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Rheological Properties and Rolling Process of Alternative Pasta Doughs

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INTRODUCTION & AIM

The growing consumer demand for healthier and more sustainable foods has promoted the reformulation of pasta using non-conventional flours (such as einkorn, spelt, whole wheat, maize, rice) and functional binding agents such as egg white, xanthan gum, and psyllium husk. These substitutions enhance nutritional quality but profoundly alter the dough's rheological and mechanical behavior, especially during mechanical deformation steps like rolling or extrusion (Romano et al., 2021; Gałkowska et al., 2021).

The viscoelastic nature of pasta dough governs its processing performance and final product texture. Small amplitude oscillatory shear (SAOS) tests describe its elastic and viscous moduli, while extensional viscosity reflects the dough's resistance to biaxial deformation—critical in sheet formation (Dobraszczyk & Morgenstern, 2003; Rouillé et al., 2005). However, translating these rheological parameters into practical indicators of processability remains a major challenge.

Mechanical parameters such as torque, power consumption, or current variation during dough processing can provide real-time information on dough structural resistance. Studies have shown that torque-based measurements correlate with rheological properties, offering a potential tool for rapid screening of novel formulations (Mitsoulis & Hatzikiriakos, 2009; Wang et al., 2024).

This study aims to bridge the gap between rheological characterization and mechanical performance by correlating viscoelastic and extensional parameters of alternative pasta doughs with torque-derived energy data during rolling.

This approach contributes to the design and optimization of pasta formulations based on real processing behavior.

METHOD

Materials

10 different formulations (see Table 1) were used with 40% hydration.

Table 1: Formulations used

No	Flour Type	Binding Agent
1	Spelt	-
2	Spelt	Egg white powder
3	Whole wheat	-
4	Whole wheat	Egg white powder
5	Einkorn	-
6	Einkorn	Egg white powder
7	Maize	Xanthan gum
8	Maize	Psyllium husk powder
9	Rice	Xanthan gum
10	Rice	Psyllium husk powder

Methods

Rheological Analyses

DHR-20 Rheometer (TA Instruments, USA) with 50 mm parallel plate at 25°C.

Frequency Sweep Test

At 0.02% strain from 0.1 to 10 rad/s

Extensional Rheology Test

1.67×10^{-5} m/s compression speed to 50% deformation

Pasta Rolling Process

Household pasta roller (Atlas Marcato, Italy) from 5 to 2 mm thickness at 60 RPM using a digital ammeter (CEM DT-9987, China) (see Figure 1) was used to estimate the torque required. Example torque profile was depicted in Figure 2.

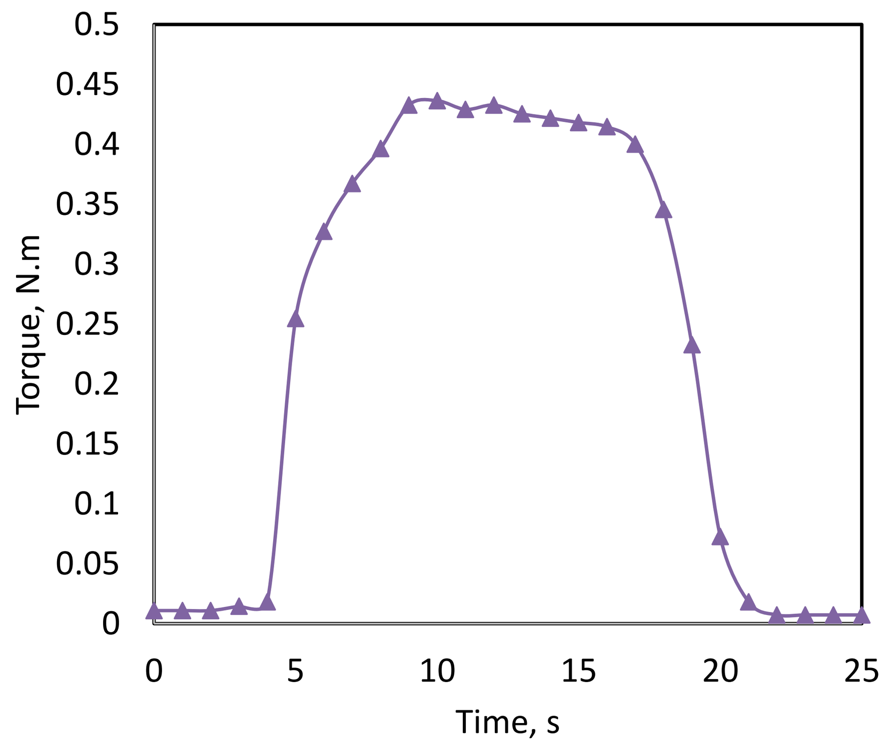


Figure 2: Representative torque profile

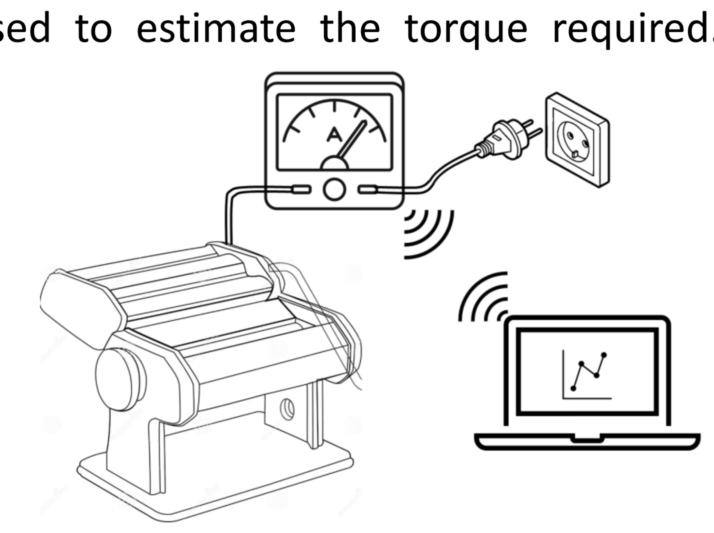


Figure 1: System used

$$M = K_t \times I \qquad K_t = \frac{1}{K_v} \qquad M = K_t \times I$$

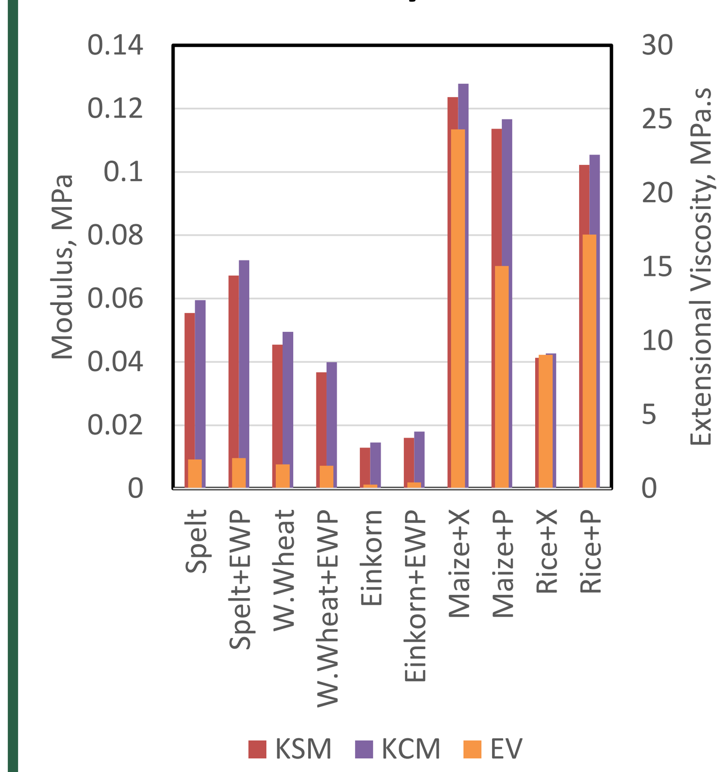
$$K_v = \frac{\omega_{RPM}}{Back\ EMF}$$

Statistical Analysis

The relation between rheological properties and energy required for dough rolling were investigated using Pearson correlation test at 95% confidence level. The analyses were conducted using Minitab software (ver.21.2, Minitab Inc., United Kingdom).

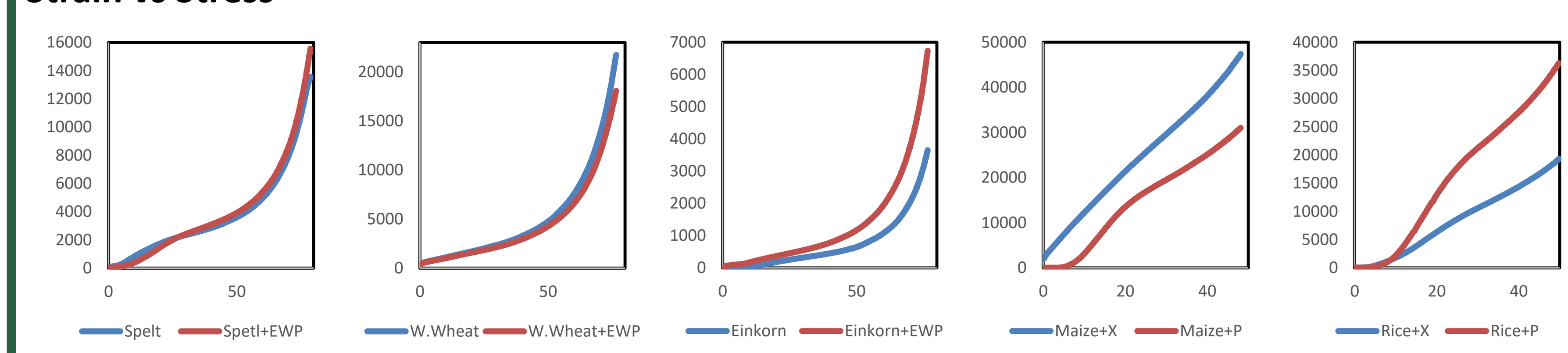
RESULTS & DISCUSSION

Linear Viscoelasticity



- Higher storage modulus consistency, complex viscosity consistency, and extensional viscosity → higher torque during rolling (Rouillé et al., 2005)
- Doughs with stronger viscoelastic structure require more mechanical energy (Dobraszczyk & Morgenstern, 2003)
- Extensional viscosity shows the strongest correlation with torque and governs sheetability (Rouillé et al., 2005)
- Doughs with lower consistency and extensional viscosity deform more easily, showing pseudoplastic behavior (Mitsoulis et al., 2009)
- Torque measurement can serve as a practical predictor of rheological behavior during processing (Wang et al., 2024)

Strain vs Stress



No effect of EWP observed

No effect of EWP observed

EWP made the dough more rigid

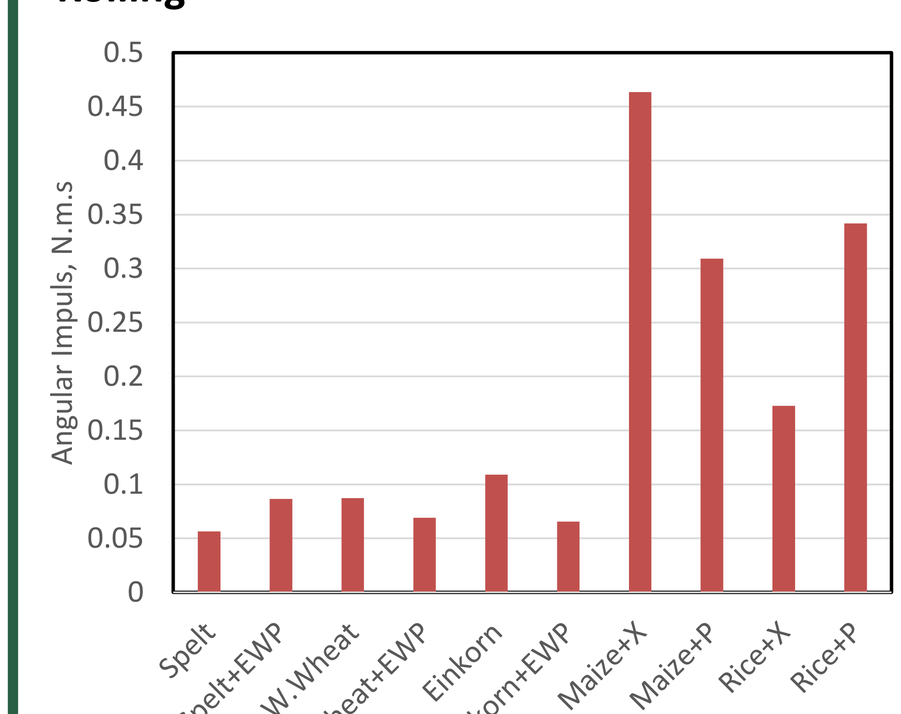
Maize+P showed viscoelastic behavior

Maize+X → Hookean solid

Rice+P held more water → more rigid structure

Rice+X → Hookean solid

Rolling



More rigid dough yielded with higher energy requirement during rolling (Wang et al., 2024)

Correlation

	SM_K	SM_n	CV_K	CV_n	EV_CV	Ang_Imp
SM_K	1.000					
SM_n	-0.872	1.000				
CV_K	1.000	-0.867	1.000			
CV_n	-0.866	0.994	-0.864	1.000		
EV_CV	0.889	-0.828	0.880	-0.782	1.000	
Ang_Imp	0.865	-0.749	0.855	-0.695	0.987	1.000

SM_K=237304*Ang_Imp+19647

CV_K=238248*Ang_Imp+22653

EV_CV=5.91×10^{7}*Ang_Imp+3.06×10^{6}

CONCLUSION

Real-time torque measurement → practical predictor of rheological behavior

Rolling → extensional rheology predictor

Rapid screening to determine suitability for pasta processing

FUTURE WORK / REFERENCES

Different types of flours and combinations will be evaluated and mathematically modeled.

Research Group Web Page

References