Abstract

Cold Plasma (CP) is an emerging non-thermal technology used to preserve and decontaminate food. The kinetics of spoilage enzyme in kiwifruit juice, viz. polyphenol oxidase (PPO) and peroxidase (POD), was investigated within the domain of 18-30 kV CP voltage, 2-10 mm juice depth, and 2-10 min treatment time. The residual activity of PPO and POD enzymes was fitted to different established kinetic models, viz. log-linear, Weibull distribution, logistic model, and n^{th} order. The inactivation order (n) value for POD and PPO were 2.07 and 2, respectively, for the CP treatment. Based on prediction (Coefficient of determination (R^2): 0.993-0.999 & root mean square error (RMSE): 0.029-1.099) and validation indices (accuracy factor (A_f): 1-1.026 and bias factor (B_f): 0.996-1.006), the Weibull, logistic, and n^{th} order model were reported to be satisfactory in explaining the enzyme inactivation kinetics. Further, based on Akaike's theory, the Akaike weight value of n^{th} order model was 57.92% and 45.56% for POD and PPO enzymes, respectively. Therefore, the n^{th} order model was considered to be the best model for predicting the residual activity of the POD and PPO enzymes. The higher D-value and half maximal activity of POD than PPO makes the former enzyme more resistant to CP treatment. The effect of CP on natural microbiota viz. aerobic mesophiles (AM) and yeasts & molds (YM) were examined within the domain of 18 - 30 kV, 2-10 mm juice depth, and 0-4 min treatment time. The maximum log reduction of AM and YM was achieved 3.02 and 2.32, respectively, at 30 kV/2 mm/4 min. The inactivation kinetics for AM and YM were established using different kinetic models, namely Weibull + tail, Geeraerd, log-logistic, biphasic, and Coroller models. First, the suitability of model was determined according to goodness of fit (R^2 and RMSE) and validation indices (A_f and B_f). The R^2, RMSE, A_f, and B_f values for the Weibull + tail, log-logistic, and Coroller models ranged between 0.939-0.999, 0.001-0.154, 1.001-1.086, and 0.992-1.024, respectively which were reported to be satisfactory in explaining the inactivation kinetics for AM and YM, respectively. Further, the most appropriate model was selected based on Akaike's theory. The log-logistic model was the best fitting for AM and YM inactivation, showing the least Akaike weight in 47.33 and 48.82% of the inactivation curves, respectively. The optimization of the CP parameters was studied in the domain of 18-30 kV of voltage, 2-6 mm of juice depth, and 6-10 min of treatment time using the response surface methodology (RSM). The experimental design utilized was a central composite rotatable design (CCRD). The effect of voltage, juice depth, and treatment time on the various responses, viz. peroxidase activity, color, total phenolic content, ascorbic acid, total antioxidant activity, and total flavonoid content, was examined. While modeling, the artificial neural network

(ANN) showed greater predictive capability than response surface methodology as the R^2 value of responses was greater in the case of ANN (0.9538 - 0.9996) than in RSM (0.9041 - 0.9853). The mean square error value was also less in the case of ANN than in RSM. The ANN was coupled with a genetic algorithm (GA) for optimization. The optimum condition obtained from ANN-GA was 30 kV, 5 mm, and 6.7 min, respectively. Further, CP-optimized (30 kV/5 mm/6.7 min), CP-extreme (30 kV/2 mm/10 min), and thermal treatment (90 °C/5 min) was compared based on the physicochemical, particle size distribution (PSD), rheological, bioactive compounds and sensory evaluation. The CP-optimized treated juice demonstrated merits over CP-extreme and thermally treated juice in terms of better stability, bioactive, and nutritional attributes retention. The thermal treatment led to the depletion of bioactive, nutritional, and sensory attributes. Furthermore, the fuzzy logic assessment indicated that the juice treated with CP optimization exhibited improved sensory attributes compared to that treated with CP extreme and thermal methods. PSD reveals that CP-treatment reduced the volume mean and sauter mean diameter from 536 to 473 nm and 534 to 462 nm, respectively, thereby, stabilizing juice. CP treatment significantly lowered the pseudo-plasticity (0.099-0.195) and consistency of juice (62.16-22.99 mPa.s^n). Ultimately, the storage study of CP-optimized (S2: 30 kV/5 mm/6.7 min), CP-extreme (S3: 30 kV/2 mm/10 min) and thermally treated (TT, S4: 90 °C/5 min) kiwifruit juice packed in glass (GL) and polyethylene terephthalate (PET) bottles at 5, 15, and 25 °C were investigated. The changes in the quality attributes were higher in PET samples than in GL bottles. The S2 in GL bottles exhibited a maximum shelf life of 100 days at 5 °C. Quality indices, including total colour change, overall sensory acceptability, and ascorbic acid, were modelled, and the zero-order model performed better than the first and second-order reaction models. Furthermore, the Arrhenius, Eyring, and Ball models were employed to model temperature-dependent reaction rates, and the Ball model performed better. So, the zero-order reaction and Ball model were combined to predict kiwifruit juice's shelf life.

Keywords: Cold plasma, kiwifruit juice, kinetic modelling, optimization, shelf life