UFOP seminar on 2nd Novembre 2021
AiF research project 20197 N

Development of new concepts for the optimization of the structure and sensory properties of reduced-fat food products by means of protein functionalization and molecular-sensory methods

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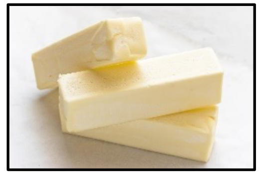
Entwicklung neuer Konzepte zur Optimierung von Struktur und Sensorik fettreduzierter Lebensmittel durch Proteinfunktionalisierung und molekular-sensorische Methoden

M.Sc. Caren Tanger, Prof. Dr.-Ing. Ulrich Kulozik

Background and Motivation



Risk for diet-related illnesses

↓

Demand for new concepts related to a significant reduction of salt, sugar and fat in food products

↓

Current concepts for fat reduction:

- Undesired side effects
- Reduction of product volume
- Negative influence on product texture and flavour perception

Sustainability matters

↓

Demand for new concepts related to the exploration of plant-based alternative food ingredients

↓

Challenges related to plant-based protein alternatives:

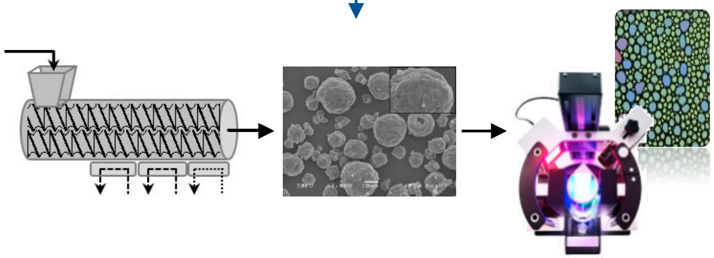
- Off-flavour
- Low solubility
- Low techno-functionality

Fat reduction in food leads to loss of consumer acceptance

Research Group I:

Food and Bioprocess Engineering

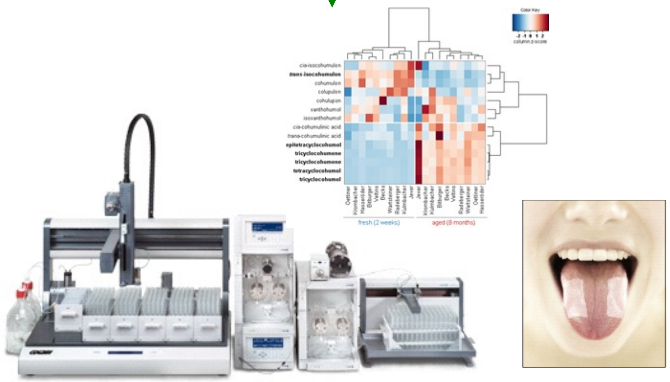
Compensation of the structural effect of fat by protein functionalization



Research Group II:

Food Chemistry and Molecular Sensory Science

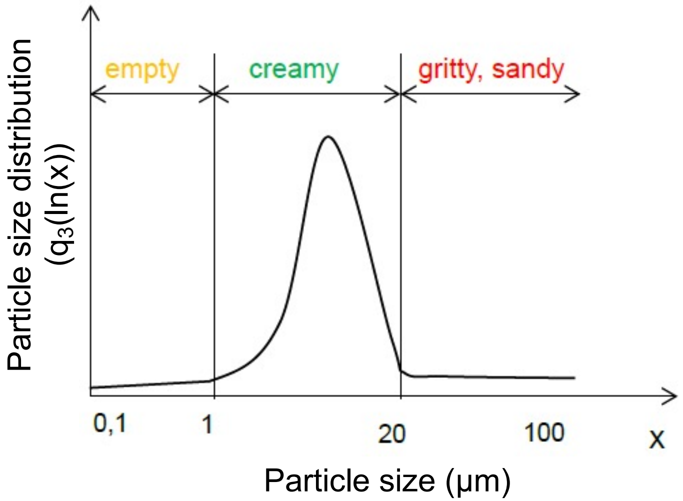
Compensation of sensory perception of fat by flavour optimization

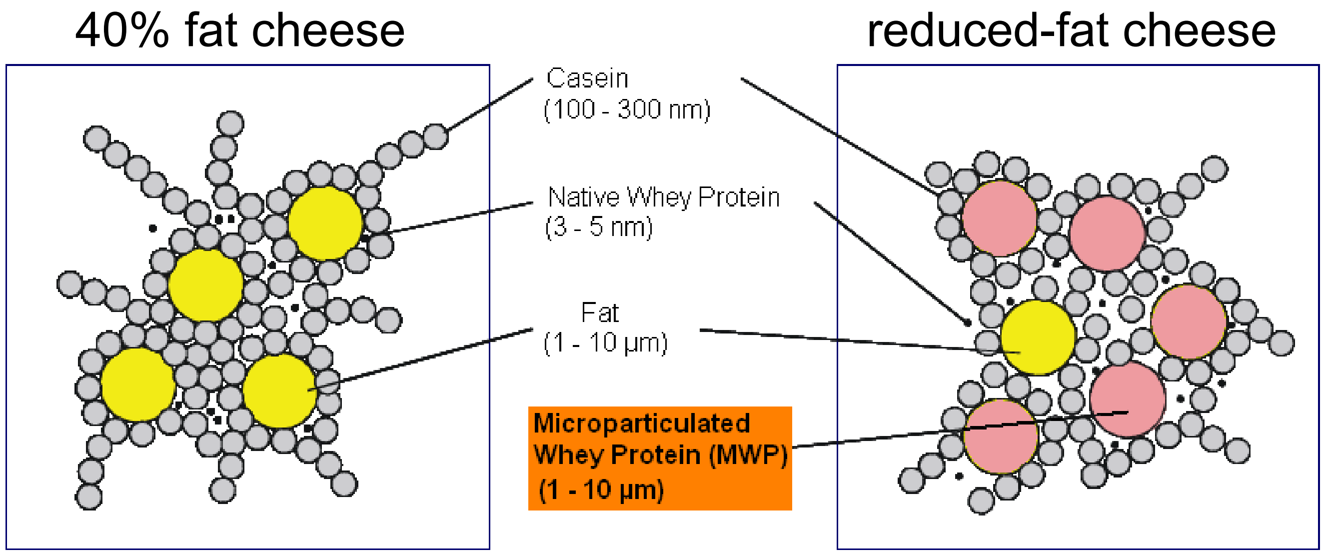


Establishment of a new platform of knowledge and methodology for the development of reduced-fat food products

Concepts for the replacement of fat in food products

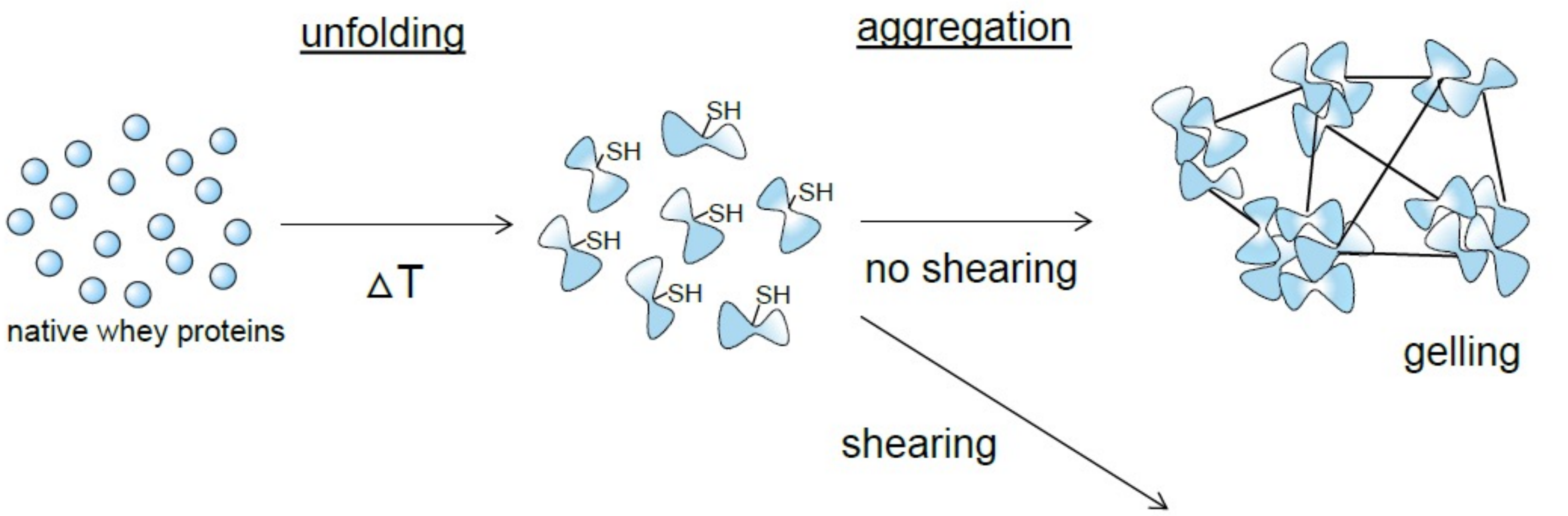
Utilization of microparticulated milk proteins to maintain a creamy mouthfeel in fat-reduced products





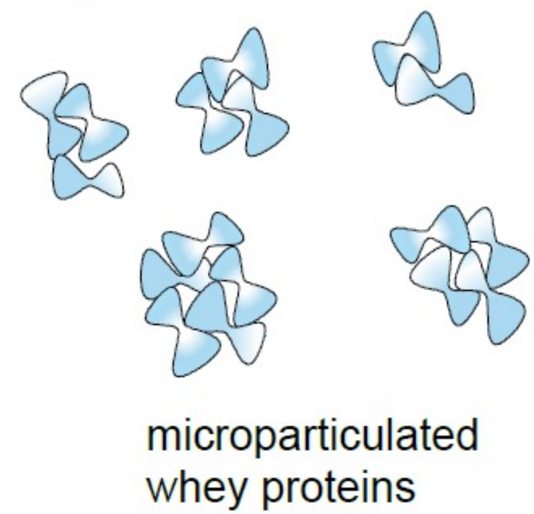
(Hinrichs, 2007)

Microparticulation of proteins

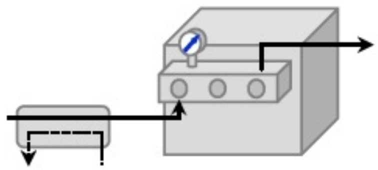


Influencing factors on aggregation

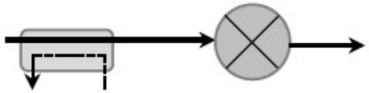
- temperature
- shear rate
- heating time
- composition (Protein, Lactose, Calcium)
- pH
- pre-denaturation of the proteins



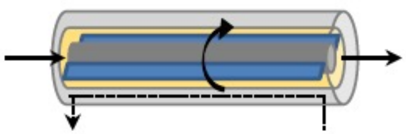
Methods for microparticulation of proteins



High pressure homogenizer

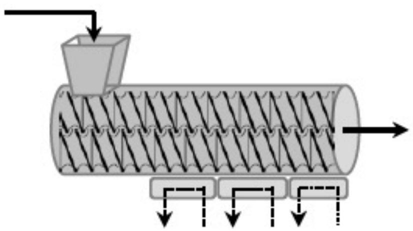


Dispersion unit



Scraped surface heat exchanger

Protein concentration as limiting factor (max. 10%)



Extruder

Advantages using extrusion for production of microparticulates:

- High viscosities and thus, high protein concentrations feasible
- High variation possibilities of process parameters
- Low holding times at high degree of denaturation
- Low amount of caking

Project Outline

WP 1 Chemical-physical and sensory characterization of purchased proteins

Lehrstuhl für Lebensmittel- und Bio-Prozesstechnik

WP 2 Functionalization of single and hybrid systems (pea, potato and milk protein)

WP 3 Characterization of surface activity and foam properties of the microparticulates

WP 4 Development of fat-reduced model milk products

WP 5 SENSOMICS- and flavor-protein-interaction-studies

WP 6 Flavor-optimization of the fat-reduced model milk products

Lehrstuhl für Lebensmittelchemie und Molekulare Sensorik

WP 7 Project management and transfer of knowledge

Physico-chemical characterization



	Pea protein isolate	Potato protein isolate	Whey protein isolate
Protein concentration	80% - 90%	80%	90%
Solubility	low	high	high
Protein profile	Several protein fractions	Two protein fractions	Two protein fractions
Nativity	low	high	high

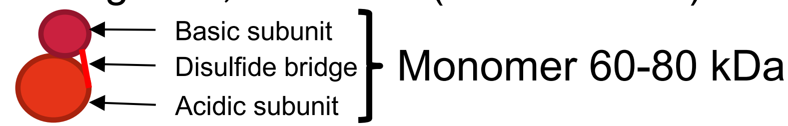
Protein profile pea

	Pea protein isolate
Protein concentration	80% - 90%
Solubility	low
Protein profile	Several protein fractions
Nativity	low

Salt soluble

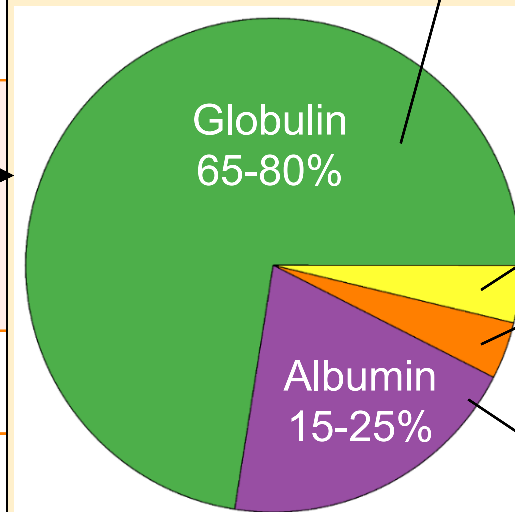
IEP: pH 4.5

11S Legumin, Hexamer (360-410 kDa)



7S Vicilin, Trimer (150-200 kDa)

7S Convicilin, Tetramer (210-290 kDa)



Glutelin <10 %

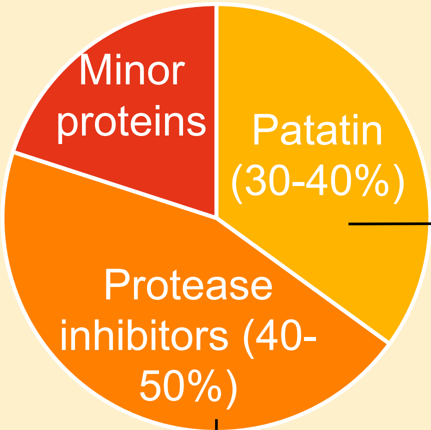
Prolamin < 10%

Water soluble

Low molecular weight protein

(Swanson, 1990; Shand et al. 2007)

Protein profile potato



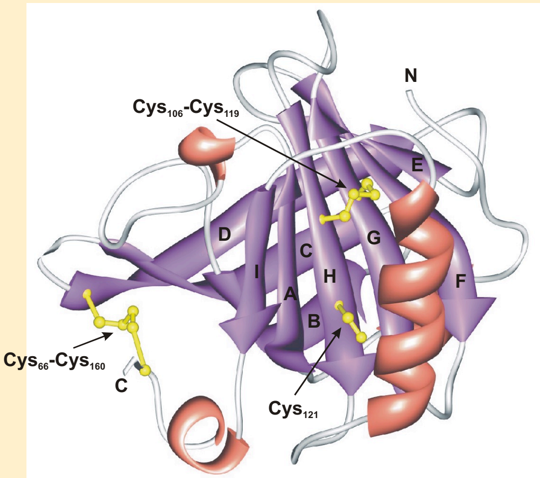
- 40-45 kDa, glycoprotein,
- Low heat stability
- 1 free thiol group

- Consist out of 7 subgroups, 5-25 kDa
- Decrease digestibility
- Inactivated upon heating

Potato protein isolate	Whey protein isolate
80%	90%
high	high
Two protein fractions	Two protein fractions
high	high

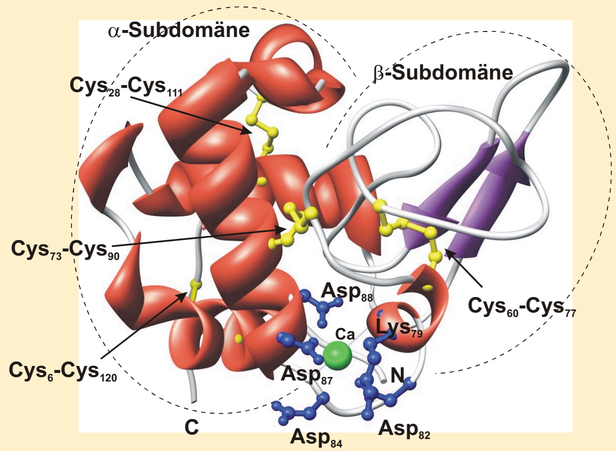
Protein profile whey

β-Lactoglobulin



- 40 – 50%
- Amount in whey: 3.5 – 5 g/l
- Globular protein
- 18.4 kDa
- 1 free thiol group
- 2 internal disulphide bonds

a-Lactalbumin



- 10 – 15 %
- Amount in whey: 1 – 1.5 g/l
- Globular protein
- 14.2 kDa
- Ability to bind calcium:
- holo-α-La (+Ca)
- apo-α-La (-Ca)

Whey protein isolate
90%
high
← Two protein fractions
high

Producing „native“ pea proteins on laboratory scale


Food Hydrocolloids 107 (2020) 105949
Contents lists available at ScienceDirect
Food Hydrocolloids
journal homepage: http://www.elsevier.com/locate/foodhyd

Influence of extraction conditions on the conformational alteration of pea protein extracted from pea flour

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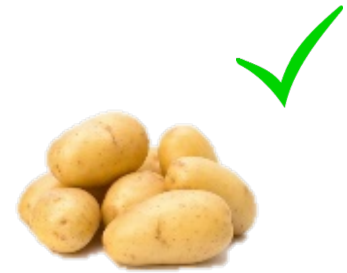
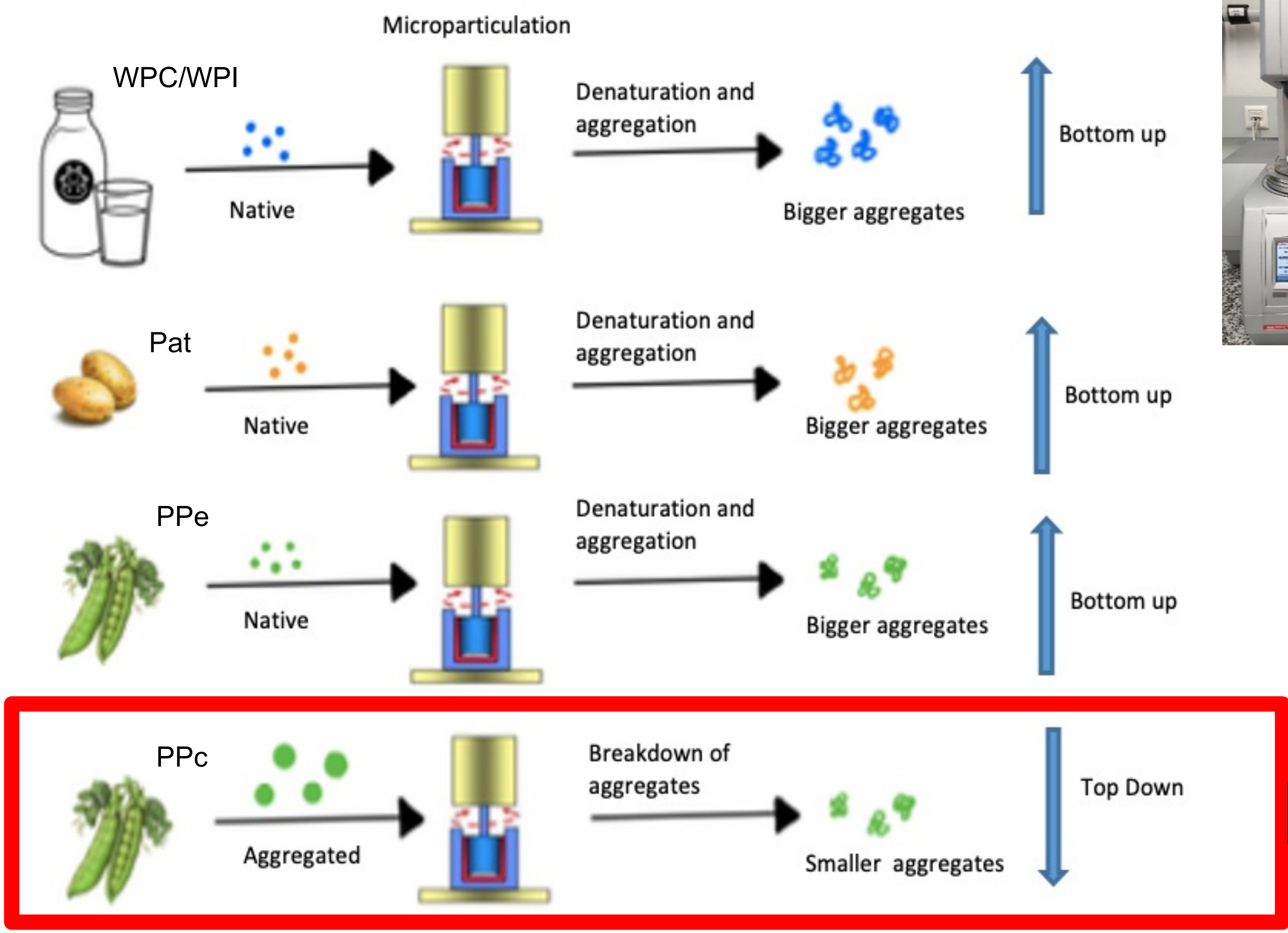
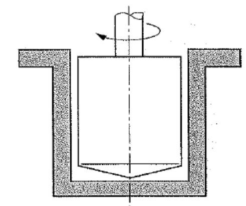


	Pea protein isolate	Potato protein isolate	Whey protein isolate
Nativity	low	high	high

Extraction method	+	-
Alkali extraction – isoelectric precipitation	fast extraction	Low solubility
Alkali extraction – isoelectric precipitation modified	High solubility, fast extraction	Possibly damaged protein structure
Salt extraction	High solubility	Low denaturation peak Long extraction
Micellar extraction	Probably lowest damage (clear denaturation peak)	Low solubility

Microparticulation of plant protein in comparison to whey protein on small scale



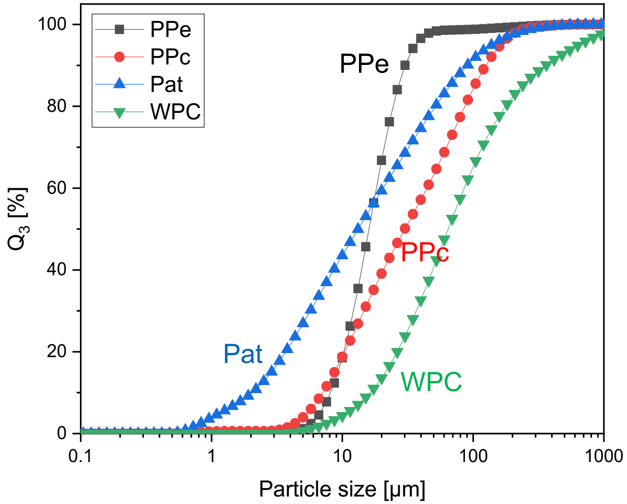


Mooney-Ewart geometry

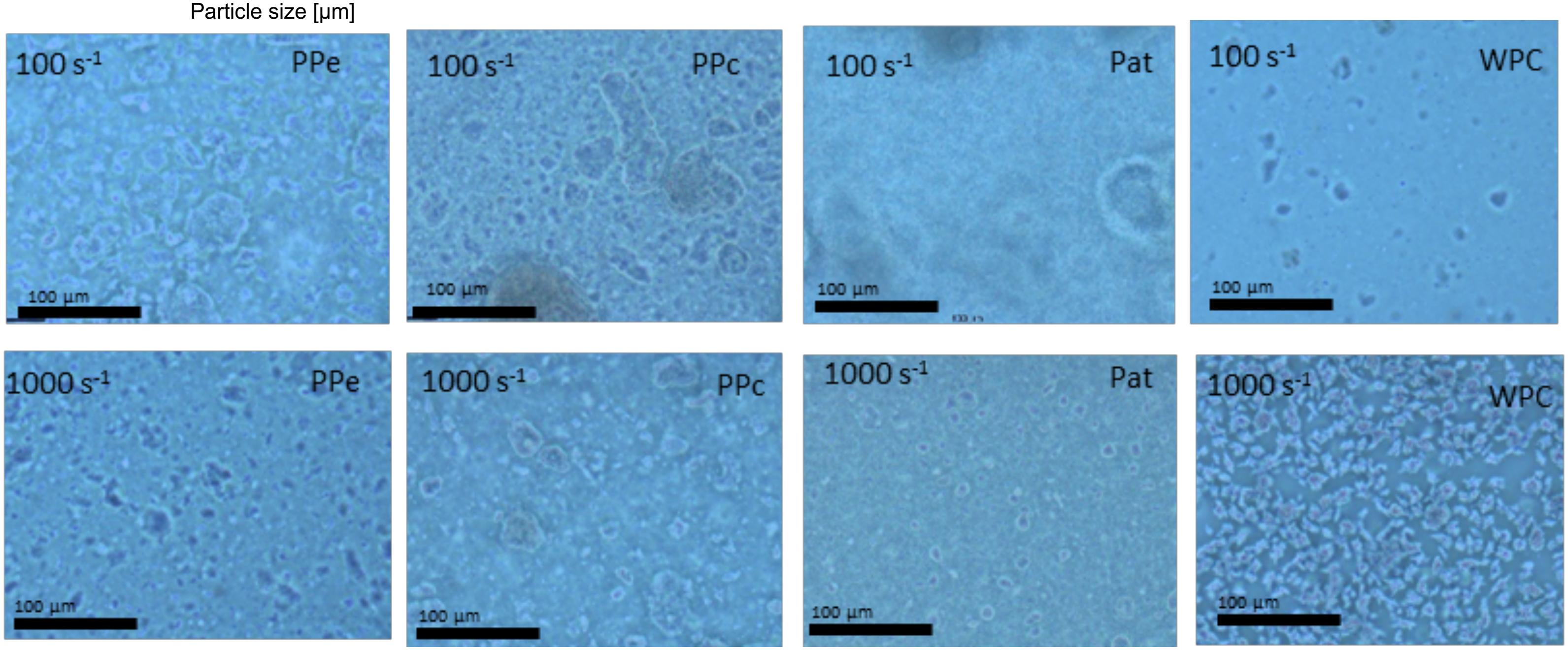
Different process to whey protein

WPC = whey protein concentrate; WPI = whey protein isolate; Pat = potato protein isolate; PPe = laboratory extracted pea protein; PPc = commercial pea protein isolate

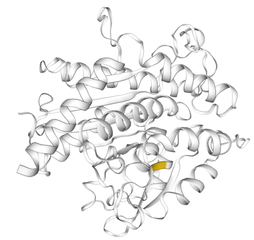
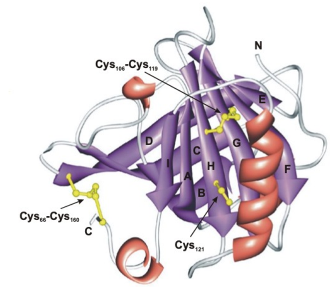
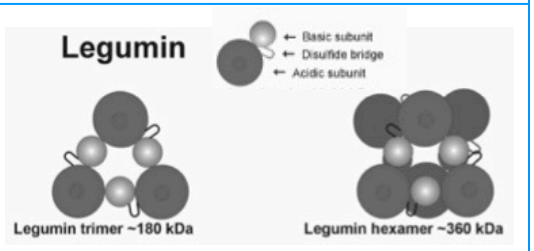
Microparticle characteristic – size and shape



- Plant protein particles are in a suitable size range
  - ➢ Extracted and commercial pea protein behave differently!
- Plant protein microparticles are round



Thermal stability of whey and plant proteins

Protein	T_{denat} [˚C]	Structure
Patatin	63	
Whey protein isolate	73	
Laboratory extracted pea protein	78	

* Commercial pea protein did not show any peak by DSC analysis → high initial denaturation

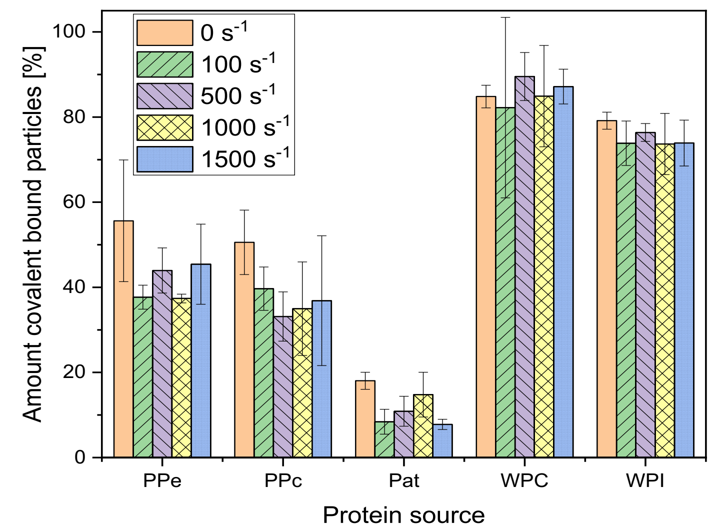
Possible reaction mechanism of thiol groups


ACS FOOD SCIENCE & TECHNOLOGY
pubs.acs.org/acsfoodscitech Article
Comparative Assessment of Thermal Aggregation of Whey, Potato, and Pea Protein under Shear Stress for Microparticulation
Caren Tanger,* Paola Quintana Ramos, and Ulrich Kulozik

Thiol reaction: $R_1\text{-SH}^* + R_2\text{-SH}^* = R_1\text{-S-S-}R_2$

Thiol-disulphide interchange: $R_1\text{-SH}^* + R_2\text{-S-S-}R_3 = R_1\text{-S-S-}R_2 + R3\text{-SH}^*$

	β-LG	Patatin	Legumin
Disulphide bonds	2	0	1-2
Thiol group	1	1	3

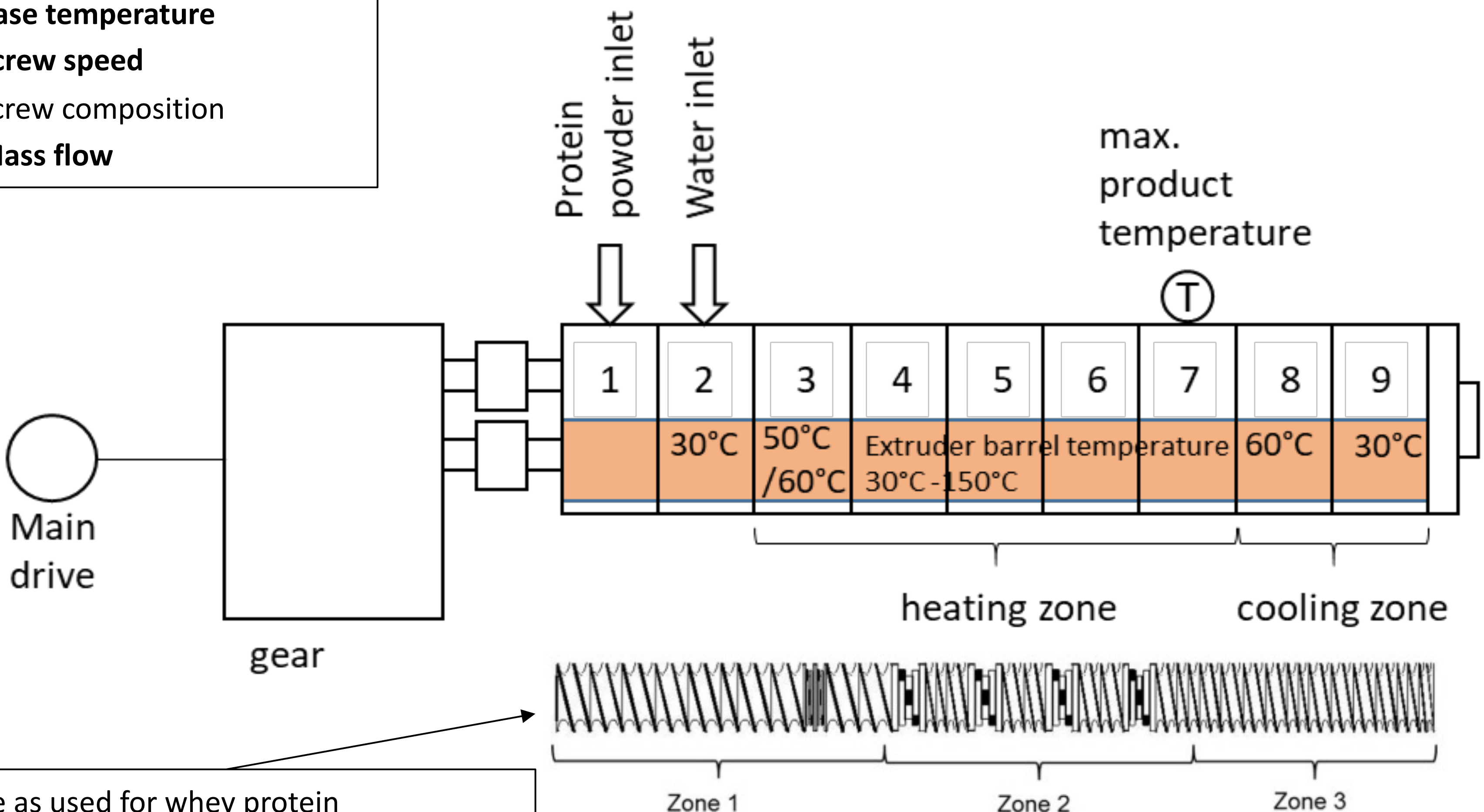


Plant protein microparticles are mostly stabilized by hydrophobic interactions
→ Softer particles compared to whey protein particles

Thermo-mechanical treatment – extrusion set-up

Process parameter

- **Case temperature**
- **Screw speed**
- Screw composition
- **Mass flow**



Same as used for whey protein microparticulation (Wolz et al. 2016)

Pea and potato protein microparticulation – large scale (extruder)

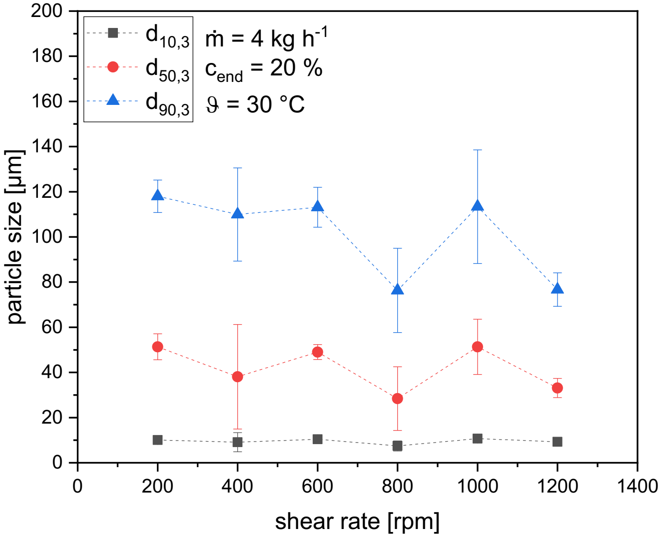
Extruded pea protein microparticles

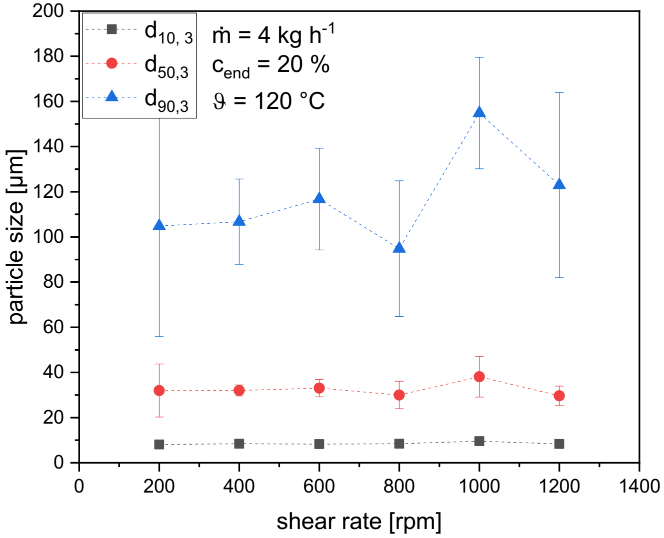
Extruded potato protein microparticles

- Pea protein microparticles have a smooth peanut butter like texture
- Potato protein microparticles are foamy and show big visible particles

➢ **Commercial pea protein isolates is investigated in more detail**

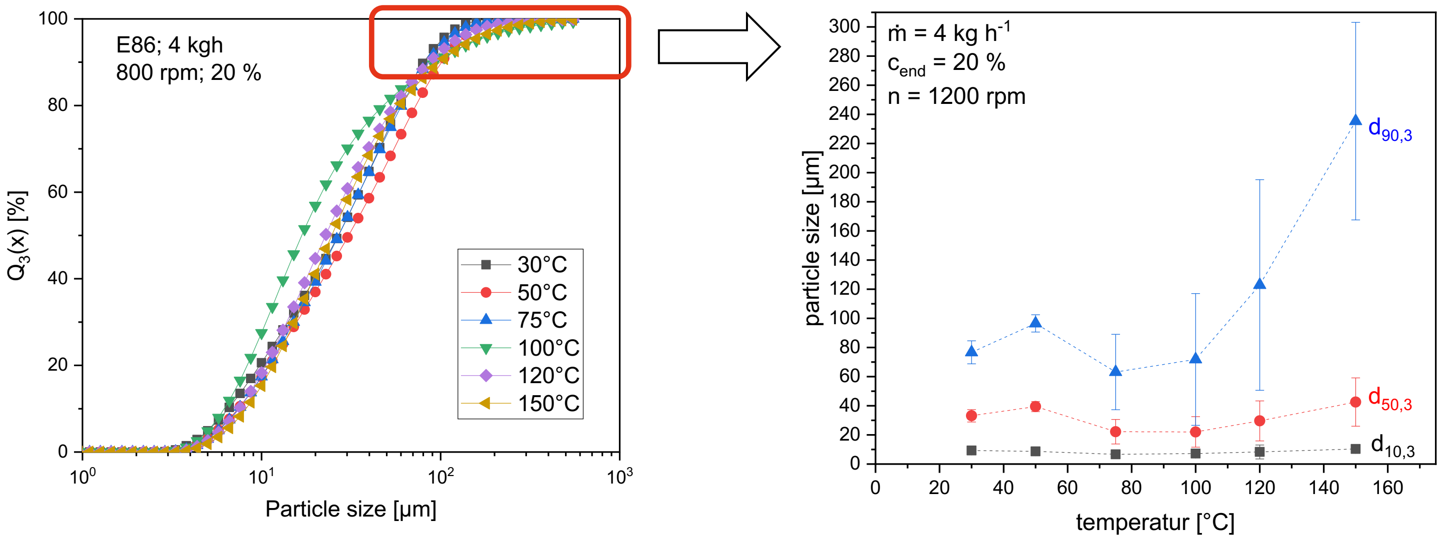
Influence of shear rate on particle size – large scale





- Small shear rate is sufficient to limit particle size and prevent gel formation
  - Similar to whey protein -> impact on particle size has only been seen at lower shear rate (< 200 rpm)
  - Below 200 rpm extrusion of pea protein was not continuous

Influence of temperature on particle size

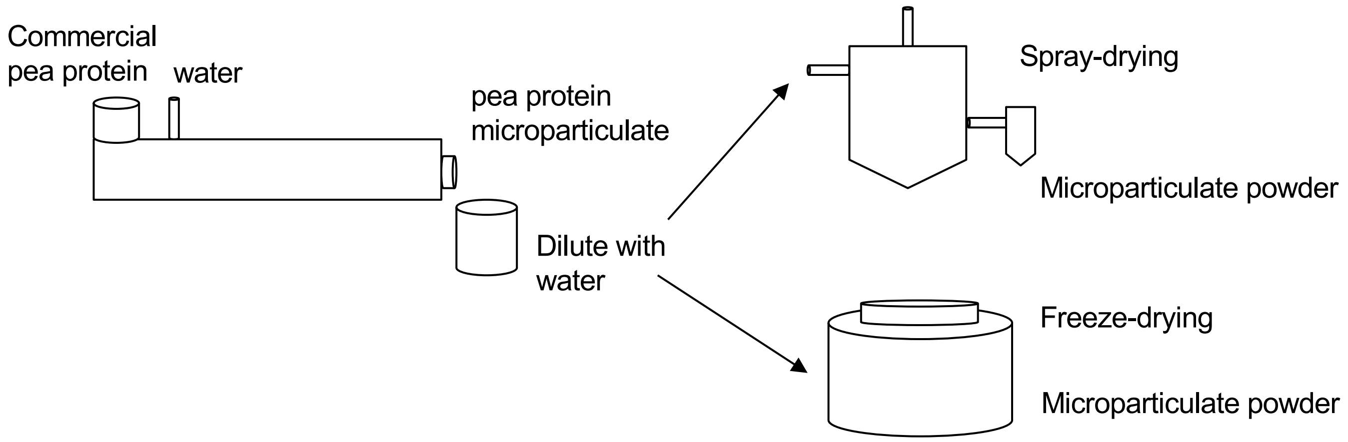


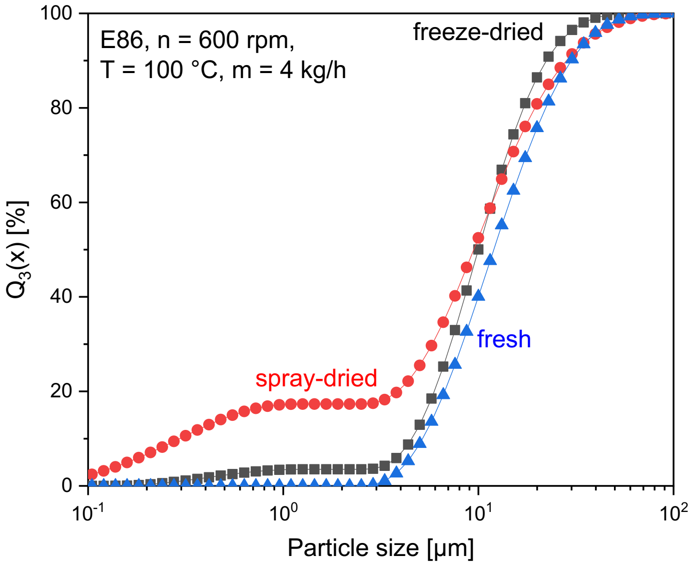
- D_{90} increase at 100° C
- Hydrophobic interaction increase in intensity with increasing temperature
- Reactivity of thiol groups increase at increasing temperatures

➢ Shear cannot limit particle growth due to the increase in intensity of protein interactoin

➢ temperatures between 75° C and 120° C most suitable

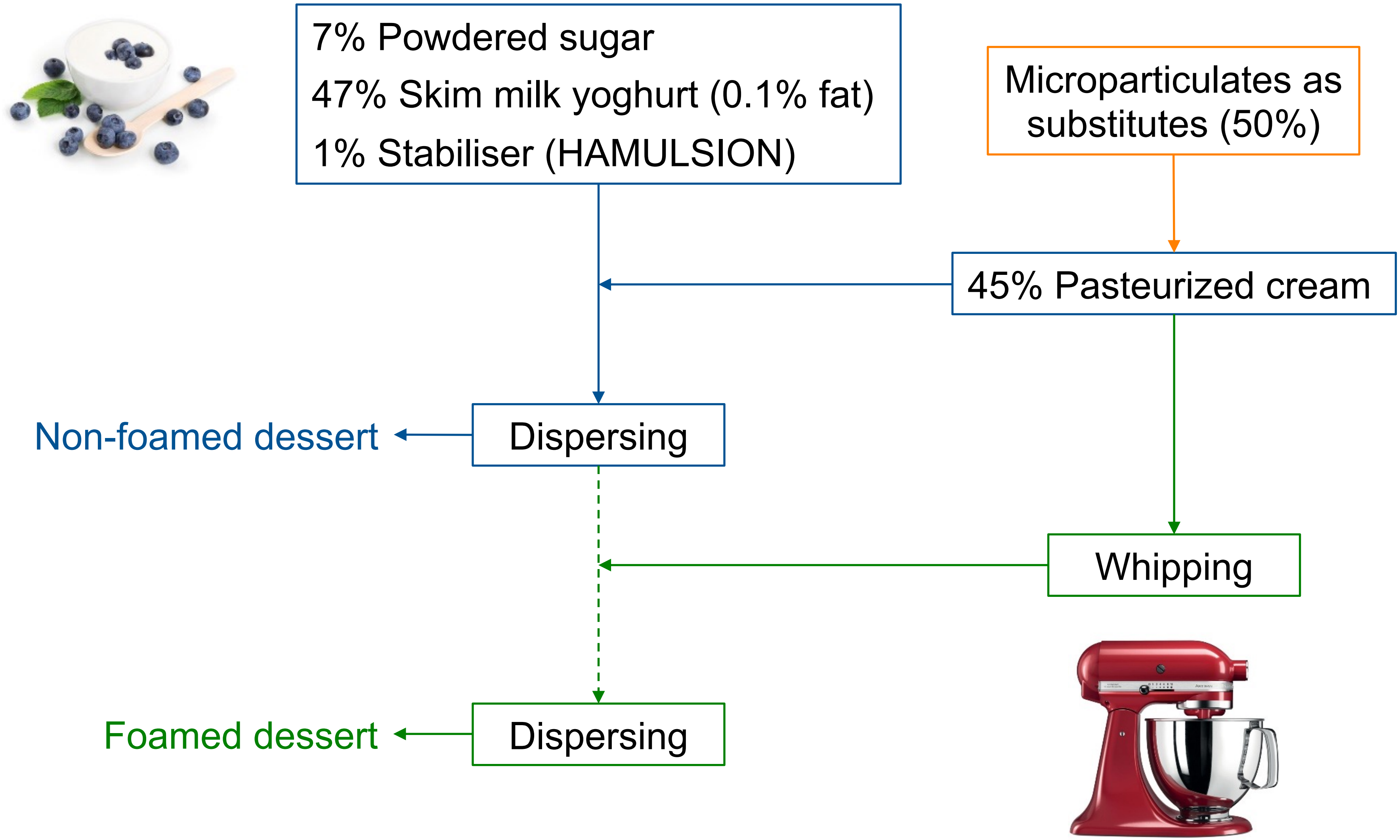
Effect of drying on particle size





- Drying does not increase particle size of microparticulate
- Drying does change protein-flavour binding

WP 4: Development of a model milk dessert

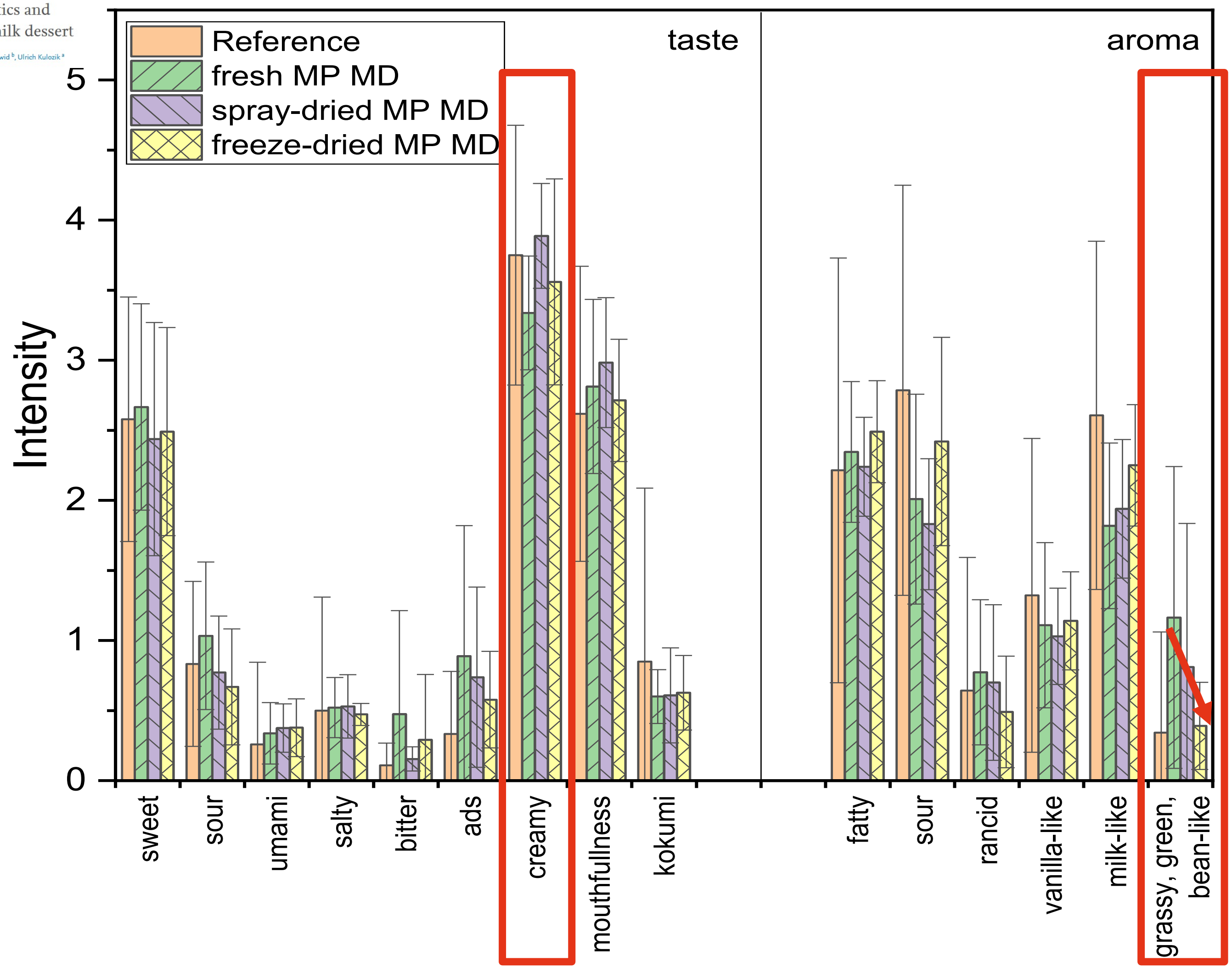


Flavour profile of full-fat and fat-reduced milk dessert

ELSEVIER
Innovative Food Science & Emerging Technologies
Available online 9 October 2021, 102851
In Press, Journal Pre-proof

Pea protein microparticulation using extrusion cooking: Influence of extrusion parameters and drying on microparticle characteristics and sensory by application in a model milk dessert

Caren Tanger [a], Florian Schmidt [a], Florian Utz [b], Johanna Kreissl [c], Corinna Dawid [b], Ulrich Kulozik [a]



Summary and Outlook

Summary:

- Different functionalities of pea, potato, and whey protein lead to different thermally induced aggregation behaviour

- Aggregates / microparticles could possibly be used as fat replacer

Outlook:

➔ Can aggregates / microparticles also be used for other applications (foam stability, emulsion stability, food structuring)?

➔ Can the microparticulation process also be used for functionalising other plant-based proteins (oat, sunflower, chickpea, etc.)?

Thank you for your attention!

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… ein Projekt der ***Industriellen Gemeinschaftsforschung (IGF)***

gefördert durch/via

iGF Industrielle Gemeinschaftsforschung

Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

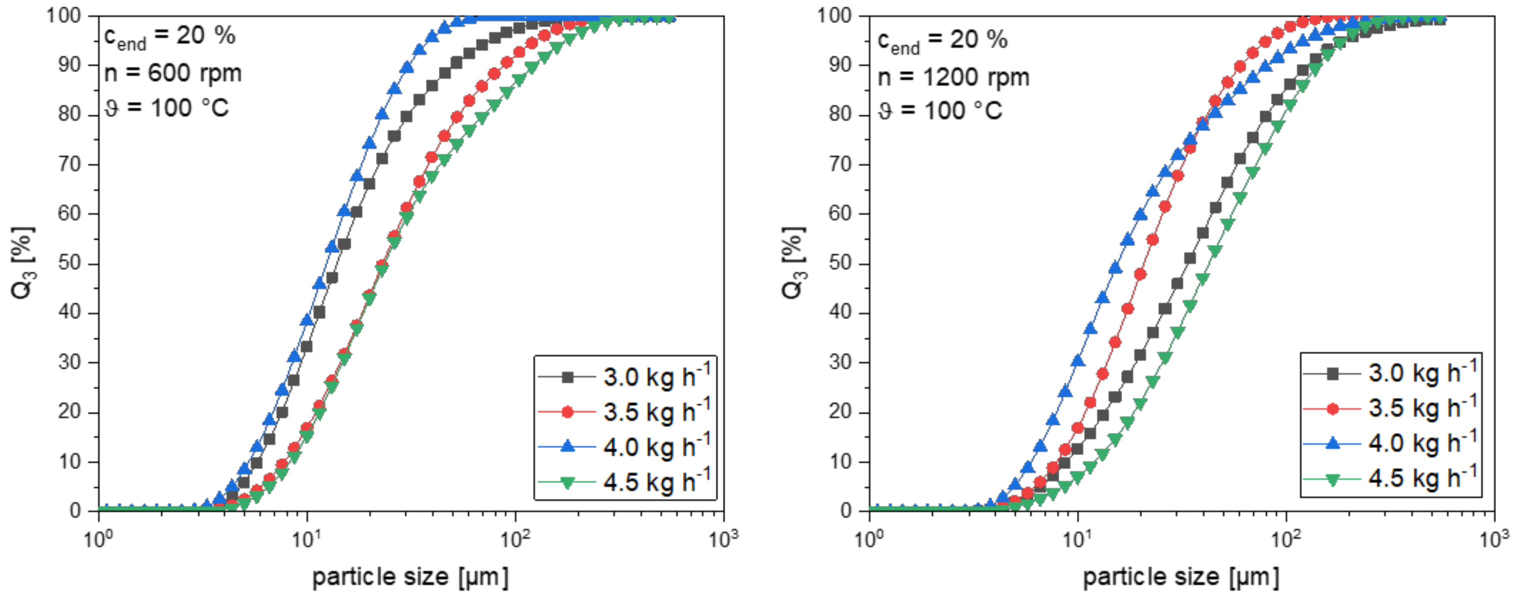
AiF Forschungsnetzwerk Mittelstand

FEI FORSCHUNGSKREIS DER ERNÄHRUNGSINDUSTRIE E.V.

Das IGF-Vorhaben 20197 N der Forschungsvereinigung Forschungskreis der Ernährungsindustrie e. V. (FEI), Godesberger Allee 142-148, 53175 Bonn, wurde über die AiF im Rahmen des Programms zur Förderung der Industriellen Gemeinschaftsforschung (IGF) vom Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages gefördert.

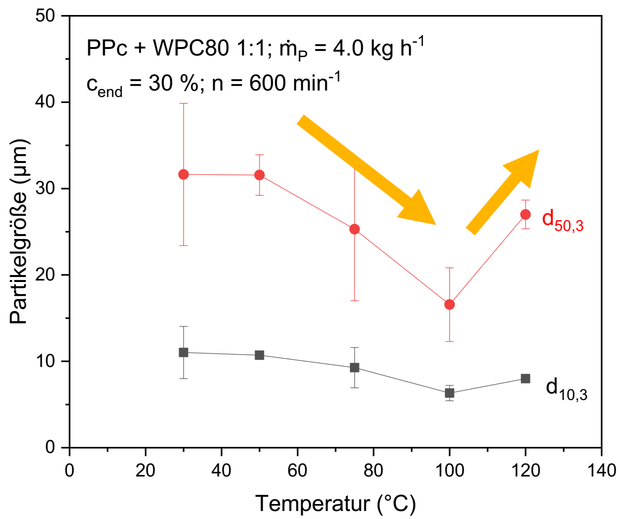
Backup- slides

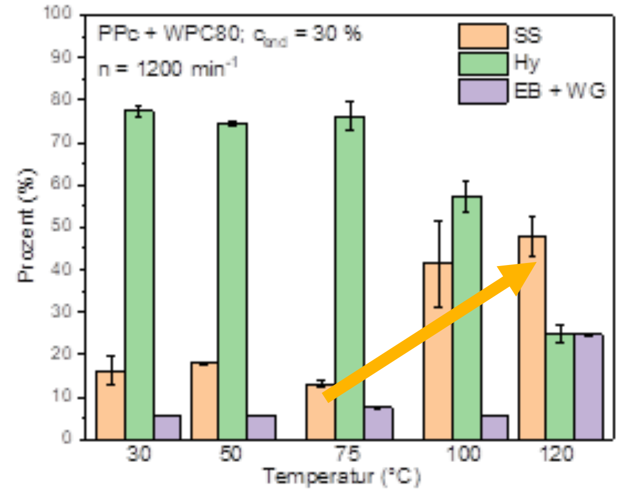
WP 2b: Influence of mass flow



- Mass flow influence screw filling
- Biggest particles at 4.5 kg / h
- Powder mass flow of 4.0 kg / h ist most suitable (smallest particles) -> same as whey proteins

WP 2 b: Hybrid systems 50:50 WPC and PPI





- In hybrid systems particle size and protein interaction are temperature dependent
  - Whey protein start to denature at 70°C -> start of thiol-disulphide interchange -> more disulphide bonds are built
  - Whey protein only fully denatured at 130°C barrel temperture (Wolz, 2016)