

The interplay between soy proteins and dietary fibre in determining structure formation during high moisture extrusion

Jiashu Li¹, Frederik Janssen¹, Diete Verfaillie^{1,2}, Deniz Z. Gunes³, Ruth Cardinaels³, Geert Van Royen², and Arno G.B. Wouters¹

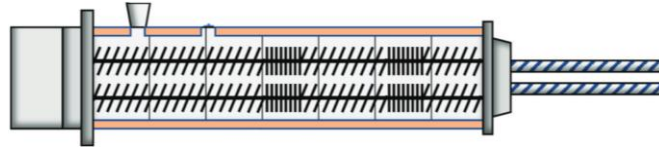
¹Laboratory of Food Chemistry and Biochemistry (LFCB), KU Leuven and Leuven Food Science and Nutrition Research Centre (LForCe)

²Technology and Food Science Unit, Flanders Research Institute for Agriculture, Fisheries and Food (ILVO)

³Soft Matter Rheology and Technology (SMaRT), KU Leuven



CONTEXT



Soybeans are a promising raw material for producing meat analogues, because of their:

- high protein content (40% of dry matter [dm])
- well-balanced amino acid composition
- high dietary fibre (DF) content (20% dm)

High moisture extrusion (HME) is a promising process to prepare meat analogues with a meat-like fibrous structure.

To form such structure, phase separation of thermodynamically incompatible components (e.g. DF and protein) is considered a key concept.

CONTEXT



A systematic study on the impact of soy protein, DF and their (joint) contribution in determining the structure and texture of meat analogues is lacking but holds promise for rationally designing such meat analogues.

APPROACH

Sample preparation

Soy dietary fibre-rich
fraction (DFF)

+

Soy protein-rich
fraction (PF)

Sample	Protein content (% dm)	DF content (% dm)
DFF	35	59
DFF:PF 8:2	46	48
DFF:PF 6:4	58	37
DFF:PF 4:6	69	26
DFF:PF 2:8	81	15
PF	92	/

Hydrated to
60% moisture



DFF
(dough-like
structure)



DFF:PF 6:4



DFF:PF 2:8



PF
(gel-like
structure)



Protein
content ↑

APPROACH

Experimental analyses

Rheometry



Oscillatory shear test at 25 and 95 °C

HME



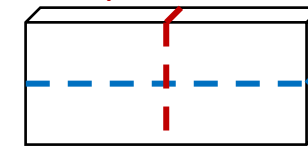
Processing conditions:

- 40-60-80-100-120-140-140-140 °C
- 60% moisture
- 600 rpm

Extrudate texture:

Cutting strength
(Warner-Bratzler)

Perpendicular



Longitudinal

Extrudate structure:

Confocal laser scanning microscopy (CLSM)

RESULTS & DISCUSSION

Rheological analyses of hydrated soy protein-based products

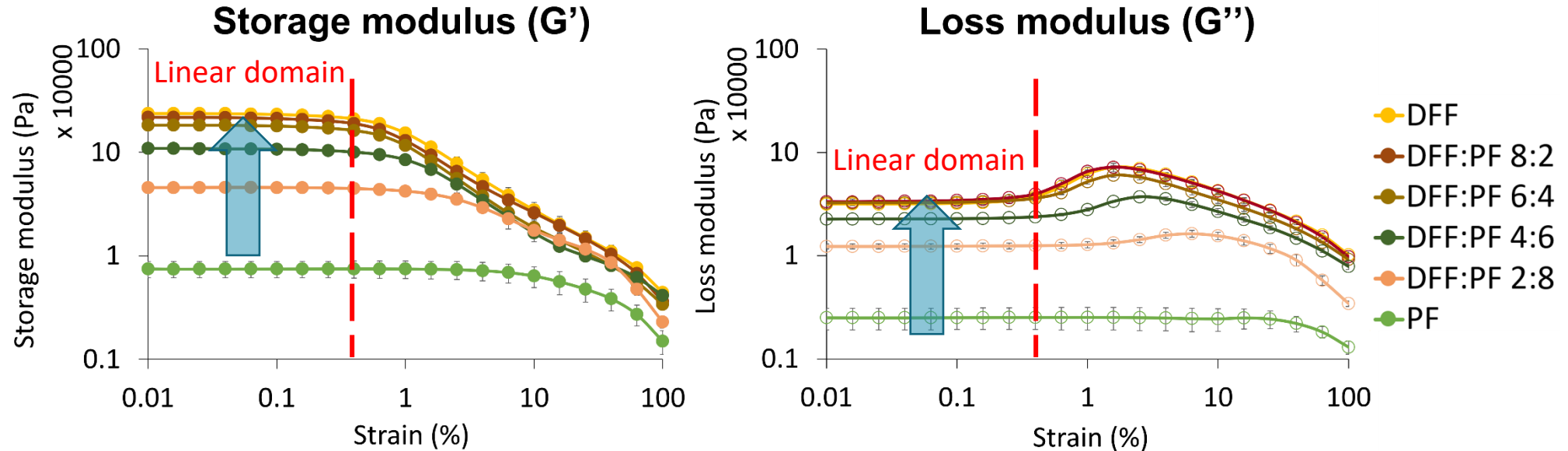


Figure 1. Storage modulus (G') and loss modulus (G'') of soy protein-based products hydrated to 60% moisture.

- In the linear domain, $G' > G'' \rightarrow$ predominantly elastic network structure
- In the linear domain, hydrated soy protein-based products with **relatively more soy DF** had higher moduli

RESULTS & DISCUSSION

Rheological analyses of hydrated soy protein-based products

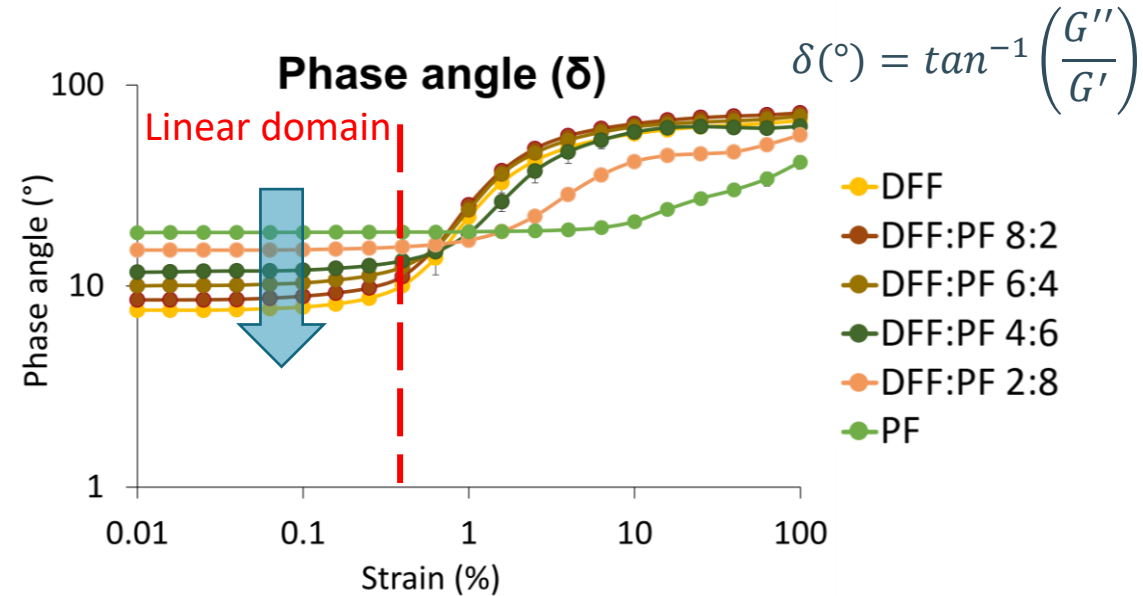


Figure 2. Phase angle (δ) of soy protein-based products hydrated to 60% moisture.

- Hydrated soy protein-based products with **relatively more soy DF** had
 - **Lower phase angles** in the **linear domain** → more elastic network structure

RESULTS & DISCUSSION

Rheological analyses of hydrated soy protein-based products

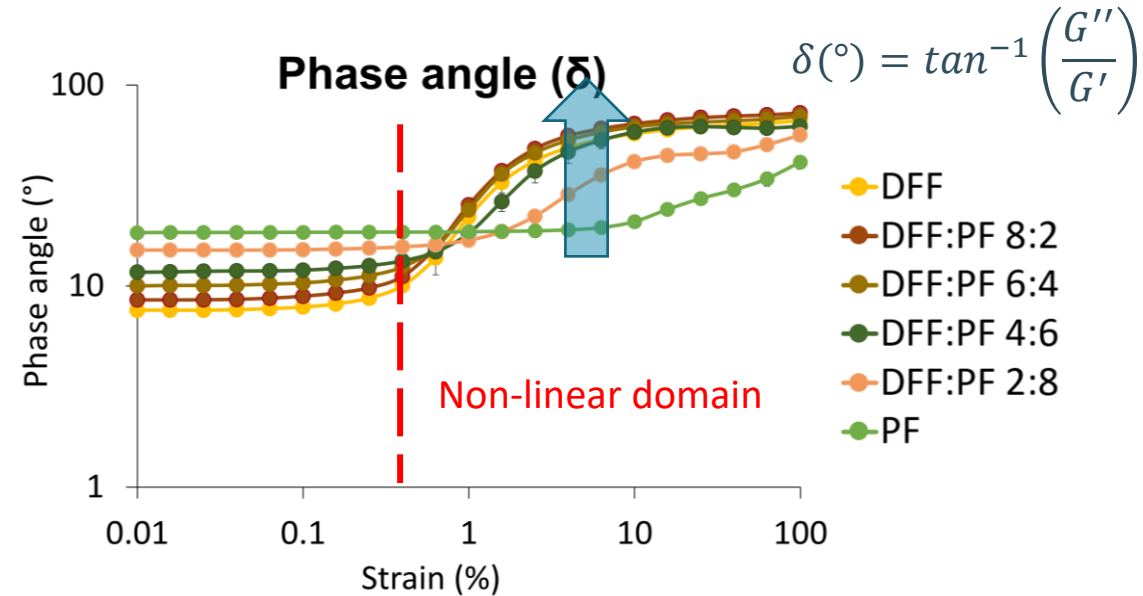


Figure 2. Phase angle (δ) of soy protein-based products hydrated to 60% moisture.

- Hydrated soy protein-based products with **relatively more soy DF** had
 - **Lower phase angles** in the **linear domain** → more elastic network structure
 - **Higher phase angles** in the **non-linear domain** → more viscous network structure

RESULTS & DISCUSSION

Rheological analyses of hydrated soy protein-based products

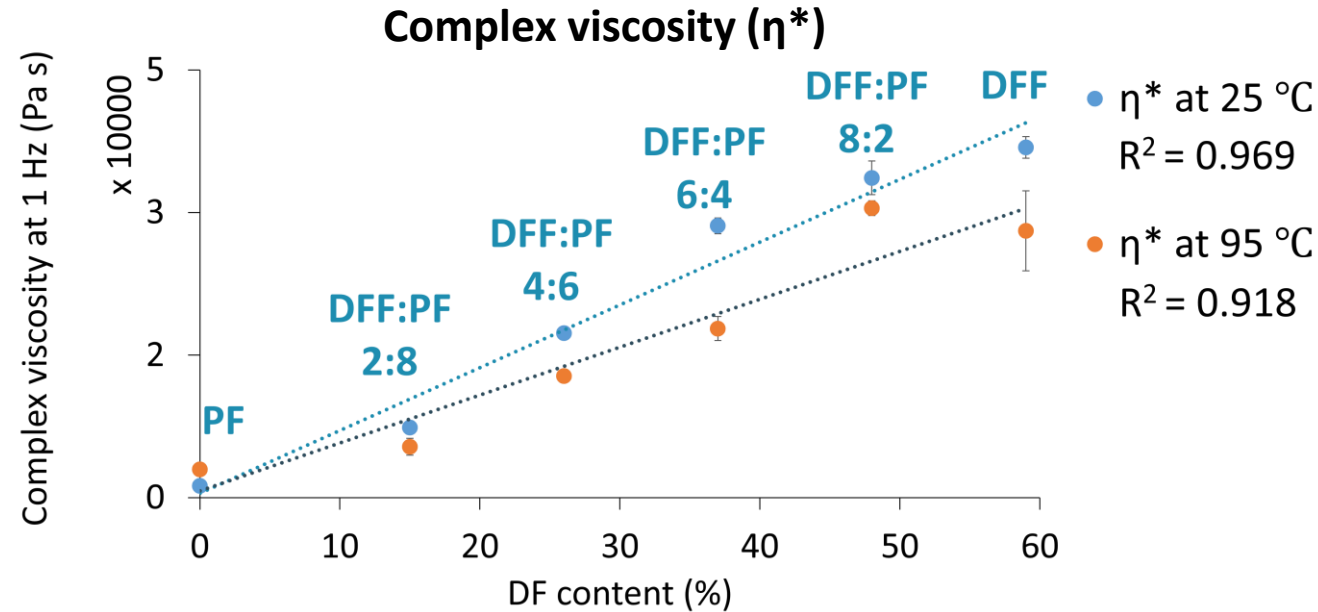


Figure 3. Complex viscosity of soy protein-based products hydrated to 60% moisture.

- Increasing the DF proportion in the hydrated DFF-PF blends resulted in a linear increase of the complex viscosity at both 25 and 95 °C

RESULTS & DISCUSSION

Structural analysis of high moisture extrudates

CLSM

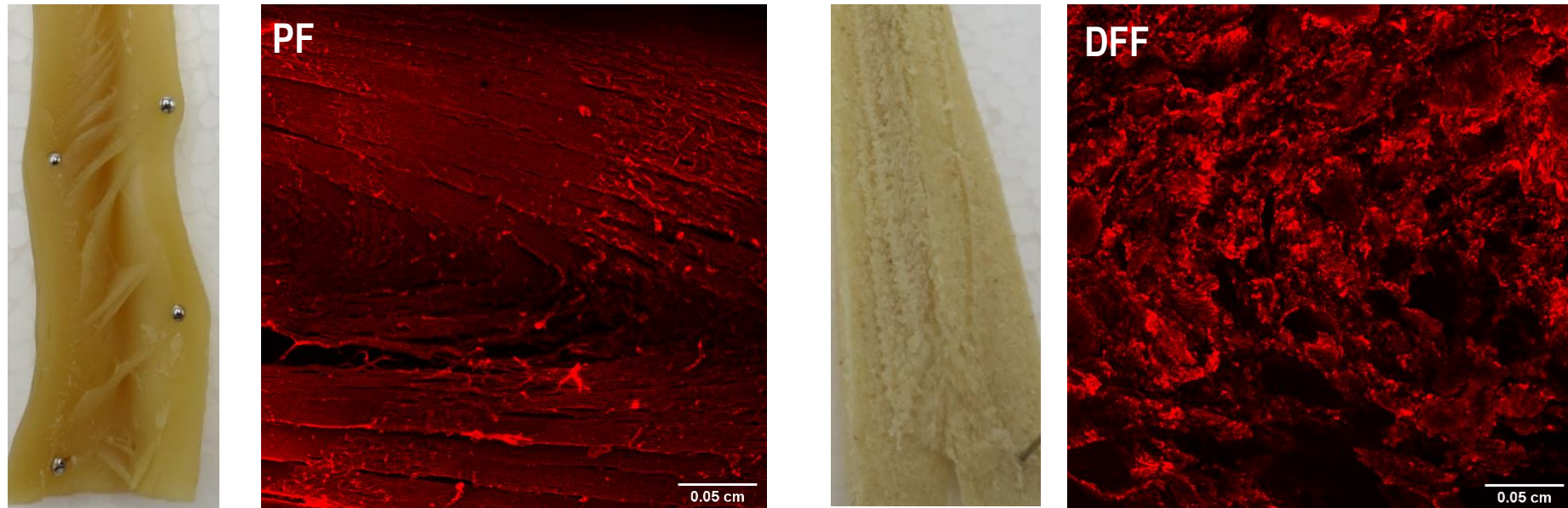
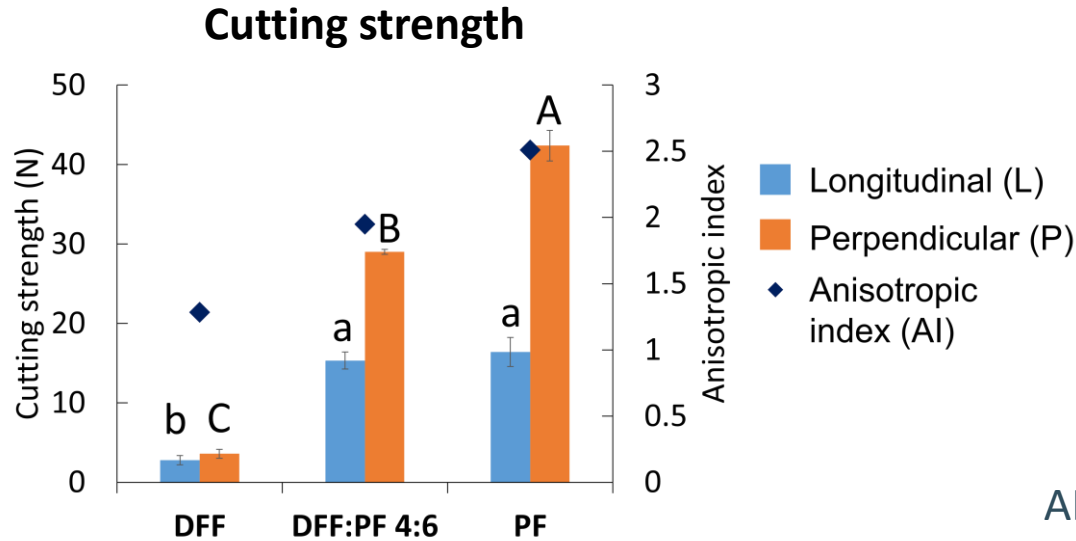


Figure 4. Digital and confocal laser scanning microscopy images of extrudates prepared from PF and DFF; proteins were stained red with Rhodamine B.

- **Extrudates produced from PF had a fibrous structure**, whereas those prepared from DFF did not.

RESULTS & DISCUSSION

Textural analysis of high moisture extrudates



$$AI = \frac{\text{Cutting strength in perpendicular direction}}{\text{Cutting strength in longitudinal direction}}$$

Figure 5. Cutting strength and anisotropic index (AI) of extrudates produced from DFF, DFF:PF blend 4:6 and PF with HME.

- **Extrudates produced with relatively more DF had a lower cutting strength and a lower AI**

RESULTS & DISCUSSION

Statistical correlation analysis

	η^* (25 °C)				
η^* (25 °C)	1.0	η^* (95 °C)			
η^* (95 °C)	0.99	1.0	Cutting strength <i>L</i>		
Cutting strength <i>L</i>	-0.93	-0.96	1.0	Cutting strength <i>P</i>	
Cutting strength <i>P</i>	-0.89	-0.94	0.97	1.0	AI
AI	-0.66	-0.98	0.73	0.84	1.0

Clear **negative correlation** between **extrudate cutting strength** and **sample complex viscosity**

CONCLUSIONS

Hydrated soy protein-based products **containing relatively more protein** had a **more viscous network structure** at both 25 and 95 °C (in the linear domain)

Most viscous
network structure



PF



DFF



Negative correlation between extrudate texture and sample rheological behavior

Most pronounced
fibrous structure



PF



DFF

High moisture extrudates prepared from hydrated soy protein-based products **containing relatively more protein** had a higher cutting strength and a higher AI, thus had **more pronounced fibrous structures**

CONCLUSIONS

Hydrated soy protein-based products containing relatively more protein had a more viscous network structure at both 25 and 95 °C (in the linear domain)



The protein-DF ratio of soy-based raw materials is a promising tool to direct the structure and texture of high moisture extruded meat analogues.

High moisture extrudates prepared from hydrated soy protein-based products containing relatively more protein had a higher cutting strength and a higher AI, thus had more pronounced fibrous structures

Most viscous
network structure



PF



DFF



Negative correlation between
extrudate texture and
behavior

fibrous structure



PF



DFF



Let's have a talk!