In-line rheometry and spectroscopy for controlled tailoring of textural and nutritional characteristics of HMEC-processed plant protein-based meat alternatives

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High moisture extrusion cooking (HMEC) is a technology to create fibrous structures from plant proteins resembling meat texture. Derived meat analogues provide similar textural mouthfeel to meat but are an alternative with only a fraction of the massive environmental impact of meat. During high moisture extrusion cooking plant protein containing materials are typically hydrated, sheared, heated (up to 170°C) and subsequently cooled and shaped in a long cooling die to avoid flash evaporation at the die exit. During such thermal and mechanical processing, proteins go through structural changes and reassemble in a shear and elongational flow-induced structure, stabilized by crosslink formation. To adjust textural and nutritional characteristics in a customized consumer-relevant range, in-line measuring methodologies for (a) the viscoelastic rheological protein melt characteristics and of (b) the product structure development, were designed and successfully adapted in extruder and cooling die sections of the HMEC process. The latter was run in traditional and novel micro-foaming modes in order to generate meat analogue products of controlled structure porosity and correlated texture and sensorially perceived tenderness.
For the first time in-line measured viscoelasticity characteristics like (a) the First and Second Normal Stress Differences (N1, N2) and (b) the shear viscosity h as a function of shear rate, temperature and water content were made in-line accessible and correlated with in-line measured spectroscopic (RAMAN, NIR) data as well as with mechanical characteristics (Young's Modulus, tensile- and cutting strength) of the resulting product structure.
Based on derived Process-Structure-Functions (PSF) and Structure-Property Functions (SPF) optimization criteria were defined in order to feed a proposed novel HMEC process control framework for improving operational stability and reproducibility. Key technological aspects that unlock the next level of production autonomy were addressed by coupling a multilayer advanced control structure with the before-mentioned in-line techniques. The developed solution aims at optimizing process parameters while keeping the meat-like fibrillar structure formation and textural sensory characteristics at the desired level. The interplay of various parameters was considered by applying a model-based predictive approach that anticipates process future changes and derives optimal set-points. Extrusion results proved potential advantages and practical implementation of the approach.