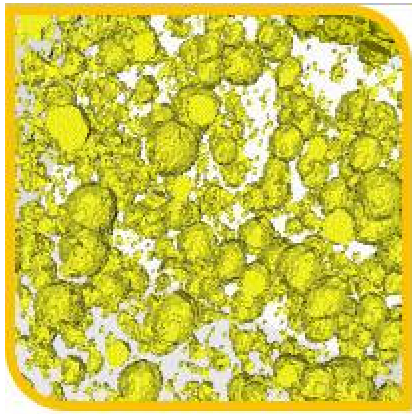
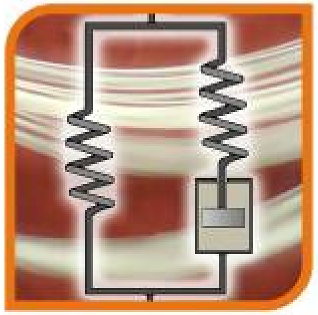
Flour quality and dough sheetability



Centre for
Grain Food Innovation



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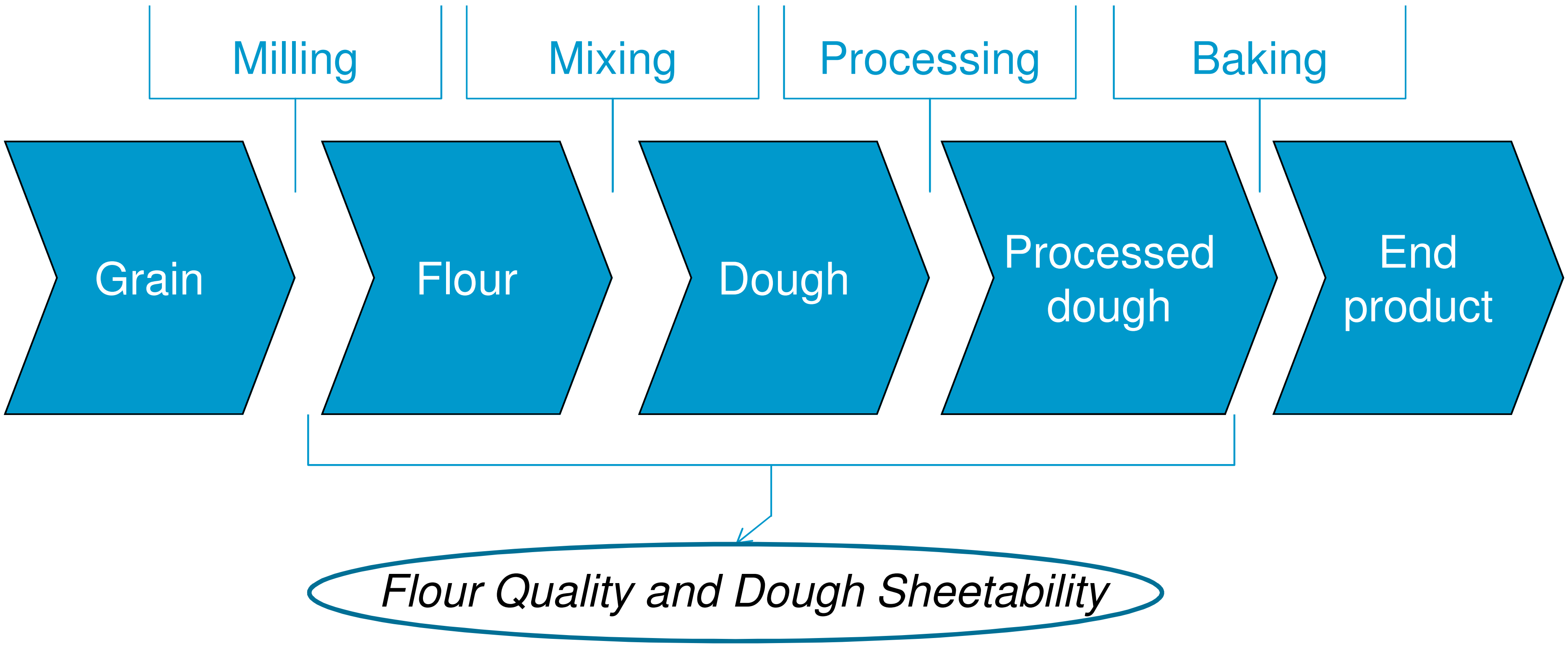
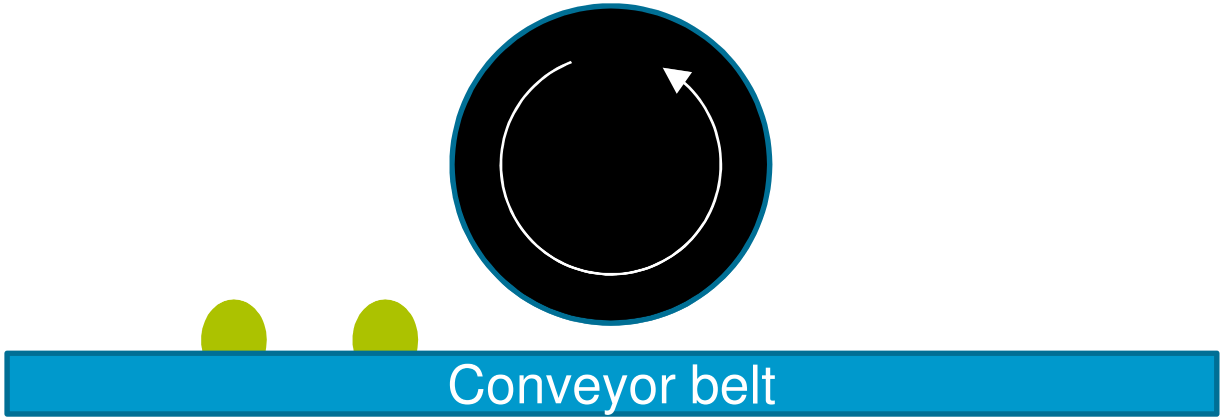
Centre for Grain Food Innovation – Adding value to low protein wheat

Target – to increase the use of low protein wheats in breadmaking - $$$

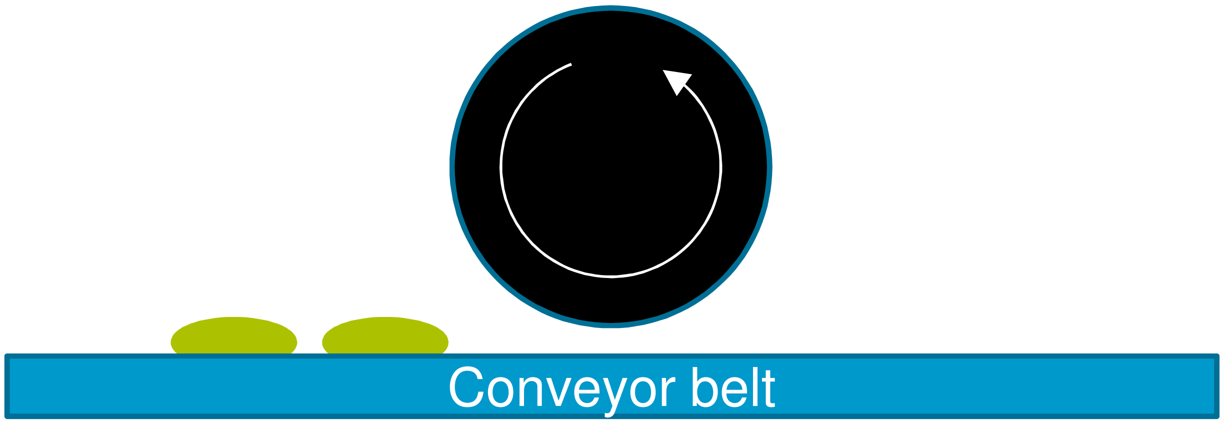


Background - the barriers to processing low protein doughs

- Dough spread on conventional bread lines (divider moulder - DM)



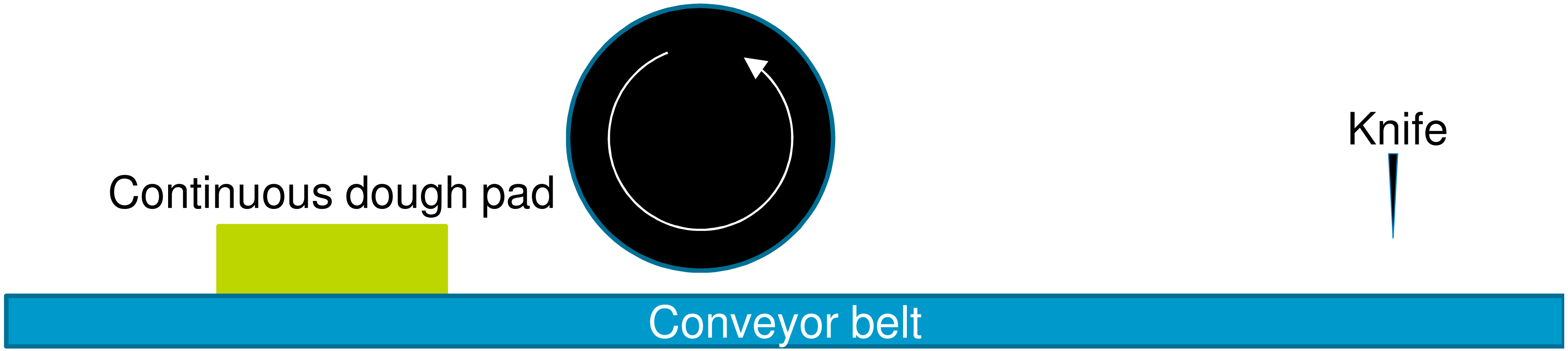
High protein doughs spread less and stay separate



Low protein doughs spread and ‘merge’

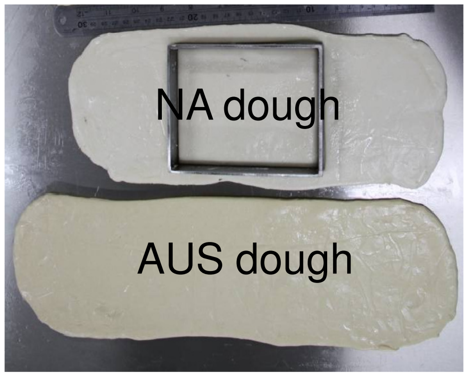
Line has to be run at lower rates!

The enabler to processing low protein doughs



High protein doughs ‘springback’ (elasticity)

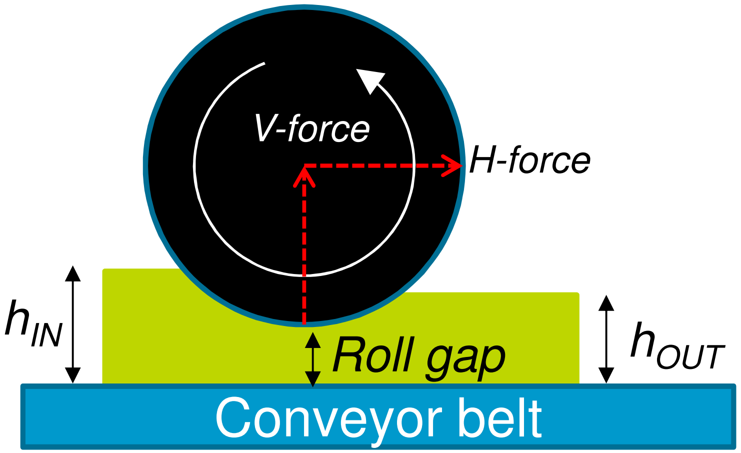
Low protein dough is less elastic



High spread / low elasticity enables predictable sheeting

Sheeting lines exist that run at competitive speeds to DM lines

Sheeting = fn(rheology!)

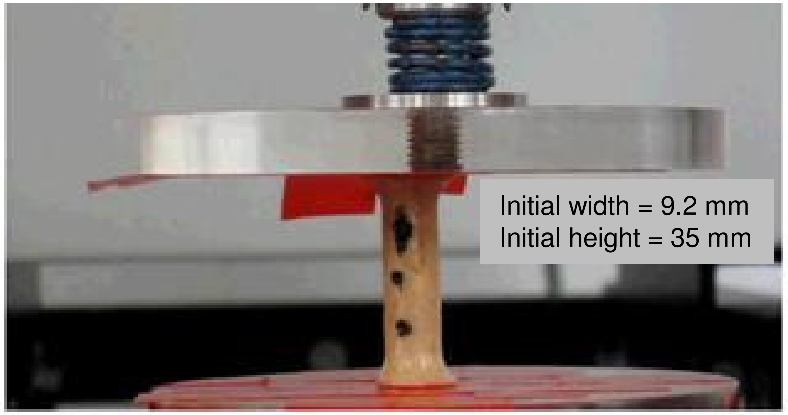


Elastic recovery = (h_{OUT} - gap)/gap

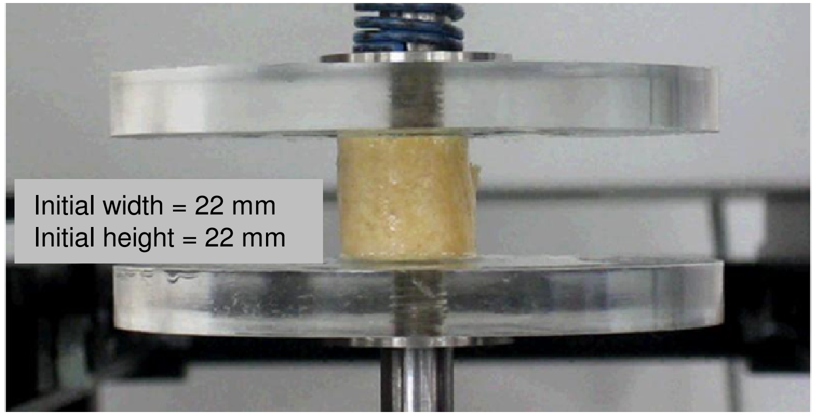
- Dough deforms and recovers – *dough elasticity*
- Dough pushes back against roller – *dough strength*
- Dough remembers – *dough is history-sensitive*
- **Objective – can we predict *h_{OUT}*?**
- ***First option -> true rheology tests***

Rheological testing: all at true strain rates

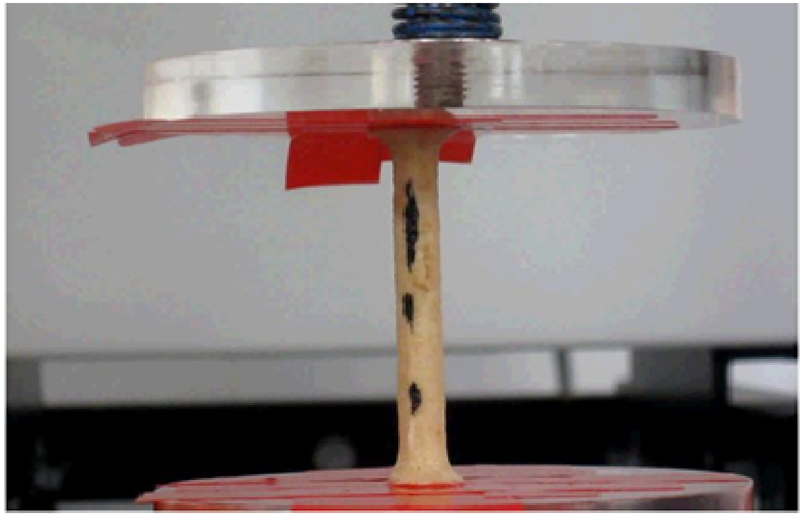
(i) Tension test; pre-experiment



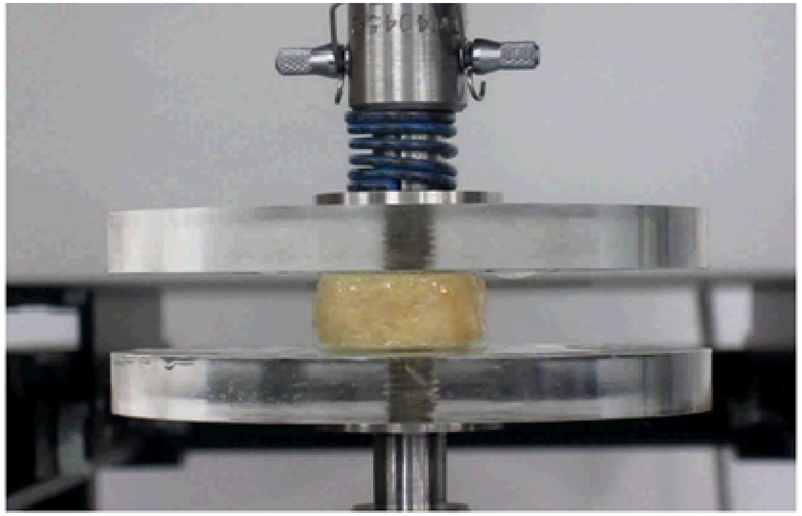
(ii) Compression test; pre-experiment



(iii) Tension test; partway through expt



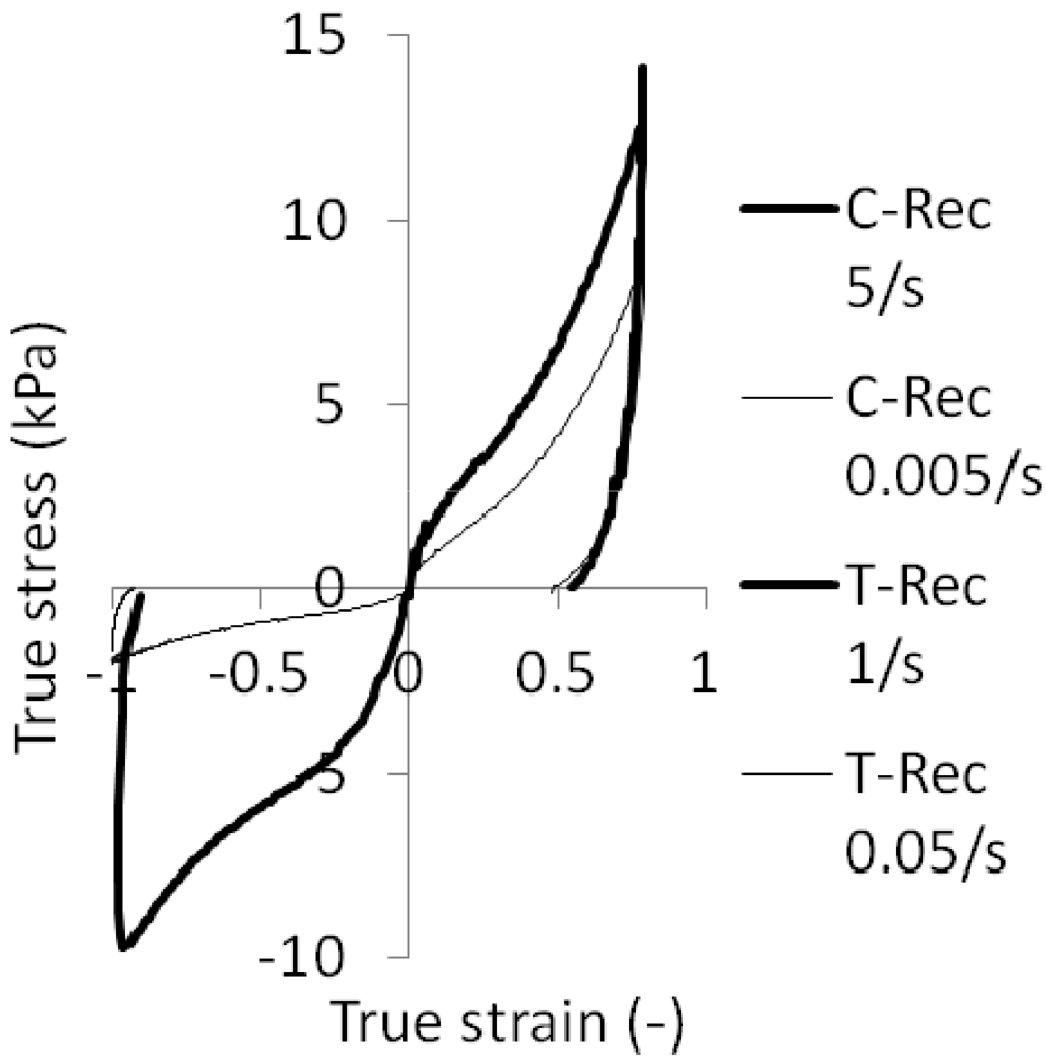
(iv) Compression test; partway through expt



Rheological testing – sample results

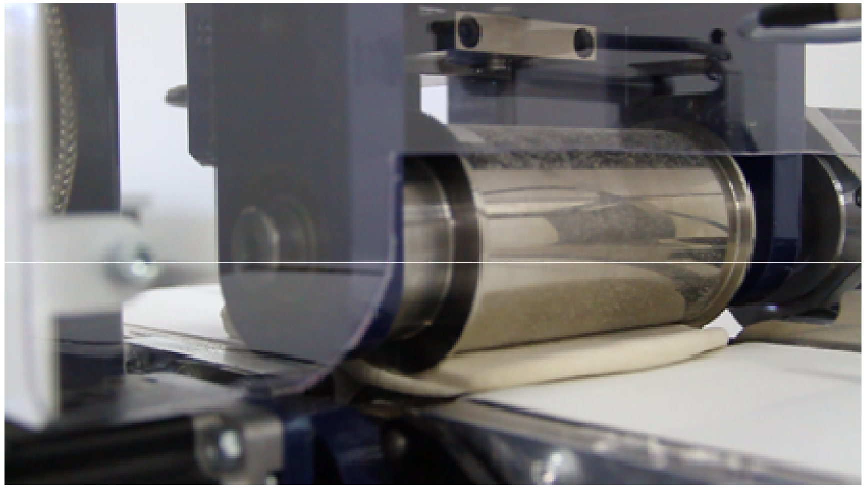
- Extension
  - Recovery ~30%

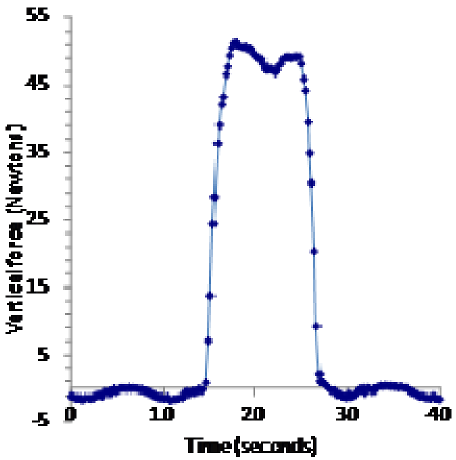
- Compression
  - Recovery ~5%

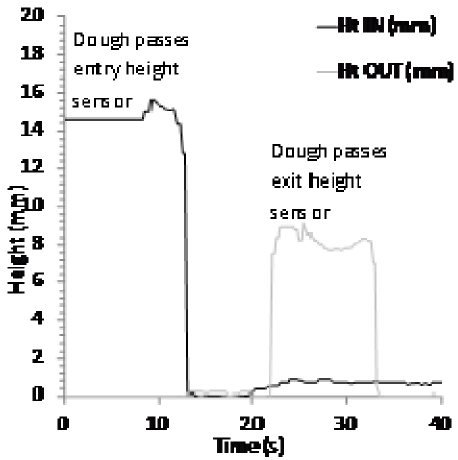


Dough sheeter

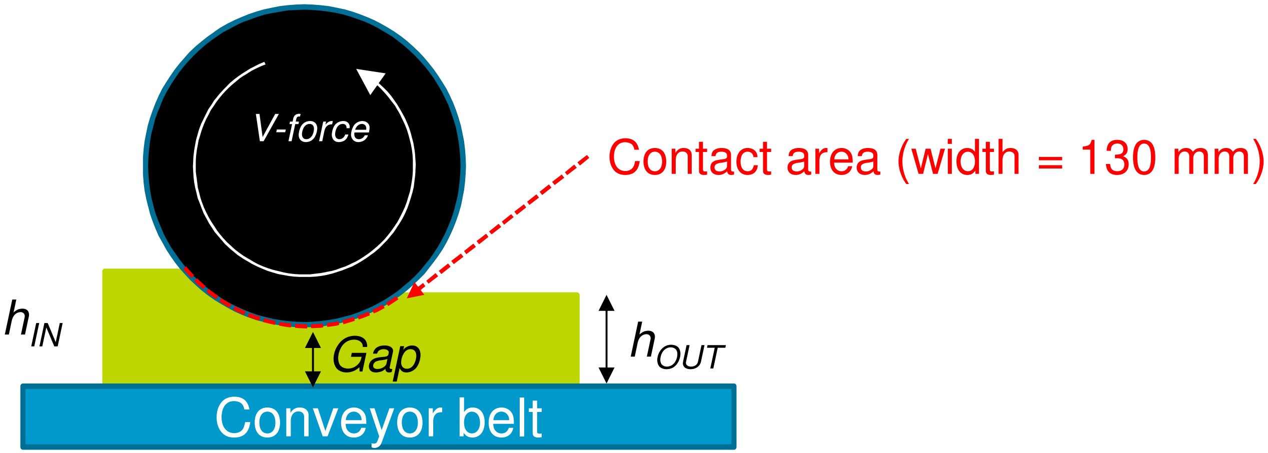
- 25mm -> 10 mm over four passes
- Both vertical and horizontal forces measured (*first time for H-forces*)







‘Simple’ predictions of force and recovery



- We know dimensions and speeds
  - Approximate true strains, rates and contact area
- We have dough rheology data
  - Approximate vertical stress, predicted V-force

Experimental *vs.* predicted

True strn (-)	Strn rate (/s)	True strs (kPa)	Contact area (cm^2)	Pred force (N)	Measured force (N)	Predicted recov.	Measured recov.
0.1	0.1	0.5	22.0	1.1	6	10%	21%
0.4	0.2	2.5	23.4	5.9	10	10%	20%
0.6	0.4	4	21.2	8.5	13	10%	26%
1.0	0.7	7.5	20.3	15.2	18	10%	23%

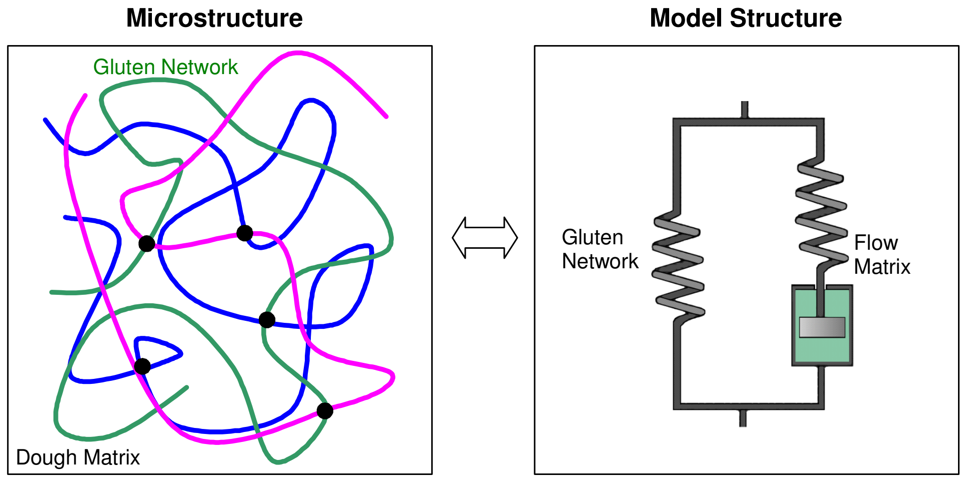
- Rheology tests cannot predict forces or recoveries
- The only alternative is FE simulation of sheeting

Prior knowledge for dough sheetability

- Xiao *et al*. (2007) - Int J. Food Sci and Tech, 42, p699-707
  - Van der Waals model for dough
  - Sheeted through lab-scale sheeter
  - Did not get dough exit thickness - *i.e*. 'sheetability'

- Chakrabarti-Bell *et al*. (2010) – J Food Eng, 100, p278-288
  - ABBM model for [one] dough
  - Wider range of gaps and speeds
  - Thickness of doughs exiting rolls in two-roll sheeter well-predicted

ABBM model – a brief introduction



Material Parameter	Value (US dough)
μ_A	0.116 kPa
κ	100 kPa
$\mathbf{a}_0$	[1,0,0]
A_f	0.0038 kPa
B_f	0.28 kPa
s	38.4
r	10
m	10 kJ/m^3
β	0.1
C	-0.12
n	1.97
τ_{base}	4.48 kPa

Hyperelastic Network A (μ_A, κ, $\mathbf{a}_0$, A_f, B_f)

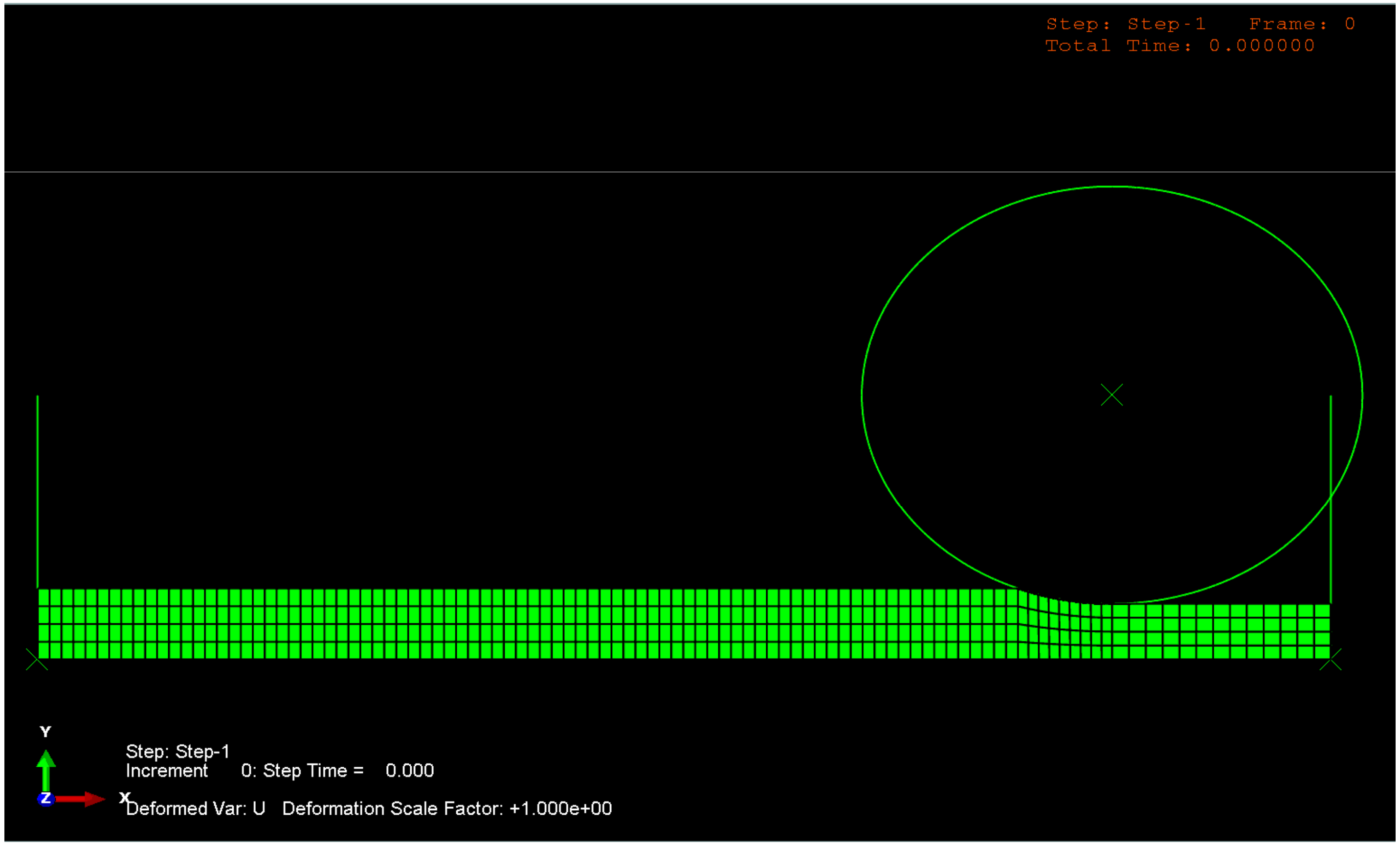
Hyperelastic Network B (s, r)

Damage Parameters (m, β, C)

Viscoelastic Flow (n, τ_{base})

Simulations

- (2D) FE simulations conducted using ABAQUS/Standard v6.11
- ‘Draw’ experiment, insert ABBM params, press ‘GO’, collect $200
- Dough moved in/out *via* ‘walls’ not belts – but will simulate this eventually



Simulations capture dough behaviours and dough differences - - - very well!

Doughs 1-3	Moisture (%)	R^2 exit thickness	R^2 horiz. force	R^2 vert. force	Doughs 4-6	Moisture (%)	R^2 exit thickness	R^2 horiz. force	R^2 vert. force
G	62.5	>0.9	0.80	0.94	HRW	62.5	>0.9	0.76	0.96
G	60.6	>0.9	0.91	0.98	HRW	60.6	>0.9	0.80	0.97
G	58.8	>0.9	0.70	0.98	HRW	58.8	>0.9	0.87	0.98
BR	62.5	>0.9	0.84	0.96	HRS	62.5	>0.9	0.92	0.96
BR	60.6	>0.9	0.74	0.97	HRS	60.6	>0.9	0.91	0.98
BR	58.8	>0.9	0.86	1.00	HRS	58.8	>0.9	0.93	0.99
W	62.5	>0.9	0.81	0.67	M	62.5	>0.9	0.98	0.99
W	60.6	>0.9	0.84	0.98	M	60.6	>0.9	0.70	0.98
W	58.8	>0.9	0.92	0.96	M	58.8	>0.9	0.75	0.93

Conclusions

- Dough differences in sheeting are difficult to get even from true rheology tests
- Dough sheetability can be predicted using (only) the ABBM model *via* FE simulation

Future work

- Extension of work to multi-roll sheeting line
  - Can we control h_{OUT} for multiple rollers?
  - Can we achieve a dial-in production rate
  - Can we change product qualities online
- ABBM model for dough
  - Can we relate parameters to structure & formulation?
  - Can we calibrate model using a smaller number of tests?

Acknowledgments

- GRDC project - *Innovative bread production from Australian wheat using dough sheeting*
- Jorgen Bergstrom, Veryst Engineering