ABSTRACT

Pineapple juice (PJ), among all processed pineapple products, is highly preferred by consumers due to its distinctive flavor and aroma. It is an excellent source of bioactive compounds, vitamins, minerals, and the health-promoting protease bromelain (BRM). Polyphenol oxidase (PPO) and peroxidase (POD) are the principal food-degrading enzymes in PJ. The inactivation kinetics of PPO and POD in PJ were examined in the experimental range of 25–45 kV for 14 min of cold plasma (CP) treatment. The findings revealed that CP parameters such as voltage and treatment time substantially reduced the enzyme activity of both enzymes, with the voltage having a more pronounced effect on enzyme activity. The kinetic models viz. log-linear, Weibull, and logistic were fitted to experimental data for enzyme inactivation kinetics. The Weibull model was best fitted to the experimental dataset among these models. The scale factor for PPO was 15.95, 10.87, and 5.73 min at 25, 35, and 45 kV, respectively, which was lower than POD with scale factor 40.74, 19.76, and 7.28 min, respectively. This shows that POD was more resistant to inactivation by CP than PPO. The effect of CP on the natural microbiota, namely, aerobic mesophiles (AM) and yeasts and molds (YM) in PJ, were examined in the experimental range of 25–45 kV for 14 min treatment. The populations of AM and YM were reduced by 4.7 and 4.1 log cfu/mL at 45 kV for 14 min CP treatment, respectively. The microbial inactivation kinetics were studied using Weibull + tail, Geeraerd, log-logistic, Coroller, and Cerf models. The Coroller model was best fitted to the experimental dataset among these models. The residual population (Nres) model parameter in the Geeraerd model explained the tailing behavior of microbes. Furthermore, the CP process parameters significantly ($p < 0.05$) reduced microbial population after CP treatment. The modeling of data in the experimental domain of 25-45 kV for 120-900 s for six quality attributes, viz., POD, BRM, total color change (ΔE^*), ascorbic acid (AA), total phenolic content (TPC), and total antioxidant capacity (TAC) were performed using artificial neural network (ANN) and response surface methodology after CP treatment. The ANN was found to be more accurate in modeling the experimental dataset. The CP process parameters (voltage and time) were optimized for PJ using an ANN coupled with the genetic algorithm (ANN-GA). The optimized condition was obtained at 38 kV for 631 s after 56 generations of GA. The optimally processed sample (S2) had 11% PPO activity, 49% BRM activity, 98% TAC, 89% AA with a ΔE^* value less than 1.97. Based on optimal conditions, CP provided an efficient POD inactivation combined with a high retention of bioactive compounds. Furthermore, CP treatment had an insignificant effect ($p > 0.05$) on the physicochemical attributes (pH, total soluble solid (TSS), and titratable acidity (TA) of PJ samples. The comparative analysis of untreated (S1), optimized CP-treated (38 kV/631 s, S2), extreme CP-treated (45 kV/900 s, S3), and thermally treated (TT, 95°C/12 min, S4) PJ was performed based on various quality attributes. The optimized CP-treated PJ showed superiority over extreme CP-treated and TT for retention of bromelain, bioactive components, and biochemical attributes. Moreover, the fuzzy logic evaluation showed that optimized CP-treated PJ had superior sensory characteristics than extreme CP and TT juice. The CP approach, like thermal treatment (95 °C/12 min), extended the shelf life of PJ by assuring microbiological safety (<1 log cfu/mL) and enzyme inactivation (> 90%). However, the thermal treatment resulted in the loss of bioactive, sensory, and

biochemical attributes. The particle size distribution indicates that CP significantly ($p < 0.05$) reduced the sauter mean and volume mean diameter from 1617 to 894 nm and 1688 to 917 nm, respectively, stabilizing PJ after CP treatment. CP treatment reduced the consistency from 1.22 to 0.31 mPa.sn and showed a pseudo-plastic behavior of PJ. Finally, the storage study and shelf-life evaluation of all four PJ samples (S1, S2, S3, S4) packed in glass (GL) and polyethylene terephthalate (PET) bottles at 5, 15, and 25 ℃ for 120 days (d) was performed. The ΔE^* and browning index increased during storage. However, the bioactive substances decreased with storage duration for all the samples. Moreover, all the samples showed a higher degradation rate for bioactive compounds at elevated temperatures. The changes in color parameters values showed zero-order kinetics, while the degradation of bioactive compounds followed a log-linear kinetics during storage. CP and TT samples reduced natural microbiota below the detection limit (<1 log CFU/mL). The residual activity (RA) of PPO for S2 decreased during storage. In contrast, S3 and S4 exhibited below 5 % RA throughout the storage. The samples packed in GL bottles showed superiority to PET bottles for maintaining a higher PJ shelf-life during storage. The shelf-life of the optimized CP-treated PJ sample packed in GL bottles was 90 d at 5 °C, 50 d at 15 °C, and 25 d at 25 °C based on AA ≥ 20 mg/100 mL, OA ≥ 5, $\Delta E^* \leq 12$, and microbial count ≤6 log CFU/mL.

Keywords: Pineapple juice, cold plasma, microbial inactivation, enzyme inactivation, kinetics, optimization, shelf life, storage study