# Applications of micro compounder as analytical tool to study the plant protein transformation

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# Meat Alternatives

Meat alternatives, meat substitutes, meat analogues, fake meat, plant-based meat, vegetarian meat, are all used in different sources to describe one thing, meats-like products that are made from plant materials.

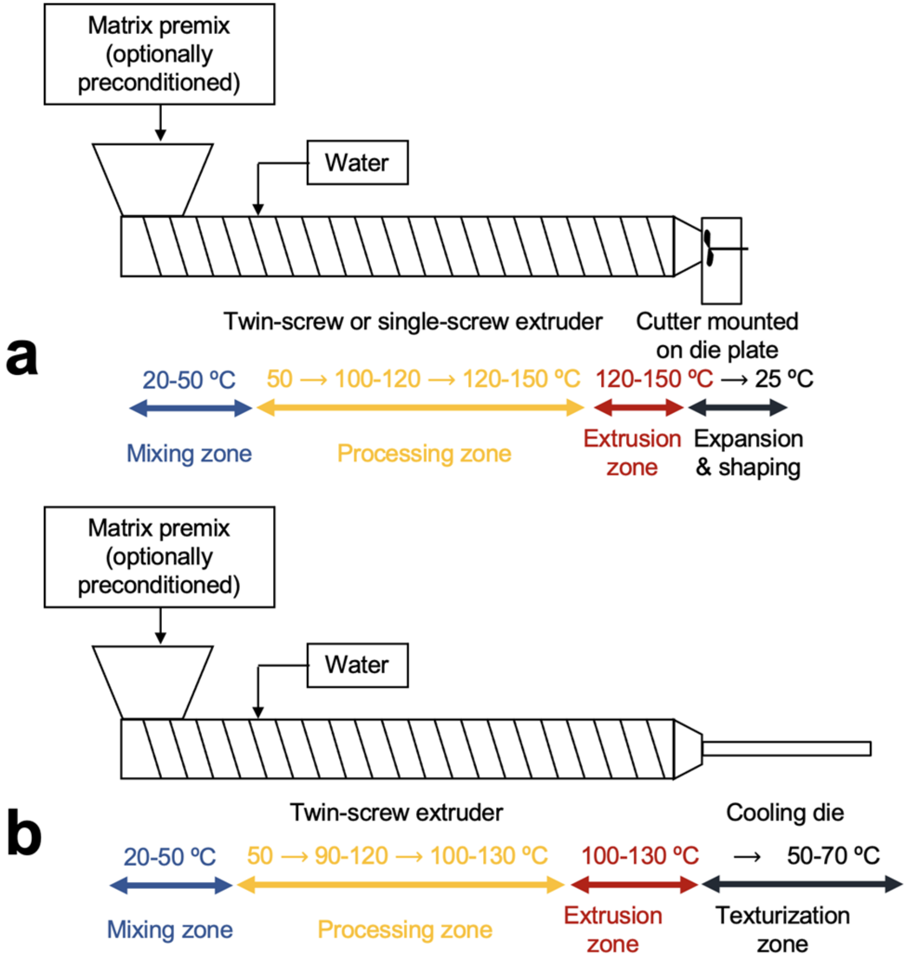
These products are eaten to replace meat products especially the need for the daily intake for proteins.

Historically consumed for several reasons including availability, religion (ex, Hinduism, Buddhism, and during Lent for Orthodox Christian), certain diseases and allergies to meat products.

Tofu and Seitan in China are the oldest meat alternatives that are well documented around 200 B.C. Thus, tempeh, Falafel “chickpeas patties”, kachori, and black beans patties are a great examples.

# Meat Alternatives

## Extrusion




Protein powder (pea, soy, chickpea) + water 10-30% = TVP

<u>80% of commercial products use TVP?</u>

Protein powder (pea, soy, chickpea) + water 40-70% = HME

# Our Group Fundamental Research

**What are our novel findings?**

Systematically studied different processing conditions such as the extrusion temperature, screw speed, feeding rate, and residence time.

Introduced the rheological properties for plant-based dough mixtures and its power to design and predict the quality.

Developed methods for different scales including technologies that has never been applied in food (for example, Micro-compounder).

Systematically studied the effects of pH on the textural properties of meat analogues.

Established that the water is the driver for the texture.

Ion strength, studied the effects of salt type and concentration on the texture.

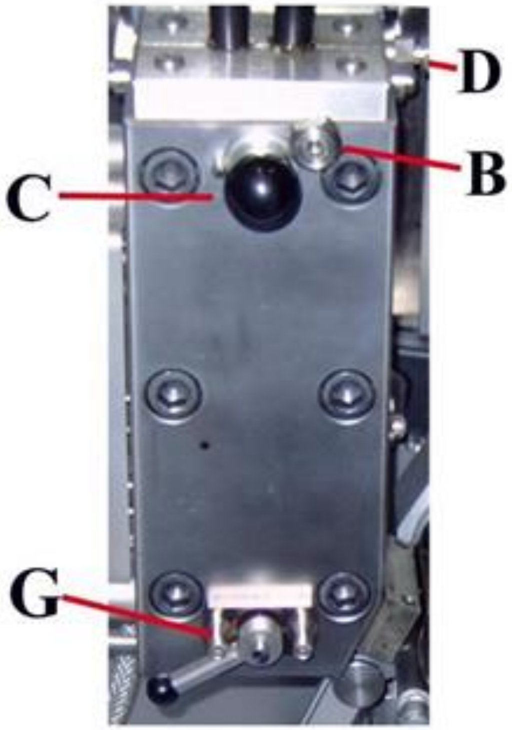
Understanding the effects of ingredients such as condiments on the texture.

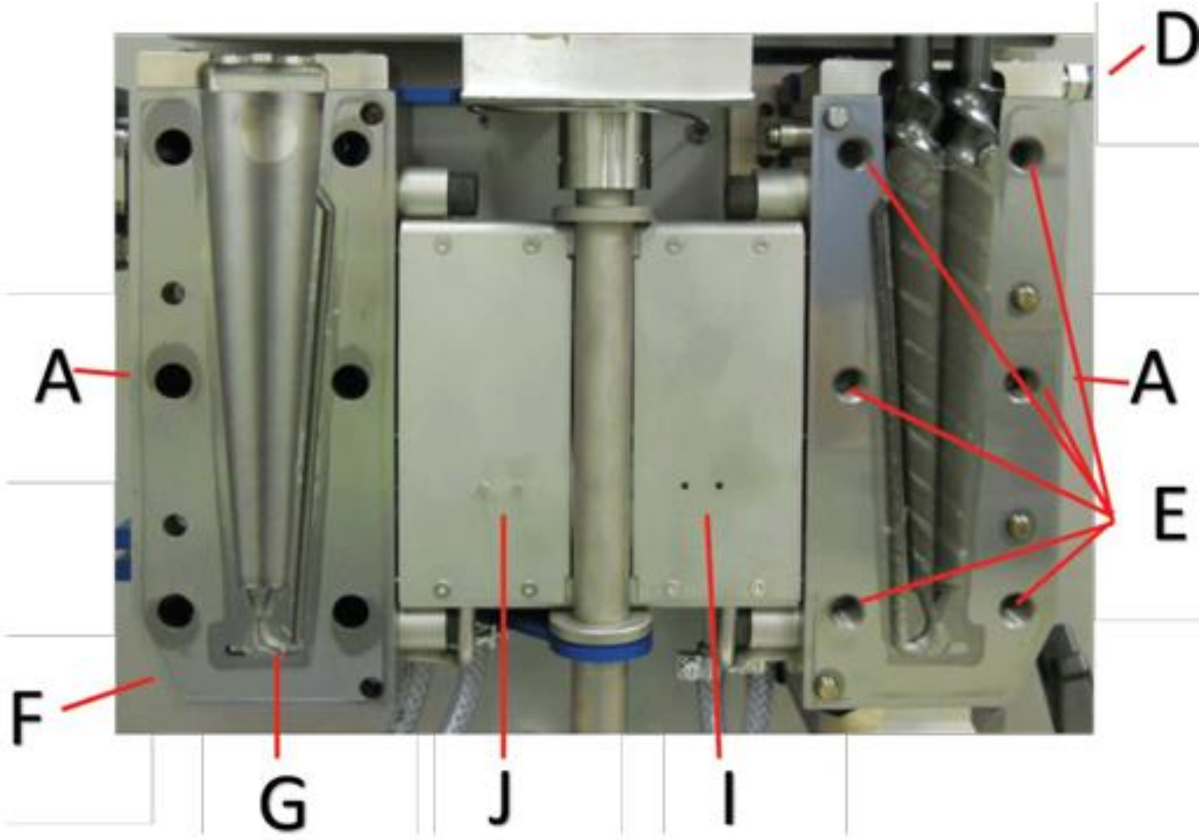
Established a method to quantify the fibrous structure formation based on swelling behavior. Affordable and simple method and adapted by food industry.

Studied the protein aging and its effects on the quality of chilled and frozen products.

Phase mapping! (Technical Expertise).

# Micro-Compounder




A - Recesses for opening the housing with the special pliers.
B - Hopper screw.
C - Hopper connection.
D - Purge connection.
E - Compounder housing bolts. F - Nozzle.
G - Recycle/extrusion valve.
I - Rear housing half.
J - Front housing half.

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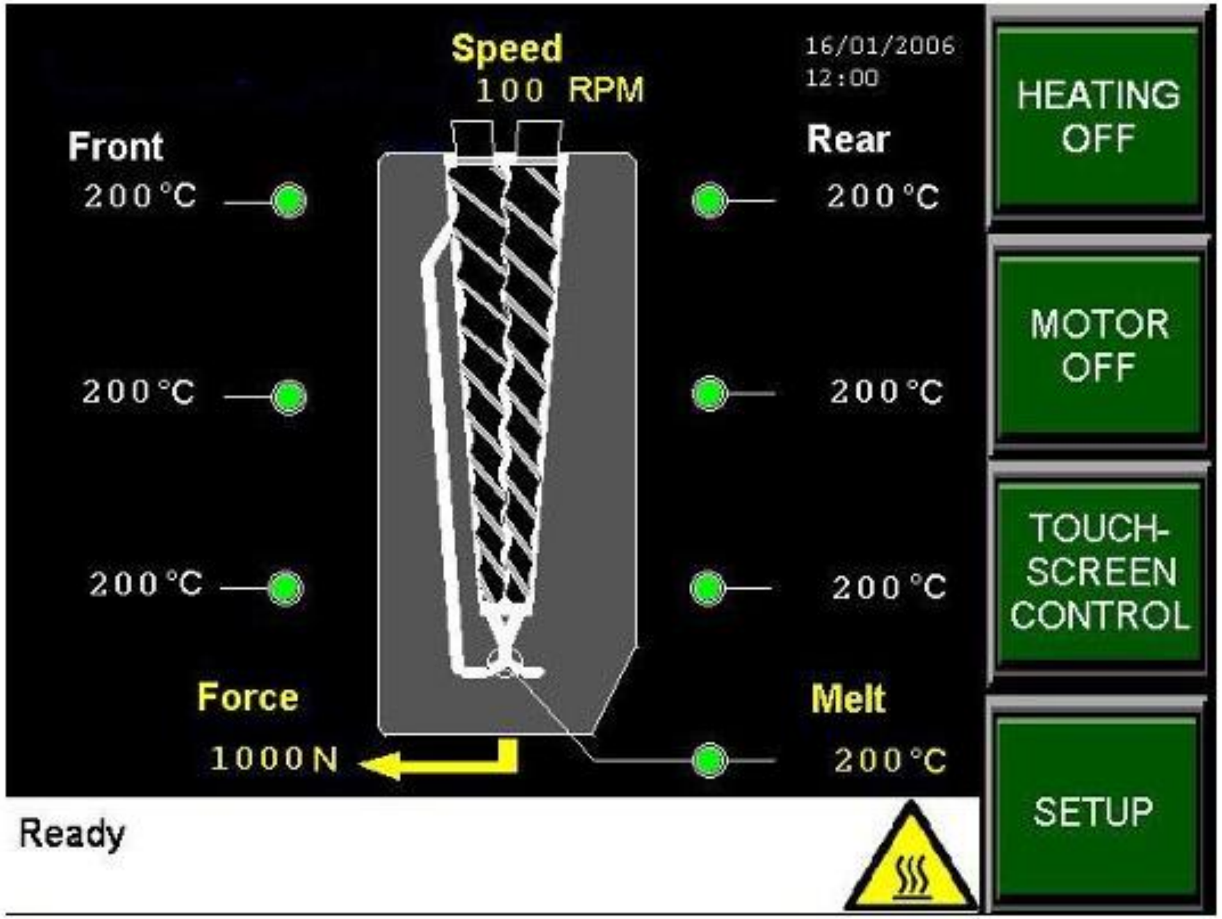
# Micro-Compounder




**Principal Dimensions MC 5**

| | |
|---|---|
| Height | : 830 mm |
| Width | : 700 mm |
| Depth | : 400 mm |
| Screw length | : 107 mm |
| Total volume | : 5.5 ml |
| Net volume | : 5 ml |

Screw speed: 5-400 rpm
Warm up time to 240 °C: 20 minutes
Cool down time (air+water): 20 minutes
Regulated heating zones: 6
Heating: 400 °C
Peak current: 10 A
Drive motor: 0.55 kW

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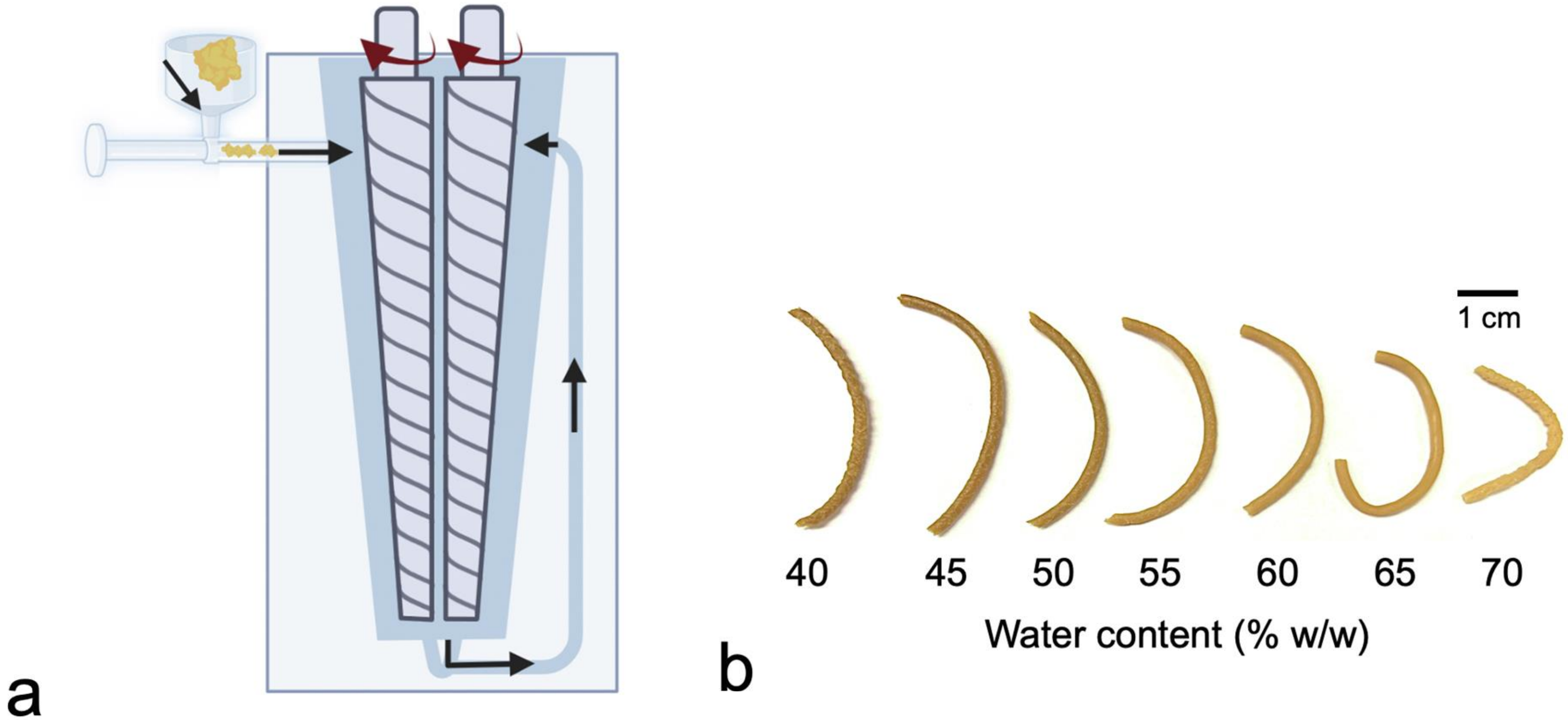


Fig. 1. a. Diagram of the micro compounder chamber. b. PPI extrudates micro compounded at various water contents.

Tingle, C. F., McClintic, K., Zervoudakis, A. J., Muhialdin, B. J., & Ubbink, J. (2023). Texturization of pea protein isolate by micro compounding. *Food Research International*, *163*, 112250.

# Micro-Compounder

$$SME = \frac{\tau \bullet \varpi \bullet t_R}{w} = \frac{\pi\tau \bullet r_m \bullet t_R}{30w} \qquad (2a)$$

where $t_R$ is the residence time in the micro compounder (s), $w$ is the sample weight (g), $\tau$ is the torque per screw (N m), ω is the angular velocity (rad/s) and $r_m = (60/2\pi)\cdot\omega$ is the screw speed (rpm).

In case the torque changes during processing, Eq. (2a) is rewritten as an integral over the time $t$:

$$SME = \frac{\pi r_m}{30w}\int_0^{t_R} \tau(t)dt \qquad (2b)$$

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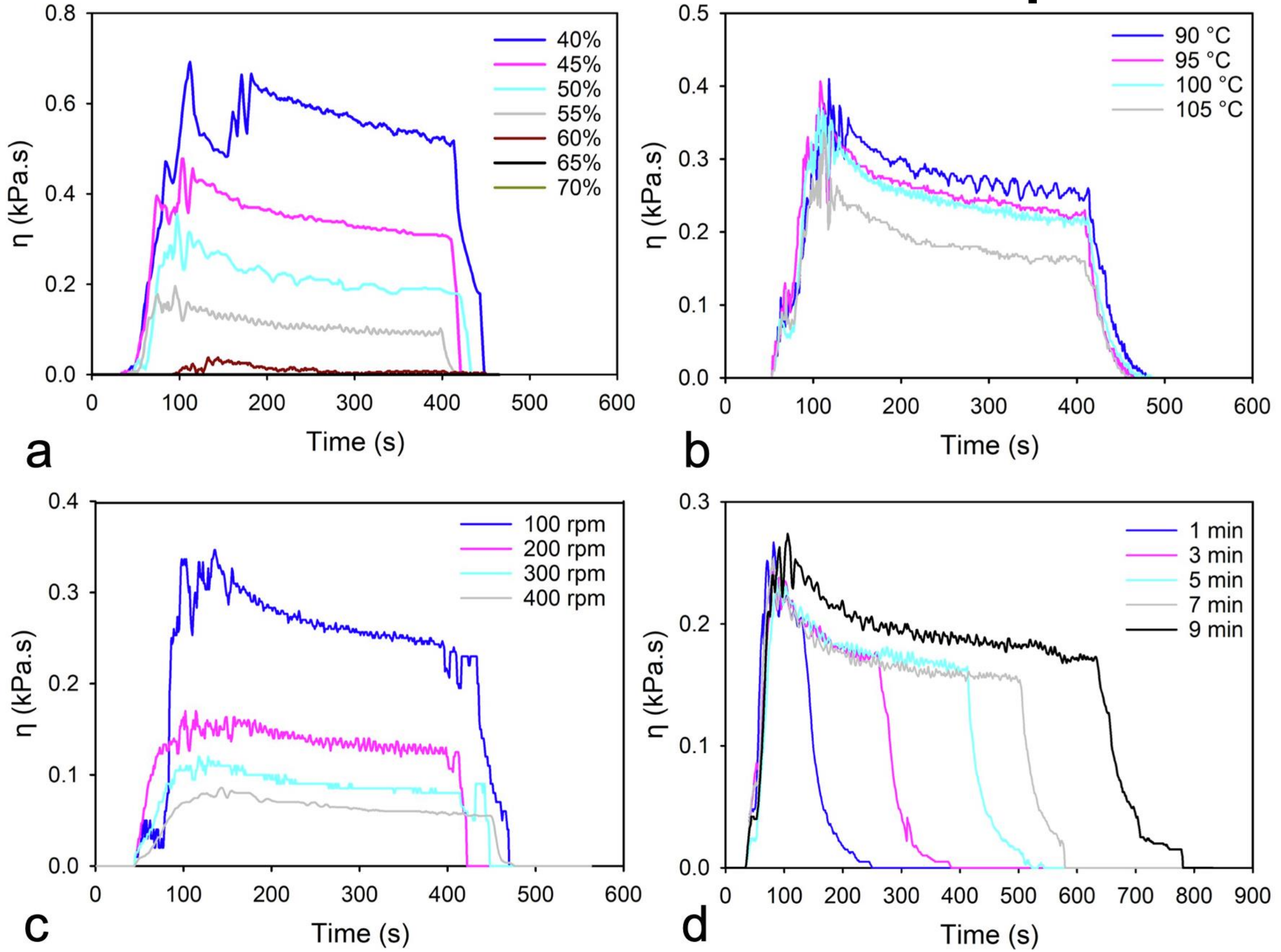


**Fig. 2.** Viscosity-time profiles of PPI during processing in a micro compounder.
**a.** Viscosity-time profiles for various water contents,
**b.** Viscosity-time profiles at various temperatures,
**c.** Viscosity-time profiles for various screw speeds,
**d.** Viscosity-time profiles for residence times.

The water content of the PPI in b.-d. is Qw = 50 % w/w. The residence time in a.-c. is tR = 300 s.

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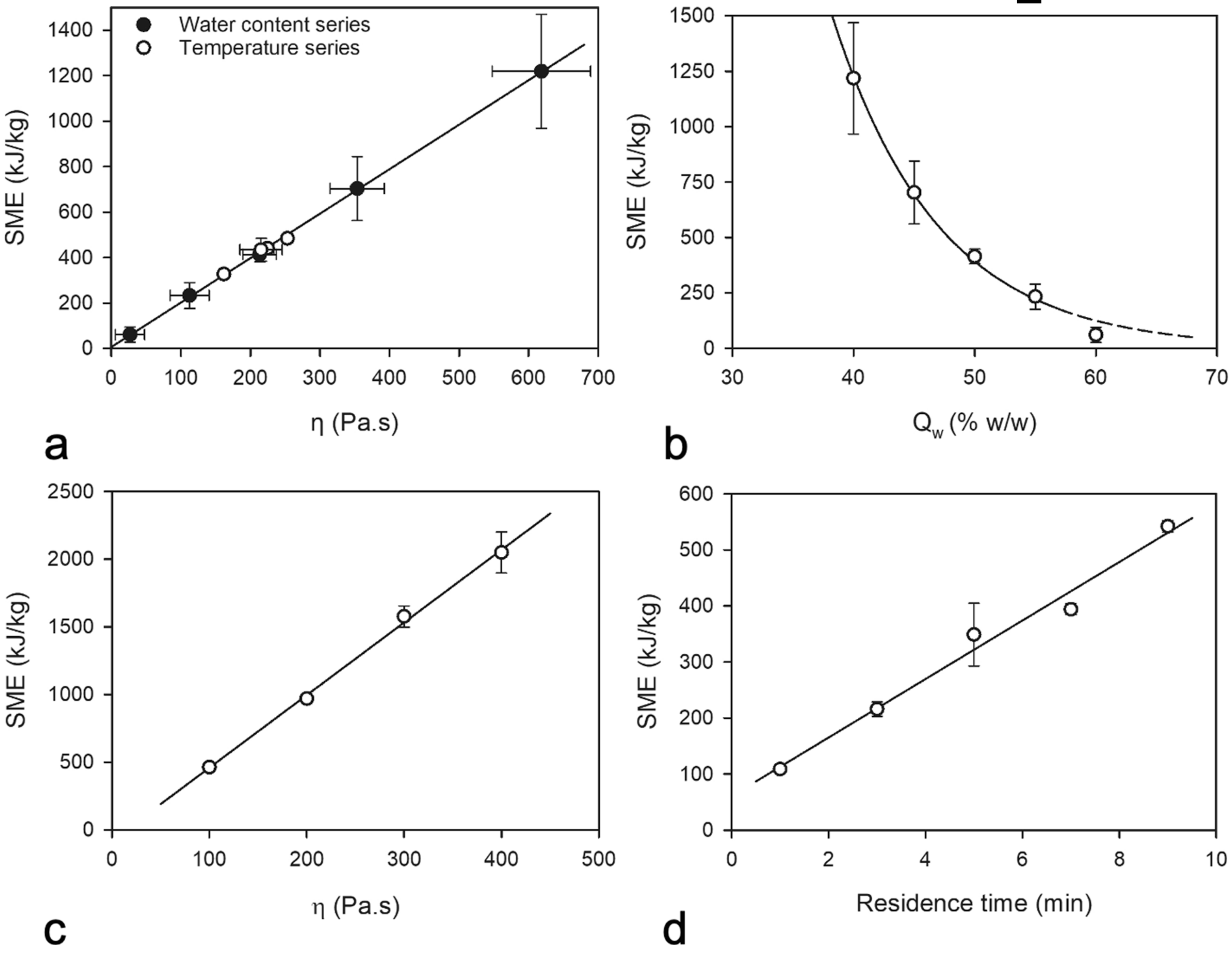


**Fig. 4.** Specific mechanical energy (SME) for the micro compounding of PPI.
**a.** SME as a function of the viscosity,
**b.** SME as a function of the water content,
**c.** SME as a function of the screw speed,
**d.** SME as a function of the residence time

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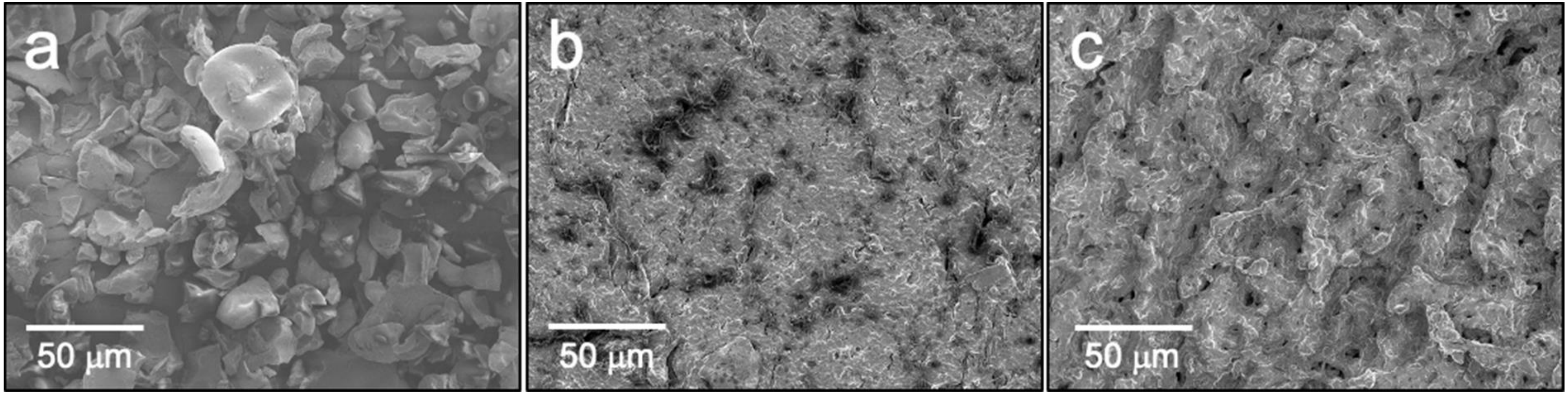


**Fig. 5.** SEM images
a. PPI ingredient
b. Micro-compounded PPI (residence time 5 min) at Qw = 50 % w/w.
c. Micro-compounded PPI (residence time 5 min) at Qw = 60 % w/w.
The samples are processed at T = 100 ◦C, a screw speed of 100 rpm and a residence time of 5 min.

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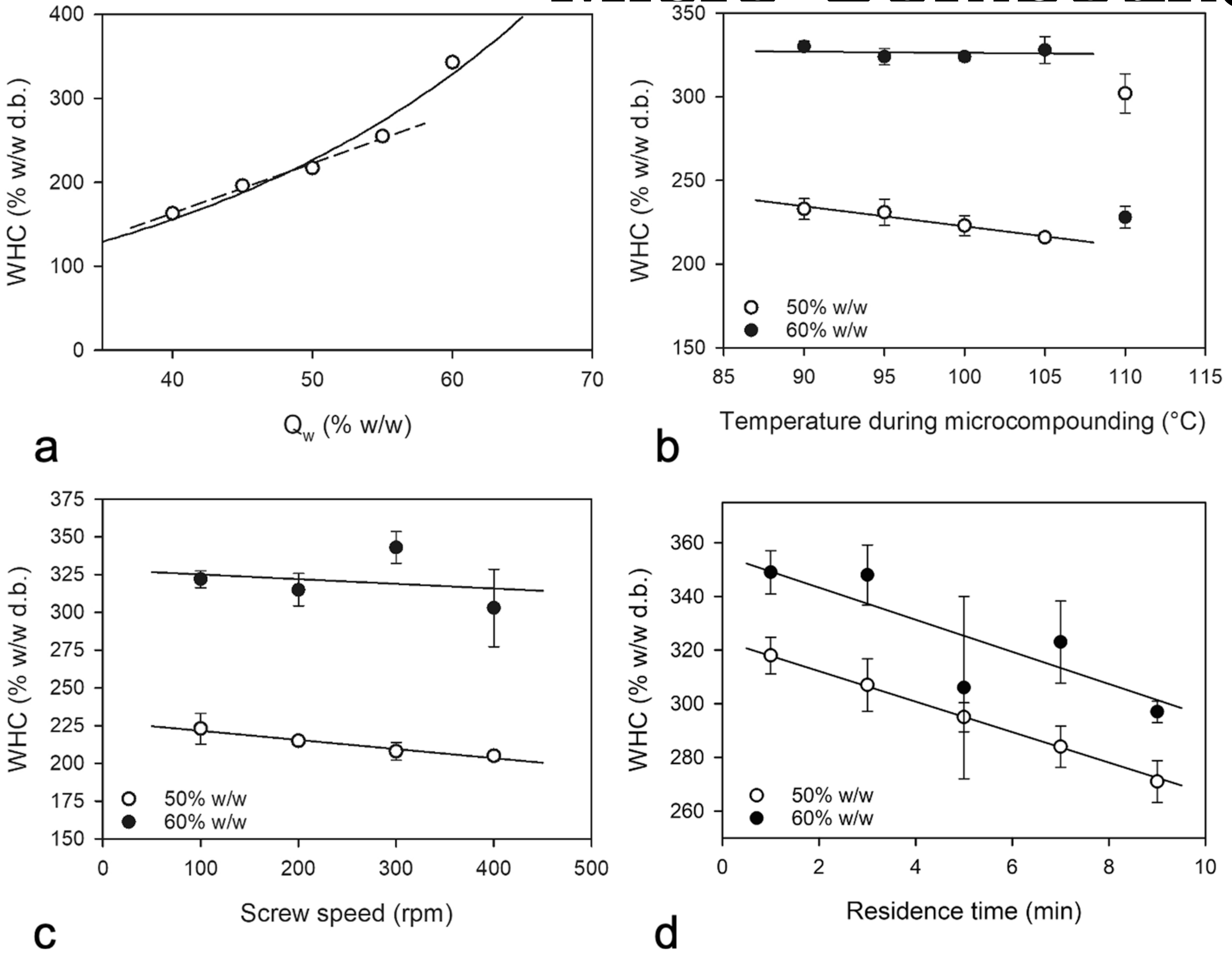


**Fig. 7.** Water holding capacity (WHC).
**a.** WHC as a function of the water content,
**b.** Dependence of the WHC on the temperature,
**c.** WHC as a function of the screw speed,
**d.** WHC as a function of the residence time


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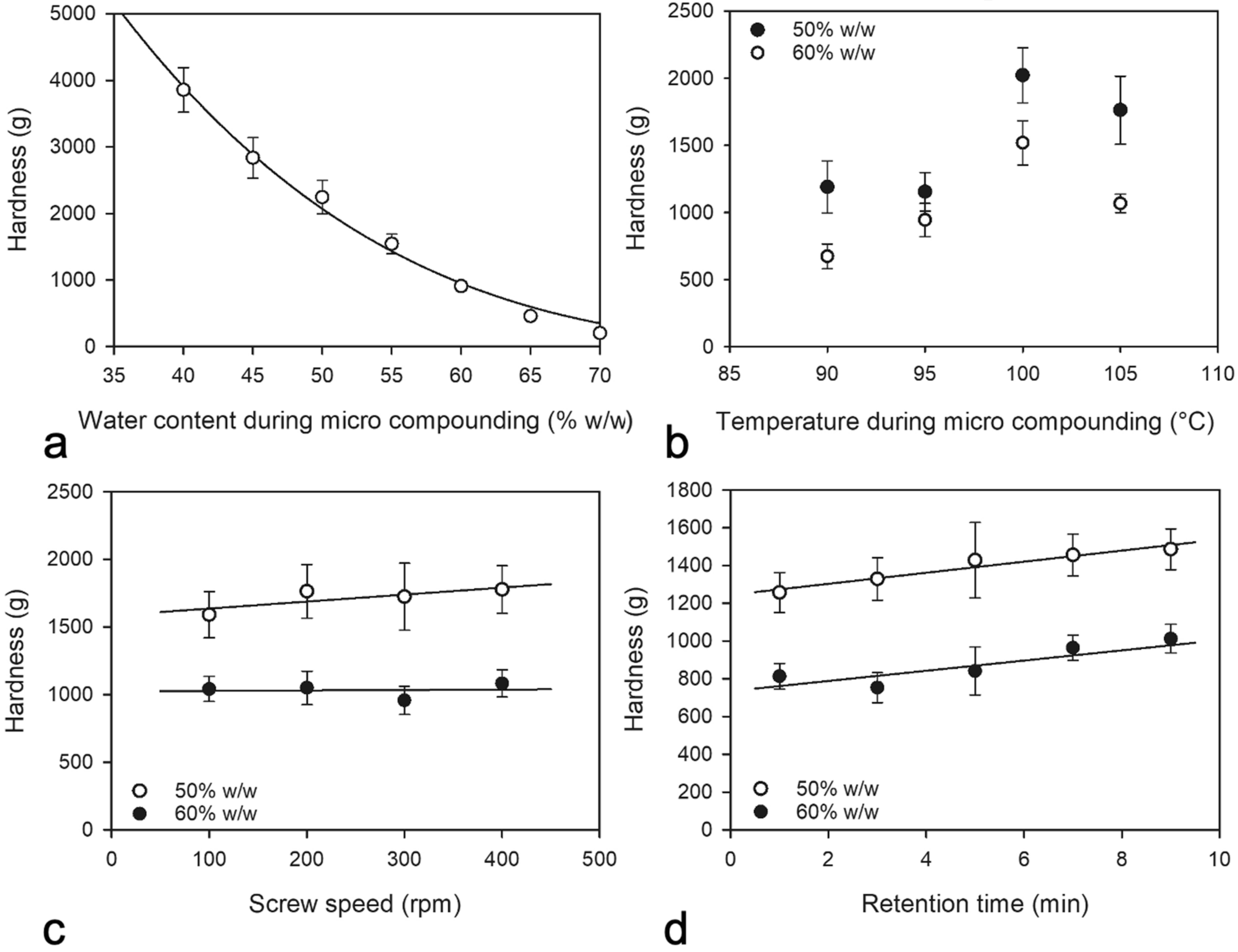


**Fig. 8.** Hardness from texture-profile analysis (TPA).
**a.** Hardness as a function of the water content,
**b.** Hardness as a function of the temperature,
**c.** Hardness as a function of the micro compounder screw speed,
**d.** Hardness as a function of the residence time

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# Micro-Compounder

Micro-compounder is analytical tool that measures the following

| Time [s] | Index Index counts every | Force [ N ] | Screw [ RPM ] | Motor Currer [ A ] | Melt Viscosity [ kPa.s ] | Screw Torque [ Nm ] | Shear Rate [ /s ] | Shear Stress [ kN/m≤ ] |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 5 | 0 | 0 | 0.4 | 0 | 0 | 0 | 0 |
| 6 | 6 | 0 | 7 | 0.6 | 0 | 0 | 0 | 0 |
| 7 | 7 | 0 | 7 | 0.7 | 0 | 0 | 0 | 0 |
| 8 | 8 | 0 | 11 | 0.7 | 0 | 0 | 0 | 0 |
| 9 | 9 | 0 | 18 | 0.7 | 0 | 0 | 0 | 0 |
| 10 | 10 | 0 | 18 | 0.8 | 0 | 0 | 0 | 0 |
| 11 | 11 | 0 | 25 | 0.8 | 0 | 0 | 0 | 0 |
| 12 | 12 | 0 | 33 | 0.9 | 0 | 0 | 0 | 0 |
| 13 | 13 | 0 | 43 | 0.9 | 0 | 0 | 0 | 0 |
| 14 | 14 | 0 | 43 | 0.9 | 0 | 0 | 0 | 0 |
| 15 | 15 | 0 | 54 | 1 | 0 | 0 | 0 | 0 |
| 16 | 16 | 0 | 54 | 1 | 0 | 0 | 0 | 0 |
| 17 | 17 | 0 | 68 | 1.1 | 0 | 0 | 0 | 0 |
| 18 | 18 | 0 | 83 | 1.1 | 0 | 0 | 0 | 0 |
| 19 | 19 | 0 | 83 | 1.2 | 0 | 0 | 0 | 0 |
| 20 | 20 | 0 | 101 | 1.2 | 0 | 0 | 0 | 0 |
| 21 | 21 | 0 | 119 | 1.2 | 0 | 0 | 0 | 0 |

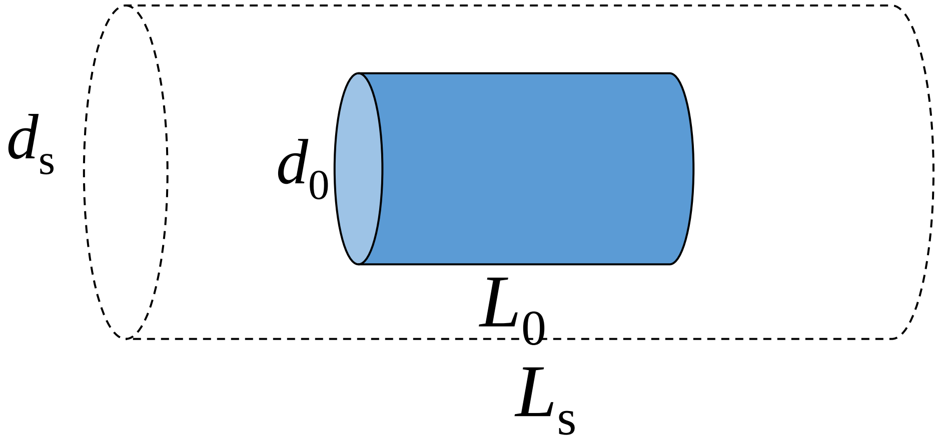
Template Tool | RPM_res | 100rpm_100C_60% | 200rpm_100C_60% | 300rpm_100C

# Micro-Compounder

## A new concept: Anisotropic swelling strain
## We applied it to validate that micro-compounded can mimic extrusion

A measure to quantify differences in swelling in the longitudinal and transversal directions:

$$\varepsilon_{s,\parallel} = \frac{L_s - L_0}{L_0} \qquad \varepsilon_{s,\perp} = \frac{d_s - d_0}{d_0}$$



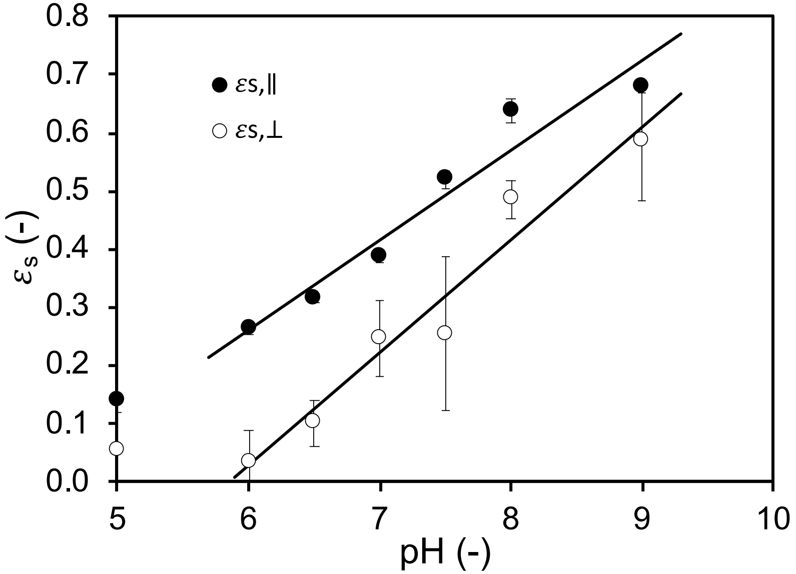

Degree of swelling determined by balancing osmotic and elastic forces

Muhialdin, B. J., & Ubbink, J. (2023). Effects of pH and aging on the texture and physicochemical properties of extruded pea protein isolate. Food Hydrocolloids, 140, 108639.

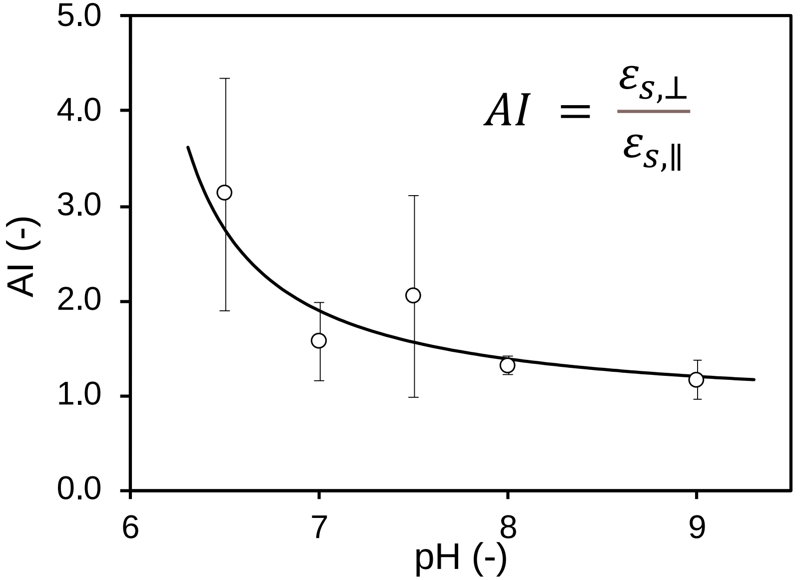
# Micro-Compounder

## Swelling anisotropy at different pH values

Longitudinal swelling strain ($\varepsilon_{s,\parallel}$) and transversal swelling strain ($\varepsilon_{s,\perp}$)




Swelling anisotropy index AI




PPI extruded at a water content of 50% w/w and T = 105 ºC

The swelling anisotropy index is a useful measure to quantify the degree of anisotropy of extruded protein matrices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# Micro-Compounder

## Swelling anisotropy tools!


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# Micro-Compounder

## Micro-compounder Demo

# Thank You
# Q&A

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