The effect of hydration and protein content on the viscoelasticity of bread dough utilizing a simple homemade cylinder-piston measurement apparatus

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- Bread is delicious
- Simple experiments with accessible setups can provide valuable conceptual understanding of theoretical concepts
- Raw bread dough is a soft viscoelastic material, and its ingredients are found in many home kitchens
- Presented here:
  - Simple experimental set up with easily sourced components
  - Measurements of the bulk modulus of raw bread dough
  - Correlation of dough composition to stiffness

Bread

- Bread is ancient and everywhere
- Dough consists primarily of water and flour along with various adjunct ingredients
- We can vary dough's apparent softness by varying parameters of its composition such as:
  - Hydration
  - Protein Content

Viscoelasticity

- Resistance to compression is characterized by bulk modulus, K

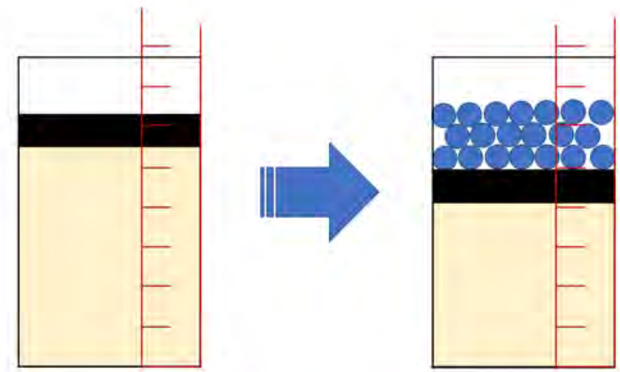
$$K = -V\frac{dP}{dV}$$

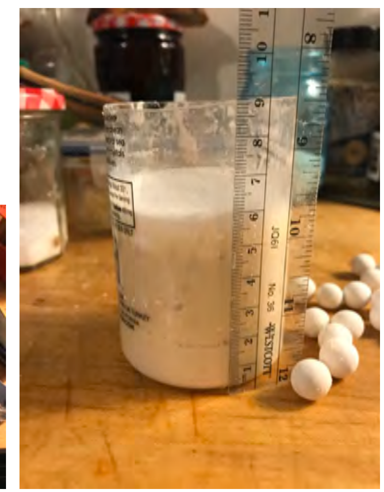
$$K = -\frac{\Delta P}{\log\left(\frac{V_f}{V_i}\right)}$$

$K = \Omega\Delta\mathrm{P},\ \Omega \equiv -\left(\log\left(\frac{V_f}{V_i}\right)\right)^{-1}$ => "inverse strain coefficient"

- If we can measure the volume change incurred by a known stress, we can determine bulk modulus and determine relative stiffness.

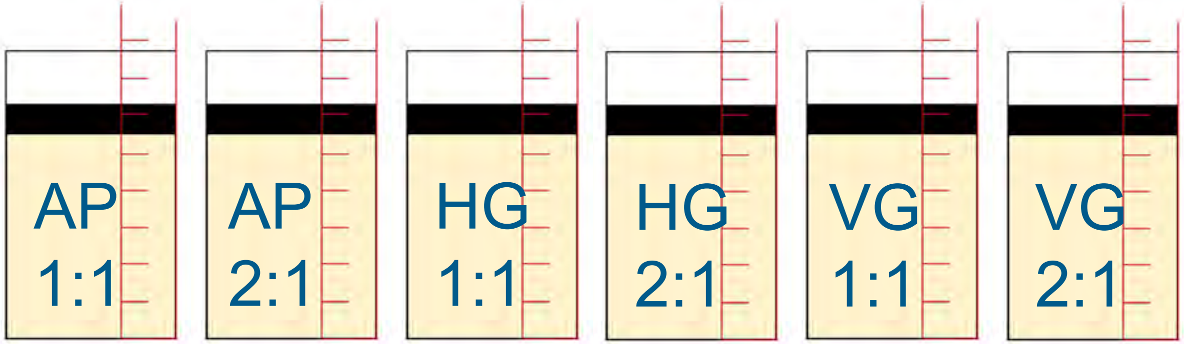
Apparatus and Measurement





Dough preparation

- Three flour protein formulations
  - 11.7%: AP
  - 14.2%: HG
  - 30.1%: VG
- Two hydration formulations
  - "100% hydration": 1:1 Water:Flour
  - "200% hydration": 2:1 Water:Flour
- Six experimental conditions



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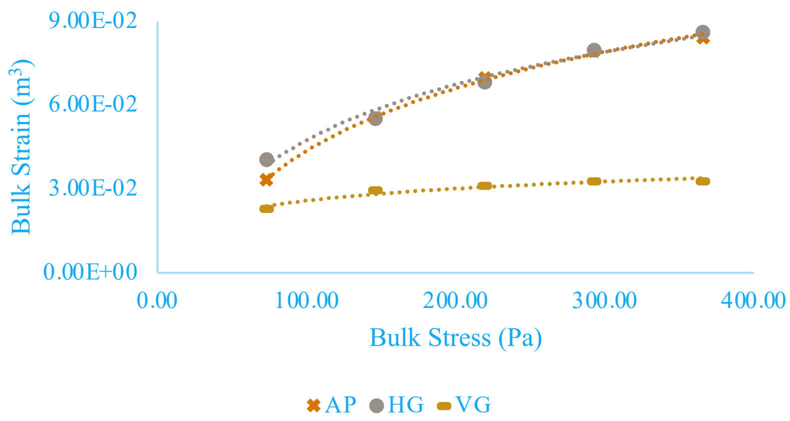
Results: Strain

Bulk Stress (Pa)	Bulk Strain (m^3) 1:1 AP	1:1 HG	1:1 VG	2:1 AP	2:1 HG	2:1 VG
73.13	3.33×10^{-2}	4.07×10^{-2}	2.30×10^{-2}	1.61×10^{-2}	1.16×10^{-2}	1.41×10^{-2}
146.27	5.56×10^{-2}	5.53×10^{-2}	2.95×10^{-2}	3.06×10^{-2}	2.17×10^{-2}	2.34×10^{-2}
219.40	6.98×10^{-2}	6.83×10^{-2}	3.11×10^{-2}	3.87×10^{-2}	3.04×10^{-2}	3.13×10^{-2}
292.53	7.94×10^{-2}	7.97×10^{-2}	3.28×10^{-2}	5.00×10^{-2}	3.48×10^{-2}	3.59×10^{-2}
365.67	8.41×10^{-2}	8.62×10^{-2}	3.28×10^{-2}	5.65×10^{-2}	3.91×10^{-2}	3.91×10^{-2}

1:1



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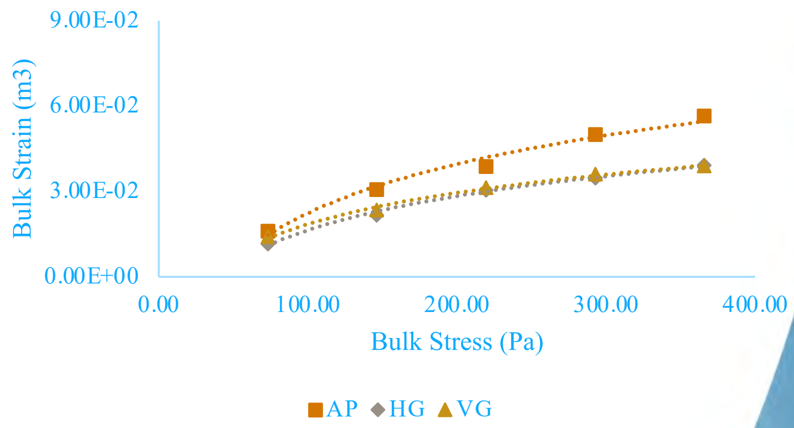
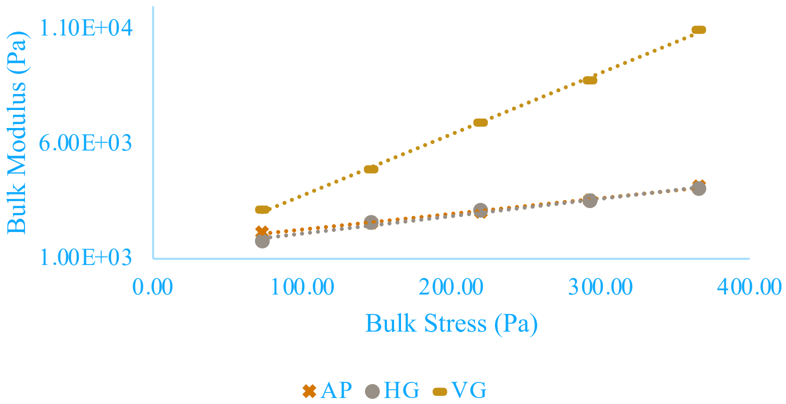


Results Bulk Modulus

Bulk Stress (Pa)	Bulk Modulus (Pa) 1:1 AP	1:1 HG	1:1 VG	2:1 AP	2:1 HG	2:1 VG
73.13	2.16×10^3	1.76×10^3	3.15×10^3	4.50×10^3	6.27×10^3	5.16×10^3
146.27	2.56×10^3	2.57×10^3	4.88×10^3	4.70×10^3	6.65×10^3	6.17×10^3
219.40	3.03×10^3	3.10×10^3	6.93×10^3	5.56×10^3	7.10×10^3	6.91×10^3
292.53	3.54×10^3	3.52×10^3	8.78×10^3	5.70×10^3	8.26×10^3	7.99×10^3
365.67	4.16×10^3	4.06×10^3	1.10×10^4	6.29×10^3	9.16×10^3	9.18×10^3

1:1



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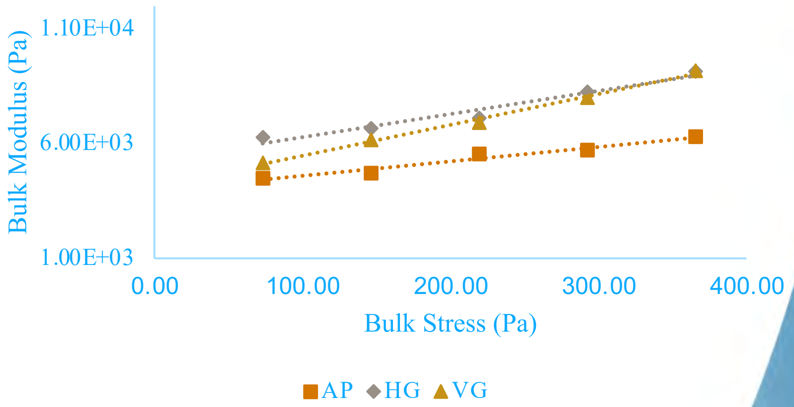
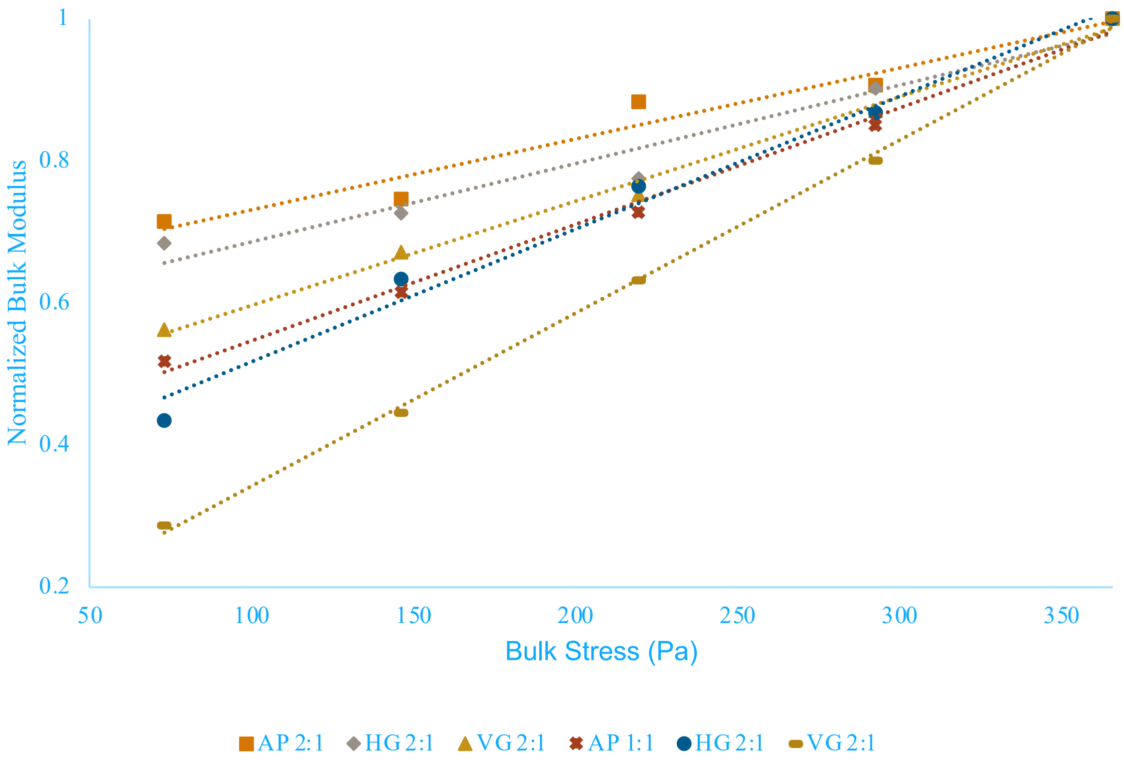
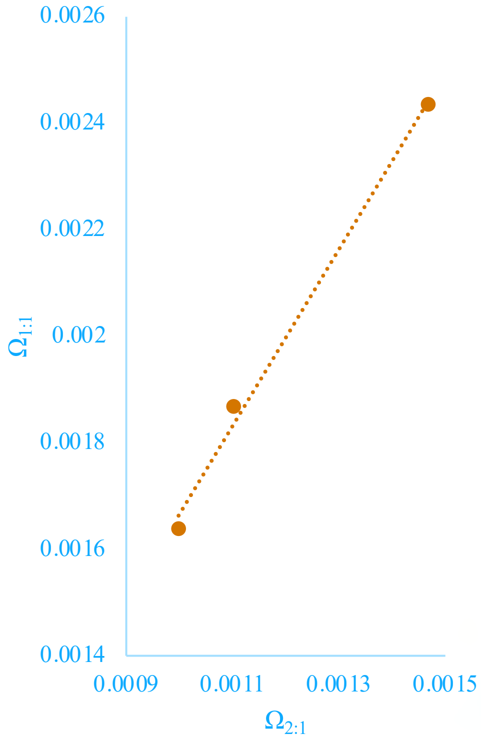


Results Normalized Bulk Modulus (Ω)





Conclusions

- Dough stiffness increases with increased protein content
- Dough stiffness decreases with increased hydration
- The experimental set up was simple, easy to make, affordable, composed of accessible materials, and produced useful results in accordance with expectations

References

- [1] C. Wang. On the compressibility of bread dough. *Korea-Australia Rheology Journal*, **18(3)** (2006) 127-131
- [2] T. Ng. Linear to nonlinear rheology of bread dough and its constituents. *Massachusetts Institute of Technology*, (2007) 79-115
- [3] M. Amjid. A comprehensive review on wheat flour dough rheology. *Pakistan Journal of Food Science*, **23(2)** (2013) 105-123.
- [4] M. Charalambides. Biaxial deformation of dough using the bubble inflation technique. *Rheologica Acta*, **41(6)** (2002) 541-548
- [5] D. Campos. Rheological behavior of undeveloped and developed wheat dough. *Cereal Chemistry*, **74(4)** (1997) 489-494

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Thank You!