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MODELING SALAMI DRYING WITH DIFFERENT APPROACHES AND VALIDATION DURING INDUSTRIAL RIPENING

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Abstract

Nowadays, ripening of salami under natural conditions has been replaced by batch production in ventilated industrial chambers. Hence, the same product quality can be obtained regardless of local, environmental and climatic conditions. Nevertheless, carefully designed and monitored process conditions are necessary to achieve the targeted weight loss and quality of dry fermented sausages. Therefore, the availability of reliable mathematical models and manageable software codes for sausage drying, maturation and optimal production are highly welcome.

This thesis deals with the development and the progressive improvement of a mathematical model (and its underlying software solving code) of sausage drying during actual industrial ripening conditions. The mathematical model considered as the start point had the following features: 1D, axi-symmetric, time-invariant cylindrical geometry; homogeneous and isotropic material; no distinction between the inner part (core) and the casing; water concentration as a distributed parameter; the internal water transfer rate as a concentration-dependent Fickian diffusion with the assumption of an effective diffusion coefficient depending on the local water content. Starting form this, different and more realistic improvements of the sausage geometrical representation have been pursued: cylindrical 2D axi-symmetric geometry, irregular 2D axi-symmetric geometry, irregular 3D geometry, cylindrical 2D axi-symmetric geometry with volume shrinking. From the comparison of the various model predictions with the experimental data that originated from external industrial-scale ripening tests, it was possible to deduce that a more realistic irregular geometry is influential on the computational load, but irrelevant to the prediction of the sausage weight loss, i.e., the most well-known process performance variable. For this reason, a simple cylindrical shape could be used to implement a more realistic variable-volume simulation model. Another assessment that was made with this study was that the ripening process can be considered isothermal because the temperature transients, e.g., occurring at startup or after a temperature set point change, have a characteristic time that is negligible when compared to that characteristic of mass transfer. A natural, but necessary development of the work has been a mathematical model of fermented sausage drying relying on an innovative description of the sausage as a heterogeneous material, i.e., separately made of lean meat and fat, and a porous medium. The fat is considered as an inert matter dispersed in the meat matrix, while the lean meat is considered as a porous medium in which the transport phenomena of water take place to the outside of the matrix during the ripening process. Porosimetry and image

analysis were applied to the meat matrix to demonstrate the goodness of the porous media approach. However, the direct implementation of the above porous media approach in a calculation code has been prevented by the lack of correlations for the water diffusion in the porous meat matrix. For this reason, an experimental setup was thought that would allow an evaluation of the dependence of the diffusivity from the local water content in the meat matrix during the drying process. The experimental apparatus allows real-time monitoring of the sample weight and water concentration profiles that are established in the material under investigation. The sample is kept in a constant-humidity, controlled atmosphere during the whole experiment. By coupling the model simulation with porous media approach and the experimental data from such an apparatus, it is possible to simulate the drying process of a particular material for which the internal water diffusion characteristics are unavailable or unrealistic in the literature. In particular, two correlations for the water diffusion in the porous meat matrix (e.g., D=*f*(local moisture content, Temperature)) were found in literature, but their application or validation to the case of meat-based food was missing. So, it was possible to determine optimal parameters for them, just tailored for the lean meat under investigation here. Therefore, with a more reliable correlation for water diffusion and the calculation code based on the porous media approach, the prediction of the drying mechanism turned out more realistic and provided added value to the knowledge of the salami curing processes.