

#### The specifications for the sustainable-design of thermo-hydro-mechanical paths for the elaboration processes of agglomerated products

Bettina Bellocq, Bernard Cuq, Thierry Ruiz, Agnès Duri-Bechemilh, Guillaume Delaplace, Fabrice Ducept

#### ▶ To cite this version:

Bettina Bellocq, Bernard Cuq, Thierry Ruiz, Agnès Duri-Bechemilh, Guillaume Delaplace, et al.. The specifications for the sustainable-design of thermo-hydro-mechanical paths for the elaboration processes of agglomerated products. 7. International Granulation Workshop, Jul 2015, Sheffield, United Kingdom. 2015. hal-01604549

#### HAL Id: hal-01604549 https://hal.science/hal-01604549

Submitted on 2 Jun2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - ShareAlike 4.0 International License



University Sheffield.

BELLOCQ Bettina<sup>1</sup>, CUQ Bernard<sup>1</sup> RUIZ Thierry<sup>1</sup>, DURI Agnès<sup>1</sup> DELAPLACE Guillaume<sup>2</sup>, DUCEPT Fabrice<sup>3</sup>

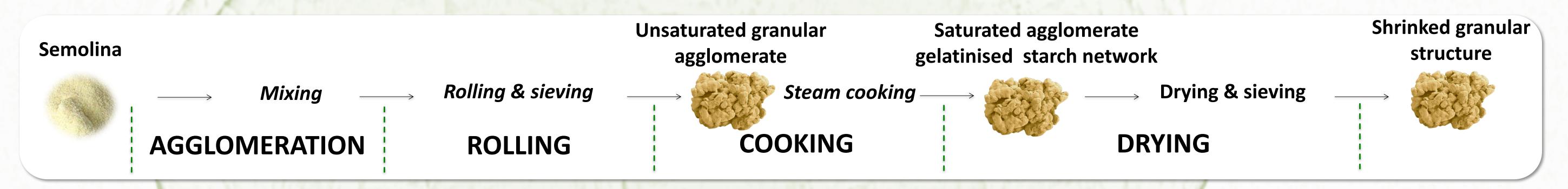
# The specifications for the sustainable-design of thermo-hydro-mechanical paths for the elaboration processes of agglomerated products

UMR 1208 IATE (INRA / SupAgro / University of Montpellier / CIRAD) Montpellier, France <sup>2</sup> U.R. 638 Processus aux Interfaces et Hygiène des Matériaux (INRA) Villeneuve d'Ascq, France <sup>3</sup> UMR 1145 GENIAL (INRA / AgroParisTech) Massy, France



### **Introduction & Objectives**

We improve theoretical foundations to understand the uses of thermo-hydro-mechanical paths of powders reactivity during the process of durum wheat into agglomerated couscous grains. The current industrial process is poorly eco-efficient and energy consuming. There is a need for a multidisciplinary approach including cereal technology, product engineering, soft-matter science and granular matter physics.

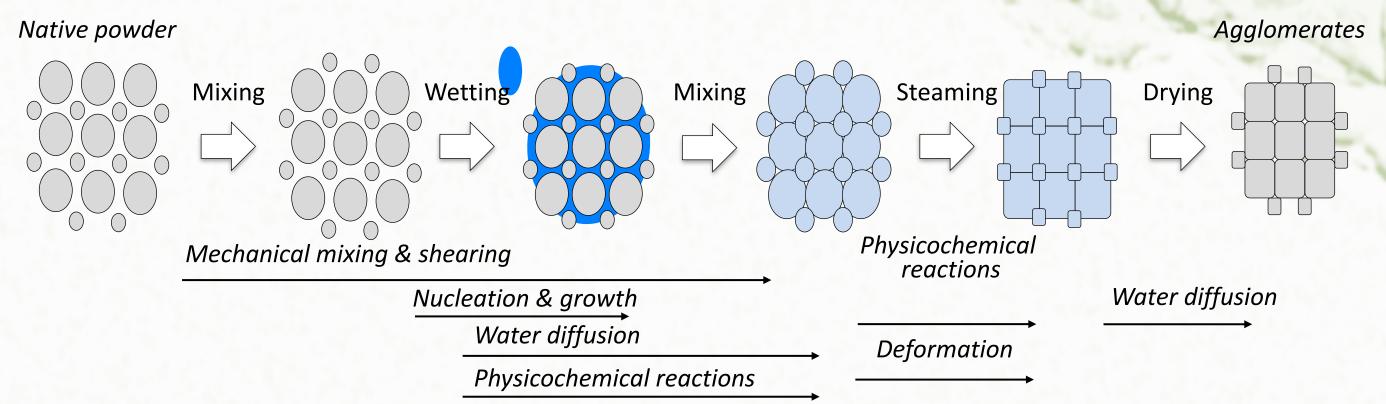


Major aims of this work are:

1. To identify and model the structuration mechanisms developed under thermo-hydro-mechanical stresses. 2. To compare the energy consumption at the process level to the energy needs for local structuring mechanisms. 3. To represent the conceptualization process using dimensionless analysis.

## **1. Mechanistic approach**

The main goal of the mechanistic approach is to determine the specific contribution of the powder reactivity during agglomeration processing. Durum wheat powders undergo reversible and irreversible physicochemical changes when submitted to thermo-hydro-mechanical stresses in relation with its composition.

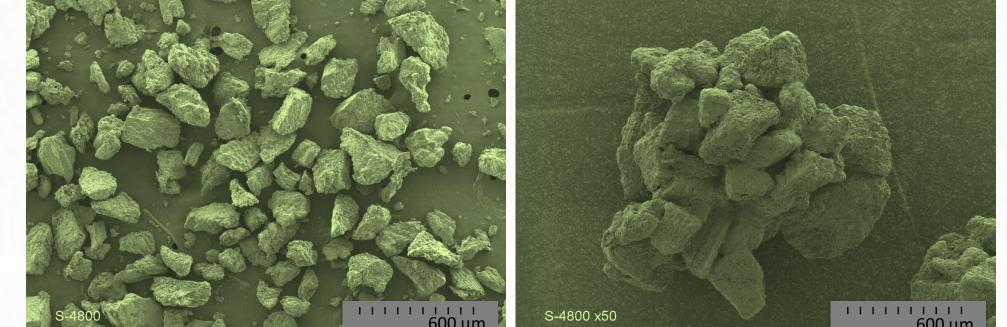


Our objective is to specifically evaluate:

The contribution of physical characteristics of particles to the agglomeration mechanisms.

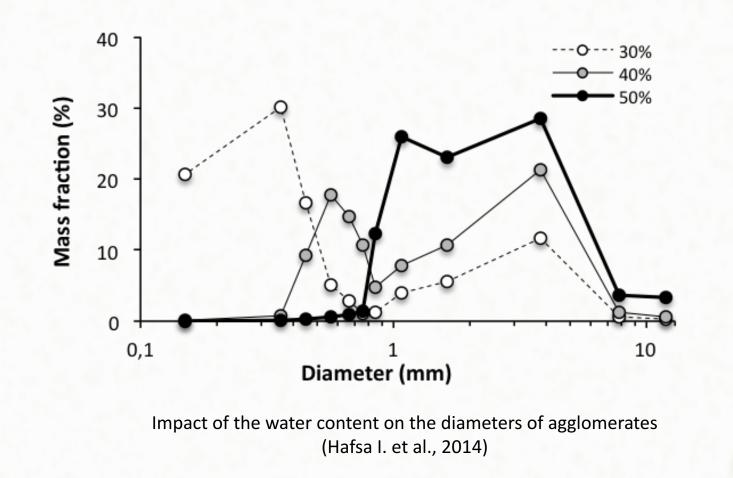
- The contribution of proteins to the irreversible physicochemical mechanisms.

This task leads to the establishment of **specifications** concerning the proteins in durum wheat. This approach will allow to identify the characteristics times and lengths, and estimate the energy requirements, for each physical and physicochemical mechanisms that are induced by the successive stages during processing.

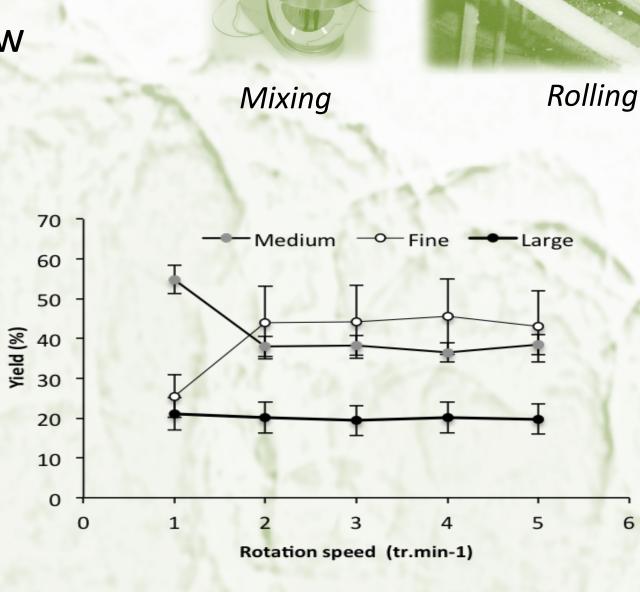


### 2. Twin product/process engineering approach

Our work is focused on morphogenesis and structuring mechanisms, using different technology modes and process conditions. In parallel, we realize measurements of the energy consumptions to estimate the energy cost of the processing of durum wheat semolina in couscous and the impact of the raw material diversity.



- **Technology modes** are selected to generate different hydro-thermo-mechanical stresses during process:
- Mechanical or pneumatic mixing process.
- Rolling with inclined rotating cylinder.
- Different cooking and drying technologies.









Cooking

Drying

**Process conditions** are selected by promoting the mechanisms as successive long-times stages or a simultaneous short-times stages and to investigate the impact of:

> - Shear - Water content - Temperature - Times

Impact of the rotation speed on the yield of different fractions of agglomerates

This approach, associated with experiments at different scales and with different pilot designs and combined with dimensional analysis, will conduct to generate specifications for the couscous process re-design.

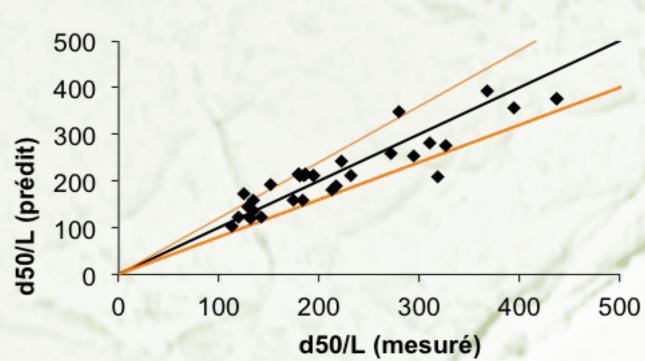
### **3. Knowledge integration approach**

Knowledge integration approach, based on conceptualization approaches, allows the elaboration of functional diagrams using dimensionless criteria. **Dimensional Analysis** (DA) is a way to allow the decomposition of the whole couscous process in a "relevant number base" (dimensionless numbers), involving many complex mechanisms.

Dimensional		Fundamental quantities		
variables	Symbol	М	L	Т
Lenght of cylinder	L	0	1	0
Acceleration of gravity	g	0	1	-2
Diameter of cylinder	D	0	1	0
Angle of cylinder	α	0	0	0
Rotation number	Ν	0	0	-1
Input Agglomerates flow rate	$D_b$	1	0	-1
Input Agglomerates density	$ ho_p$	1	-3	0
Input Agglomerates median diameter	d <sub>p</sub>	0	1	0
Outlet agglomerates median diameter	d <sub>50</sub>	0	1	0

Example of a dimensional matrix on an inclined rotating cylinder

The approach is to initially list the influential variables to create a dimensional matrix. The dimensional matrix allows to express the relationship linking process the target parameter to the key process parameters. The target parameters are chosen from the physicochemical properties of the final agglomerated powder.



The diagonalization of the matrix allows to define the coefficients of the dimensionless numbers and the final model. The target parameter be mathematically values can described by the product of exponential and powers laws.

Model example to predict the water drop size obtained from different nozzles (Mandato S. et al., 2012)

Acknowledgments: The authors would like to thank the Agence Nationale de la Recherche (ANR) for its financial support through the scientific program "Dur-Dur".