Plasma–activated water as a disinfectant agent for fresh–cut lettuce: the role of hydrogen peroxide and nitrite

J. C. Chamorro[12], G. Denoya[23], C. L. Prevosto[12], S. Vaudagna[23]
[1] *Universidad Tecnológica Nacional, Facultad Regional Venado Tuerto, Grupo de Descargas Eléctricas, Argentina*
[2] *Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina*
[3] *Instituto Nacional de Tecnología Agropecuaria (INTA), Instituto Tecnología de Alimentos (ITA), Argentina*

Abstract: This study investigates the roles of H_2O_2 and NO_2^- in the disinfectant treatment of fresh–cut lettuce using plasma–activated water (PAW). PAW enriched with NO_2^- achieved greater reductions in microbial counts compared to PAW enriched with H_2O_2. Our findings suggest that food processing could be enhanced by using off-site generated PAW enriched with NO_2^-.

1. Introduction

Plasma activated water (PAW) has emerged as a promising non–thermal technology for food processing. [1]. Currently, stability of PAW during the storage time is a key topic in the literature [2]. However, the efficacy PAW is reduced during storage due to the destruction of long-lived species [3]. For example, during the generation of PAW at atmospheric pressure, H_2O_2 and NO_2^- are simultaneously formed and remain closely linked, even in different plasma reactors [4]. Nevertheless, H_2O_2 and NO_2^- cannot coexist stably in PAW under acidic conditions, as they quickly react to form peroxynitrous acid (ONOOH), whose short lifetime limits its practical application despite its high antimicrobial efficacy [5]. This study investigates the role of H_2O_2 and NO_2^- in off–site generated PAW stored for 3 days and its disinfectant effect on fresh-cut lettuce during 7 days of refrigerated storage.

2. Methods

PAW was generated using a millisecond pulsed-DC glow discharge (~100 W) in atmospheric-pressure air with a water cathode. Two different discharge operating conditions were used during PAW generation: (i) a closed reactor, confining the glow discharge within a gaseous chamber to promote NO_2^- production (PAW-NO_2^-); and (ii) an open reactor, allowing gas exchange with the ambient air to promote H_2O_2 production (PAW-H_2O_2) [6]. Activation time was 30 min and the PAW was stored at 4 °C for 3 days before treatments. Lettuce samples were immersed for 10 minutes in each type of PAW. The control group consisted of lettuce samples washed with tap water.

3. Results and Discussion

PAW-NO_2^- achieved 46.76 mg/L of NO_2^- (with H_2O_2 undetectable) and a pH of 2.39, while PAW-H_2O_2 achieved 30.63 mg/L of H_2O_2 (with NO_2^- undetectable) and a pH of 2.72. Figure 1 compares their antibacterial efficacy against the lettuce natural microbiota: aerobic mesophilic RAM and Enterobacteriaceae. Bacteria exposed to lethal PAW doses did not recover during 3 days, but PAW efficacy declined by day 7. Overall, PAW-NO_2^- achieved greater microbial reductions than PAW-H_2O_2. Inactivation by PAW-NO_2^- was linked to NO and NO_2 radicals from nitrous acid dissociation, while PAW-H_2O_2 acted through hydroxyl radicals (OH·) via the Fenton reaction.

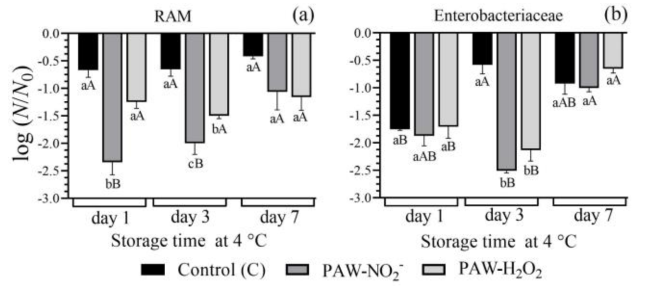

Fig. 1. Antibacterial efficacy of PAW-NO_2^- and PAW-H_2O_2 on fresh–cut lettuce during storage at 4°C: aerobic mesophilic RAM (a) and Enterobacteriaceae (b)

4. Conclusion

This study investigates the role of H_2O_2 and NO_2^- in off–site generated PAW stored for 3 days and disinfectant effect on fresh-cut lettuce during 7 days of refrigerated storage. Bacteria exposed to lethal PAW doses did not recover during 3 days, though PAW efficacy declined by day 7. Findings suggest that off-site generated PAW, particularly when enriched with NO_2^-, enhances food processing applications.

Acknowledgement

This work was supported by grants from the Universidad Tecnológica Nacional (PID 8460-8461) and the support from Agencia Nacional de Promoción de la Investigación, el Desarrollo Tecnológico y la Innovación, Argentina (PICT 2021–00769). J. C. C., G. D., S. V. and L. P. are members of the CONICET.

References

[1] R. Thirumdas et al., Trends Food Sci. Technol., **77**, 21−31 (2018).
[2] C. Ran et al., Plasma Sources Sci. Technol., **33**, 015009 (2024).
[3] Q. Wang et al., LWT, **149**, 111847 (2021).
[4] P. Lukes et al., Plasma Sources Sci. Technol., **23**, 015019 (2014).
[5] B. Fina et al., Food Control, **163**, 110530 (2024).
[6] B. Santamaría et al., IEEE Trans. Plasma Sci., **52**, 1923−1929 (2023).