Flow process and heating conditions modulate the size and properties of whey protein aggregates

Domitille de Guibert, Marie Hennetier, Guillaume Delaplace, Romain Jeantet, Alain Riaublanc, Yingying Gu

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INRA SCIENCE & IMPACT

Flow process and heating conditions modulate the size and properties of whey protein aggregates

D. de Guibert[1,2*], M. Hennetier[3], Y. Gu[4], F. Martin[1,2,4], A. Riaublanc[5], G. Delaplace[4], R. Jeantet[2,1]

[1]INRA, UMR 1253 Science and Technology of Milk and Eggs, F-35042 RENNES
[2]Agrocampus Ouest, UMR 1253 Science and Technology of Milk and Eggs, F-35042 RENNES
[3] EI Purpan, Agro-physiology Laboratory, F- 31000 TOULOUSE
[4] INRA, UMR8207 UMET, Interface Processes and Hygiene of Materials, F-59650 LILLE
[5] INRA, UR1268 Biopolymers Interactions Assemblies, F- 44000 NANTES

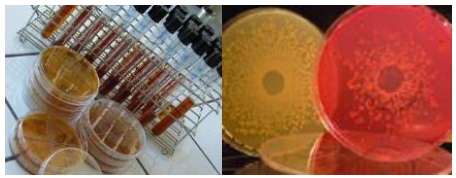
*E-mail address: domitille.deguibert@inra.fr

AGRO CAMPUS OUEST · PÔLE AGRONOMIQUE OUEST · Bba · Région PAYS DE LA LOIRE · Région BRETAGNE · Milk Valley PROFIL

A multidisciplinary and multiscale approach, reinforced by two high-calibre facilities:

Dairy Platform

Biological Resource Centre



STLO

- **Structuration / destructuration mechanisms of food matrix:**

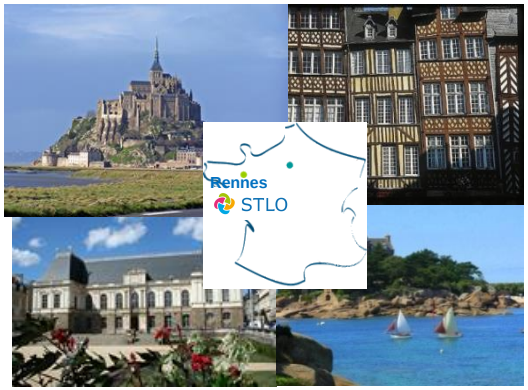
  from structural characterisation to digestion

- **Dairy processing and cheese making:**

  toward sustainable dairy systems

- **Microbial interaction:**

  food matrix and host cell



CONTEXT

Consumer expectation

- Good organoleptic quality
- More natural and healthy products

Milk Valley PROFIL

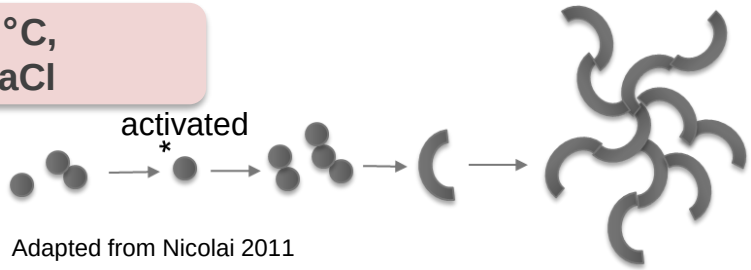
2014-2019
Joelle LEONIL

Industrial expectation

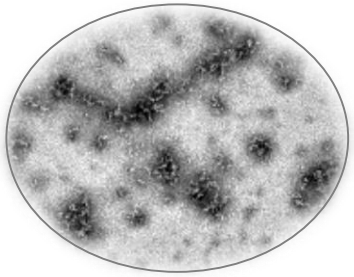
- Target regular products properties by using additives
- Use less additives as possible (Clean label)
- **Add value to milk protein (technofunctional interest)**

Fractal aggregates : Whey protein aggregates

WPI, 80°C, pH 7, NaCl



Adapted from Nicolai 2011



- Repeated pattern
- Soluble
- Low density
- Fractal dimension (Df) ≈ 2.2

PROPERTIES OF FRACTAL AGGREGATES AND RESEARCH QUESTION

Properties of fractal aggregates

- **Increase viscosity**
- **Gel**
- **Limit syneresis**
- **Bind fat droplet in emulsions**
- **Resist to heating**

Lab scale

Ag size

[Protein]

[NaCl]

Scale up

Pilot continuous scale

Ag size

Process levers ?

Research question

At pilot scale, does the process parameters influence the **characteristics of fractal aggregates** obtained, in relation to different transport phenomena (heat, momentum, mass)?

PROCESS LEVERS INVESTIGATED

Heat treatment pilot

5% WPI, 10mM NaCl

20°C

Preheating exchanger

50°C

Tubular heat exchanger

80°C

Dynamic holding

Process parameters

Experiment realised in triplicate

Flow regime upon heating / Re
(laminar 2000, transient 3200, turbulent 6900)

Heating residence time
(short 7s / intermediate 46s / long 69s)

Outlet heating temperature
(70°C, 80°C, 85°C, 90°C)

Flow rate

Inner diameter

Target temperature

SIZE AND SHAPE CHARACTERIZATION

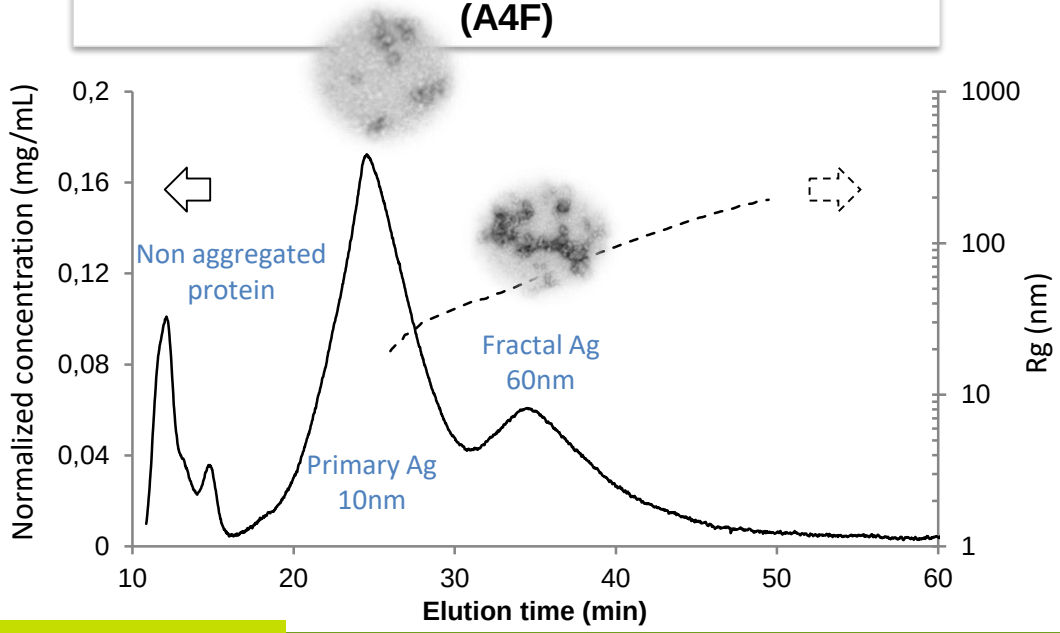
PROCESS LEVERS

WPI powder

Fractal aggregates with different size

Size characterization

Asymmetrical Flow Field-Flow Fractionation (A4F)



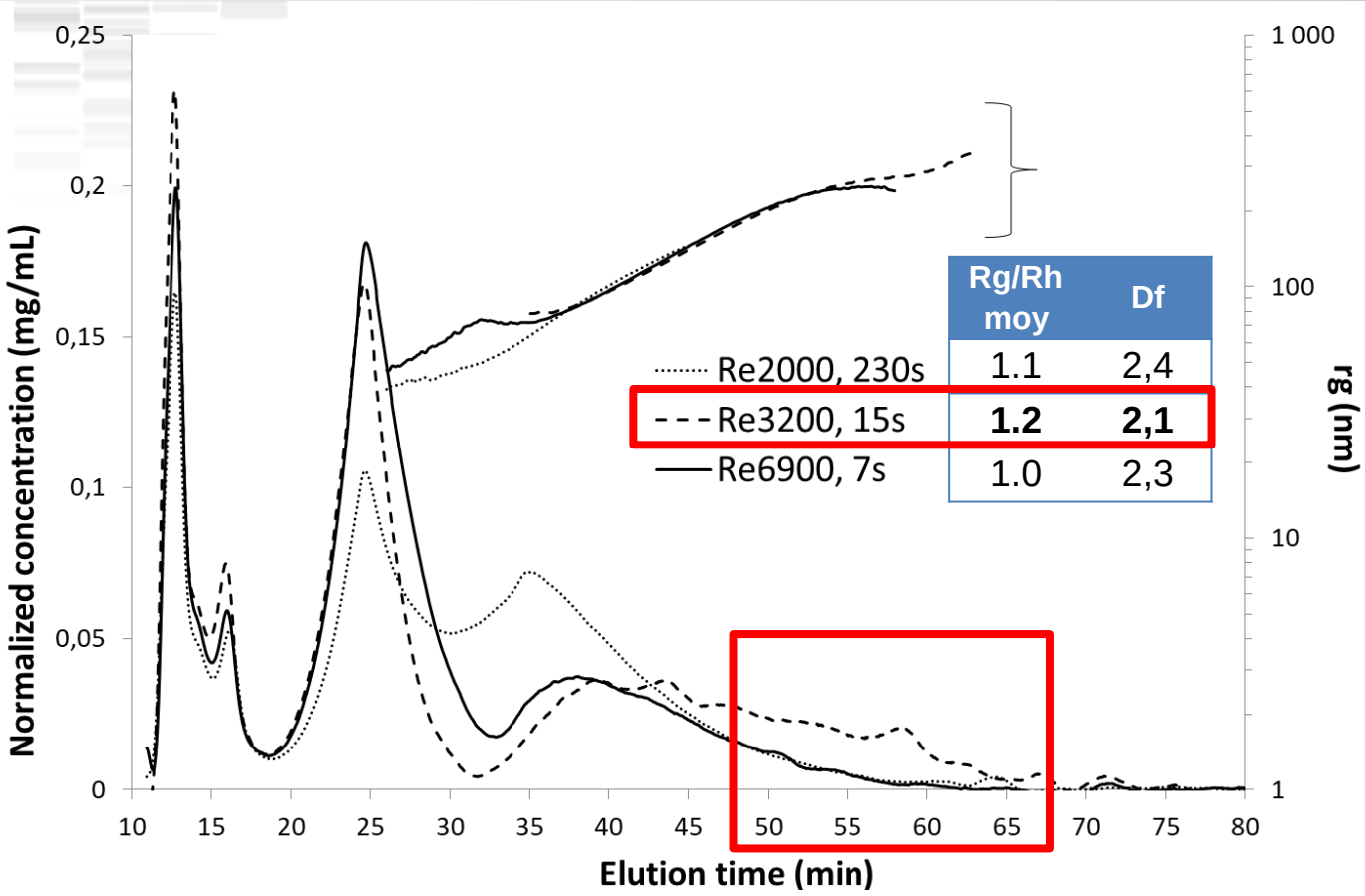
Shape characterization

Shape factor (Rg/Rh)
(0,78 for homogeneous sphere to 2,36 for stiff rod*)

Fractal dimension
(1 for rod to 3 for sphere**)

*Brewer 2011
**Loiseleux 2017

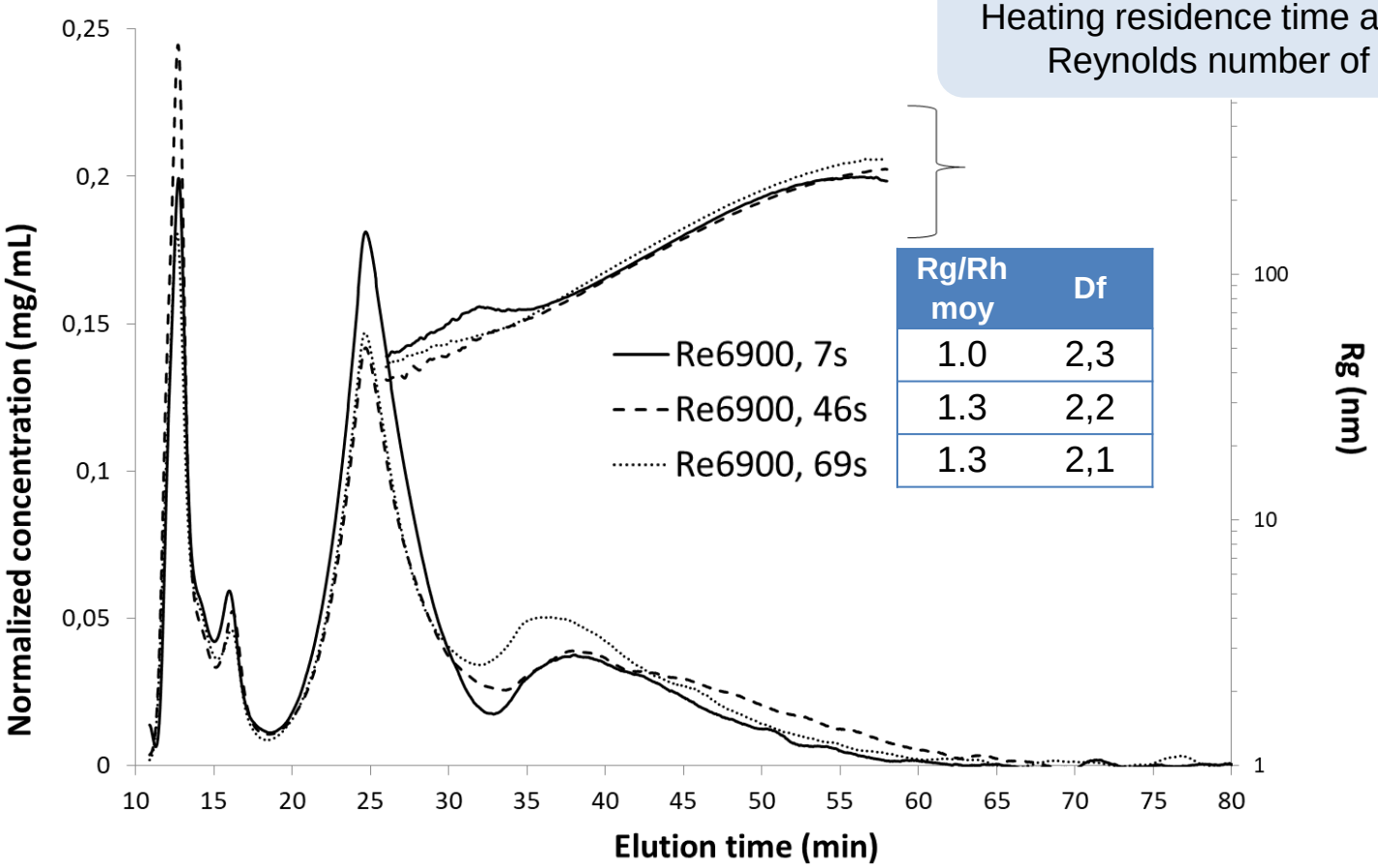
AGGREGATES SHAPE AND SIZE ARE MODIFIED IN INTERMEDIATE FLOW REGIME



A more **opened structure** and an increase of aggregates **size** is obtained in **transient flow regime**

HEATING RESIDENCE TIME HAVE NO IMPACT

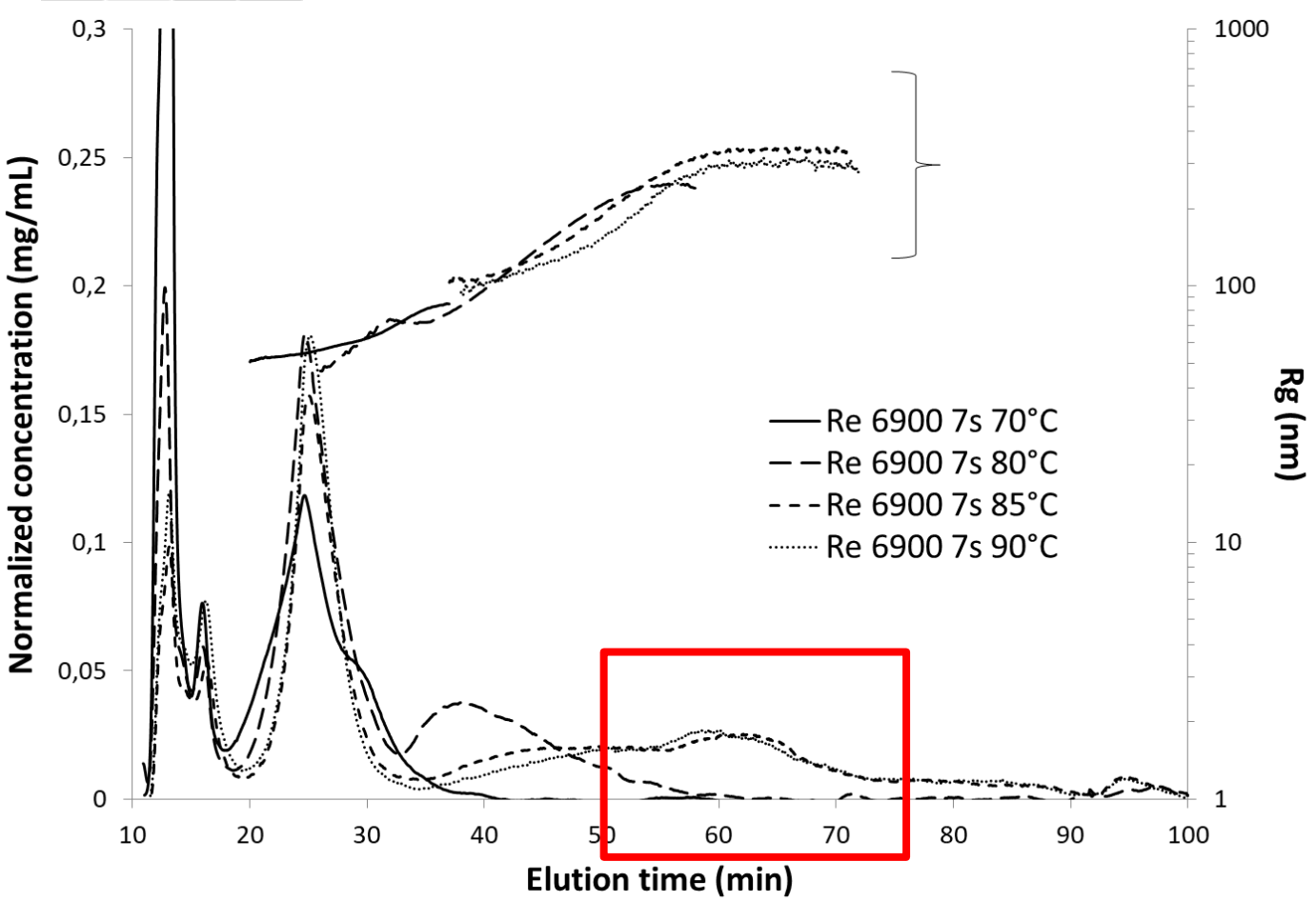
Same conclusions with varying Heating residence time at constant Reynolds number of 2000.



Rg/Rh moy	Df
1.0	2,3
1.3	2,2
1.3	2,1

Heating residence time has no impact on aggregate size compared to f**low regime** in the range investigated.

HEATING TEMPERATURE MAINLY INFLUENCE AGGREGATE SIZE



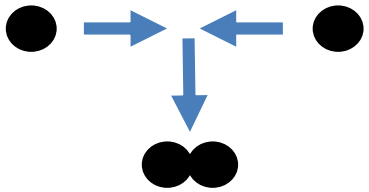
Formation of **larger aggregates** at a temperature **up to 85°C**.

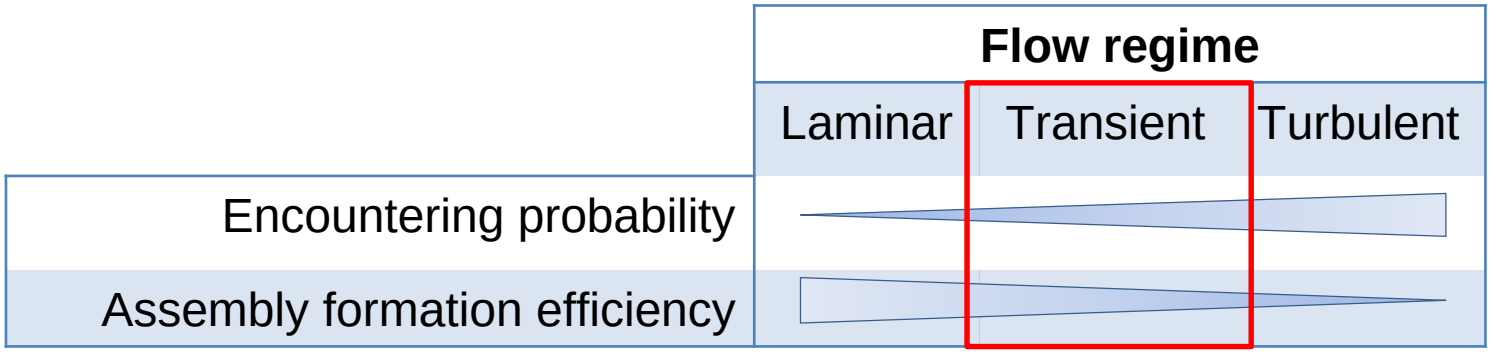
MECHANISMS INVOLVED IN THE FORMATION OF FRACTAL AGGREGATES BY CONTINUOUS PROCESSING

Simmons (2007) : The final size of aggregates depends on particle collision and breakage

Turbulent structure 100 to 400 times > Ag size (kolmogorov scale)

Association mechanism governs the growth of fractal aggregates.
No breakage.

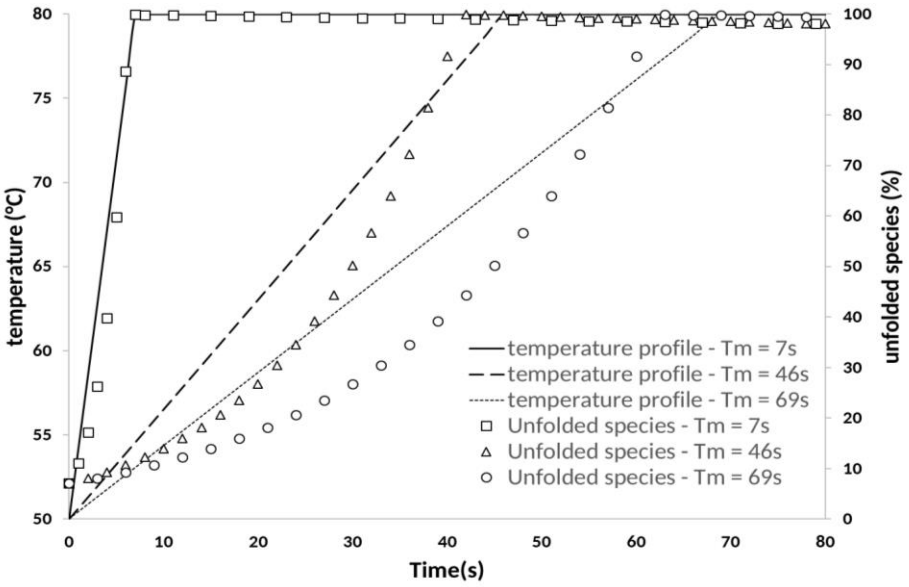


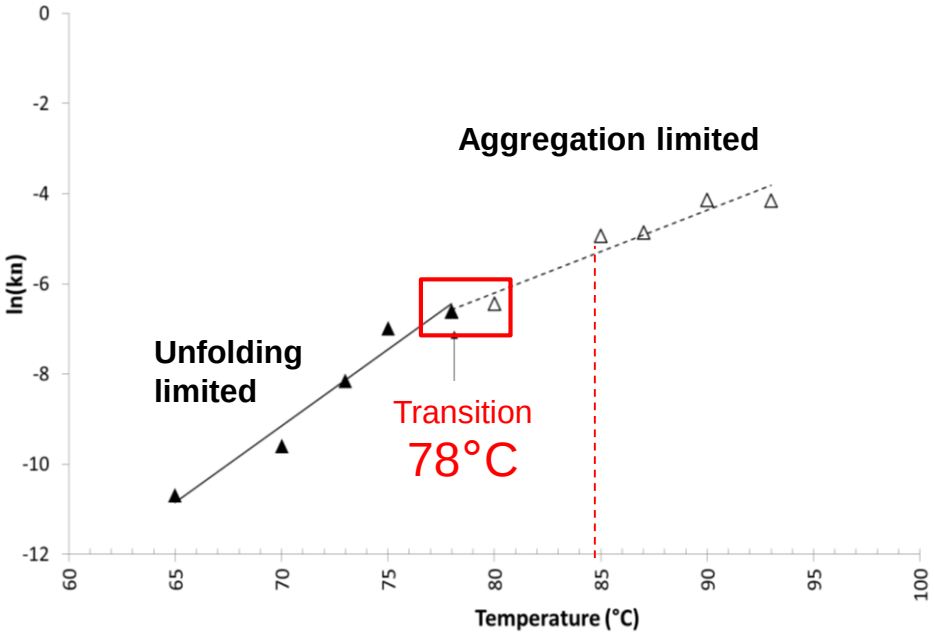


Association mechanism privileged

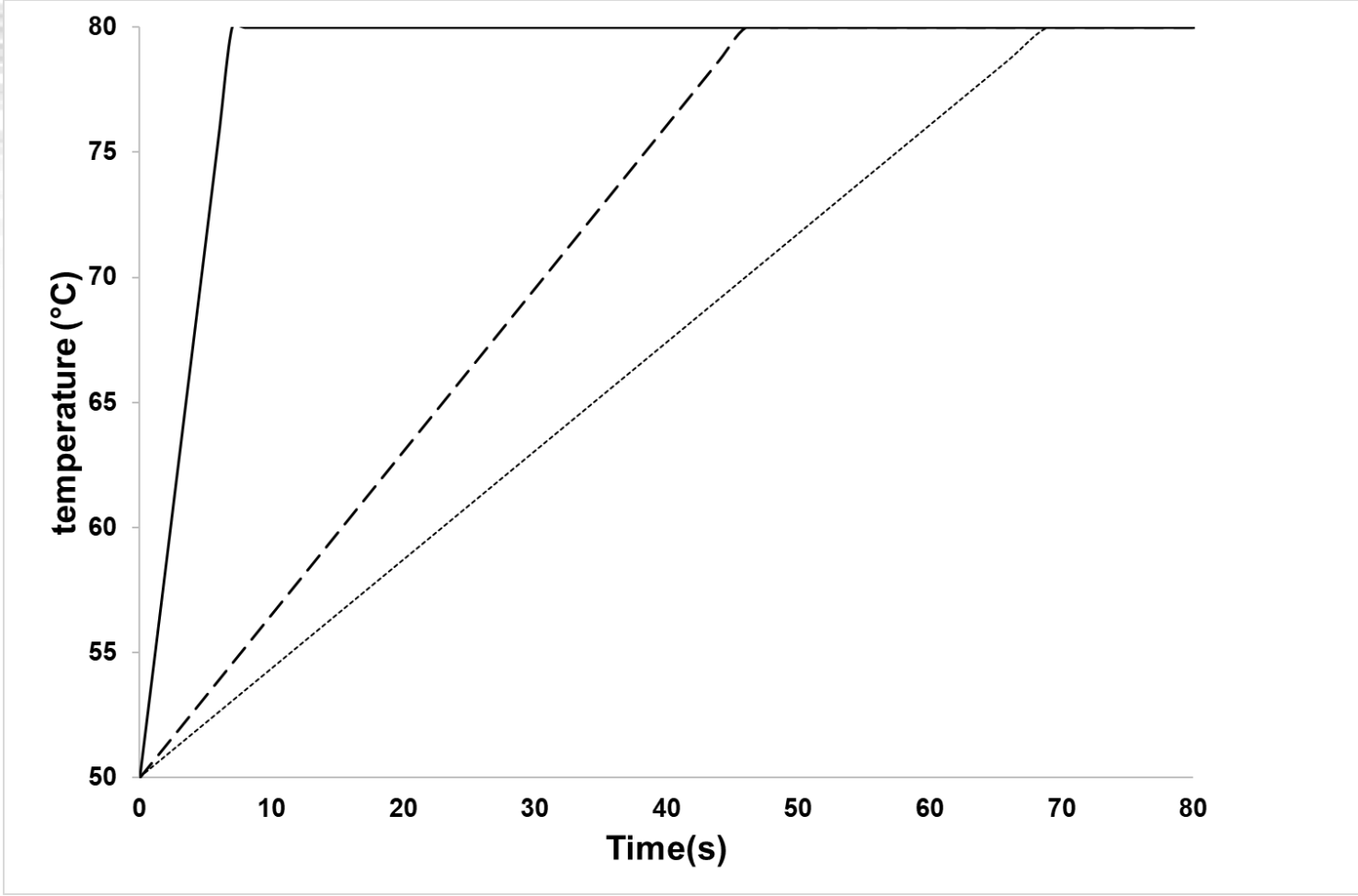
MECHANISMS INVOLVED IN THE FORMATION OF FRACTAL AGGREGATES BY CONTINUOUS PROCESSING

Whatever the heating residence time, **100% of βlg is unfolded** at the exit of the heating zone. No additional reactive material should be expected while **increasing heating residence time**





At 85°C, the unfolding of reactive βlg is instantaneous and non limiting, resulting in the formation of **larger aggregates**.


80
75
70
65
60
55
50
temperature (°C)
0
10
20
30
40
50
60
70
80
Time(s)

CONCLUSIONS

Physicochemical parameters

↓ SCALE UP

Process parameters

Flow regime

Transient regime : ↗ Aggregate size
↗ Structure opening

No breakage

Heating residence time

100 % βlg unfolded at the exit of the heating zone
No impact of heating residence time

Outlet heating temperature

T°≥ 85°C : Unfolding of βlg instanteneous and non limiting
↗ Aggregate size / Apparition of a 4th population

Fractal aggregates size control

Different functional properties

Texture
Heat stability
Emulsion stability

New healthy and more natural products.

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Thank you for your attention

STLO