



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

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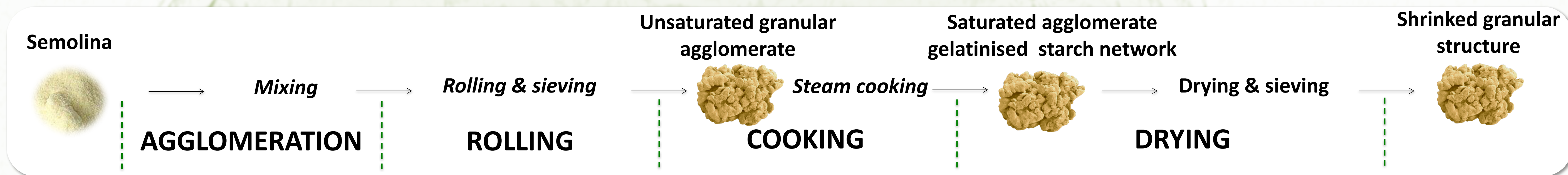
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We improve theoretical foundations to understand the uses of **thermo-hydro-mechanical paths of powders reactivity** during the process of durum wheat into **agglomerated couscous grains**. The current industrial process is poorly eco-efficient and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



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**.

- The contribution of **physical characteristics** of particles to the **agglomeration mechanisms**.
- The contribution of **proteins** to the **irreversible physicochemical mechanisms**.

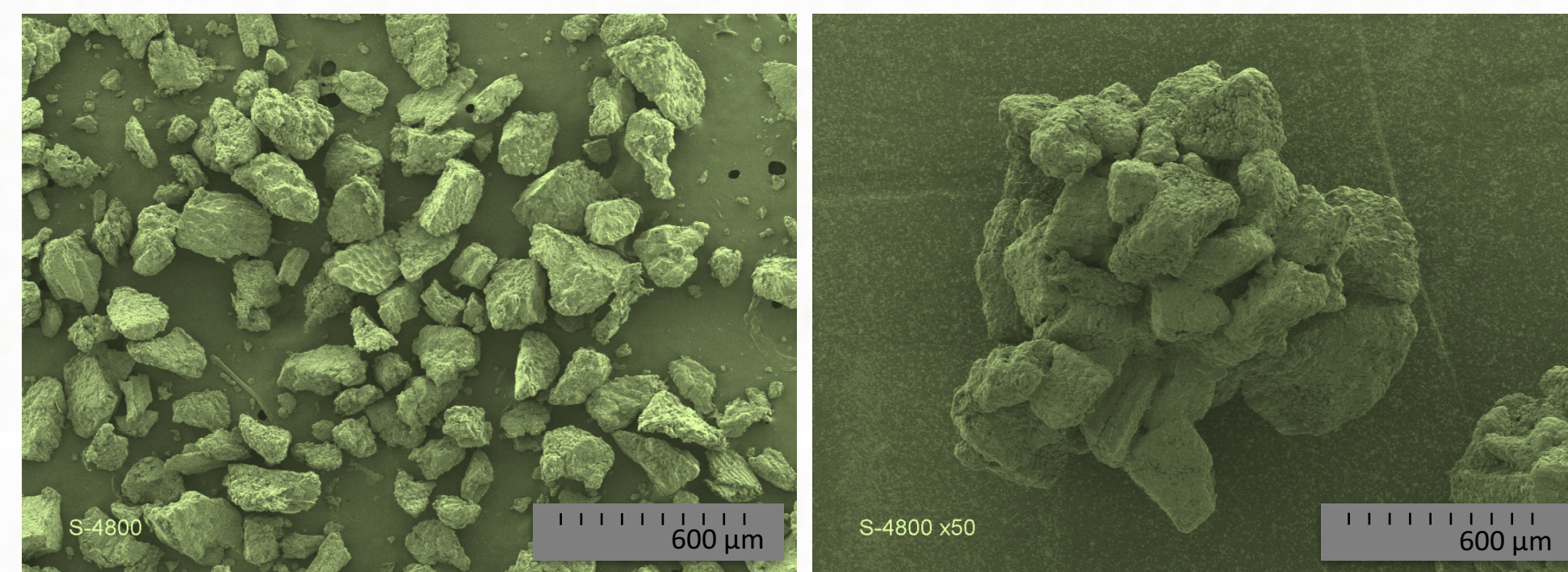
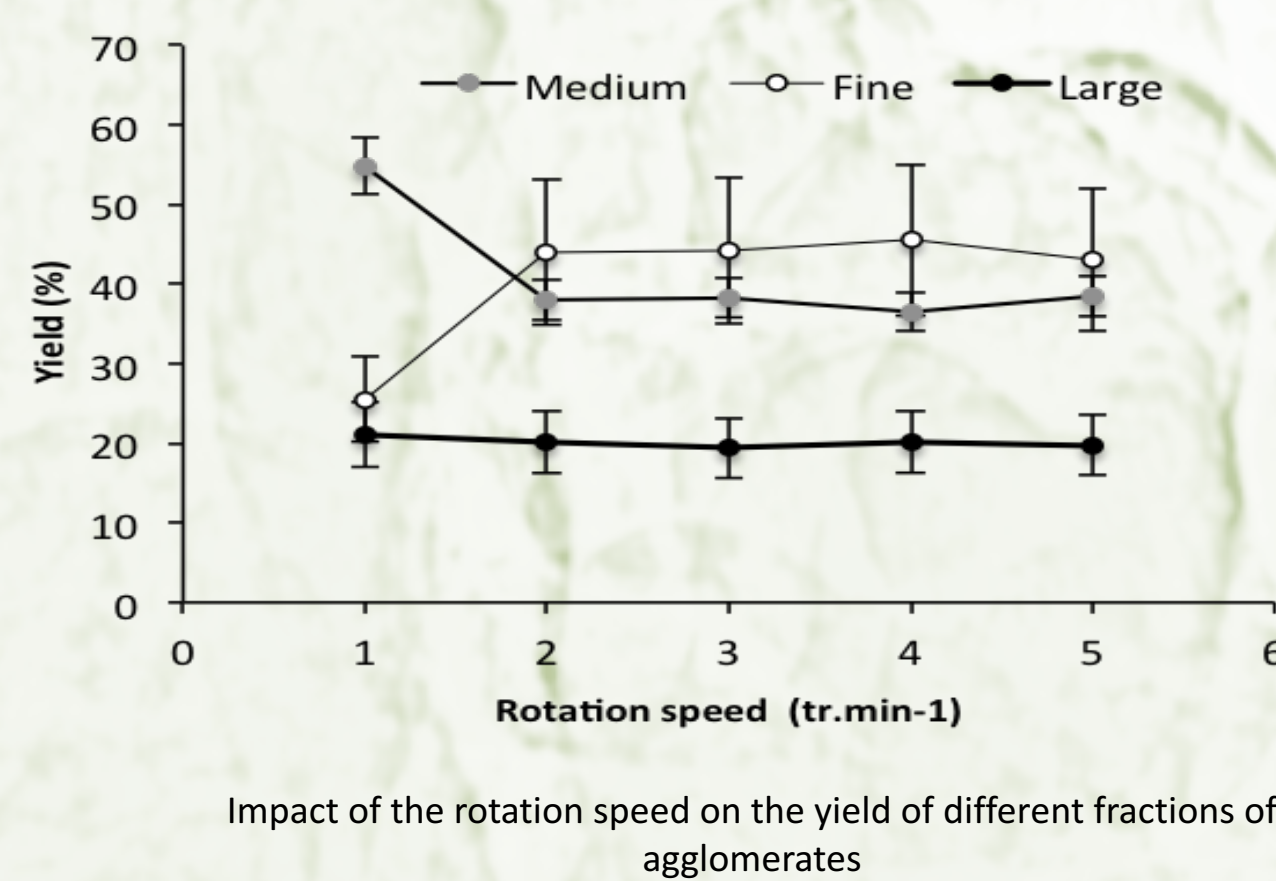


Figure 1 is a line graph showing the mass fraction (%) of agglomerates as a function of their diameter (mm) for three different water contents: 30%, 40%, and 50%. The x-axis is logarithmic, ranging from 0.1 mm to 10 mm. The y-axis is linear, ranging from 0% to 40% mass fraction. The 30% water content series (dashed line with open circles) peaks at approximately 0.3 mm. The 40% water content series (solid line with open circles) peaks at approximately 1.5 mm. The 50% water content series (solid line with filled circles) peaks at approximately 2.5 mm. The data indicates that higher water content leads to larger agglomerate sizes.

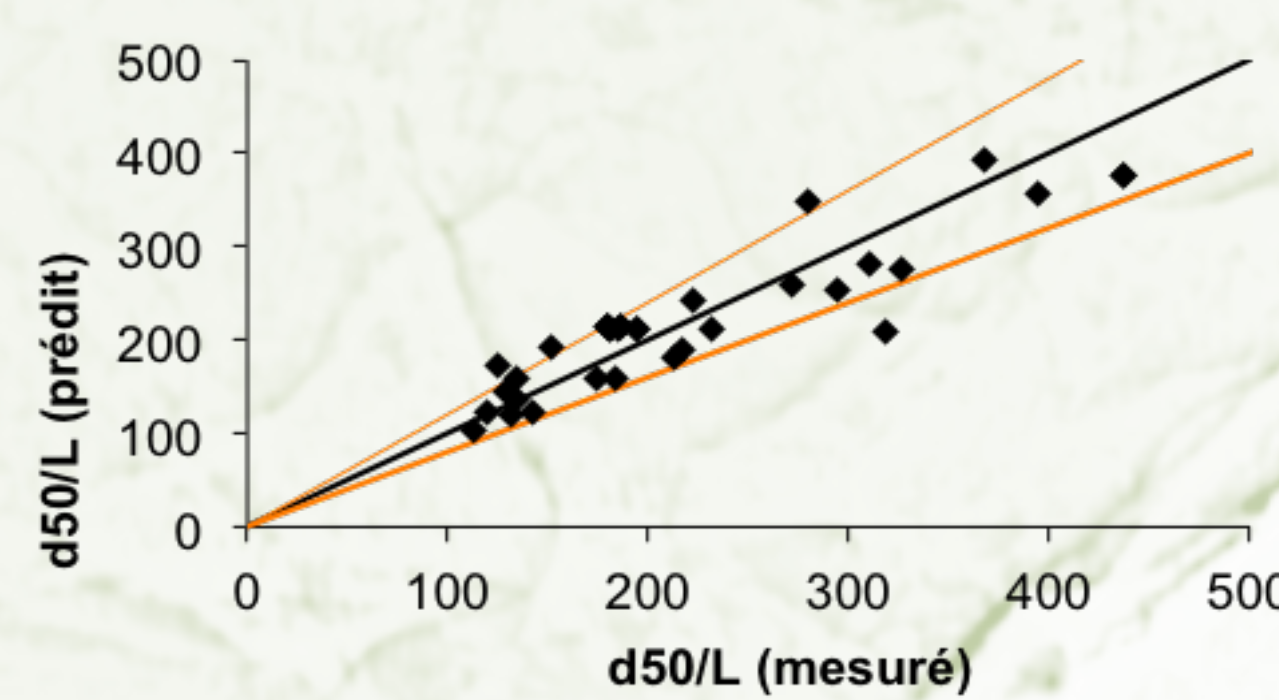
Diameter (mm)	30% Water Content (Mass fraction %)	40% Water Content (Mass fraction %)	50% Water Content (Mass fraction %)
0.1	0	0	0
0.2	21	0	0
0.3	30	0	0
0.4	17	10	0
0.5	5	18	0
0.6	2	15	0
0.8	1	8	13
1.0	0	8	26
1.5	0	6	23
2.0	0	11	29
2.5	0	22	29
3.0	0	12	0
4.0	0	2	4
5.0	0	1	4

- Mechanical or pneumatic **mixing process**.
- Rolling with **inclined rotating cylinder**.
- Different **cooking** and **drying technologies**.



- Shear
- Water content
- Times
- Temperature

The approach is to initially list the influential variables to create a dimensional matrix. The **dimensional matrix** allows to express the process relationship linking 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 values can be mathematically described by the product of **exponential** and **powers laws**.