Accounting for uncertainty and variability in food processing and post-processing kinetic calculations: the case of nutritional deterioration in fruit and vegetable products

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During fruit and vegetable processing and subsequent storage/handling, bioactive compounds, such as vitamins, are prone to degradation, with temperature being the main quality loss rate determinant. Such nutrients are frequently applied as quality indices of products from production to final use and serve as design criteria of both processing (conventional or novel) and subsequent food chain. In an integrated approach, quantitative assessment of the effect of processing and post processing parameters on nutrient stability, enables optimization of the relevant stages of product lifecycle. This can be implemented by using alternative mathematical approaches of various complexity ranging from the typical deterministic kinetic analysis to stochastic approaches incorporating parameter uncertainties and inherent variabilities.
The objective was to estimate nutritional degradation and approach product quality and shelf life calculations through an integrated scheme, based on Monte Carlo and Bayesian principles, accounting for kinetic parameter uncertainty and material/process/distribution/storage variability during actual product lifecycle. The stochastic approach for process optimization and effective management is demonstrated via case study computations, based on experimental data, on representative thermal and nonthermal processes of alternative fruit/vegetable products and Vitamin C as the target nutrient index.
The presented case involved high pressure processing (600 MPa, 40°C, 4 min) or thermal pasteurization (80°C, 60 s) of refrigerated Navel orange juice, followed by a kinetic study of post processing nutritional degradation. In the Bayesian analysis a distribution was used to describe each kinetic parameter. Additionally, Monte Carlo simulations were implemented to account for statistical uncertainty and/or variability, such as various temperature conditions reported in the actual cold chain, retrieved from a big data base. Results showed that orange juice products optimally processed, either thermally or by high pressure, maintained acceptable Vitamin C content (up to 50% loss) for a shelf life expressed by a distribution in the 50-65 d range, vs 100-115 d, respectively, taking into account mathematical uncertainty and food chain variability. In comparison to the respective single value estimates of 60 and 110 d, based on fixed parameter values and constant temperature conditions, the distributions obtained by stochastic approaches more realistically depict the expected product quality variation.