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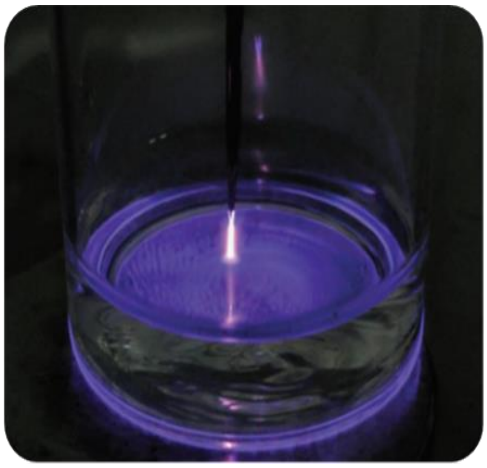
Development of novel plasma technology for enhanced shelf-life, quality and safety of meat and meat products



Key external stakeholders:
Prepared consumer foods sector, meat processors, policy makers

Practical implications for stakeholders:

Cold atmospheric plasma (CAP) is considered an emerging non-thermal technology, which has demonstrated applications for food product decontamination, gaining the interesting of the food industry. This technology can be simply described as the fourth state of matter; it results from applying energy (heat, voltage or light) to a gas, initiating a breakdown of individual gas molecules into free electrons, ions and metastable species. Recently, applications of this technology have been used in food products such as fresh produce, grains and meats with the aim to inactivate enzymes and foodborne pathogens. Nitrites have been used as a curing agent since they were discovered to play a role in the development of the distinctive cured meat colour, in the inhibition of lipid oxidation, and in the control of spoilage and pathogenic microorganisms. The growing concern among consumers about the potential carcinogenic risks of synthetic curing agents, and the increased popularity of 'all-natural' and 'clean-labelled' food products, have led the food industry to search for alternative curing methods and ingredients. Moreover, proteins, as food ingredients, are employed in the food industry, not only for their high nutritional value, but also because of their techno-functional properties. Modifications of their native structure, from the action of external factors such as pH, temperature or processing by emerging technologies, can lead to a change of their functionality; and consequently, their applicability. This project has shown the suitability of CAP to modify the functionality of food ingredients to achieve the desired properties of a specific food product, with no effect on the fatty acid profile, nutritional quality indexes and oxidation of lipids after the treatment. In addition, plasma is proposed as a new method for the production of nitrites to use in cured meat products as well as a tool for meat decontamination.

Main results:

- Non-thermal technologies have potential as decontamination technologies
- Cold plasma can be used to modify the functionality of food ingredients to achieve the desired properties of a specific food product.
- Brine solutions produced by the air plasma system contained sufficient nitrites to be used as a nitrite source for curing beef jerky.
- Significant reductions in the population of spiked *L. innocua* were observed in the brines and in the meat when plasma was used.

Opportunity / Benefit:

Plasma is identified as a potential technology for food decontamination and associated shelf-life extension of food products. Moreover, plasma-curing could supply a suitable source of nitrite for meat products and, further optimisation of the technology could see applications for meat decontamination. Depending of the native structure and nature of the protein, CAP treatment affects the functional properties in different ways. The findings point to the specific nature of plasma-protein interactions and the need for individual proteins to be studied as a function of plasma conditions.

Collaborating Institutions: Technological University Dublin

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1. Project background

Cold atmospheric plasma (CAP) is considered an emerging non-thermal technology which can be simply described as the fourth state of matter; it results from applying energy (heat, voltage or light) to a gas, initiating a breakdown of individual gas molecules into free electrons, ions and metastable species. CAP is a novel processing technology, which has demonstrated its ability for food product decontamination, gaining the interesting of the food industry. When CAP is applied to water-based liquids, it changes their characteristics (pH and electrical conductivity) and the resulting liquids are named as plasma-activated water (PAW). Depending on the nature of the discharge gas, reactive oxygen species (ROS – ozone, O_3; hydrogen peroxide, H_2O_2; hydroxyl radical, ·OH) and reactive nitrogen species (RNS – ONOO−, peroxy nitrite; NO_3^-, nitrate; NO_2^-, nitrite and the corresponding acids, nitrogen oxides NOx) are generated in the PAW. In recent years, applications of plasma technology have been used in food products such as fresh produce, grains and meats with the aim of inactivating enzymes and foodborne pathogens. CAP has been proved to be particularly interesting for the meat industry sector, as it can efficiently inactivate bacteria, moulds, biofilms, yeasts, spores, and other hazardous microorganisms, including potential bio-terrorism agents in meat products. Nitrites have been used as a curing agent since they were discovered to play a role in the development of the distinctive cured meat colour, in the inhibition of lipid oxidation, and in the control of spoilage and pathogenic microorganisms. The growing concern among consumers about the potential carcinogenic risks of synthetic curing agents, and the increased popularity of 'all-natural' and 'clean-labelled' food products, have led the food industry to search for alternative curing methods and ingredients. Moreover, proteins, as food ingredients, are employed in the food industry, not only for their high nutritional value, but also because of their techno-functional properties. Modifications of their native structure, from the action of external factors such as pH, temperature or processing by emerging technologies, can lead to a change of their functionality and consequently, their applicability. Therefore, before scaling up plasma processing technology, it is necessary to optimise this technology to find a correct balance between safety and quality.

2. Questions addressed by the project:

To evaluate the potential of plasma-activated brine (PAB) as a nitrite source for the curing of beef jerky, the effects on the quality parameters and on the microbial reduction of inoculated *L. innocua*. To investigate the effect of CAP on the techno-functional properties of two common food ingredients: gelatine, as an example of partially hydrolysed protein and haemoglobin as an isolated and native protein; in addition, the effects were also evaluated on a novel source of functional proteins extracted from a meat co-product: lung protein extract (ELP), as an example of an isolated protein blend.

3. The experimental studies:

- Beef slices were cured for ~18 h at 4 °C in brine solutions containing 0, 100 or 150 ppm of sodium nitrite, 150 ppm of sodium chloride (NaCl) and 100 ppm of sugar.
- PAB were generated by a plasma beam system operating for 10 min/100 ml at 20 kHz and supplied with air or nitrogen (N_2) gas.
- Forty grams of each protein (gelatin, hemoglobin and lung protein extract) were treated between two aluminum plate electrodes (outer diameter = 158 mm) separated by two polypropylene (PP) dielectric layers (2 mm thickness) forming a dielectric plasma barrier (DBD) reactor. Discharge voltage was set at 80 kV (RMS) with a treatment time of 15 minutes.
- Solubility, emulsifying capacity, rheological and gelation properties, water and oil holding capacity and surface hydrophobicity were measured.

4. Main results:

- Significant higher levels of nitrites in brines activated by air-plasma (90–184 ppm)
- No significant differences were found in the texture and lipid oxidation levels of samples cured in

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PAB compared to standard curing.

- A significant higher a* value (6.45 ± 0.50, p < .001) was observed in samples cured in PAB.
- Significant reductions (p < 0.01) of 0.5 log CFU/mL in the population of *L. innocua* were observed in the brines and of 0.85 log CFU/g reduction in the jerky when cured in PAB.
- CAP increased protein solubility, reduced significantly (p<0.05) the emulsifying capacity, significantly decreased (p<0.05) the gelation temperature of pork gelatine and ELP, improved significantly (p<0.05) the water holding capacity of both pork gelatine and ELP, suggesting a partially denaturalisation of the proteins present in these samples. Moreover, CAP increased significantly (p<0.05) the hydrophobicity surface of haemoglobin.

5. Opportunity/Benefit:

Plasma technology has the potential to be used as an alternative nitrite source with minimal impact on product quality; moreover, the results of the microbiological study showed that further optimizations of plasma technology for meat curing could be a successful strategy for meat decontamination. Depending of the native structure and nature of the protein, CAP treatment affects the functional properties in different ways. The findings point to the specific nature of plasma-protein interactions and the need for individual proteins to be studied as a function of plasma conditions. For instance, the solubility of the proteins extracted from bovine lung decreased significantly after treatment, while its oil holding capacity had a significant improvement. Thus, treated lung proteins could be employed in meat products, where oil holding capacity is more important than solubility. Further developments in the area of novel processing technologies and an increase in the awareness of their potentials is likely to lead to some degree of uptake by the industry in the medium-long term, fulfilling the growing demand for minimally processed and safe foods

6. Dissemination:

Main publications:

- Pérez-Andrés, J. M., Charoux, C. m. M., Cullen, P., & Tiwari, B. K. (2018). Chemical modifications of lipids and proteins by nonthermal food processing technologies. Journal of agricultural and food chemistry, 66(20), 5041-5054.
- Pérez-Andrés, J. M., de Alba, M., Harrison, S. M., Brunton, N. P., Cullen, P., & Tiwari, B. K. (2020). Effects of cold atmospheric plasma on mackerel lipid and protein oxidation during storage. LWT, 118, 108697.
- Pérez-Andrés, J. M., Álvarez, C., Cullen, P. J., & Tiwari, B. K. (2019). Effect of cold plasma on the techno-functional properties of animal protein food ingredients. Innovative Food Science & Emerging Technologies, 58, 102205.
- Inguglia, E.S., Oliveira, M., Burgess, C.M., Kerry, P.J, Tiwari, B.K. (2020). Plasma-activated water as an alternative nitrite source for the curing of beef jerky: influence on quality and inactivation of Listeria innocua. Innovative Food Science and Emerging Technology 59, 102276; https://doi.org/10.1016/j.ifset.2019.102276

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