Supplementary Material

Emulsions stabilized by pea protein – hydration and protein distribution

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Reduction of scattering data

For both SANS and SAXS data reduction included several steps.

a) Masking of bad or noisy detector pixels.
b) For SANS, the relative efficiency of detector pixels is taken into account by normalization to the incoherent scattering from a 1 mm sample of water. This also provides for an absolute scale factor. For SAXS, the relative pixel efficiency is pre-recorded and allowance made in the data files.
c) Subtraction of sample holder scattering that has been scaled to account for the attenuation in the sample.
d) Azimuthal averaging to generate one dimensional data sets of intensity against momentum transfer (Q).
e) Background corrected data have been scaled by the thickness of the sample. The thin windows in the SAXS measurements and the filling procedure do cause some uncertainties of the thickness for these samples that might give rise to 15% uncertainty in the absolute intensity but would not change the overall shape of the scattering curves. This problem does not arise with the SANS data.
f) There is some variation in the scattering from the Kapton used as SAXS windows. This gives rise to small errors in the subtraction around 0.4 $Å^{-1}$. We exclude this region in our further analysis.

Density and elemental composition of rapeseed oil

The density of the rapeseed oil was measured as 0.917 g cm^{-3} in 20°C with an Anton Paar 4500M density meter. This compares well with previously reported values (Olsmats & Rennie, 2024). The fatty acid composition is reported by McDowell *et al*. (McDowell, et al., 2017) and Konuskan *et al*. (Konuskan, et al., 2019) and the average is presented in Table S1. The calculated SLD based on the density and the composition are within 15%. The SLD was determined as 0.1×10^{-6} $Å^{-2}$.

Fatty acid	**Chemical composition**	**%**
Arachidic	$C_{20}H_{40}O_2$	0.7
Behenic	$C_{22}H_{44}O_2$	0.6
Erucic	$C_{22}H_{42}O_2$	1.0
Gadoleic/Eicosenoic	$C_{20}H_{38}O_2$	2.2
Gamma linolenic	$C_{18}H_{30}O_2$	8.4
Linoleic	$C_{18}H_{32}O_2$	19.2
Oleic	$C_{18}H_{34}O_2$	60.0
Palmitic	$C_{16}H_{32}O_2$	4.6
Palmitoleic	$C_{16}H_{30}O_2$	0.2
Stearic	$C_{18}H_{36}O_2$	2.0

Table S1. Fatty acid composition of rapeseed oil.

Extra Data

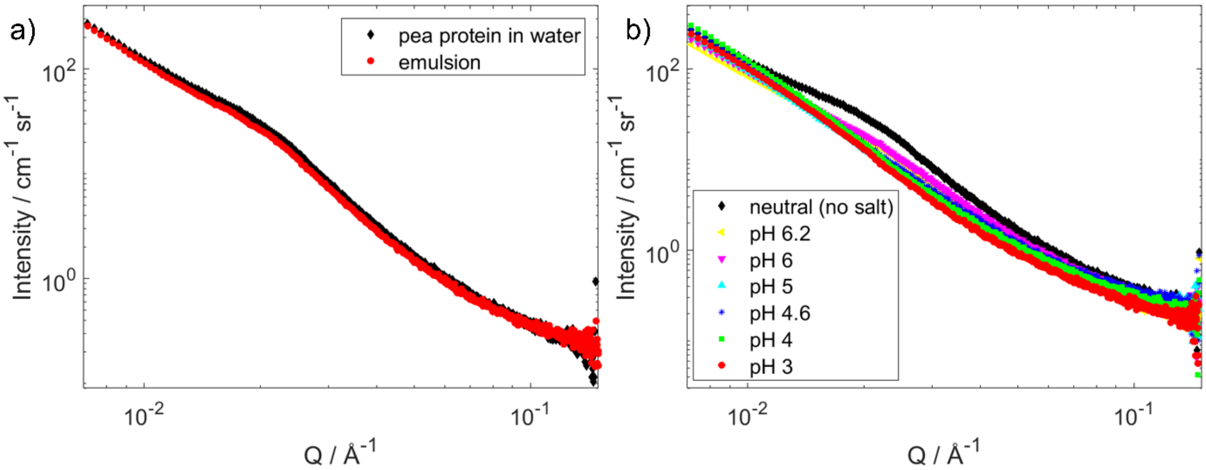

Figure S1. SAXS data for pea protein dispersions in water/buffer and in an emulsion for comparison. a) A dispersion of 15 % w/v pea protein in water and an emulsion with total composition 40% v/v oil and 7.5% w/v protein. The data are normalized by the volume fraction of the aqueous phase. b) Dispersions of 15% w/v pea protein in 0.1 M citrate buffer at pH 3 to 6.2 and in water at neutral pH.

Sample	Core shell sphere scale	Core radius / µm	Shell thickness / Å	Core SLD / 10^{-6} Å^{-2}	Shell SLD / 10^{-6} Å^{-2}	Core polydispersity (Gaussian)	Shell polydispersity (Gaussian)
60/40/5	0.40	6.0	50	0.1	0.6 & 2.2	0.5	0.5
60/40/7.5	0.40	3.5	50	0.1	0.6 & 2.2	0.5	0.5
60/40/10	0.40	3.0	50	0.1	0.6 & 2.2	0.5	0.5
60/40/12.5	0.40	2.0	50	0.1	0.6 & 2.2	0.5	0.5

Table S2. Full set of core shell sphere model fit parameters for the pea protein stabilized emulsions with different pea protein concentrations that are shown in Figure 6. The two values for the SLD of the shell correspond to the samples with 9.5 and 34.7% D_2O respectively.

Sample	Fractals scale	Fractal particle radius / Å	Fractal aggregate size / Å	Fractal dimension	Fractal particle SLD / 10^{-6} Å^{-2}	Radius polydispersity (Gaussian)
60/40/5	0.050	60	1000	2.7	0.6 & 2.2	0.5
60/40/7.5	0.075	60	1000	2.7	0.6 & 2.2	0.5
60/40/10	0.100	60	1000	2.7	0.6 & 2.2	0.5
60/40/12.5	0.125	60	1000	2.7	0.6 & 2.2	0.5

Table S3. Full set of fractal aggregate model fit parameters for the pea protein stabilized emulsions with different pea protein concentrations in Figure 6. The two values for the SLD of the particles that form the fractal aggregates correspond to the samples with 9.5 and 34.7% D_2O respectively.

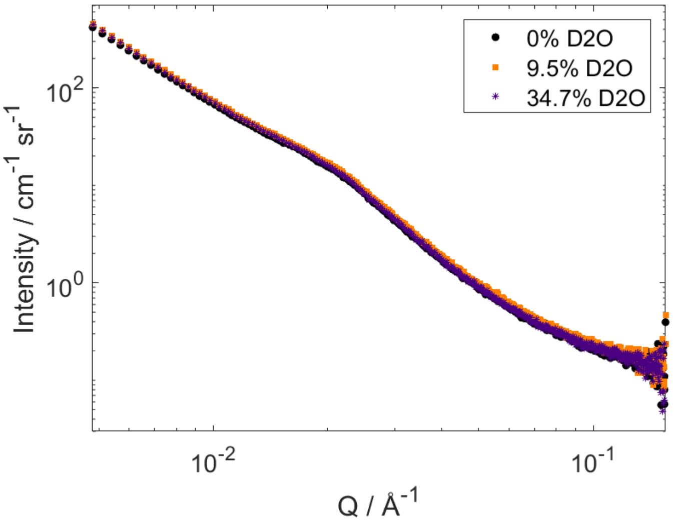

Figure S2. SAXS data for emulsions with composition 60% v/v water, 40% v/v rapeseed oil and 7.5% w/v pea protein and different D_2O concentrations in the aqueous phase. There are no significant differences between the samples with different D_2O content.

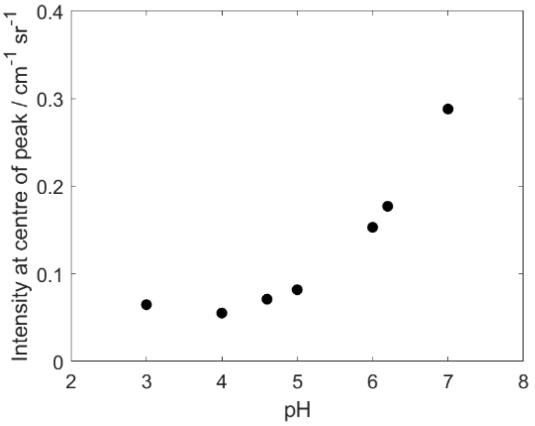

Figure S3. Intensity at 0.023 $Å^{-1}$, at the centre of the peak from the scattering data, as a function of pH. Full SANS curves are plotted in Figure 3b in the main article.

pH	Intensity at centre of peak / cm^{-1} sr^{-1}	Aggregation / % v/v
3.0	0.065	96
4.0	0.055	100
4.6	0.071	93
5.0	0.082	89
6.0	0.153	58
6.2	0.177	48
neutral	0.288	0

Table S4. Degree of aggregation for pea protein at different pH.

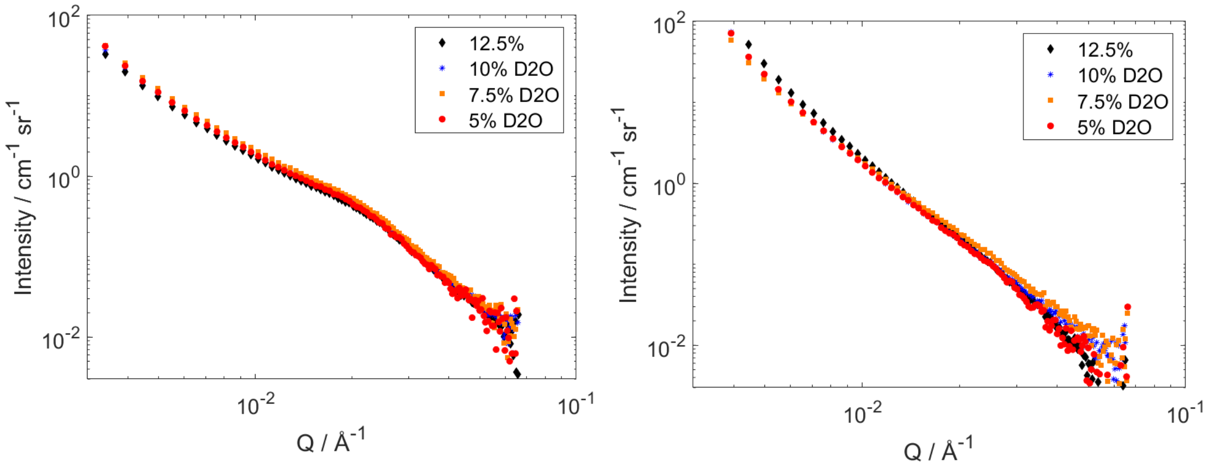

Figure S4. SANS data for 40% v/v oil-in-water emulsions with a series of different concentrations of 7.5-12.5% w/v protein normalized by the protein in the aqueous phase from the model fits. a) 9.5% D_2O in the water phase to match out most of the scattering from the oil droplets. The overlap of the curves suggests that the scattering is dominated by the pea protein in the aqueous phase in this region of *Q*. b) 34.7% D_2O in the water phase to match out most of the protein. The upturn of the curves at lower *Q* with higher protein content suggests that there are smaller oil droplets forming.

References

Konuskan, D. B., Arslan, M. & Oksuz, A., 2019. Physicochemical properties of cold pressed sunflower, peanut, rapeseed, mustard and olive oils grown in the Eastern Mediterranean region. *Saudi Journal of Biological Sciences*, 26(2), pp. 340-344.

McDowell, D., Elliott, C. T. & Koidis, A., 2017. Characterization and comparison of UK, Irish, and French coldpressed rapeseed oils with refined rapeseed oils and extravirgin olive oils. *Eur. J. Lipid Sci. Technol.*, Volume 119, p. 1600327.

Olsmats, E. & Rennie, A. R., 2024. Pea protein [Pisum sativum] as stabilizer for oil/water emulsions. *Advances in Colloid and Interface Science*, Volume 326, p. 103123.