Computational design and manufacturing of microwave systems for food processing

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Microwave (MW) processing, at 2450 and 915 MHz frequencies, is widely used by the food industry with its high-energy efficiency. Recent concerns on sustainable processing for reduced energy with high-quality products make it attractive while industrial systems still do not achieve a uniform electric field distribution. This results in non-uniform temperature distribution with quality losses. The objective of this study was to present a computational design approach from the lab- to pilot and industrial scale systems.
For this purpose, a mathematical model was first developed to determine the electric field and temperature distribution in a lab-scale system and validated with experimental data for various processing conditions. Then, a pilot-scale continuous system was optimally designed using this model for the optimal location of magnetron size of the cavity, and it was manufactured by IFTECH. Following the second set of validation in this system, industrial scale tunnel systems with various number of magnetrons (9, 18 and 36) were computationally designed.

The experimental model validation studies in lab- and pilot-scale systems were carried out with agar (97% solid) and Tylose samples (75% water content), and the models were validated by using the experimental temperature change data (the RMSE values for both cases were lower than 2 °C). The pilot-scale system was recognized with the optimal electric field and temperature distribution within the cavity. For designing industrial scale systems, a higher number of magnetrons led to significant issues for electric field distribution, and various designs were introduced for different food products (e.g. required design for pasteurization of particulate foods differed from the design for thawing of larger size products). For the same tunnel design, the use of 9 magnetrons was determined to lead to a more uniform electric field distribution with improved efficiency compared to the higher number of magnetrons while the applied frequency was a significant factor.
The significance of computational design for efficient MW system manufacturing was presented, and it was demonstrated that the industrial scale manufacturing and further processing required a significant design and optimization study for sustainable processing.

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