Novel organic-based postharvest sanitizer formulation using Box Behnken design and mathematical modeling approach: a case study of fresh pistachio storage under modified atmosphere packaging

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Abstract

In the present study Box Behnken Design (BBD) and Artificial Neural Network-Genetic Algorithm (ANN-GA) hybrid system were used for predicting and optimizing a new organic-based postharvest sanitizer for fresh pistachio nuts under modified atmosphere packaging, combining different concentrations of five generally recognized as safe (GRAS) ingredients including H_2O_2 (1, 3 and 5%), Na_2CO_3 (1, 3 and 5%), K_2CO_3 (1, 3 and 5%), citric acid (CA) and acetic acid (AA, 1000, 5500 and 10,000 mg L^{-1}). The nuts were submerged in sanitizer solutions for two minutes then dried for five minutes in ambient condition and packaged in polyethylene bags injected with ambient atmospheric gas (21% O_2, 0.03% CO_2, and 87% N_2). BBD as a computer-based design of experiment (DOE) tool reduced the cost, labor and time needed to perform the experiment by reducing the number of treatments from 243 to 40 while ensuring the well-sampled experiment design. NaOCl (100 mg L^{-1}) and distilled water (DW) were used as controls for the validation experiment. The ANN-GA described relations between five input (H_2O_2, Na_2CO_3, K_2CO_3, CA, and AA) and four output (total viable count, enzymatic browning, overall acceptability, and taste) variables. Sensitivity analysis was used to find the most important ingredient as input variable affecting output variables. ANN-based models could effectively fit the supplied data on the total viable count and quality parameters of pistachios to various concentrations of the ingredients in the sanitizers. Based on the ANN-GA results, the input variables concentrations of 3.6% H_2O_2, 3.9% Na_2CO_3, 3.2% K_2CO_3, 8118.5 (mg L^{-1}) CA, and 8202.8 mg L^{-1} AA could result in the lowest total viable count

(0.07 log colony forming units (CFU g^{-1})). The lowest amount of enzymatic browning (1.48%) can be obtained by applying a mixture of 4.26% H_2O_2, 3.7% Na_2CO_3, 3.7% K_2CO_3, 7785.4 mg L^{-1} CA, and 7363.5 mg L^{-1} AA. The highest overall acceptability (1.38) can be achieved using a mixture of 3.0% H_2O_2, 3.0% Na_2CO_3, 3.4% K_2CO_3, 8190.1 mg L^{-1} CA, and 8316.7 mg L^{-1} AA. The best taste (1.21) was predicted to be attained using a combination of 3.3% H_2O_2, 4.1% Na_2CO_3, 3.9% K_2CO_3, 8114.5 mg L^{-1} CA, and 7574.0 mg L^{-1} AA. According to the sensitivity analysis, AA was the most important factor in reducing total viable count and enzymatic browning and enhancing overall acceptability. The validation test showed that the optimized sanitizer for total viable count was superior to the 100 mg L^{-1} NaOCl which is the most used commercial sanitizer for fresh crops.