FEATURE

Plasma: from the Northern Lights to agri-food's future technology

Researchers at TEAGASC, DIT and PlasmaLeap Technologies are leading the way in cold plasma research, where physics and biology meet.

Plasma is big stuff; in fact, it makes up 99.999% of the visible universe and is the fourth state of matter. However, unlike the other states of matter, plasma generally does not naturally exist on Earth under everyday conditions, apart from events such as the Northern Lights. Hence plasma must be artificially generated from neutral gases. Making plasma involves gas ionisation where free electrons are accelerated by an electric field, which collide with gas molecules, and consequently free additional electrons. Those electrons are in turn accelerated and free more electrons. The result is an avalanche multiplication that permits electrical conduction through the gas. This process is called the Townsend discharge, named after Irish physicist John Sealy Townsend, who discovered the fundamental mechanism of ionisation. The discharge requires a source of free electrons and a significant electric field; without both, the phenomenon does not occur.

Applications for the agri-food sector

A perusal of the scientific literature points to a surge in interest in plasma applications in the agri-food sector. One of the key advantages of employing plasma technology in such applications is the unique cocktail of short-lived reactive species it provides. The potential applications of plasma technology are extensive and include: microbial decontamination; food shelf life extension; pest control; toxin elimination; food and package functionalisation; plant fertilisation; and, many others (Sarangapani *et al.*, 2018). We can expose biological matter to a direct plasma discharge and/or the resultant 'after-glow' of reactive species it provides (**Figure 1**).
A relatively new approach for the delivery of plasma-generated species to biological targets is to 'activate' water or other liquids through exposure to plasma discharges (**Figure 2**). This results in plasma-activated water (PAW), which can be used as an active washing agent or bio-fertiliser. Such an approach is advantageous for its ease of application, defined dose, storability and off-site generation. PAW displays, for a period of time, reactive properties which may be used for either disinfection of the water itself or as a wash agent for surfaces. Exciting areas of plasma agri-food research include food preservation, agriculture, and food odours and waste.

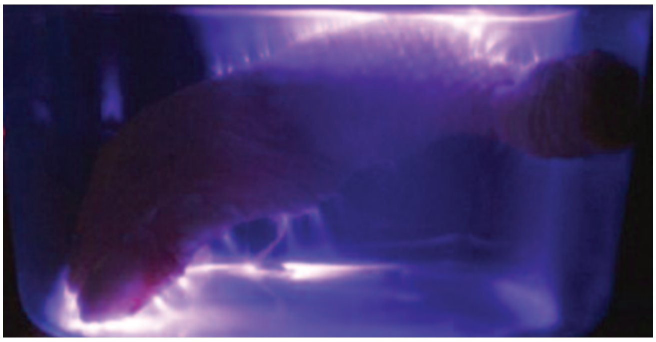

FIGURE 1: In-package plasma treatment of chicken meat.

Food preservation

Many of the plasma species generated are highly reactive and plasma is often cited for its multi-modal mechanisms of antimicrobial action. Plasma species have a broad spectrum of lifetimes (nanoseconds to hours) dependent on both plasma conditions and available reactive matter such as organic material. This leads to a useful window of activity with regard to plasma treatment and afterwards the conversion of plasma species into inert gas (Sarangapani *et al.*, 2018). Exposure of foods to plasma gas species or washing in PAW can significantly extend the shelf life of foods. In particular, we are interested in replacing processes such as chlorine washes with such technologies, as the efficacy is similar but the process does not leave any chemical residues.

Agriculture

Plasma discharges and PAW can be used for plant growth (as a cheap nitrate fixation process) and also as a bio-pesticide. As the process uses only atmospheric air it can be considered an environmentally sustainable and economically viable technology. **Figure 3** shows the effects of using PAW on the growth of soybean plants.
Plasma also dramatically enhances the germination rates and vitality of plant seeds. Plasma is also a promising technology for control of pests in stored cereal crops and as an environmentally friendly bio-pesticide for plants in the field (Misra *et al.*, 2016).

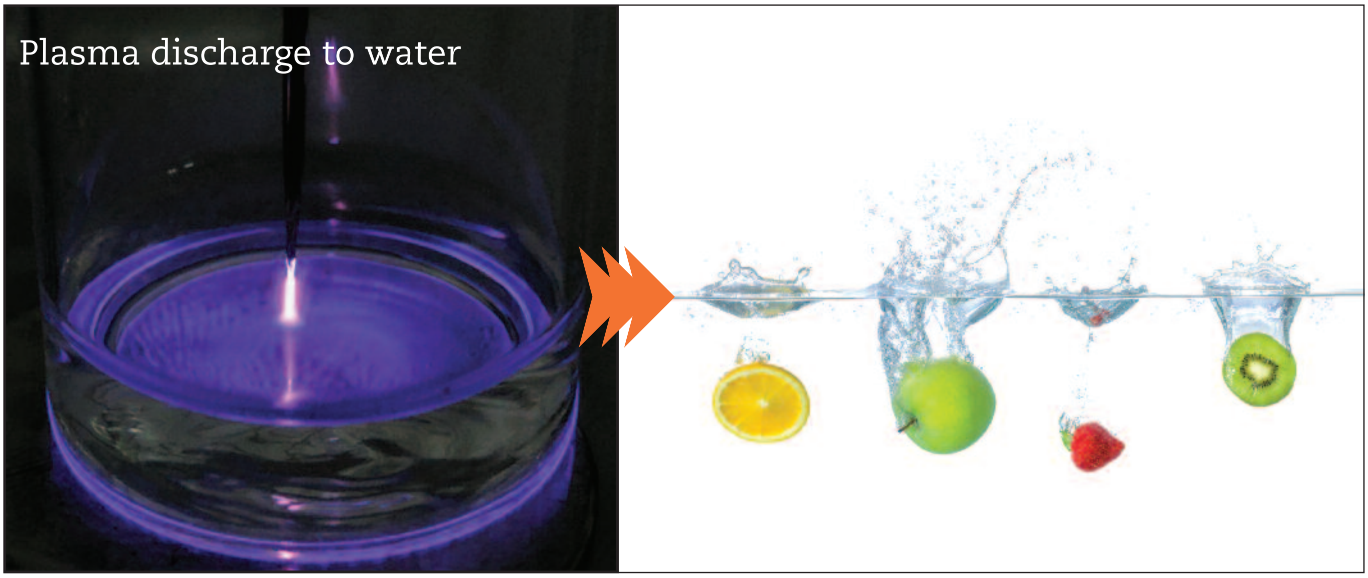

FIGURE 2: Making plasma-activated water (PAW) and product immersion in PAW.

FIGURE 3: PAW for soybean growth enhancement.

Food odours and waste

Plasma can be used as an effective technique for industrial and animal house odour treatment. Teagasc, in conjunction with the BioPlasma group at Dublin Institute of Technology, are currently developing a plasma technology for odour breakdown, which is funded by Meat Technology Ireland (MTI). Reducing food losses and waste is identified as a global challenge. Recently, the feasibility of using the technology for biological waste pre-treatments has attracted attention. Our initial study demonstrates delignification in spent coffee waste leading to a suitable substrate for bioethanol production (Ravindran *et al.*, 2017).

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The unique physics and chemistry found with cold plasma offers agri-food industries a new technology-driven tool for supporting a sustainable food industry. Technology developments offering the potential for process scaling coupled with the use of only atmospheric air as the inducer gas means that plasma is both technologically and economically viable as a food and agri processing aid (Sarangapani *et al.*, 2018). Irish research and technology companies including Teagasc, DIT and PlasmaLeap Technologies are leading the way in this new field of research, where physics and biology meet.

References

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