Contribution of maize starch and pea protein to the mechanical properties of plant-based food

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Introduction

For the development of starch-based foods, it is desired to control the mechanical properties of gels. This can be done by addition of other ingredients, such as protein.
In maize starch (MS) – pea protein isolate (PPI) composite gels, water is not evenly distributed between the components. Determining the water content in the present phases allows to calculate the effective concentration of the respective ingredients, and thus, with the help of theoretical models, to estimate their contribution to the mechanical properties of the composite gels.

CLSM micrographs

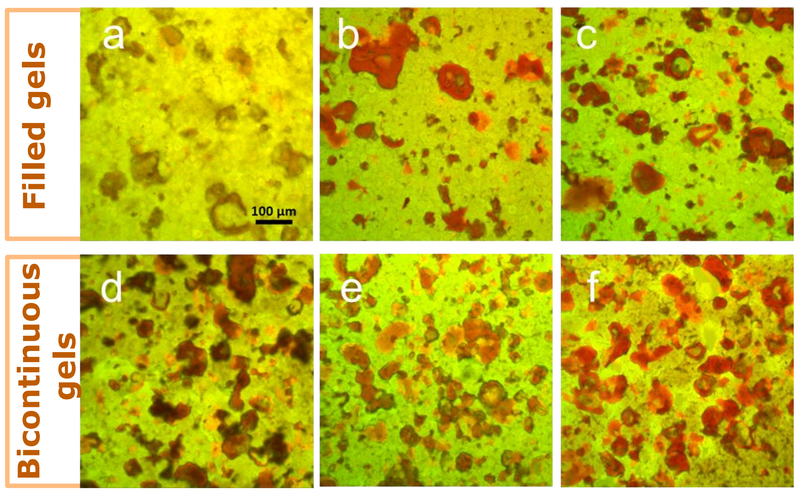

Figure 1. CLSM micrographs of MS gels (12 g starch + 88 g water) with increasing PPI content (starch phase: green; protein phase: red). (a): 2.0%; (b): 3.9%; (c): 5.7%; (d): 7.4%; (e): 9.1%; (f): 10.7% PPI.

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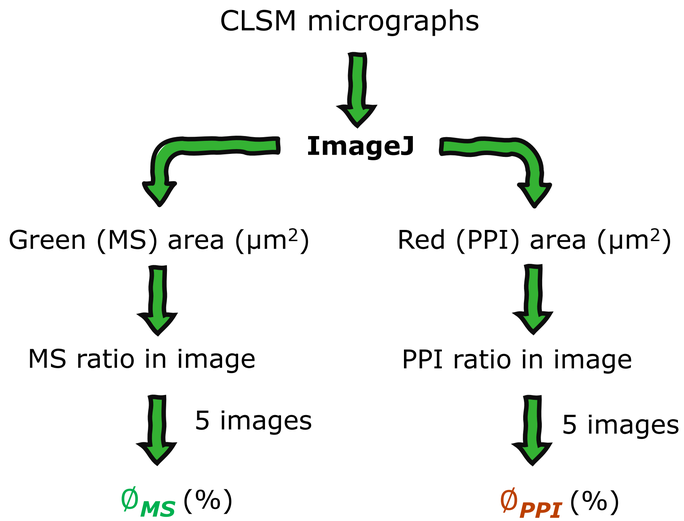
Water distribution



Theoretical concentrations & moduli

$$C_{MS} = \frac{m_{MS}}{(0.67m_{MS} + 0.74m_{PPI} + m_{water}) * \emptyset_{MS} - 0.67m_{MS}}$$

$$C_{PPI} = \frac{m_{PPI}}{(0.67m_{MS} + 0.74m_{PPI} + m_{water}) * \emptyset_{PPI} + 0.26m_{PPI}}$$

Table 1. Theoretical concentrations and moduli of MS and PPI in their corresponding phase.

PPI in recipe (%)	$\emptyset_{MS}$ (%)	$\emptyset_{PPI}$ (%)	C_{MS} (%)	C_{PPI} (%)	G'_{MS} (kPa)	G'_{PPI} (kPa)
2.0	88.5	11.5	13.3	17.0	3.2	0.9
3.8	76.7	23.3	15.0	16.6	4.0	0.8
5.7	69.5	30.5	16.3	18.7	4.7	1.6
7.4	63.7	36.3	17.4	20.5	5.4	2.9
9.1	67.0	33.0	16.4	27.2	4.8	16.4
10.7	61.3	38.7	17.6	27.5	5.4	17.4

Mathematical models

Smith model
(For filled gels)

$$G' = \frac{3M + 4.5 + (10.5M - 10.5)\emptyset}{3M + 4.5 - (3M - 3)\emptyset} G'_m$$

Davies model
(For bicontinuous gels)

$$G_c'^{1/5} = \emptyset_{MS} G_{MS}'^{1/5} + \emptyset_{PPI} G_{PPI}'^{1/5}$$

Measured & estimated moduli of gels

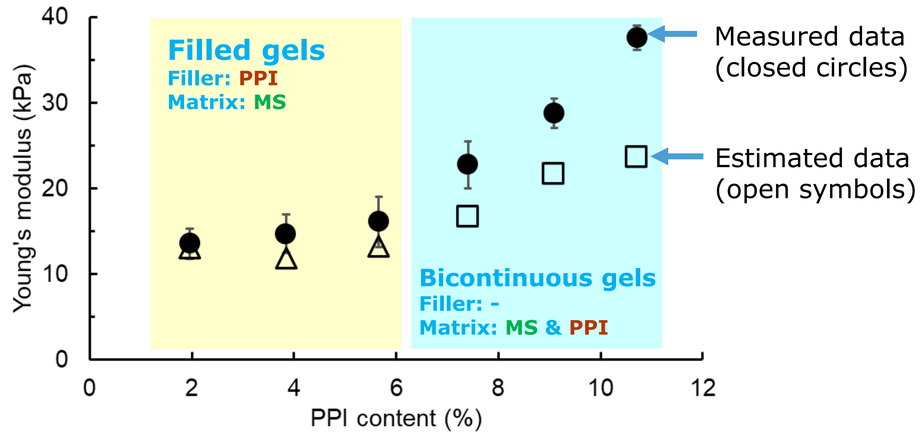


Figure 2. Young's moduli of starch gels with increasing protein content: Measured data (closed circles), estimated values based on the Smith (open triangles) and Davies models (open squares).

Conclusions

- Smith and Davies models can be used to predict the moduli of composite gels.
- In starch gels with protein fillers, the MS network dominated the gel properties, unless the stiffness of PPI fillers was remarkably higher than that of MS network.
- In bicontinuous gels, the protein network dominated the mechanical properties.