Snapshot Report

Plasma-Activated Water

A Cold Plasma Wash Water Technology for Meat Safety and Shelf-Life Extension

Project Code	Prepared by	Date Submitted
2016-1326	Koentadi Hadinoto, Javiera Barrales Astorga and Francisco J. Trujillo	19/09/22

Project Description

This project developed and validated a novel non-thermal plasma (NTP) technology for microbial control of red meat. The technology produces plasma activated water (PAW) by ionising air with electric fields. The ionised nitrogen and oxygen species from the air diffuse into water, generating highly reactive oxygen and nitrogen species (RONS) in the water, such as nitrite (NO_2^-), nitrate (NO_3^-), hydrogen peroxide (H_2O_2) and ozone (O_3). RONS are the key components that are responsible for the temporary bactericidal effect of PAW, killing microbes when spraying PAW on meat surfaces. The benefits of the approach is that no chemicals are used except water and air. The formed RONS are active for a short period of time and react with organic matter, leaving no residues. The approach is scalable, environment and consumer friendly and low cost to operate; provided that the capital investment for the generation of PAW has been covered. The emphases of this project were:

- On the control of regulated pathogens on fresh meat (e.g. *Salmonella* and verotoxin-producing *Escherichia coli*), which are continuing to emerge.
- On the control of *clostridium spp*, linked to blown pack spoilage.
- On the control of total viable bacteria and specific spoilage bacteria such as *Pseudomonas*, Lactic acid bacteria etc., which contribute to total meat bio-burden and shortening of shelf-life.
- On the development of a non-thermal plasma system for bacterial decontamination. PAW is produced from water, air and electricity and does not require steam, heat or chemicals, facilitating a more hygienic, energy efficient and controlled manufacturing process.
- On treating meat in the order of seconds, or few minutes, to ensure the feasibility of the system for industrial scale treatments.
- That the system is versatile and scalable.

The aim of this project was to improve industry capability for controlling food safety and microbial spoilage of fresh meat through provision of increased shelf-life, safety-profiles, reduced operational costs and opening of new market opportunities.

Project Content

This project comprised the development of a PAW technology, its scale-up production from 0.05 L to 2 L, its effect of the nutritional and quality of meat, its application on meat surfaces, and its projected capital cost to scale-up PAW technology for the small and medium scale enterprise producers. This will facilitate the decision-making process for further research stages and the technological implementation in the Australia's red-meat industry.

To achieve the objectives of this projects, four phases were implemented. This includes:

- Phase 1: System Design and Optimisation of the Antimicrobial Efficacy
- Phase 2: Optimisation of Processing Conditions for Microbial Decontamination of Meat by Non-Thermal Plasma Treatment
- Phase 3: Assessment of the Effect of Plasma Treatment on the Nutritional and Organoleptic Properties of Meat
- Phase 4: Scale up and application of Plasma-Activated Water (PAW) to Meat

Project Outcome

- PAW reduced planktonic cell populations of *P. fluorescens, L. lactis* and *B. thermosphacta*, *E. coli, L. monocytogenes and S.* Typhimurium

- Favourable reductions in pathogenic species inoculated onto beef and lamb cuts with PAW.
- When compared to wash water treatments, PAW also showed a continued antibacterial effect for up to 35 min and thereby reducing risks of cross contamination through water run-off.
- PAW treatment resulted in a lower anaerobic population when compared to water.
- PAW treatment greatly improved not only the safety of beef but also retained and in some cases improved quality parameters, particularly those of importance for consumer acceptability such as limiting the extent of lipid oxidation, limiting the rise in pH during storage and improving beef tenderness.
- The production of PAW was subsequently scaled up to 200 mL, 250 mL, 500 mL, 1 L and finally 2 L, which is an important achievement because most of reported studies produced PAW in mL to achieve similar decontamination efficiencies.
- different reactor configurations were evaluated optimizing the processing parameter. A novel hybrid plasma discharge (HPD) reactor was designed achieving a remarkable efficiency. The electric-field simulation in the HPD reactor demonstrated the simultaneous formation of high electric field regions on both the HV electrode and the ground electrode within one power source, which explains its remarkable performance. This work was just published in the highest impact factor journal of *Elsevier* in chemical engineering, the Chemical Engineering Journal (Impact Factor = 16.744). PAW demonstrated the dual benefits of exceptional RONS energy efficiencies (up to 11 $g \cdot kW^{-1} \cdot h^{-1}$) and high bacterial removal (99%) at 30 seconds compared to literature studies, which take several minutes or hours to achieve same level of inactivation.
- The plasma system combined with ultrasound maximised the production of RONS, hence, increasing the RONS energy efficiency.
- The capital cost related to implementing the scale-up PAW technology for the small and medium scale enterprise producers were estimated to be AU$ 362,767 and AU$ 1,252,051, respectively.

Benefit for Industry

Based on the outcomes presented in The Final Report, PAW can enhance meat safety, extending shelf-life and quality retention, particularly in those of importance for consumer acceptability such as limiting the extent of lipid oxidation, limiting the rise in pH during storage and improving beef tenderness. PAW can also promote sustainable processing because of its simple operation, as it is produced from water and electrical discharges, and its potential to be integrated in meat processing industries. No chemicals are used during the production of PAW, meaning that there is no chemical waste. PAW can save water consumption by up to 40.4%.