Elaboration of cereals and legumes-based extruded foods guided by rheology and simulation

KRISTIAWAN M. (1), DELLA VALLE G. (1), BERZIN F. (2)
1 INRAE, UR 1268 Biopolymers Interactions and Assemblies (BIA), Nantes, France
2 Universitde Reims Champagne Ardenne, INRAE, FARE, UMR A 614, Reims, France

Many starch-based foods, such as textured ingredients, breakfast cereals, snacks, and more, are produced by extrusion. However, there is a growing interest in developing sustainable agriculture and diversifying the supply of healthy and balanced foods from local legumes. Legumes, composed of proteins (20-30% dry basis), dietary fibres (10-30%) and starch (40-50%), and low in sugar, unsaturated fat and sodium, are a sustainable source of nutrition for human consumption and can also be used as a natural nitrogen fertilizer. Despite nutritional advantages of legumes (high protein content, low glycemic index) over their grain-based counterparts, extruded legume-based foods are still rare. Despite significant advances in extrusion modelling and simulation, the design of extruded products at the industrial level still relies on trial and error approach.

A global 1D twin-screw extrusion model, implemented in a simulation software, Ludovic®, was used to predict flow variables along the screws and die, and to design different starchy products with targeted structure and properties. An experimental database has been compiled with seven formulations for manufacturing extruded foods from starches, breakfast cereals, legumes flours such as pea and fava bean, and bran-enriched wheat flour. This database includes thermal and physical properties of solid and molten states, melt viscous behaviour model, and experimental results on extrusions, such as extruder’s configurations and operating conditions, and structure and properties of extruded foods.
The extrusion model satisfactorily predicted product temperature at the die exit (T) and Specific Mechanical Energy (SME).

A sensitivity analysis of flow variables (T, SME, viscosity) at the die exit was carried out on the formulation, extruder's configuration and operating conditions, generating extruder's working charts. The results established satisfying relationships between the predicted flow variables and product features such as structural changes of starch and protein, structure (density, cellular structure) and functional properties. Extruder’s operating conditions leading to targeted food features can be assessed from these relationships. The satisfactory correlations justified the use of the extrusion model as a computer-aided tool for designing starchy foods by extrusion. Moreover, the capacity for predicting food features is extremely vital to reducing time and labour costs in industrial foods R&D.