



Les procédés d'agglomération par sollicitations mécaniques. Application à la structuration de la semoule de blé dur pour la fabrication du couscous

Bettina Bellocq, Bernard Cuq, Agnès Duri-Bechemilh, Thierry Ruiz

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LES PROCÉDÉS D'AGGLOMÉRATION PAR SOLLICITATIONS MECANIQUES.

*APPLICATION A LA STRUCTURATION DE LA SEMOULE DE BLÉ DUR POUR LA
FABRICATION DU COUSCOUS.*

Bettina Bellocq

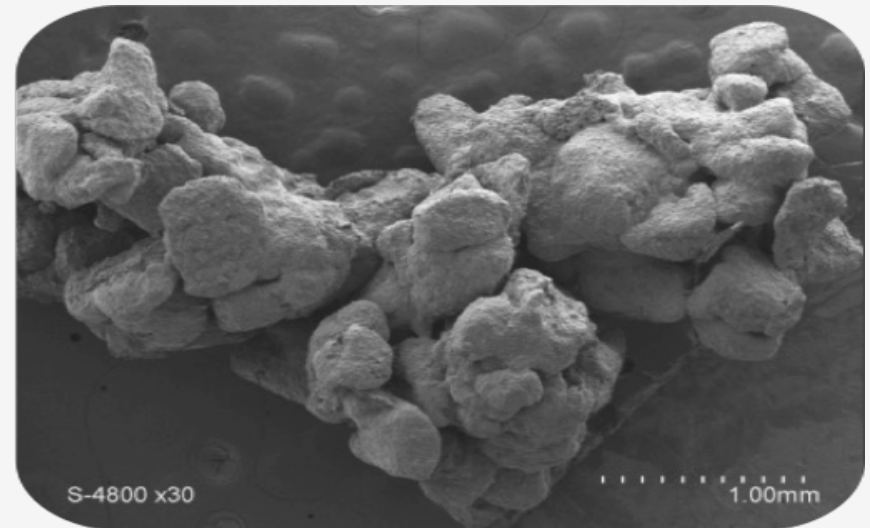
Under the supervision of:

Pr. Bernard CUQ, Dr. Thierry RUIZ and Dr. Agnès DURI

UMR IATE – INRA Montpellier – France

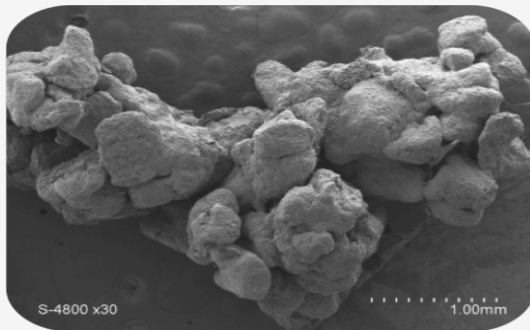
**16^{ème} Congrès de la Société Française de Génie des
Procédés**

Nancy – 12 Juillet 2017





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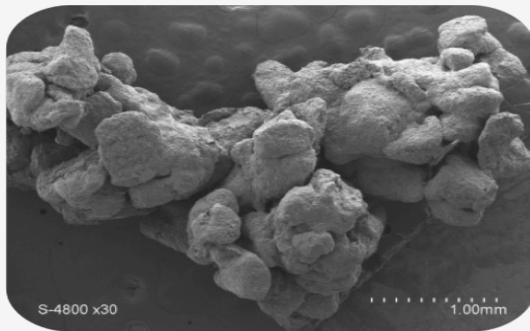
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1.1. WET AGGLOMERATION OF FOOD POWDERS

Agglomeration is largely used to **improve** the powders **properties** and **behaviour**:

- *Reduction in dust production.*
- *Enhancement in flowability.*
- *Increase in bulk density.*
- *Reduction in segregation.*

During the agglomeration process...
...the **native small particles** are gathered to form **larger assemblies** with specific **porous structures**, called the **agglomerates**.



Agglomerated food powders

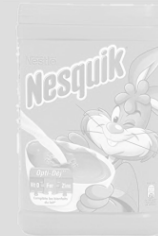
- *Cocoa beverage powders*
- *Instant soluble coffee*
- *Culinary powders*
- *Flavors powders*
- *Protein powders*
- *Infant formulas*
- *Couscous grains*
- *Dairy powders*
- *Milk powders*
- *Bakery mixes*
- *Starch*

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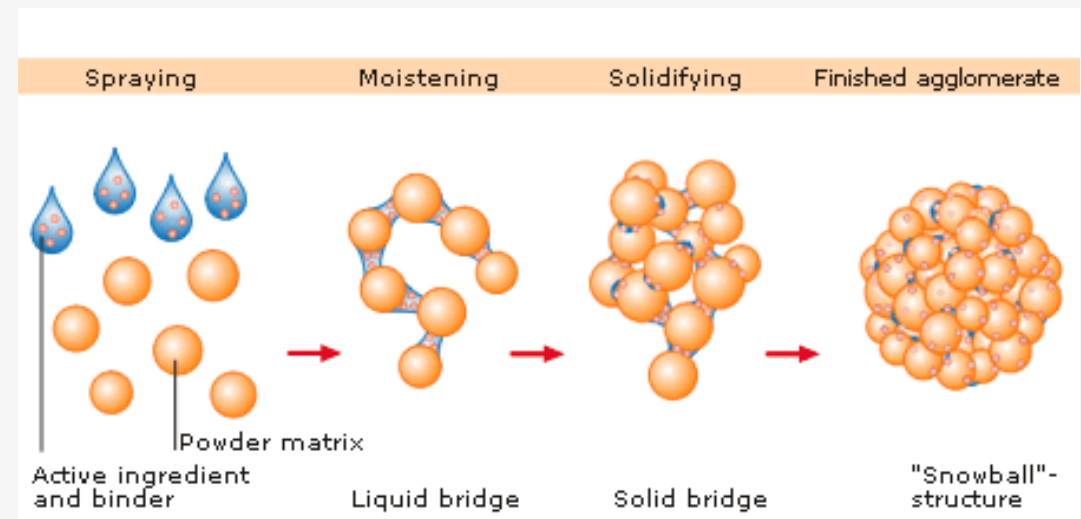
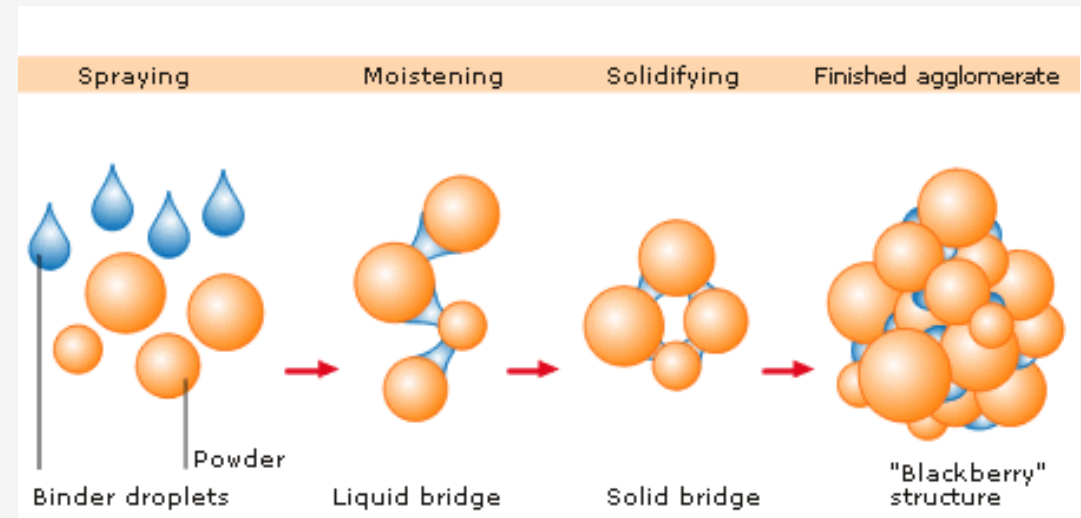
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1.2. WET AGGLOMERATION - PROCESS

During the agglomeration process, a **liquid binder (water)** is **sprayed** over an **agitated powder bed**.

It generates **attractive interactions** and **links** between the native particles and...

... Promotes the **spatial arrangement of the native particles** with the binder.



<http://www.cjtech.co.kr/Process%20Principles%20Agglomeration%20Granulation.htm>

1.2. WET AGGLOMERATION - PROCESS

Different technologies have been used for wet agglomeration processes. They can be classified in **two categories according to the type of the mixing energy**.

The **pneumatic mixing granulators** (e.g. steam jet, spray drying, or fluid bed) use **air steam to agitate** the particles under low shear conditions.



Ex. Fluidized bed

The **mixing granulators** (e.g. mechanical mixer, pan, disk, or drum granulators) use **mechanical system** to agitate the particles.

Ex. Planetary mixer



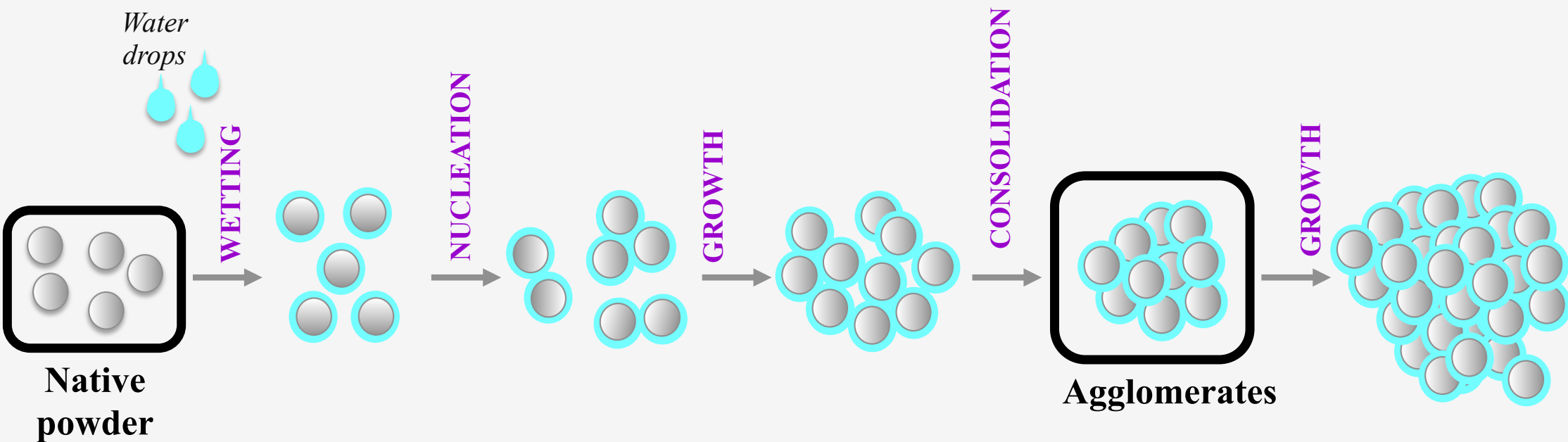
The **variability of the raw materials** associated with the **differences between different apparatus** induce a high degree of **complexity in the process**.

1.3. WET AGGLOMERATION - MECHANISMS

Wet agglomeration process is classically described as a combination of successive mechanisms at different rates :

- **Wetting and nucleation.**
- **Growth and consolidation.**
- *Breakage, erosion, rupture*

The **cohesion forces** generate **interactions** between particles, and promote granules **growth**.

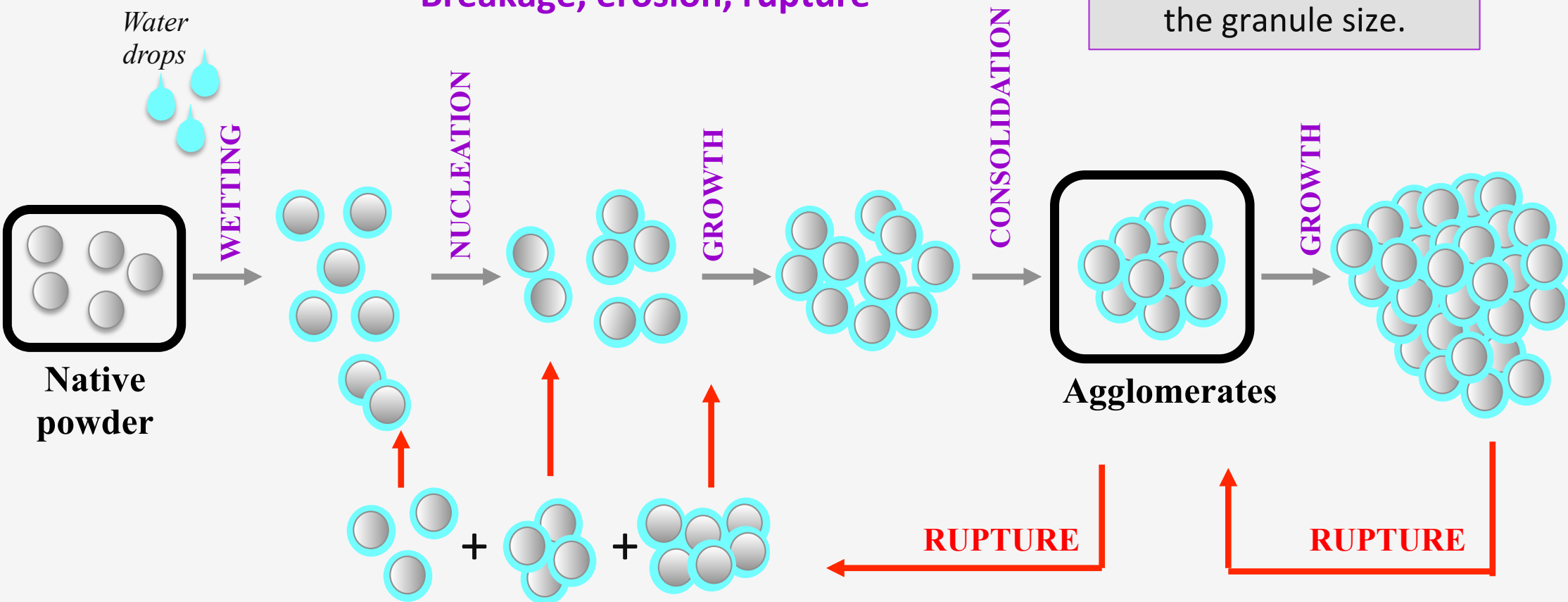


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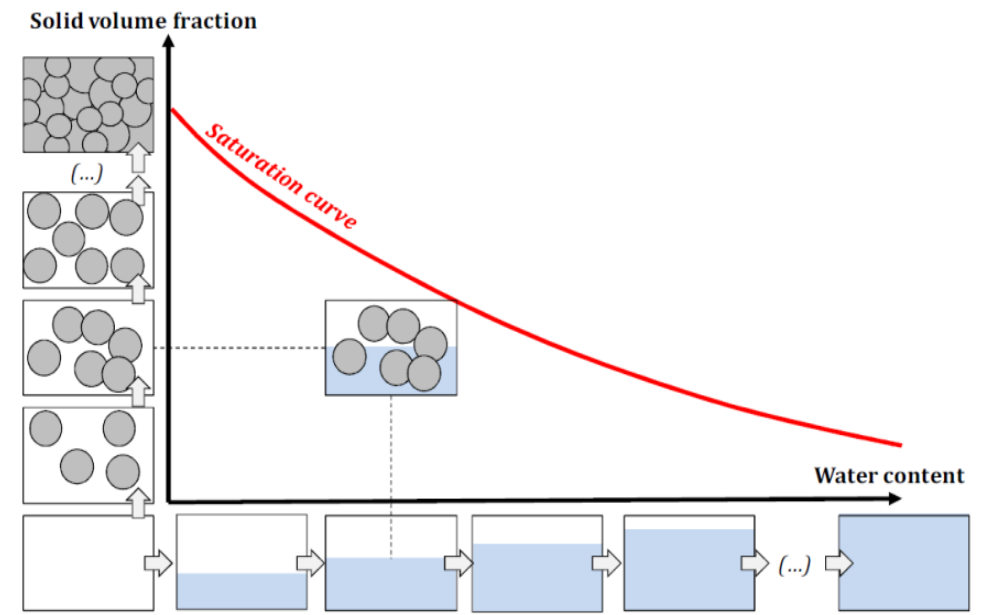
The **rupture forces** and **shearing** effects, lead to **breakage** and to reduce the granule size.



The wet agglomeration process is a **balance** between **growth** and **breakage**

1.4. HYDROTEXTURAL APPROACH

Hydrotextural approach is used to describe **agglomeration mechanisms** based on changes in **compactness** and **diameter** of the agglomerates as a function to the **water content**.

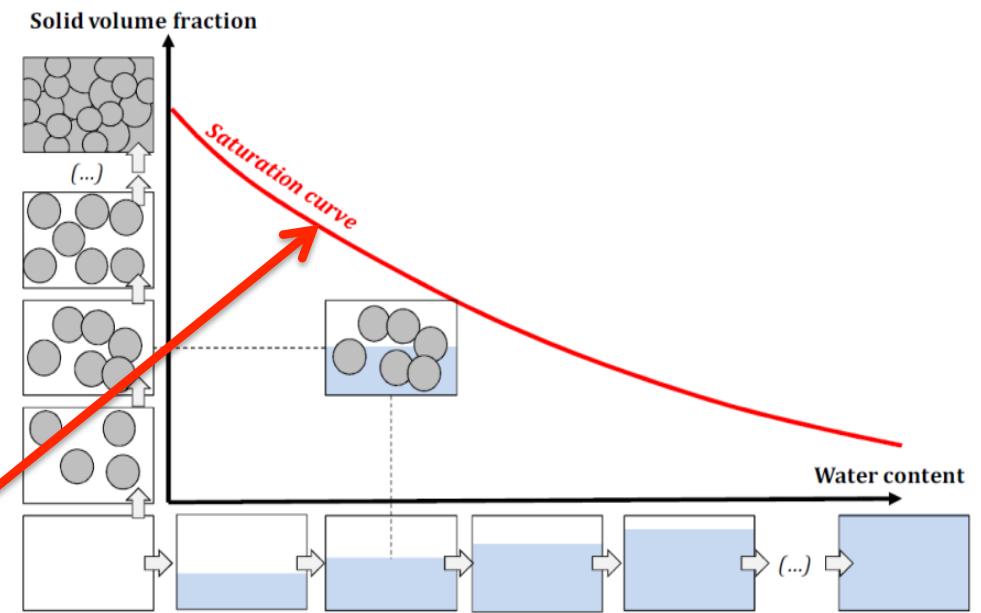


Schema of the hydrotextural diagram (Ruiz et al., 2005)

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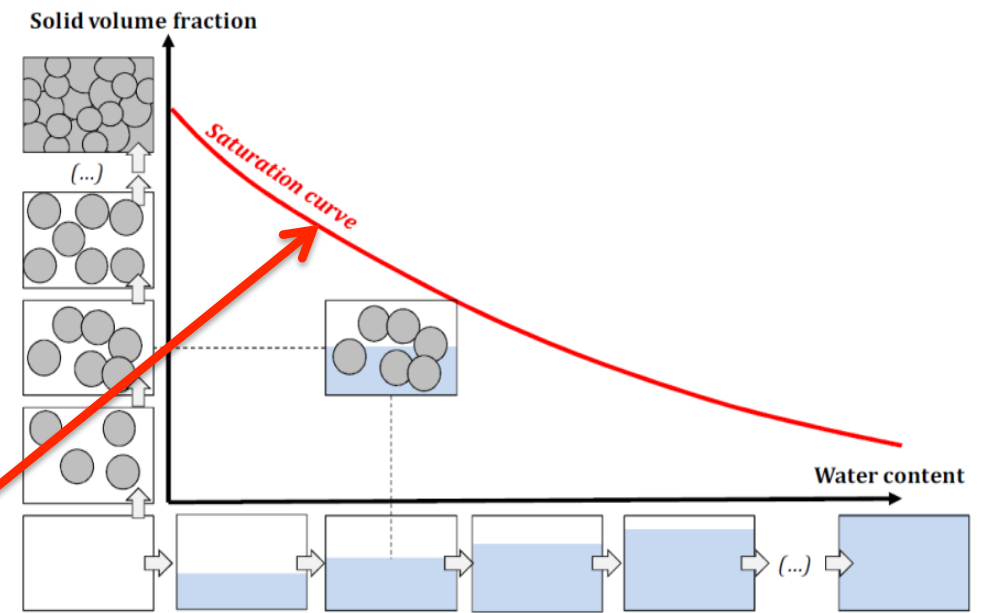


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Schema of the hydrotextural diagram (Ruiz et al., 2005)

Agglomerates were analysed by measuring :

Size

Water content

Compactness

Saturation degree

= Median diameter

= *Mass of water / Mass of dry product*

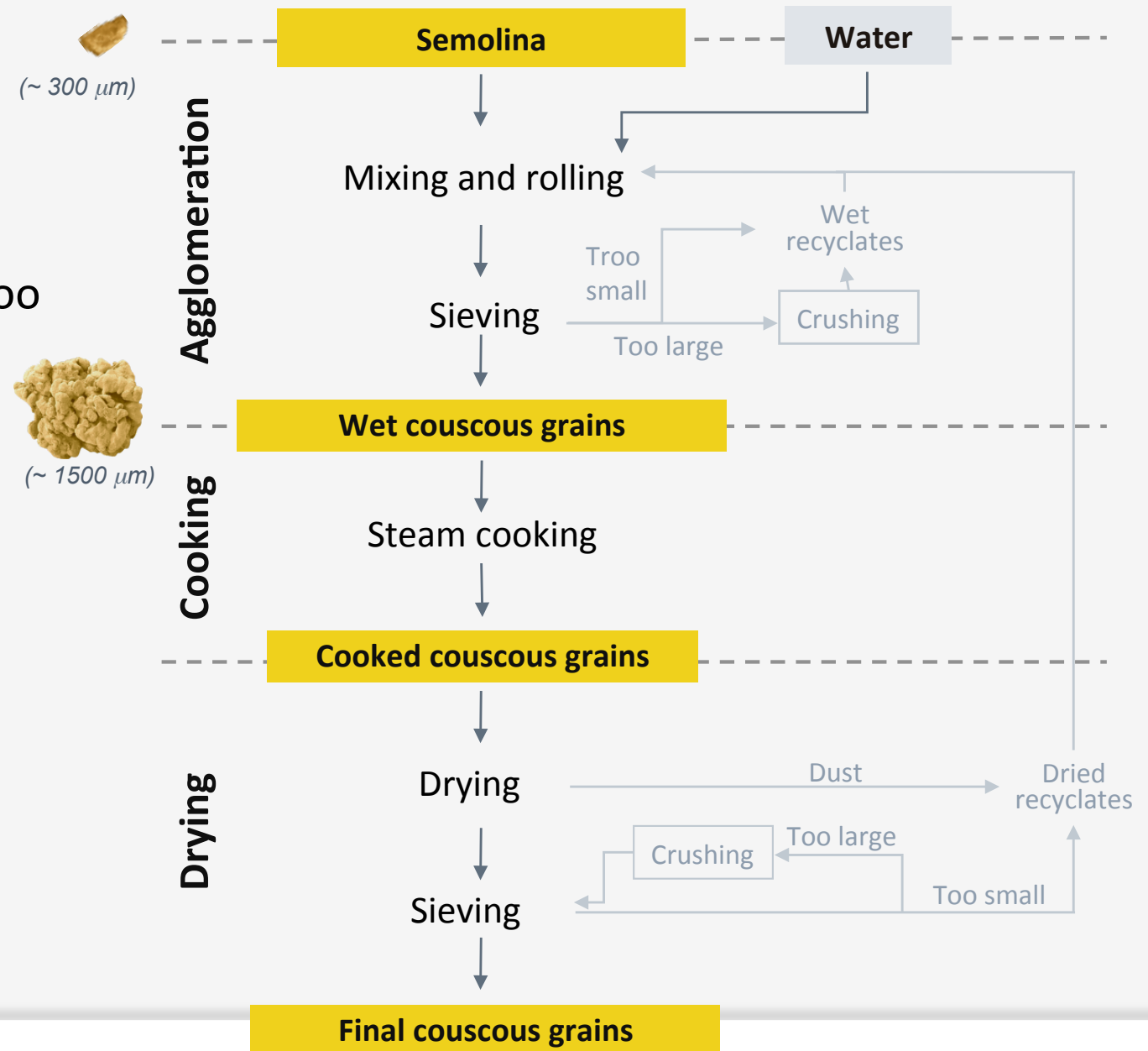
= *Volume of solid / Total Volume*

= *Volume of liquid / Volume of void*

1.5. CASE OF THE COUSCOUS GRAINS

- 3 unit operations.

- Polydispersity of the size cause a high ratio of out of scope (too large >2 mm, or too small <1 mm).

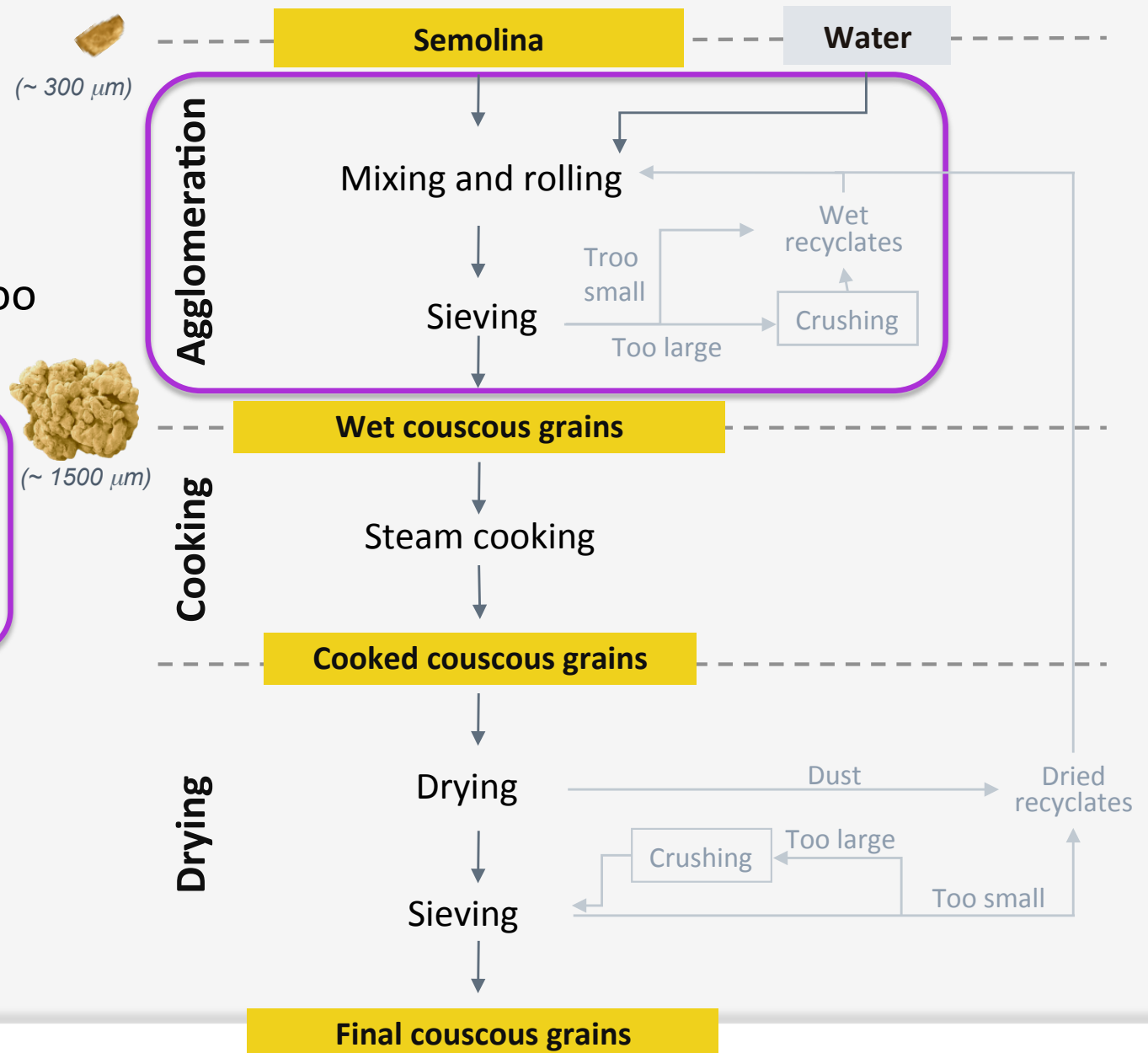


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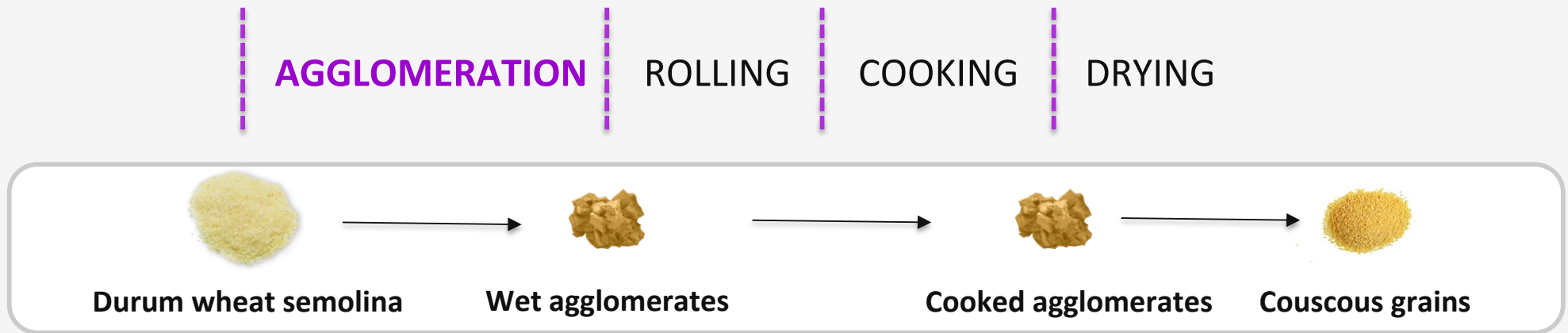
- 3 unit operations.

- Polydispersity of the size cause a high ratio of out of scope (too large >2 mm, or too small <1 mm).

- Agglomeration is a key unit operation to control the size of the couscous grains.



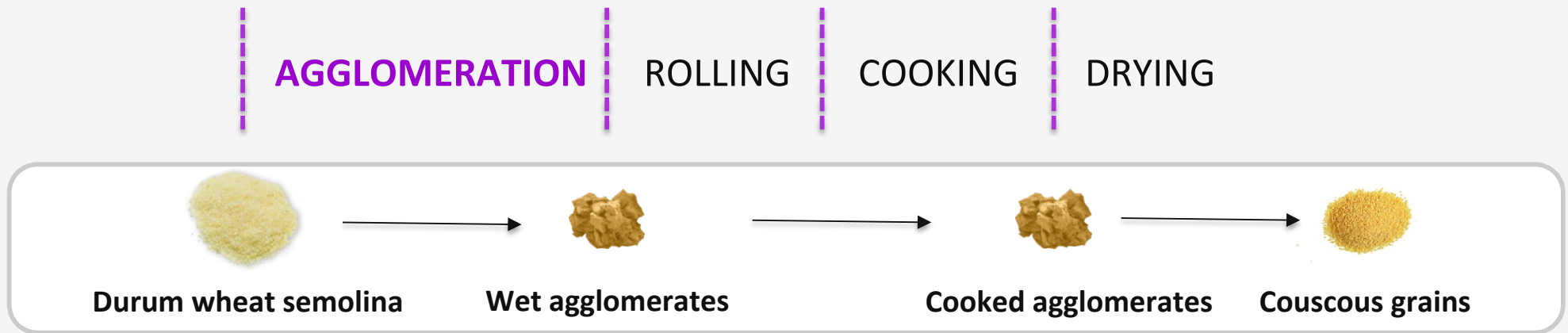
1.6. OBJECTIVES



Our objectives were:

- To **describe the agglomeration** by analysing experimental investigations.
- To understand how **the process** impact the agglomeration.
- To understand how **the raw material (diameter and protein)** impact the agglomeration.

1.6. OBJECTIVES

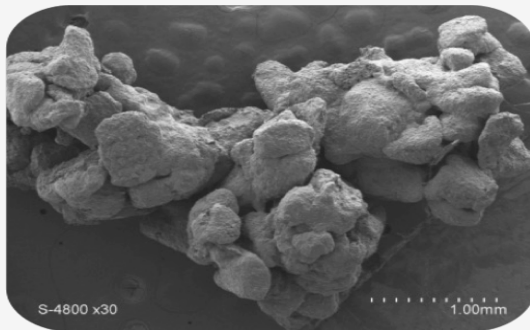


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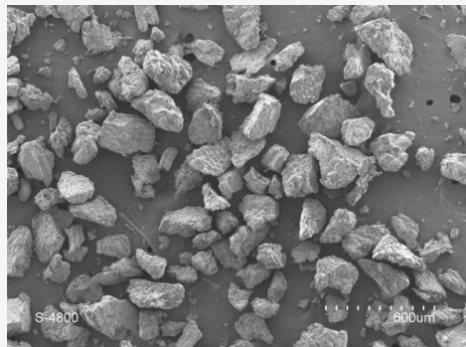
2.1. RAW MATERIAL

Wheat powder (**durum wheat semolina**)

- **Large** particles ($d_{50} = 287 \mu\text{m}$) with **distribution** of diameters.
- **Dense** native particles (not porous).

Biochemical composition : **starch** (85%), **proteins** (12%), **fibres** (2%), and **lipids** (1%).

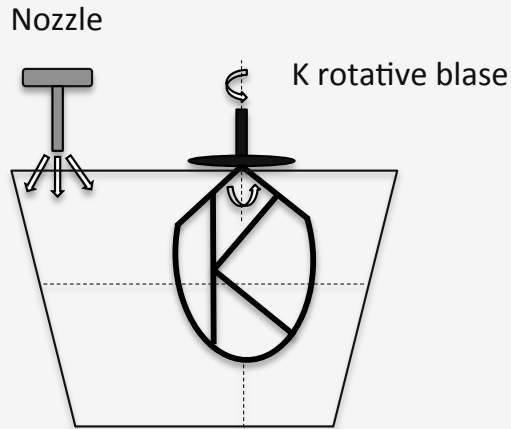
- Components are **partly soluble**.



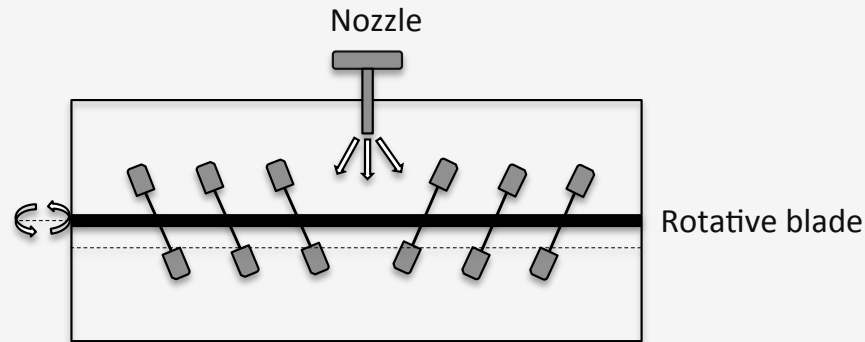
Durum wheat semolina

Characteristics	Values	Method
Water content (%)	16.4 (± 0.5)	Method 44-15A AACC
Protein content (%)	12.4 (± 0.4)	Method 050 (AFNOR)
Particle size median diameter (μm)	287 (± 8)	Laser granulometry
Particle size span (-)	1.56 (± 0.17)	Laser granulometry
True density (g/cm^3)	1.478 (± 0.005)	Helium pycnometry
Plastic limit (%)	59 (± 1)	Atterberg tests
Liquid limit (%)	76 (± 2)	Atterberg tests

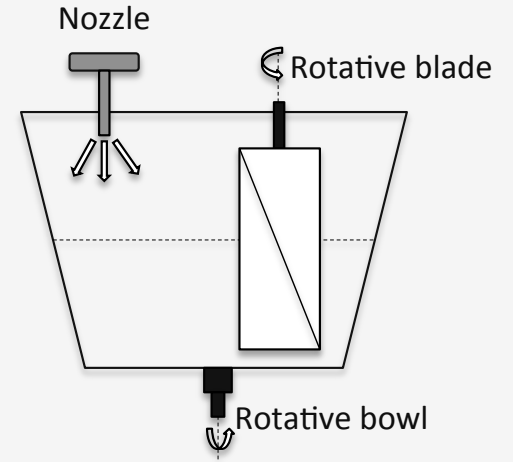
2.2. MECHANICAL MIXERS



Planetary mixer



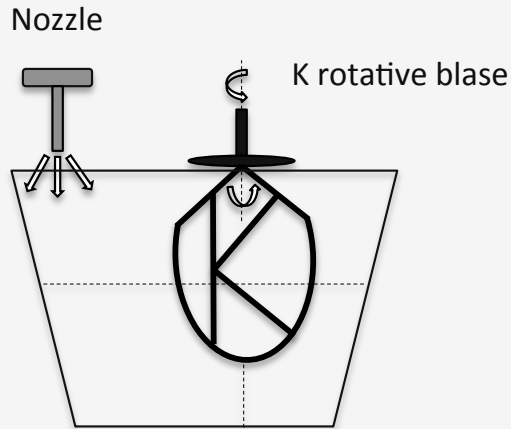
Horizontal mixer



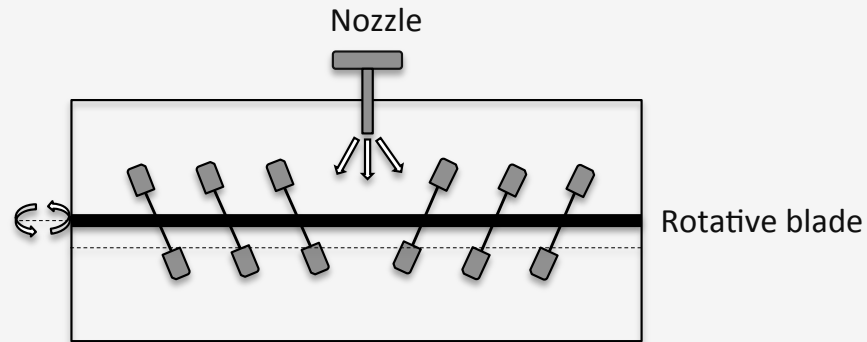
Vertical mixer

Mixers	Speed (rpm)	Froude number (-)	Water content (-)	Mixing time (min)
Planetary	70 - 180	0.03 - 0.16	0.33 - 0.38 - 0.45	0 - 5 - 15
Horizontal	114 - 228	0.02 - 0.05	0.39 - 0.42 - 0.49	0 - 5 - 15
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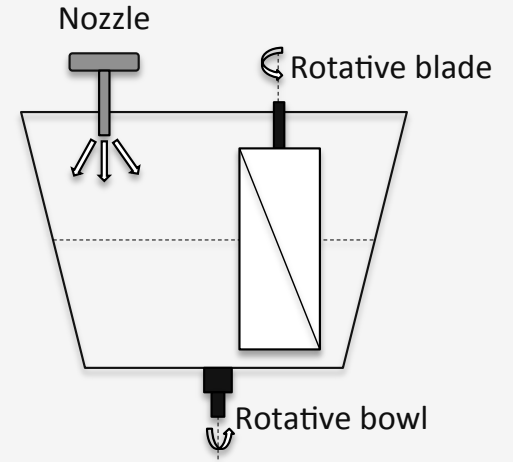
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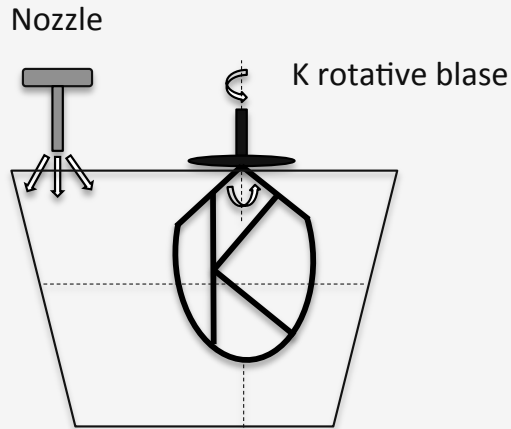
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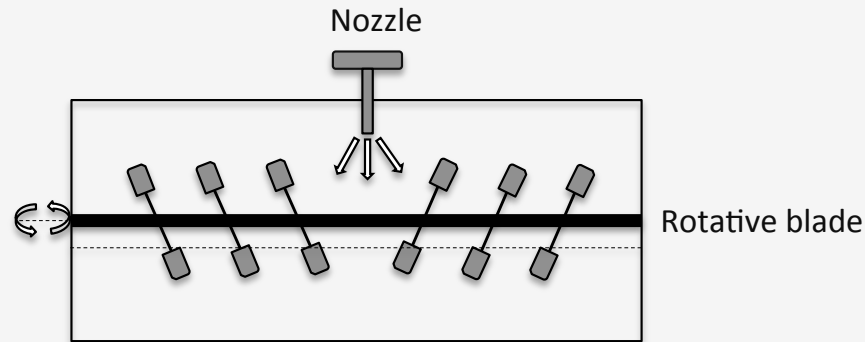
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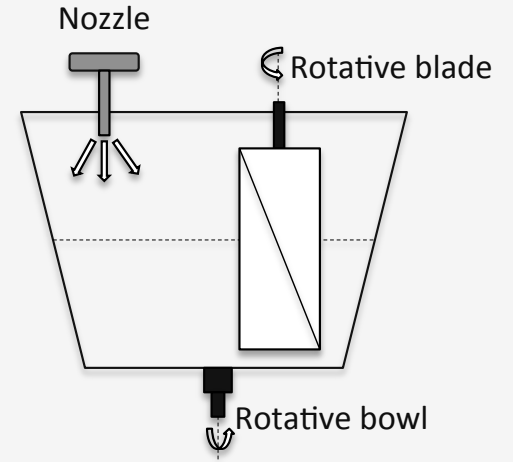
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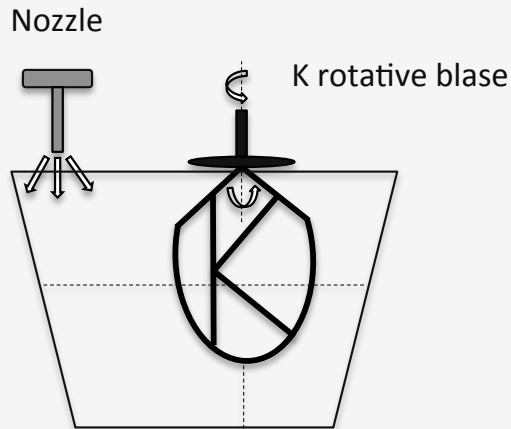
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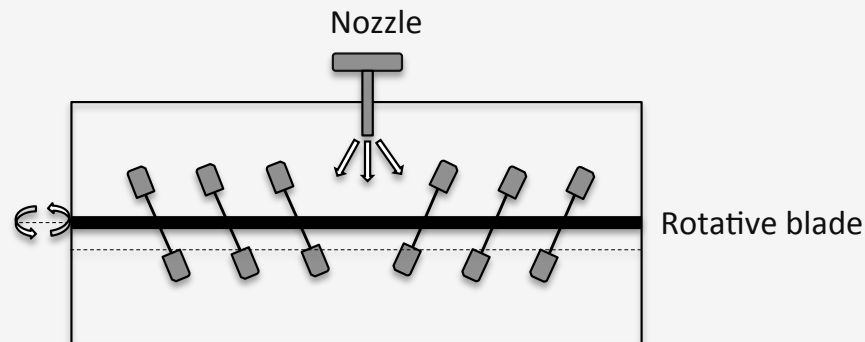
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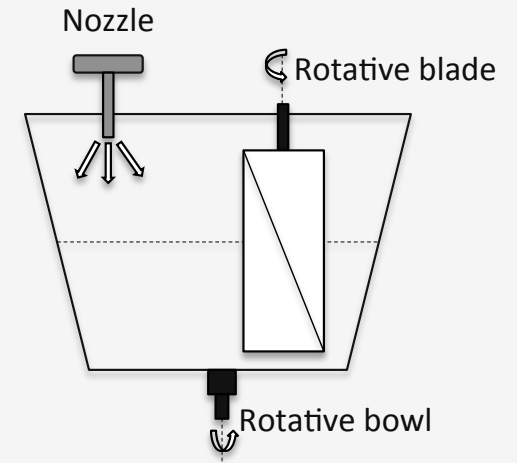
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2.3. WET GRANULATION PROCESS



Power consumption by the mixer arm during the process.



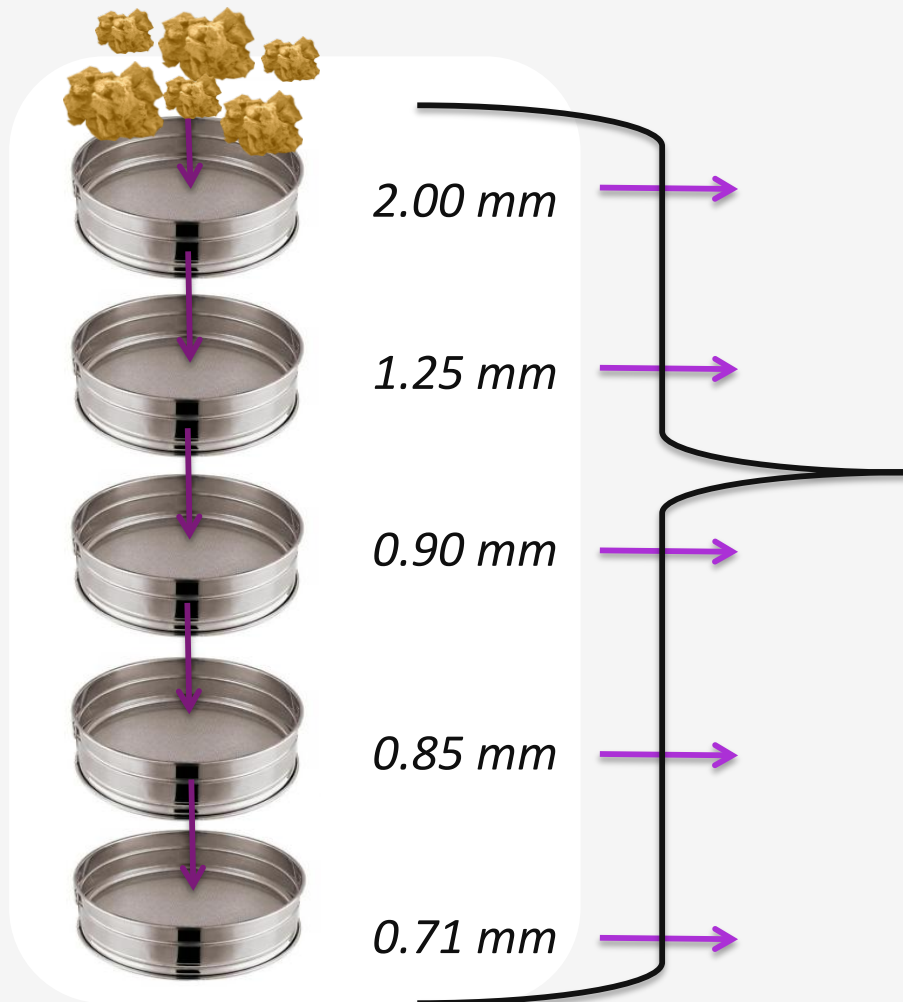
Water added manually or using a water **spraying nozzle** with a **constant flow rate** (2 g/sec).



Final mass close to 50% of the capacity of the mixer.

2.4. AGGLOMERATES CHARACTERISTICS

To **describe the agglomeration mechanisms** and the product characteristics, we evaluated the **size distribution** and the **agglomerates characteristics on each sieve**.



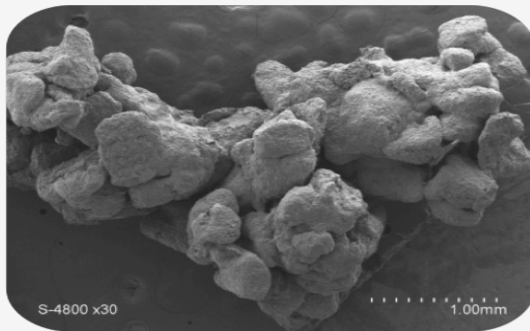
Size distribution *by sieving: d50, span, yield per sieves.*

Distribution of water content *by weighing after oven drying at 105°C for 24h.*

Distribution of compactness *hydrostatic balance (Precisa serie 321 LX 120+ density kit).*



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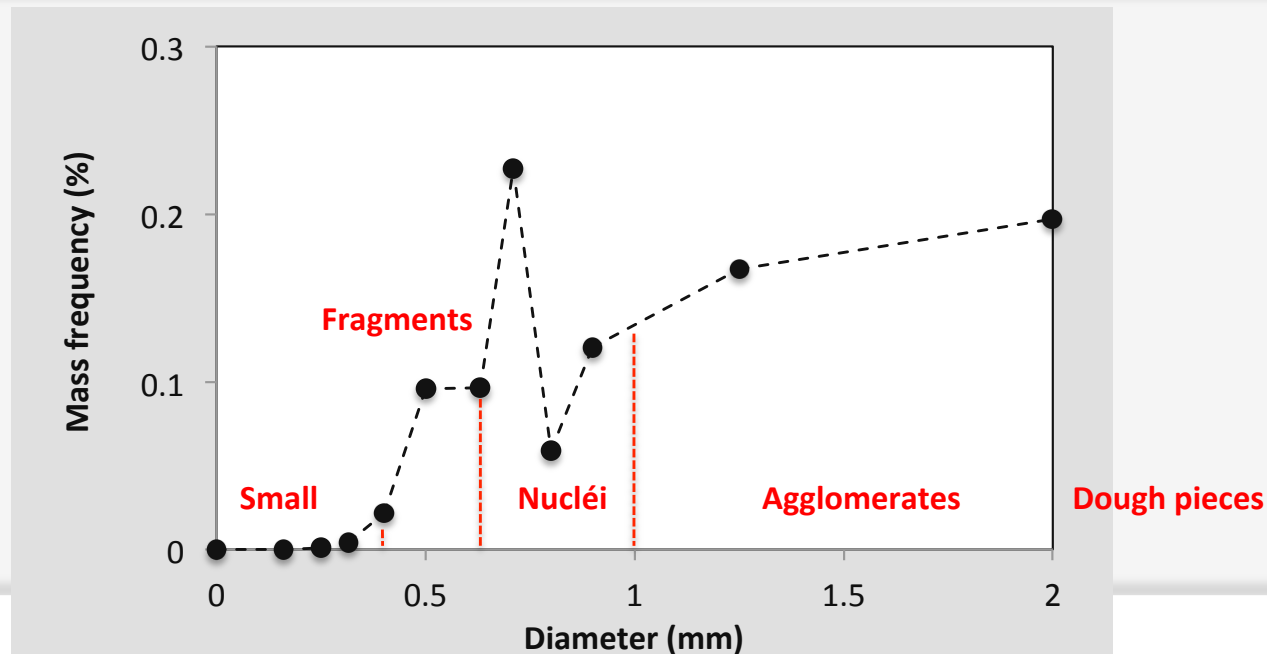
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3.1. DESCRIPTION OF THE GRANULATION

Large dispersion in size was observed. Specific shape and hydrotextural characteristics allow distinguishing **5 types of structures** according to their diameter:

- **Small** (0.3 – 0.5 mm) = native particles of semolina
- **Fragments** (0.5 – 0.6 mm) = mechanical erosion of larger structures
- **Nuclei** (0.6 – 1.0 mm) = primary association of semolina particles
- **Agglomerates** (1.0 – 2.0 mm) = association of fragments and/or nuclei
- **Dough pieces** (>2.0 mm) = association of agglomerates which passes the percolation state



3.1. DESCRIPTION OF THE GRANULATION

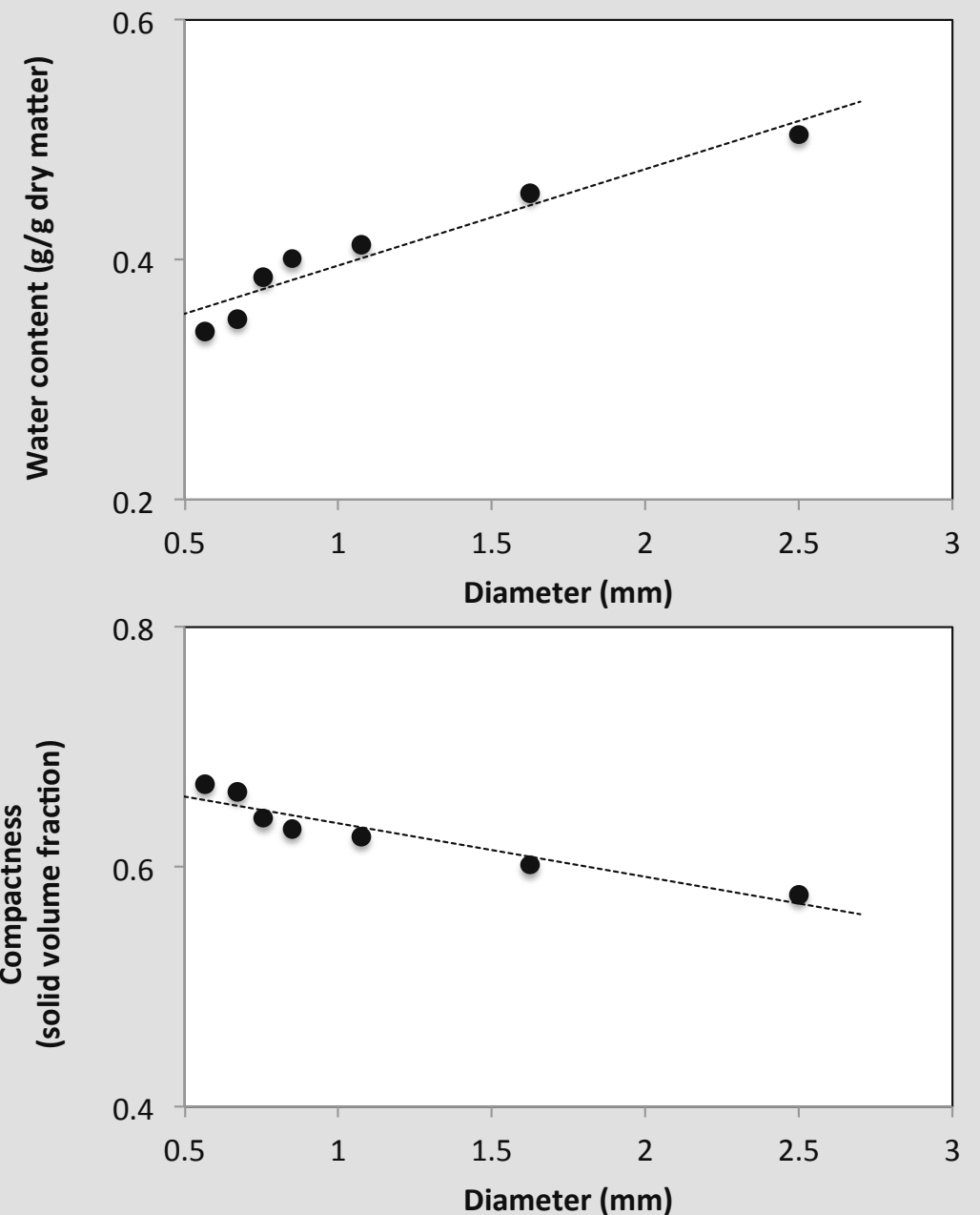
Agglomeration growth of semolina to produce couscous grains leads to:

- **Increasing water content**
- **Decreasing compactness**

according to an **increase in the median diameter** of the structures.

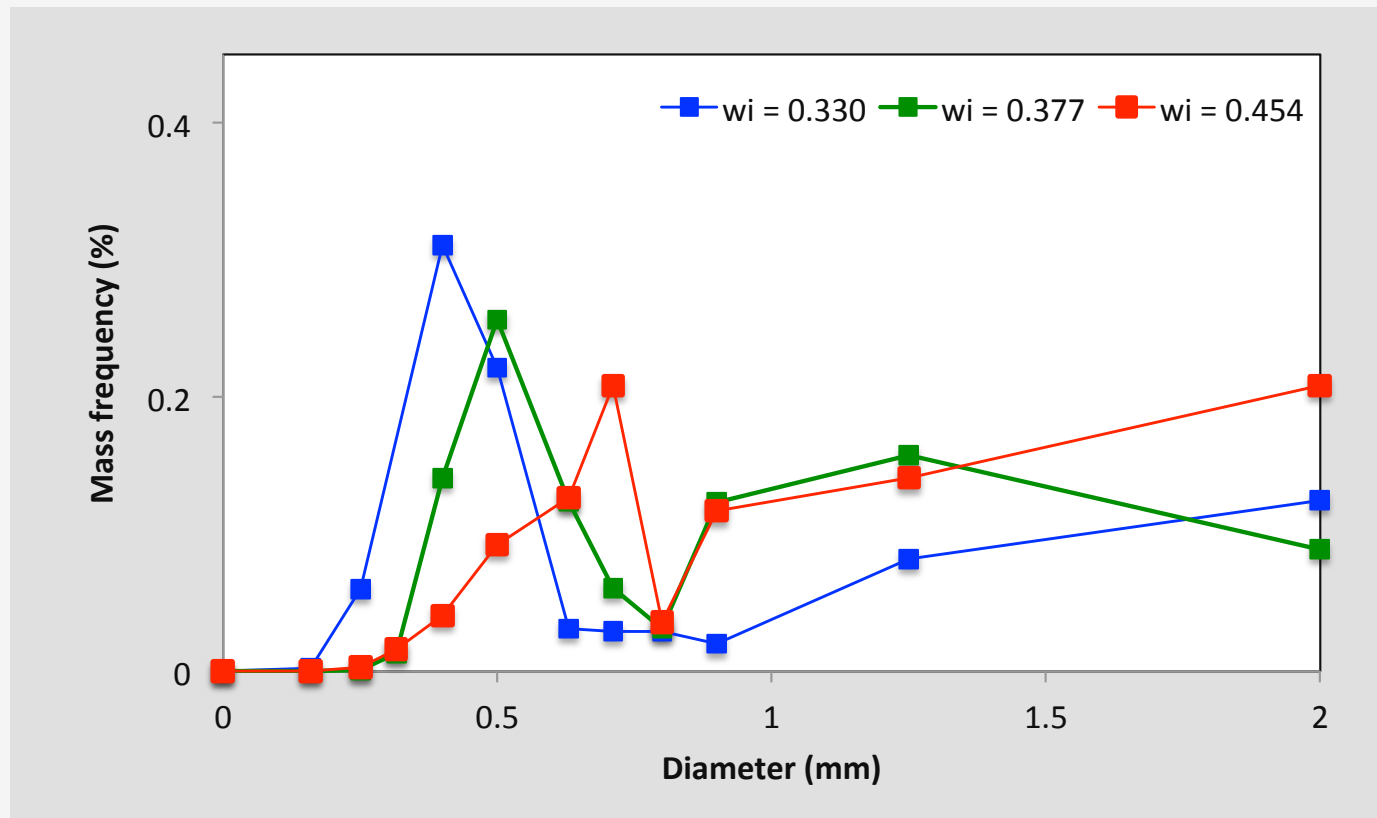
Evolution of the size distribution of the agglomerated structures with water content and compactness shows:

- A **continuous growth** process associated with the expansion of their internal structure.
- A **fragmentation** of the dough pieces.



3.2. IMPACT OF THE WATER CONTENT

Polydispersity of the size. **5 structures** with specific characteristics of size, compactness and water content.

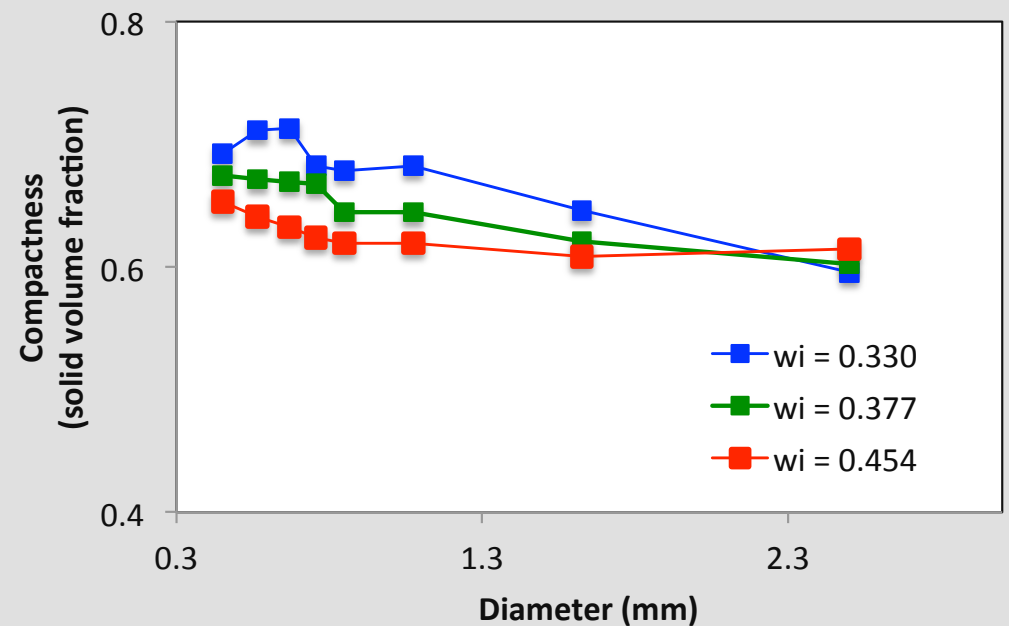
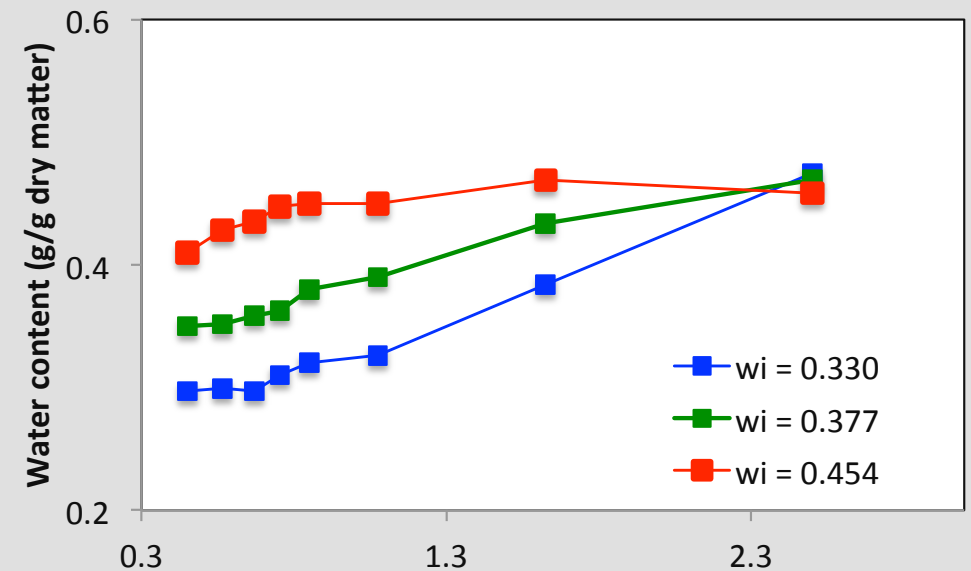


An **increase of the water content** lead to an **increase of the median diameter** of the population in the mixer after the granulation.

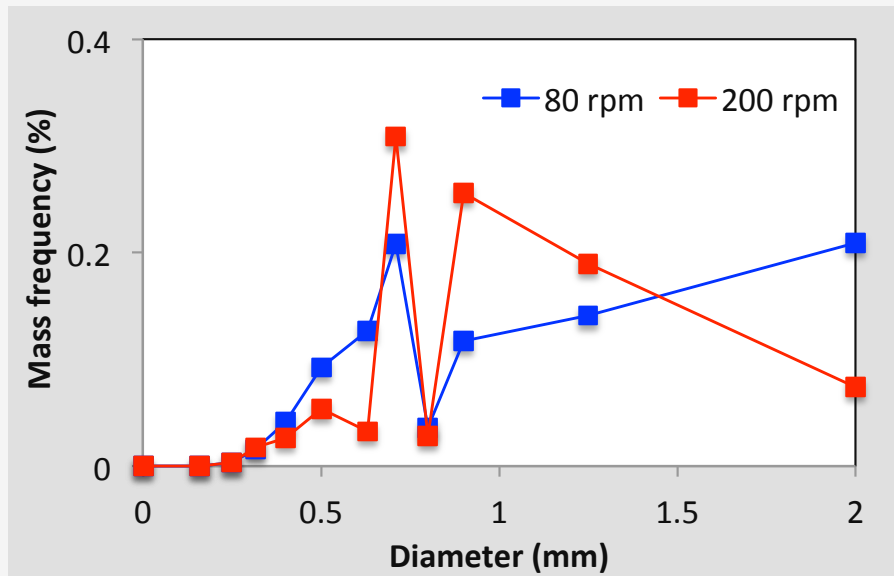
3.2. IMPACT OF THE WATER CONTENT

An increase of the water content **increase the mean water content** of each structure after the granulation.

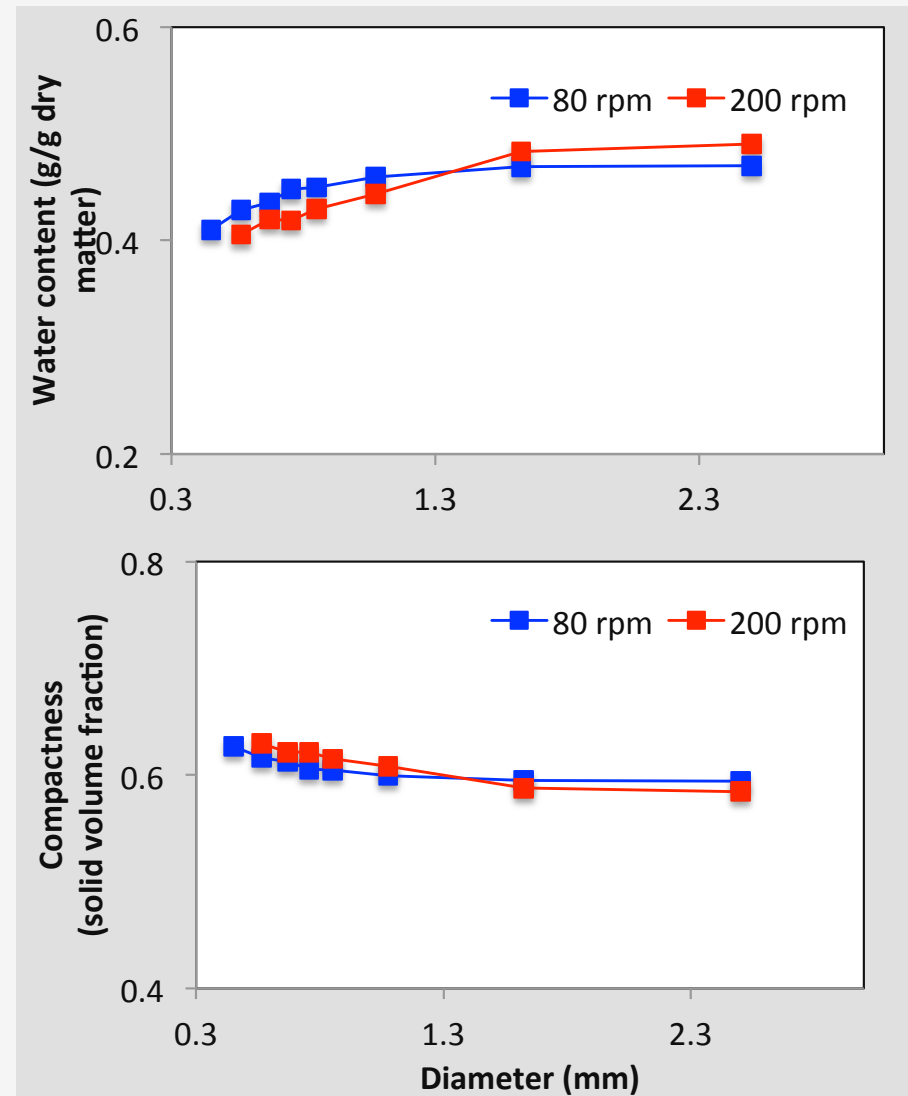
An increase of the water content **decrease the mean compactness** content of each structure after the granulation.



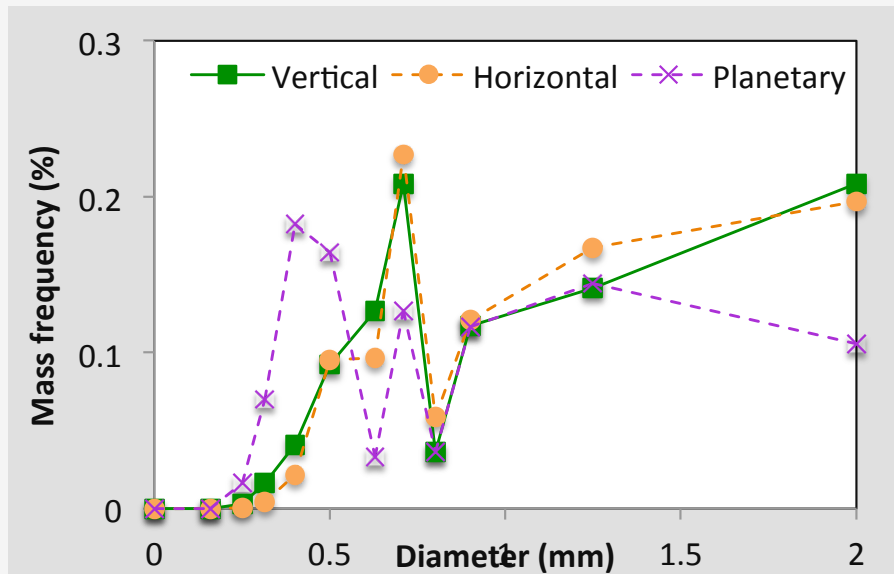
3.3. IMPACT OF THE MIXING SPEED



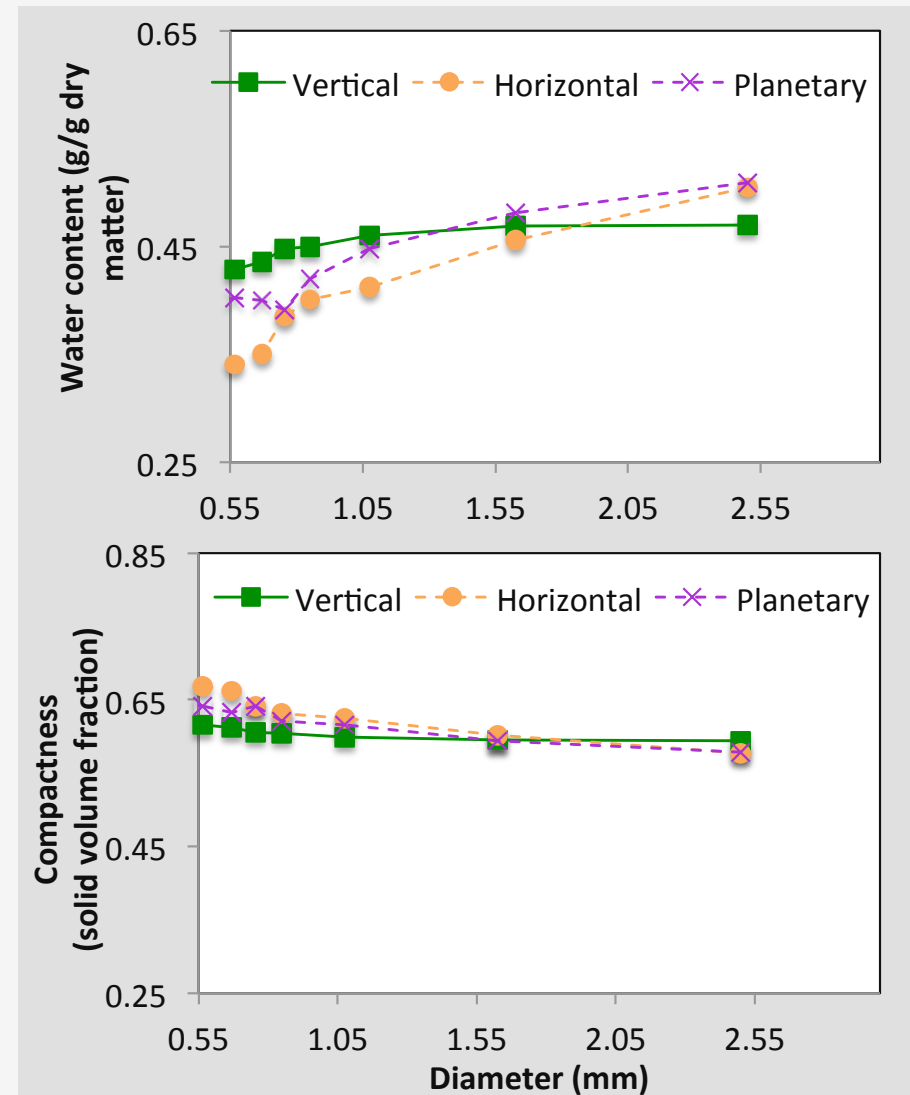
- The ratio of the 5 structures is different → An increase of the speed leads to an **increase of the breakage and erosion mechanisms.**
- **No impact of the speed in the water content and the compactness of each structure.**



3.4. IMPACT OF THE MIXERS

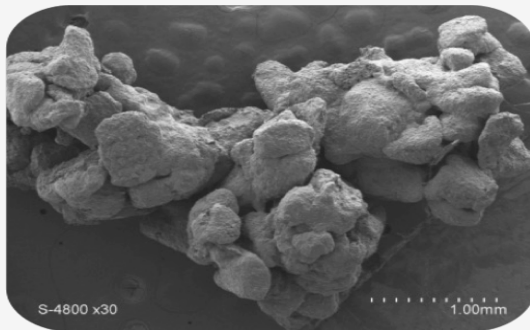


- The ratio of the 5 structures is different → More **breakage and erosion mechanisms** in the planetary mixer.
- The mixers **do not have an impact** on the **water content** and the **compactness** of each structure.





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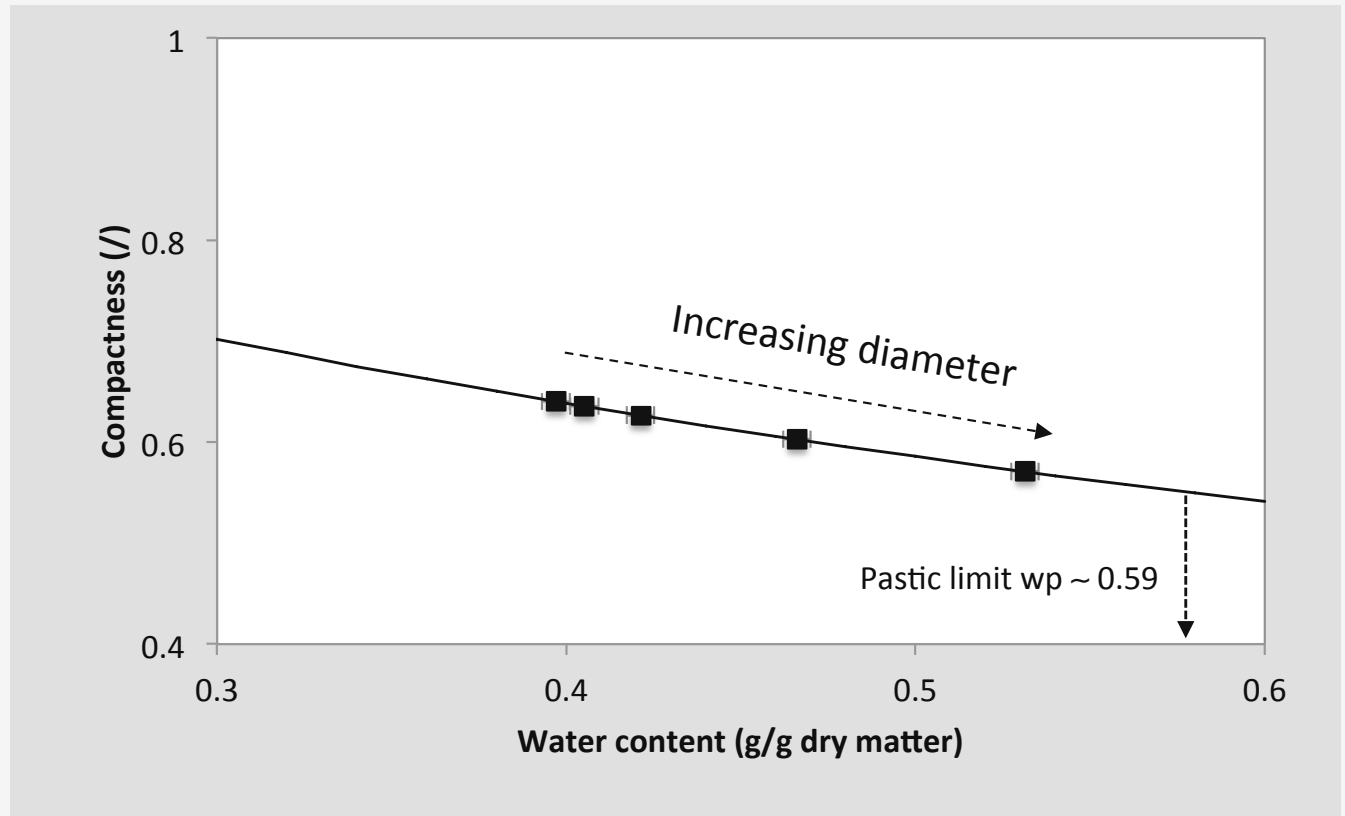
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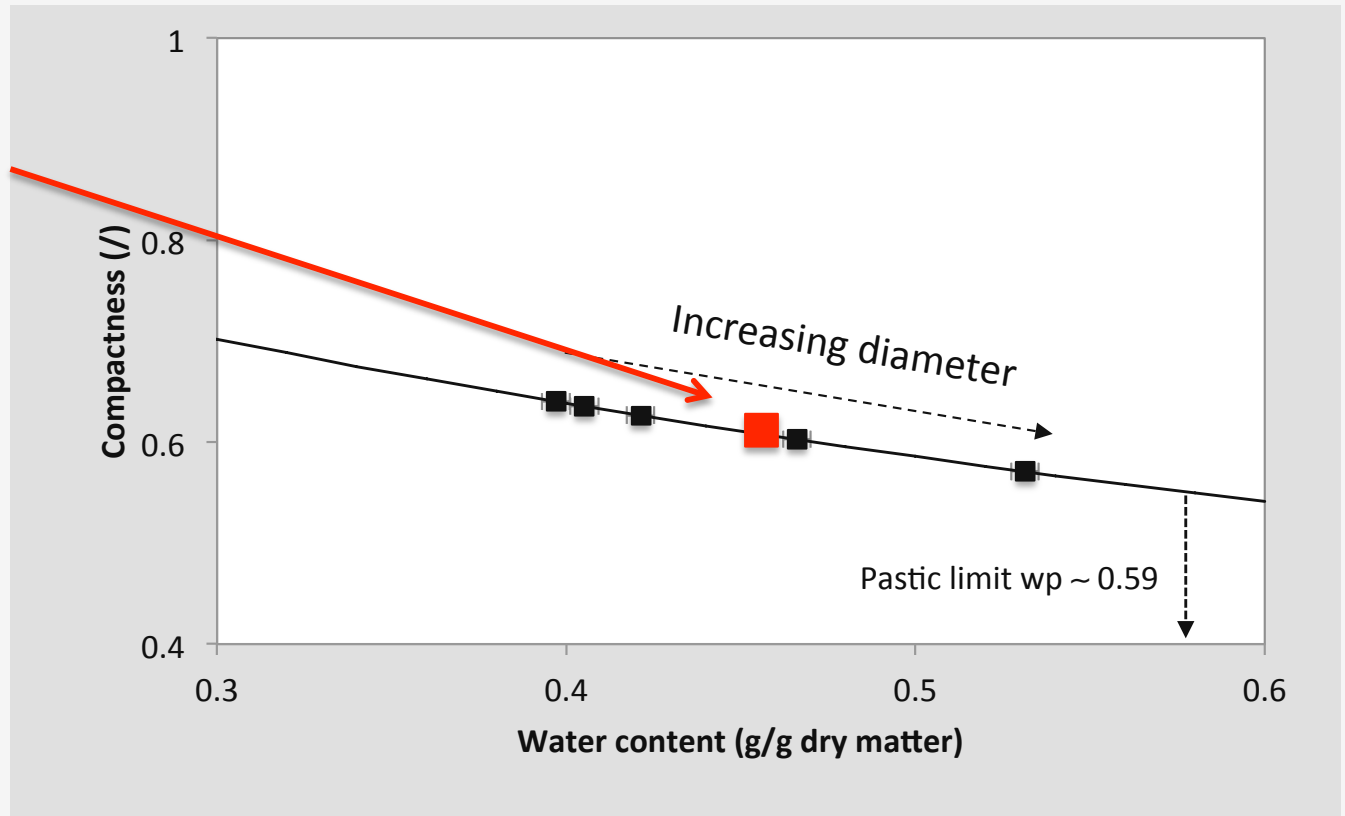
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4.1. DATA ANALYSIS



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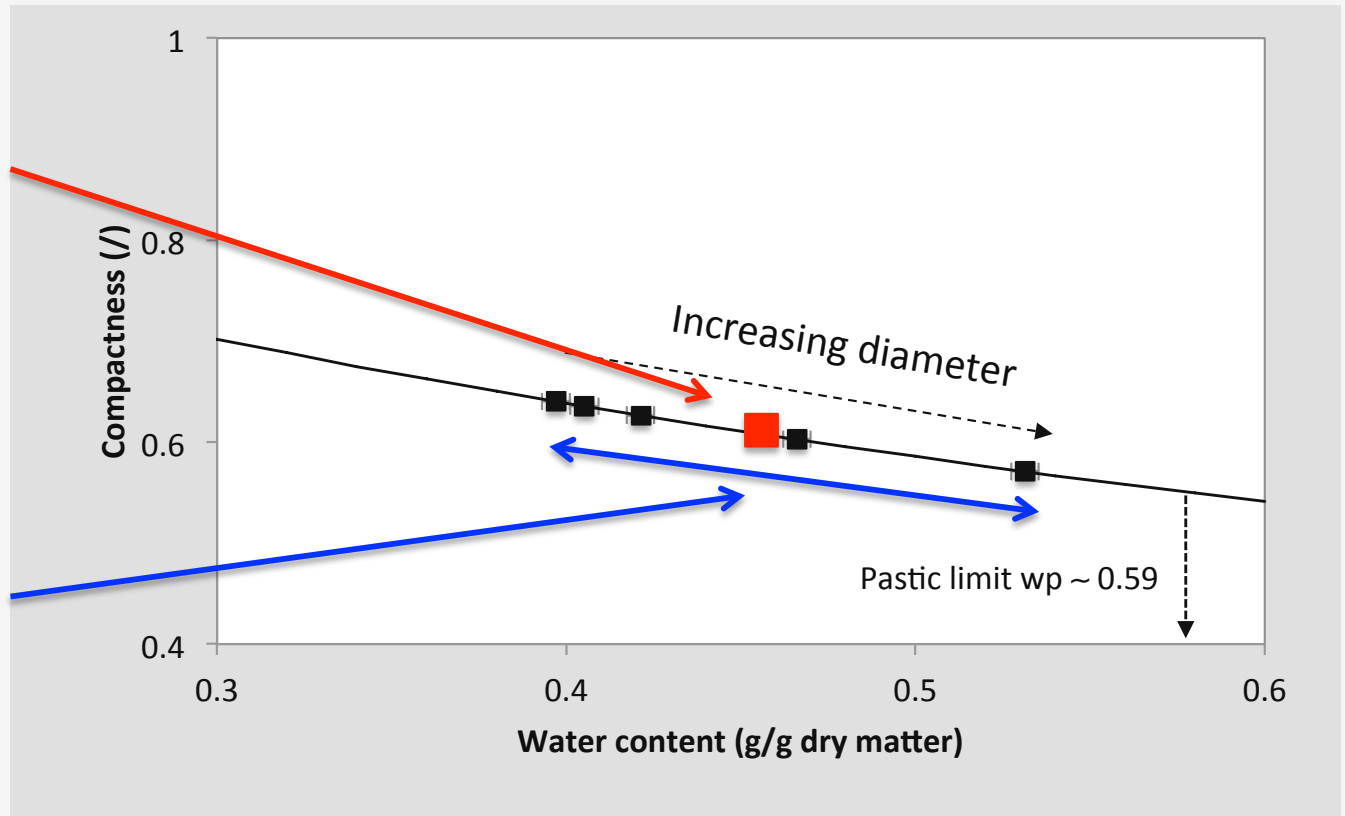
Analysis of the **mean values** of water content and compactness.



4.1. DATA ANALYSIS

Analysis of the **mean values** of water content and compactness.

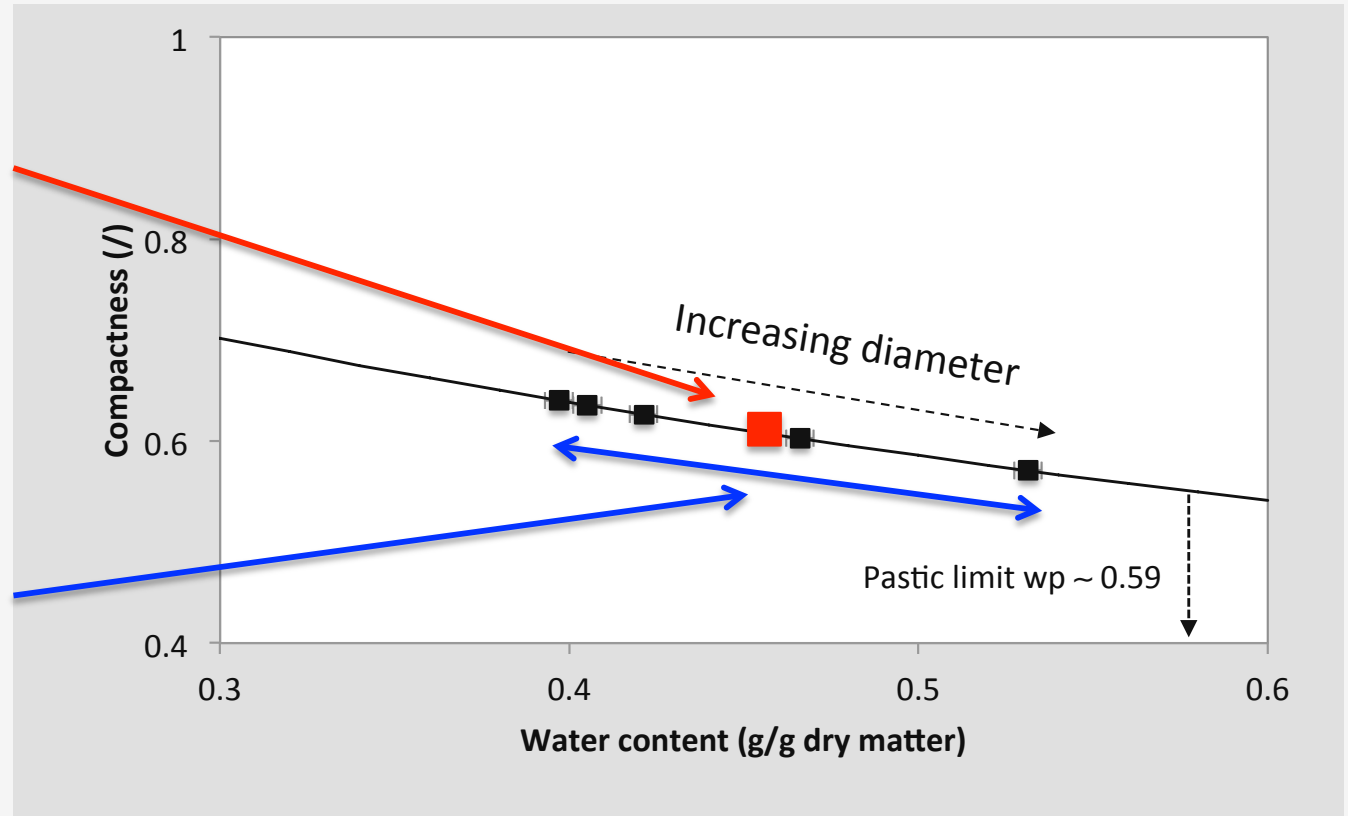
Analysis of the **heterogeneity** of water content and compactness around their mean values.



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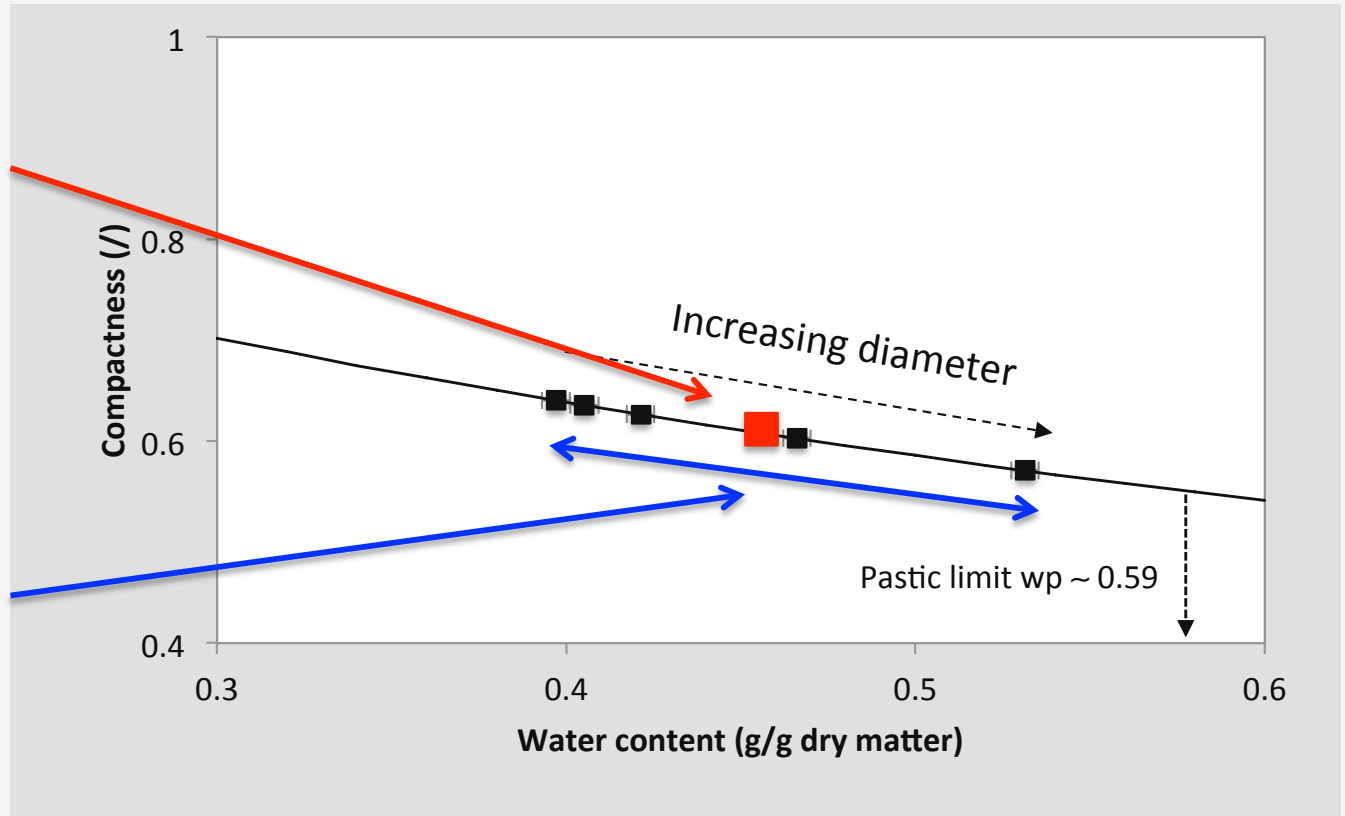
Global heterogeneity

$$W_G = (W_{\max} - W_{\min}) / W_{\text{moy}}$$

4.1. DATA ANALYSIS

Analysis of the **mean values** of water content and compactness.

Analysis of the **heterogeneity** of water content and compactness around their mean values.



Global heterogeneity

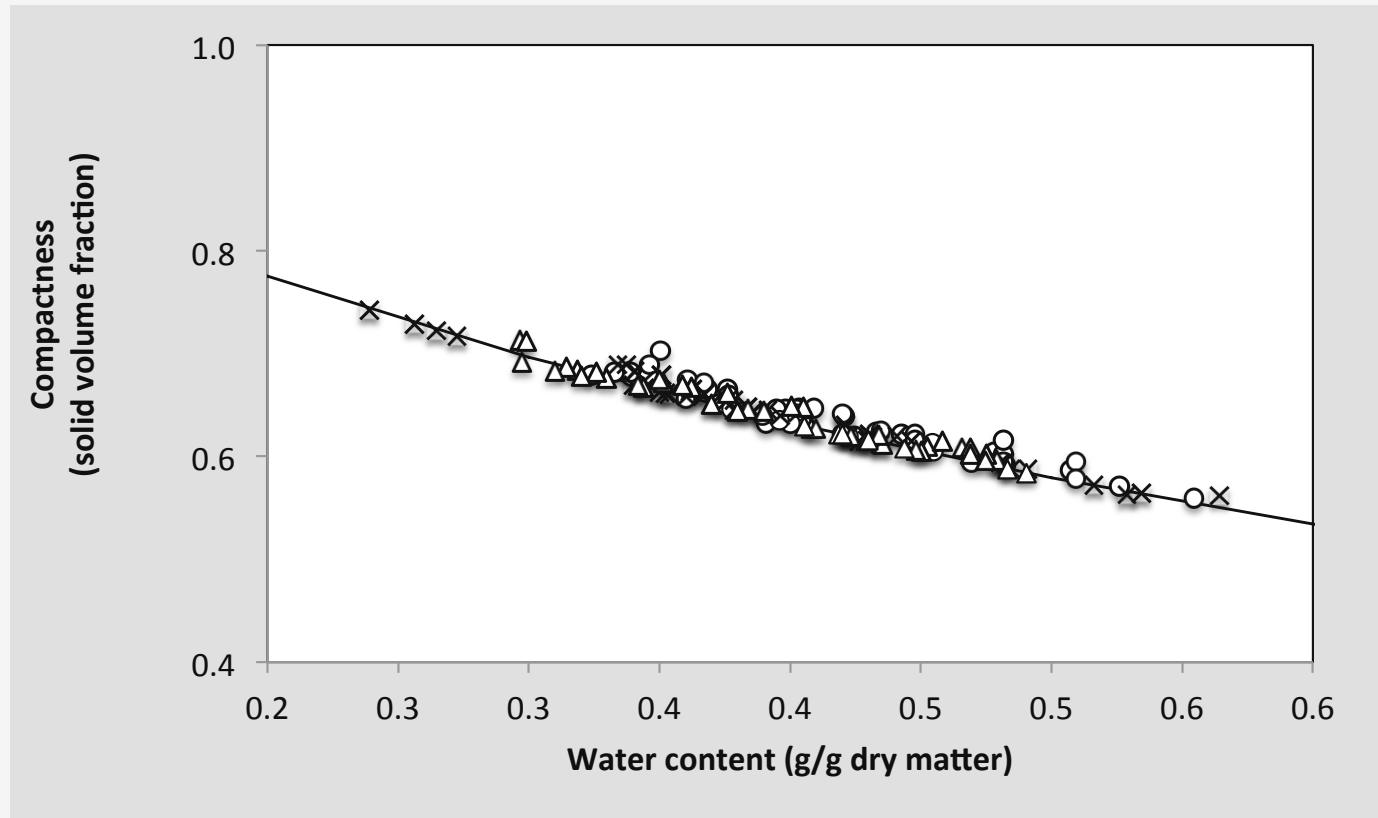
$$W_G = (W_{\max} - W_{\min}) / W_{\text{moy}}$$

Local heterogeneity

$$W_L = (W - W_{\text{moy}}) / W_{\text{moy}}$$

4.2. MEAN VALUES ANALYSIS

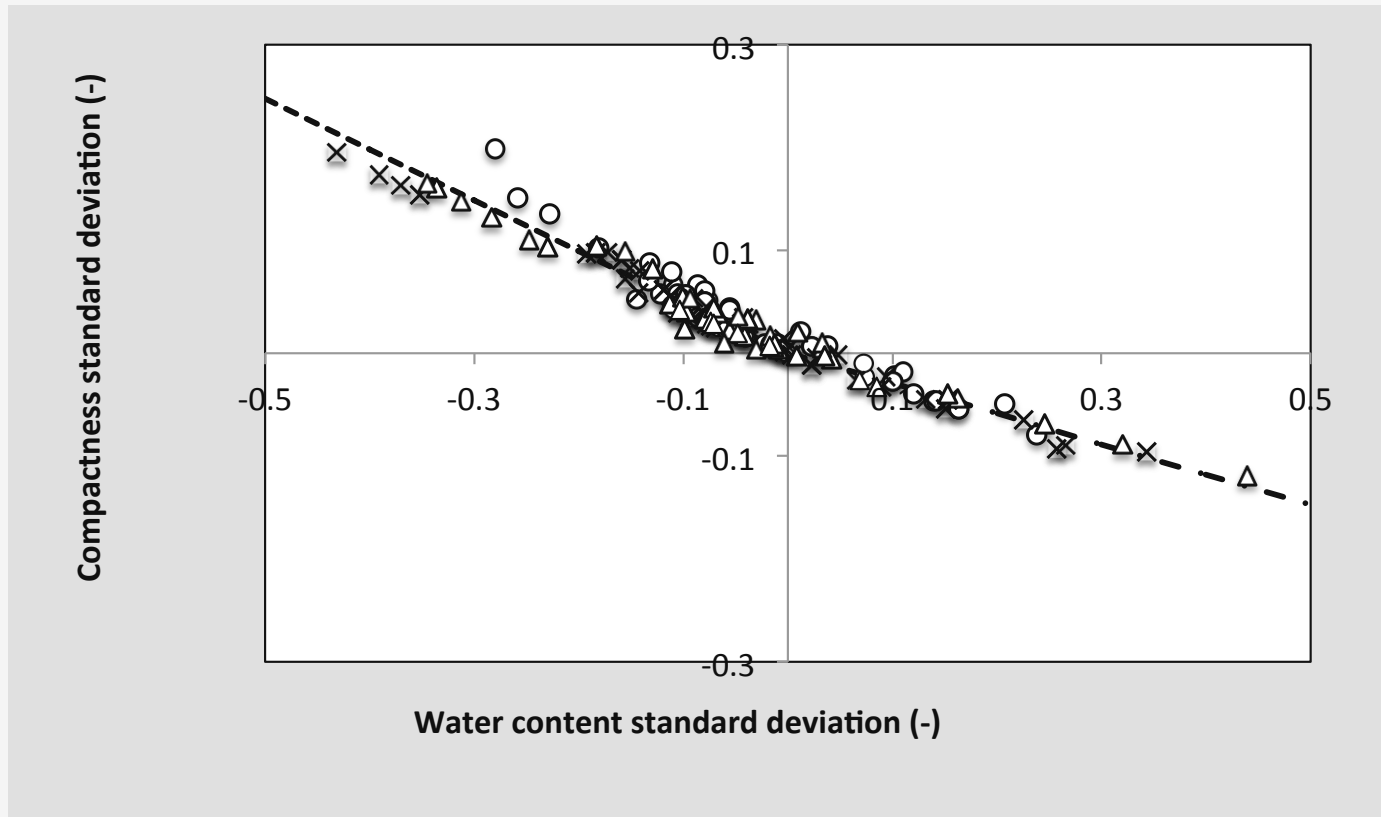
We have represented on the diagram **the mean values** of **water content** and **compactness** of the structures **for all the process conditions**.



The process conditions **do not change the hydrotextural properties** of the structures: they are **all saturated by water**.

4.3. LOCAL HETEROGENEITY ANALYSIS

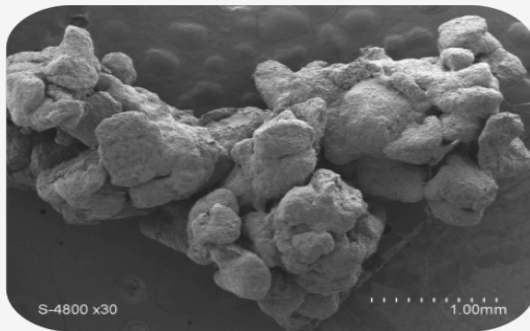
The **fluctuations** of the **water content** and the **compactness** are **correlated** around their respective mean values **for all the process conditions**.



The growth of the agglomerates respects an **association by same sizes and hydro-textural categories**.



Plan



1

INTRODUCTION - WET AGGLOMERATION

2

DURUM WHEAT SEMOLINA AND MIXERS

3

IMPACT OF THE PROCESS

4

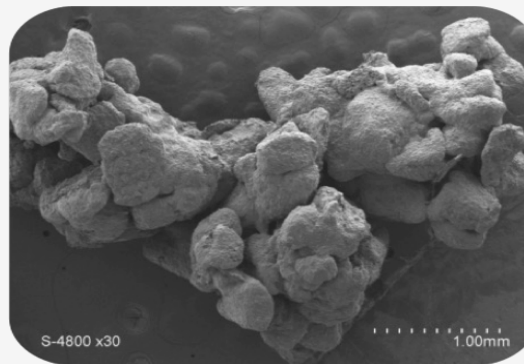
HYDROTEXTURAL ANALYSIS

5

CONCLUSION

CONCLUSION

- **5 structures** in the mixer after the granulation.
- Continuous growth process is associated with the **expansion of the internal structure**.
- The **process** (water content, speed and mixers) has a **significant influence on the yield** of the agglomeration, but...
- ... **does not have an influence on the agglomerates properties** (water content and compactness) as a function to their size.
- **Fluctuations** of the water content and the compactness are correlated around their respective mean values → **association by same sizes and hydro-textural categories**.



Thanks for your attention

QUESTIONS ?

Bettina Bellocq

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UMR IATE – INRA Montpellier – France

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Nancy – 12 Juillet 2017

