
Combination of acoustic imaging and machine learning algorithms for the rapid characterization of jelly-based products

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Quality monitoring of jelly-based foods is an important issue to determine average compositional, textural, and/or rheological properties and sensory quality. In this sense, the development of non-destructive and low-cost systems for real-time prediction of the composition of these products plays an essential role in the industry. Further, the use of machine learning algorithms combined with real-time process information could contribute to achieving this goal. Thus, the main aim of this work was to assess the capability of using acoustical images obtained by ultrasound technology combined with machine learning algorithms for rapid and non-destructive prediction of jelly concentration on jelly-based products. For this purpose, jellies (bovine gelatin 1%, 5%, and 10% w/v) were prepared in silicon and polystyrene plates (diameter 9 cm, height 1.5 cm) in which ultrasonic measurements were conducted following a pre-established pattern (60 × 60 points separated by 1 mm). Images were built using three energy-related ultrasonic parameters computed in the time domain (peak to peak voltage, square norm, and integral). Principal component analysis (PCA) was calculated using the aforementioned ultrasonic parameters to extract uncorrelated latent variables which summarized 100% of experimental data variability. Subsequently, Support Vector Machines (SVM), Regression Trees (RT), Random Forest (RF), k-Nearest Neighbors (kNN), and Artificial Neural Networks (ANN) were used to describe the product concentration as a function of acoustics images projected in latent space and type of packaging material. Machine learning techniques were trained 100 times in a holdout approach, employing 75% of the experimental data set for training purposes and leave-one-out cross-validation, and the remaining 25% of the experimental data set was considered for the external validation process. Hyperparameters of each technique were optimized using multifactor analysis of variance (ANOVA) for minimizing the mean square error (MSE). The SVM model provided the highest goodness in the model validation ($R^2_{adj} > 99$ and $MRE < 5\%$), suggesting that the methodology proposed in this work is of interest for the reliable, rapid, and accurate prediction of the concentration in jelly products packaged in different materials and its further in-line industrial application.