Towards enhanced chlorine control: Mathematical modeling for free chlorine kinetics during fresh-cut carrot, cabbage and lettuce washing

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Abstract

In this study, we developed a novel produce-specific mechanistic model to predict free chlorine (FC) dynamics during washing of disk-cut carrots, cut cabbage, and cut iceberg lettuce, in 3 L and 50–100 L tanks, and of shredded iceberg lettuce in 3200 L pilot-plant trials. Ranges for two key parameters: β (L mg^{-1} min^{-1}) the apparent reaction rate constant of FC with produce constituents, and γ, the fraction of the increase of chemical oxygen demand (COD) contributing to the reaction, were determined at the 3 L scale. For disk carrots $\beta \in [0.05,0.09]$ and $\gamma \in [0.054,0.078]$, for cut cabbage $\beta \in [0.05,0.10]$ and $\gamma \in [0.09,0.12]$, and for cut iceberg lettuce $\beta \in [0.03,0.06]$ and $\gamma \in [0.07,0.14]$. Taking values from these ranges the model was able to consistently predict experimental FC dynamics (decay and replenishment), indicating robustness of the apparent reaction rate constants across scales. Comparing sequential changes in COD with turbidity and total dissolved solids (TDS) relative to produce washing rates, our results also illustrate that turbidity and TDS may not be reliable predictors of FC decay rates across produce types and experimental scales. In concert with future experiments, these models could serve as important tools aimed at validating FC compliance within operational limits as well as guiding large-scale commercial experiments focused on improving chlorine management strategies relevant for industry.