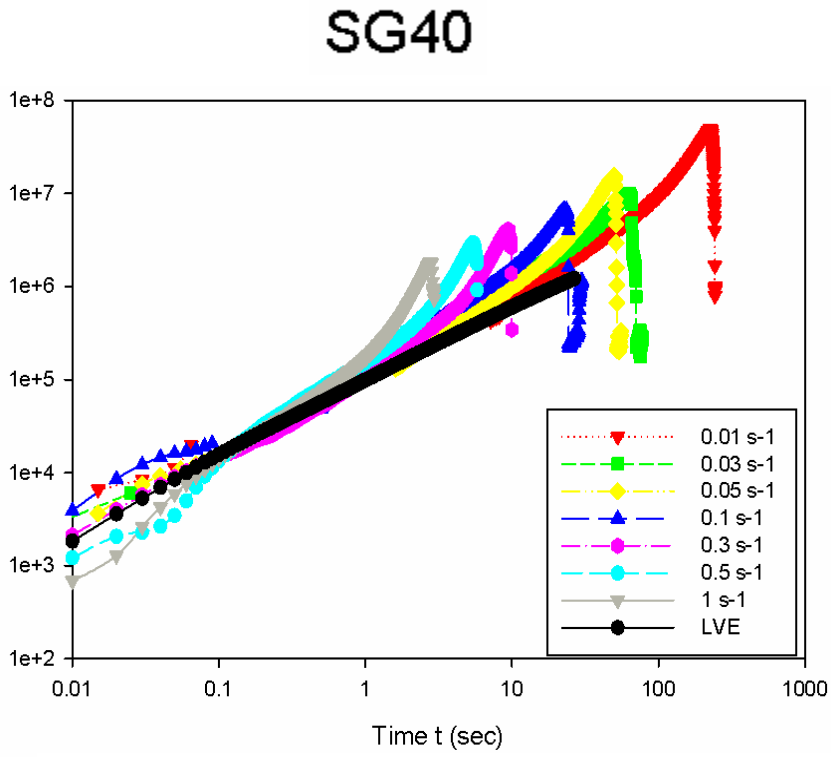


SG60 at $0.5s^{-1}$



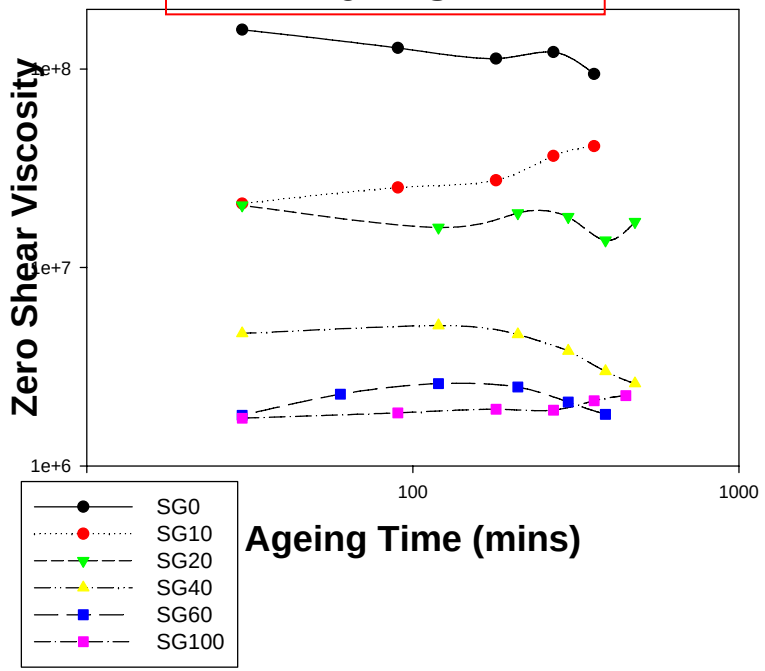
SER


SG20
Transient Ext Viscosity he+
1e+7
1e+6
1e+5
1e+4
1e+3
1e+2
0.01
0.1
1
10
100
1000
Time t (sec)
0.01 s-1
0.03 s-1
0.05 s-1
0.1 s-1
0.3 s-1
0.5 s-1
1 s-1
LVE

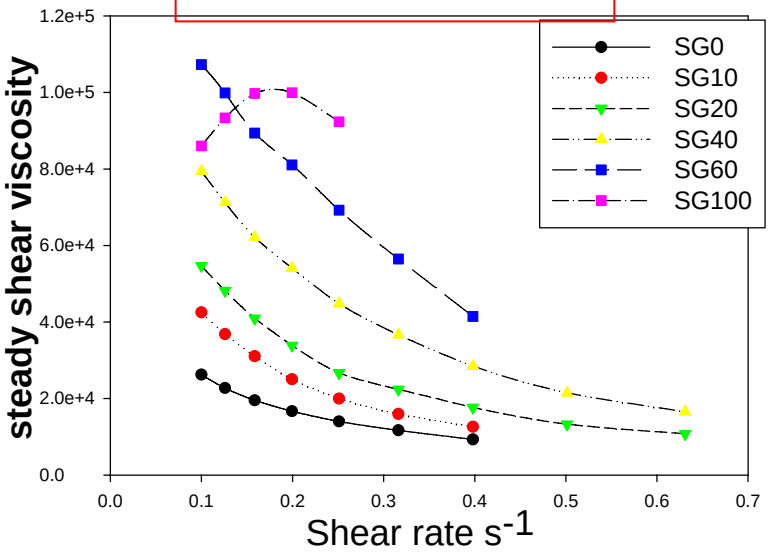

SG40
1e+8
1e+7
1e+6
1e+5
1e+4
1e+3
1e+2
0.01
0.1
1
10
100
1000
Time t (sec)
0.01 s-1
0.03 s-1
0.05 s-1
0.1 s-1
0.3 s-1
0.5 s-1
1 s-1
LVE

Steady and Zero shear viscosity

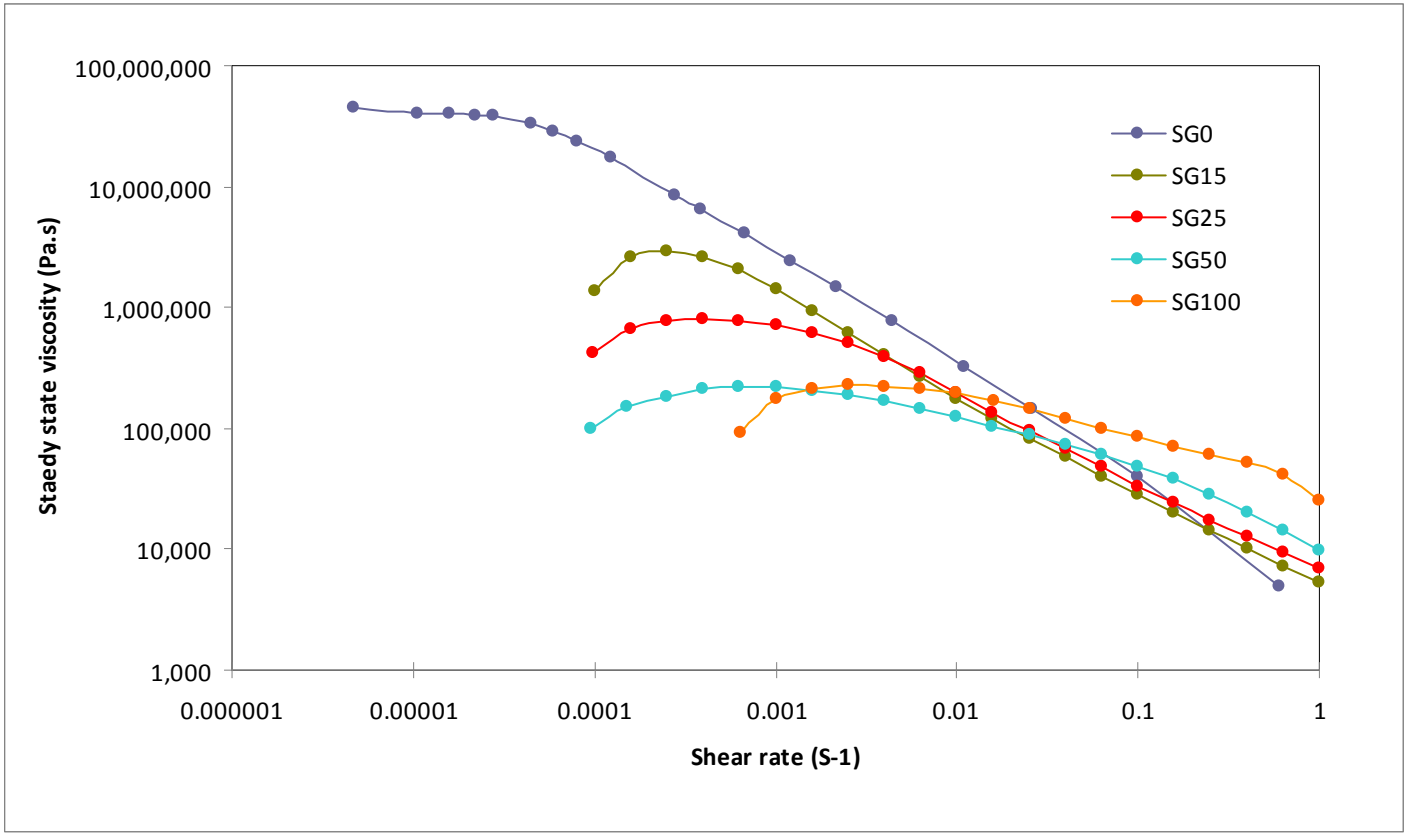
Shear rate ~10^{-4} to 10^{-8} s^{-1}



Shear rate ~10^{-1} to 10^{0} s^{-1}



Stress Ramp


100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
Staedy state viscosity (Pa.s)
0.000001
0.00001
0.0001
0.001
0.01
0.1
1
Shear rate (S-1)
SG0
SG15
SG25
SG50
SG100

Conclusions

- **SRFS** works reasonably well on all starch gluten composition
- **As the gluten content increases**: Structural Relaxation time increases, Storage & loss modulli decreases
- **SER has shown that**: Rupture time increases as strain rate decreases, Strain hardening observed only above 40% gluten
- **Creep and steady shear studies**: At low Shear rates i.e. between 10^{-8} to 10^{-4} S^{-1}, the viscosity *deceases* with increase in gluten and at higher shear rates between 0.1 to 10 S^{-1}, the viscosity *increases* with increase in gluten.

Thank You