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

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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 mechanical forces in grain 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 and mechanisms, 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.

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
- Times
- Water content
- Temperature

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.

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.

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