Cold plasma: Applications and future perspectives within the food and drink industry

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Overview

- Introduction to plasma (what is it?)
- Potential applications
- Look at work conducted at Campden BRI
- Summary

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What is Cold Plasma?

What not to expect

Cold blood

Cosmetic cream

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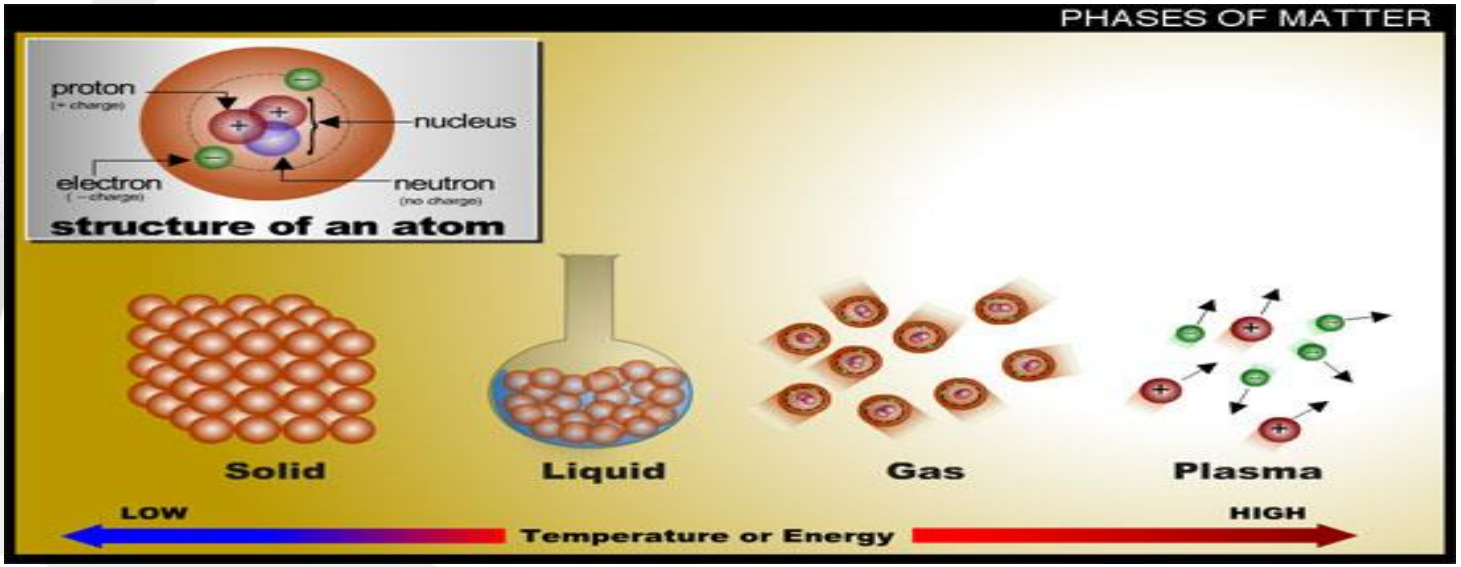
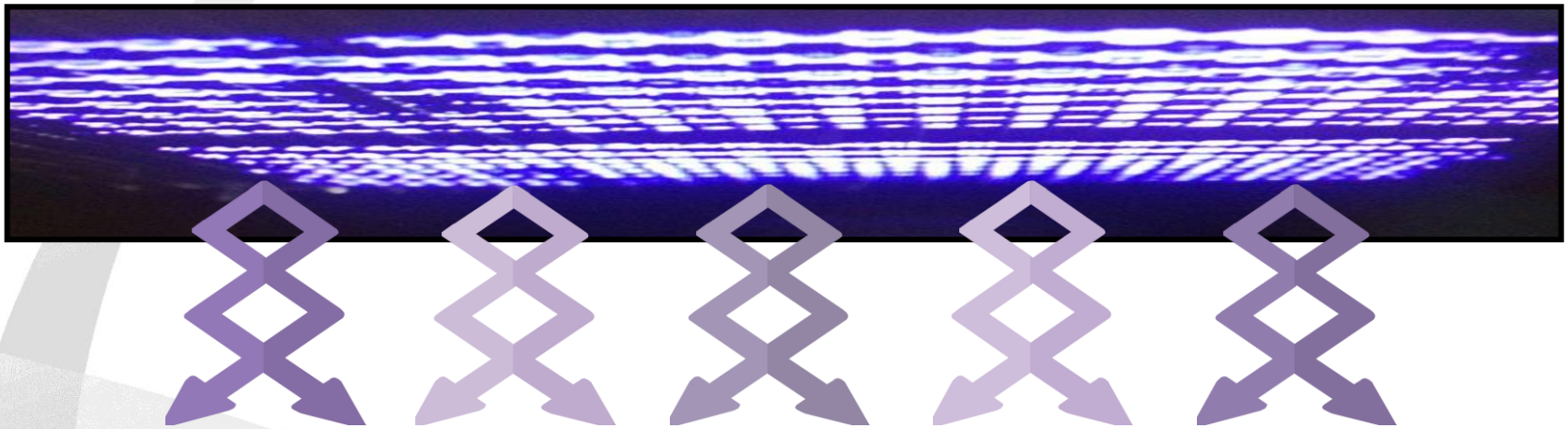
Cold Plasma



- Plasma is otherwise known as the 4th state of Matter
- Applying energy to a gas can break down the atoms into more basic constituent parts.

Cold Plasma system



- Provide a source of highly reactive and biologically relevant chemical species close to room temperature using a gas and electricity.

- Cold plasma is a dry treatment so would also be an ideal disinfection tool for processors of low water activity products.

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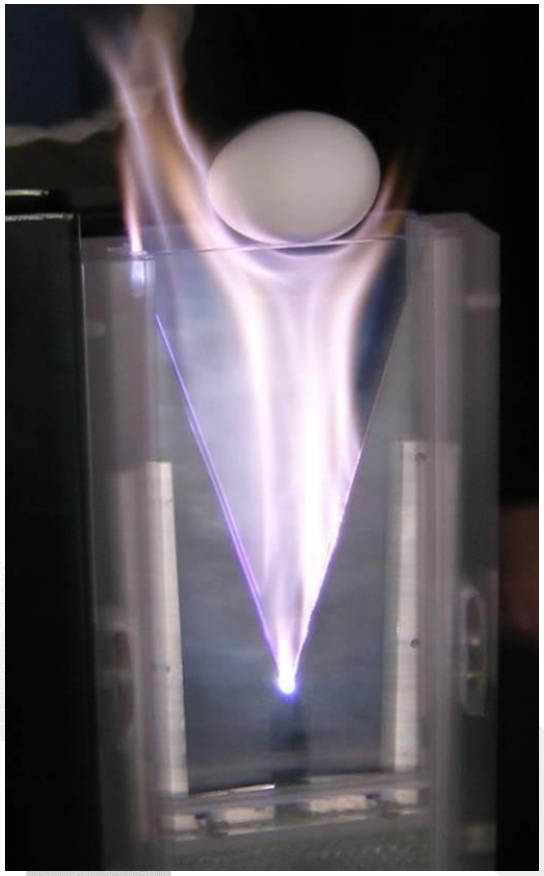
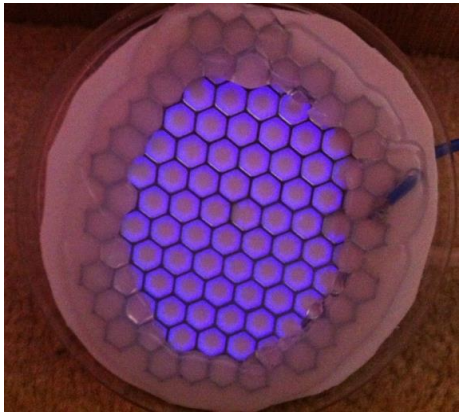
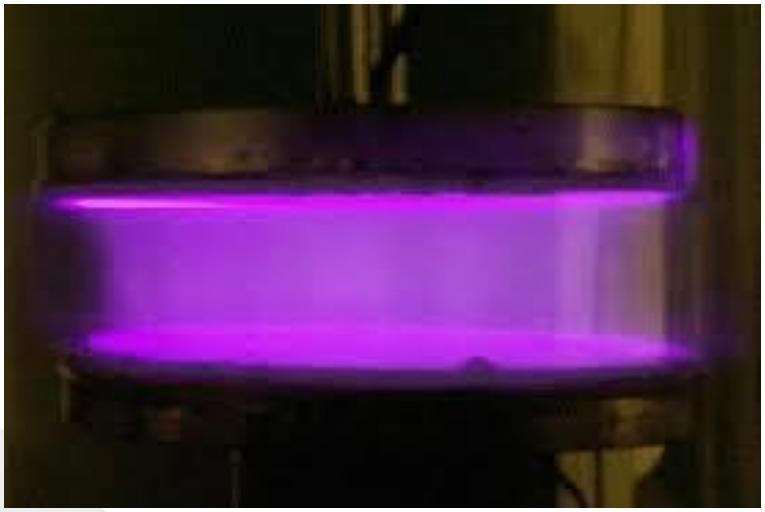
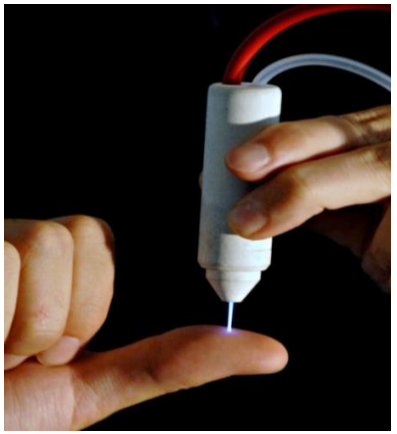
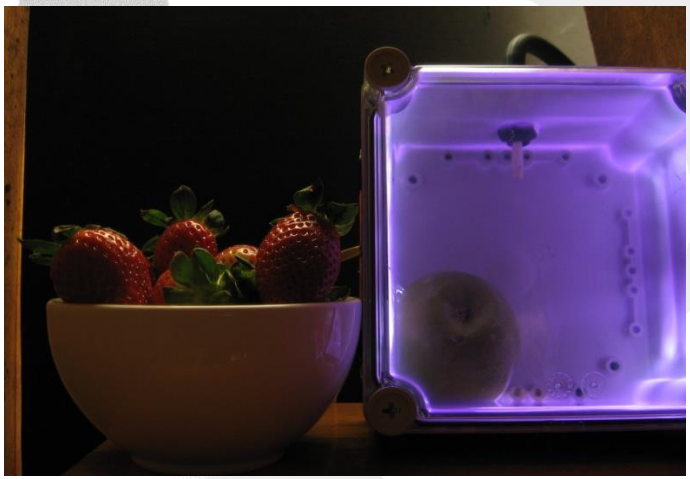
Cold plasma

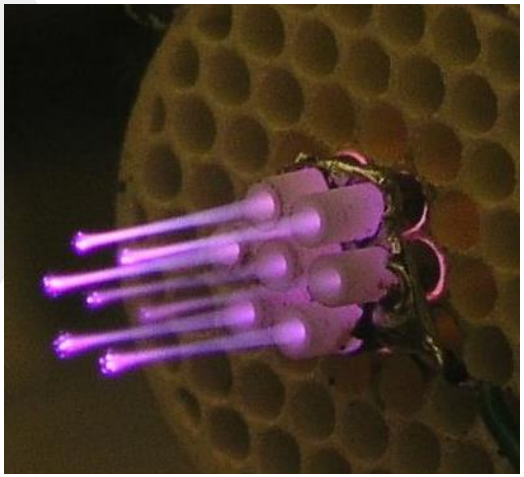


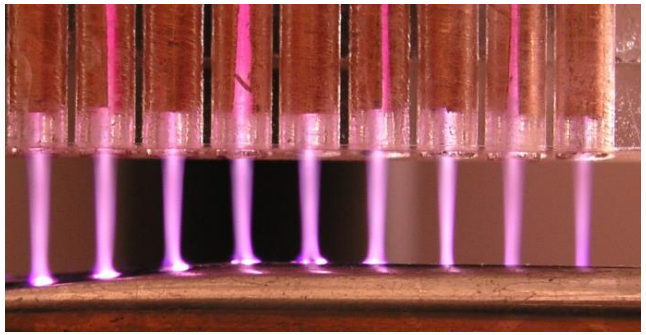












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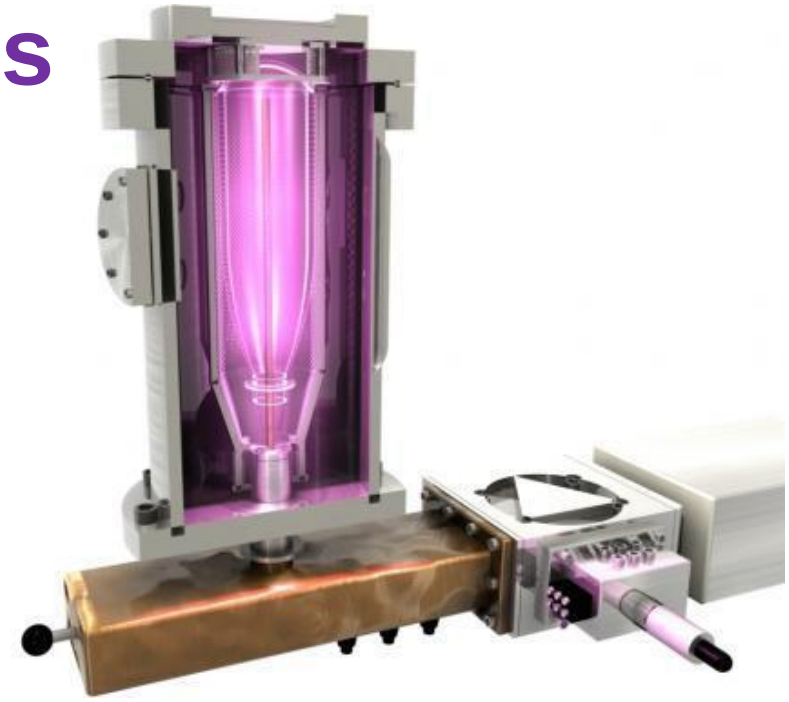
Potential plasma applications

- **Air decontamination** of airborne bacteria (particularly important for turbulent air flows such as those in fridges).
- **Liquid treatment** for removal of organic chemicals, bacteria and biofilms.
- **Surface decontamination** of Foods, process equipment, packaging and work surfaces.

Packaging treatments

- Barrier properties by deposition of barrier layers towards gases (oxygen, carbon dioxide, water vapour)



M Deilmann Institute for plasma technology, RUHR Universität Bochum

- Plasma can immobilise bioactive compounds onto the surfaces of packaging

- Applying active packaging to fresh fruits and vegetables

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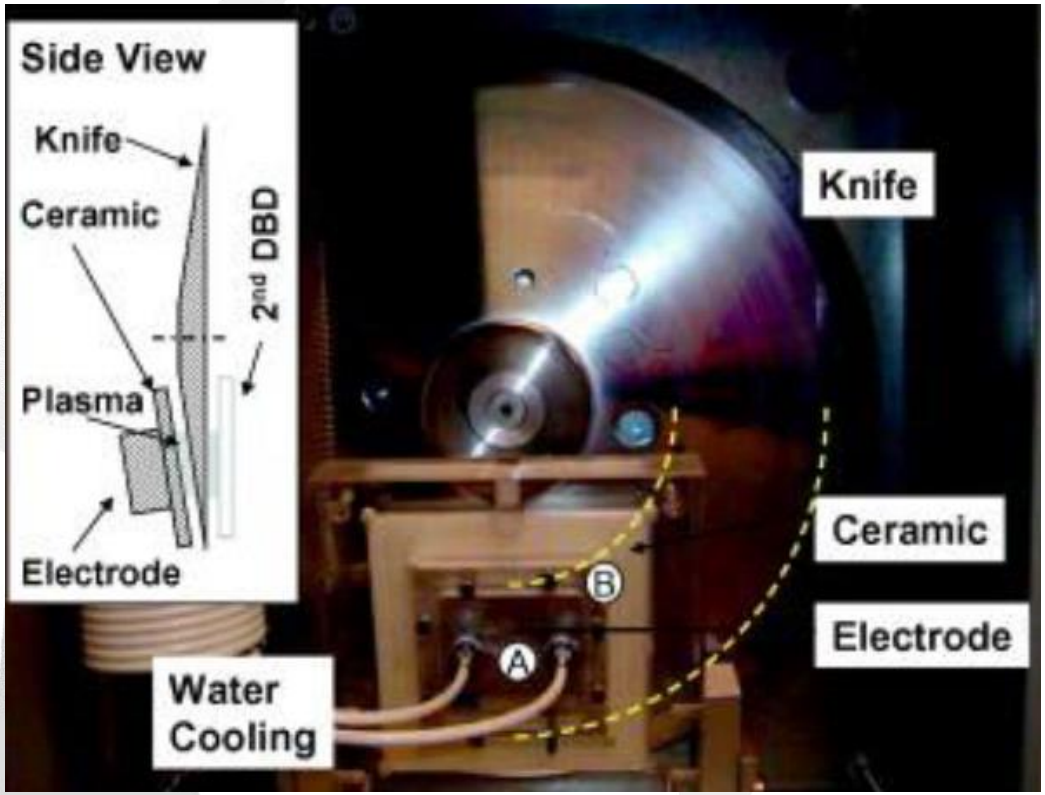
Equipment decontamination



F. Leipold et al. / Food Control 21 (2010) 1194–1198

Plasma disinfection of a cutting knife

Knife is a ground electrode
Potential for plasma disinfection during production

A log 5 reduction of *L. innocua* was obtained after 340 s of plasma operation

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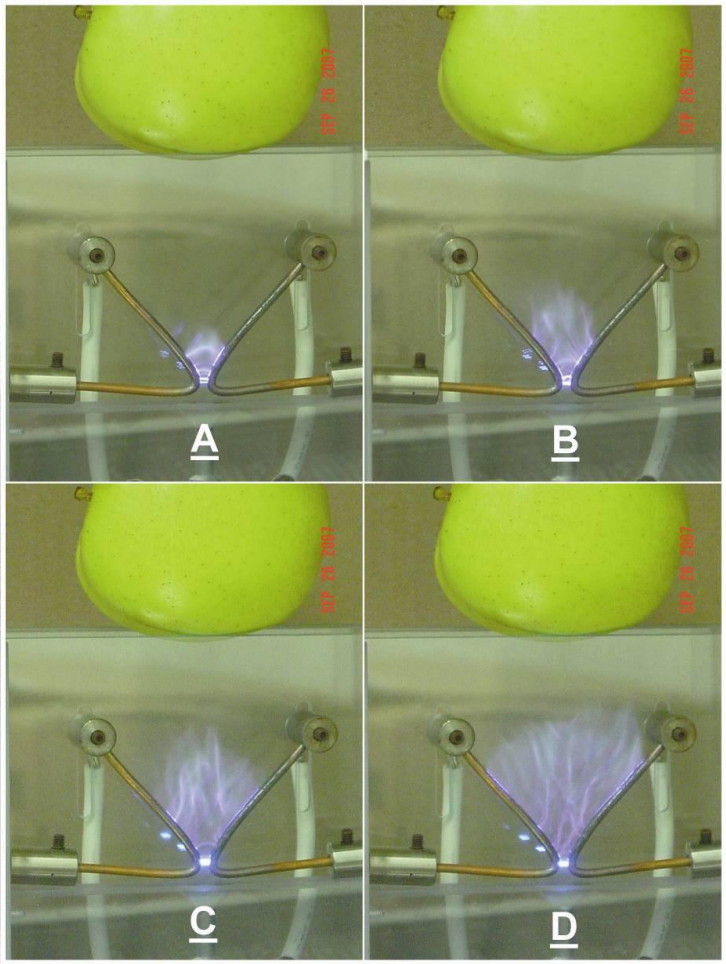
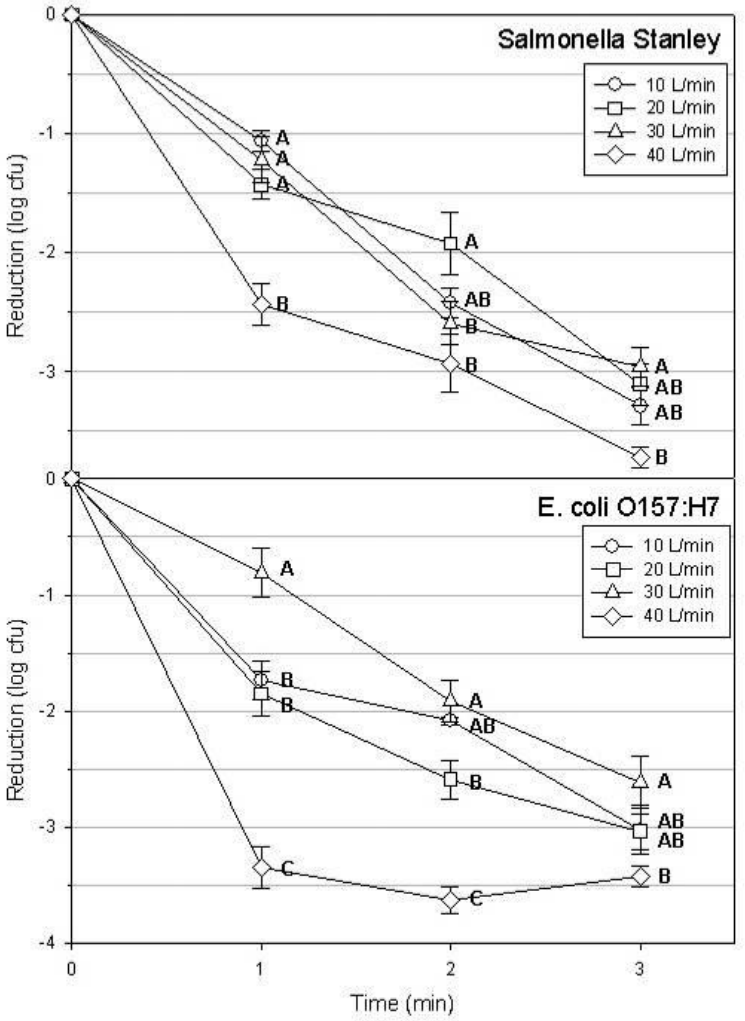
Food treatments





Niemira and Sites. 2008. J Food Prot.

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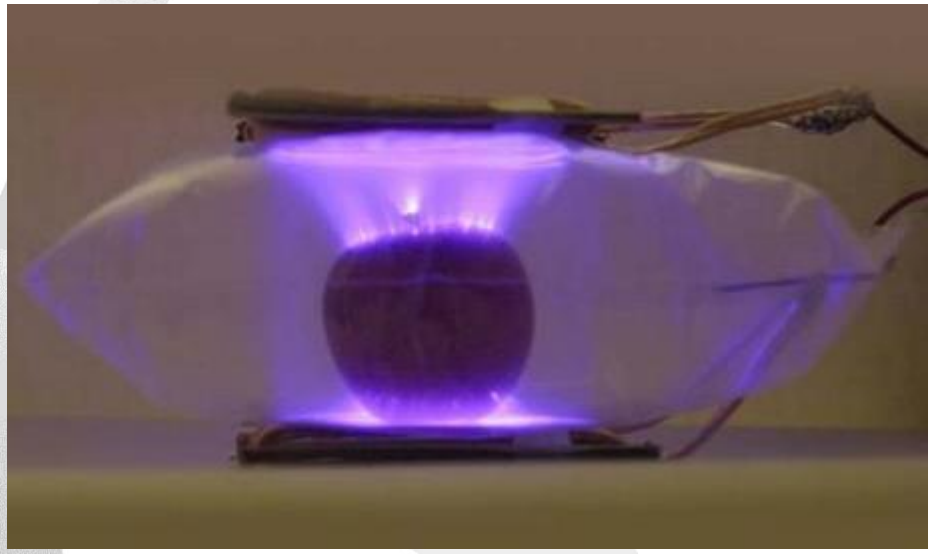
Safe Bag

EU funded project **–SAFE-BAG**



- Short exposure times (20-45 s) and left for 24 hrs can eliminate *E. coli*

- Packaging materials tested are: Polypropylene (PP) and Low density polyethylene (LDPE)
- Good results also with cardboard, paper board and glass.

http://www.safebag-fp7.eu/

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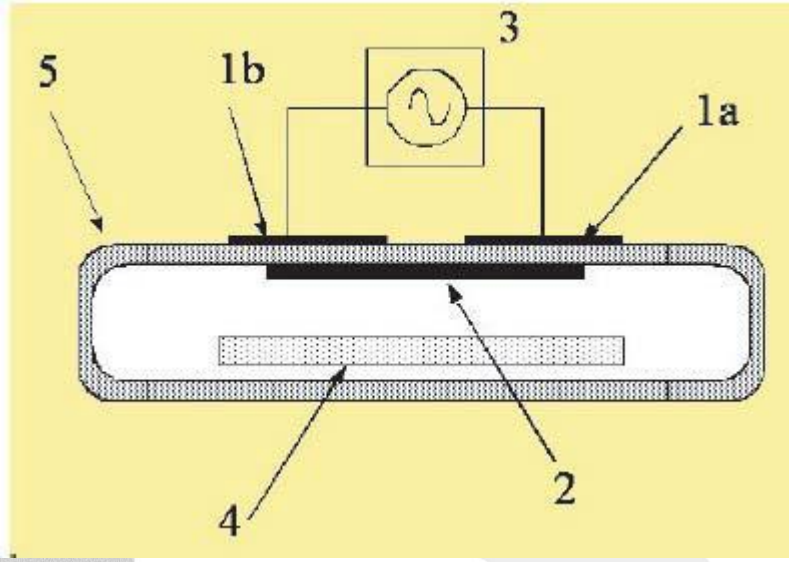
Plasmalabel™



- Labels act as electrodes to generate a plasma in pack
- A 4 log reduction of *B. subtilis* spores was achieved for 10 min exposure to the plasma species
- The treatment of tomatoes demonstrated no mildew growth after 14 days
- Shelf life has also been extended for strawberries.

Schwabedissen, A. et al. 2007. *Contrib. Plasma Phys. 47, 551-558*

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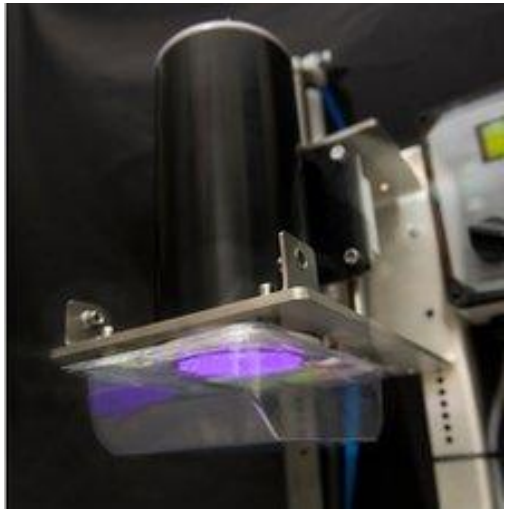
Anacail

- Plasma is generated on the outside of the packaging material.



- Anacail ozone generator, changing a precise amount of the oxygen in the pack into ozone.

http://www.bbc.co.uk/news/uk-scotland-scotland-business-21390274

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Feasibility experiments at Campden BRI

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Mung bean decontamination

FSA funded project

Inoculated bacterial cocktail

1. *Salmonella* Typhimurium
2. *Salmonella* Enteritidis
3. *Salmonella* Mbandaka
4. *Salmonella* Senftenberg
5. *Salmonella* Saint Paul 1092 from bean sprouts

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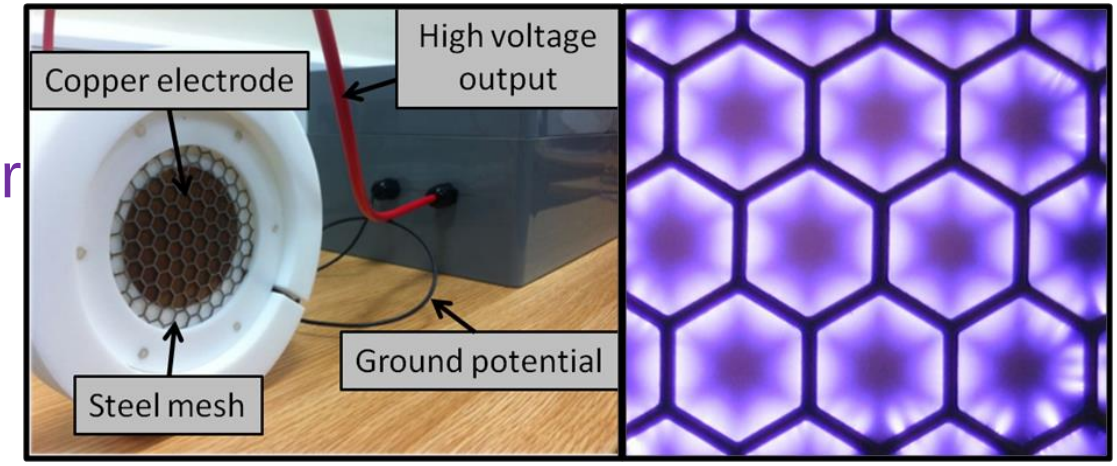
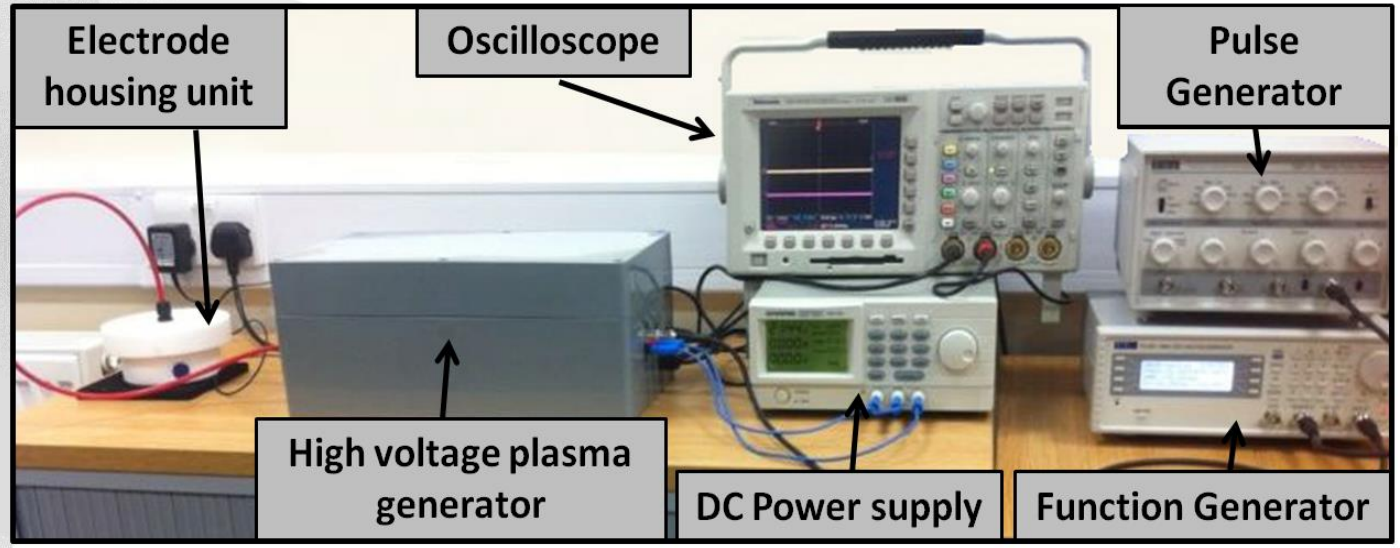
Plasma system

- 9 different combinations of power and duty cycle were tested for different treatment times





Designed by Dr James Walsh from the University of Liverpool

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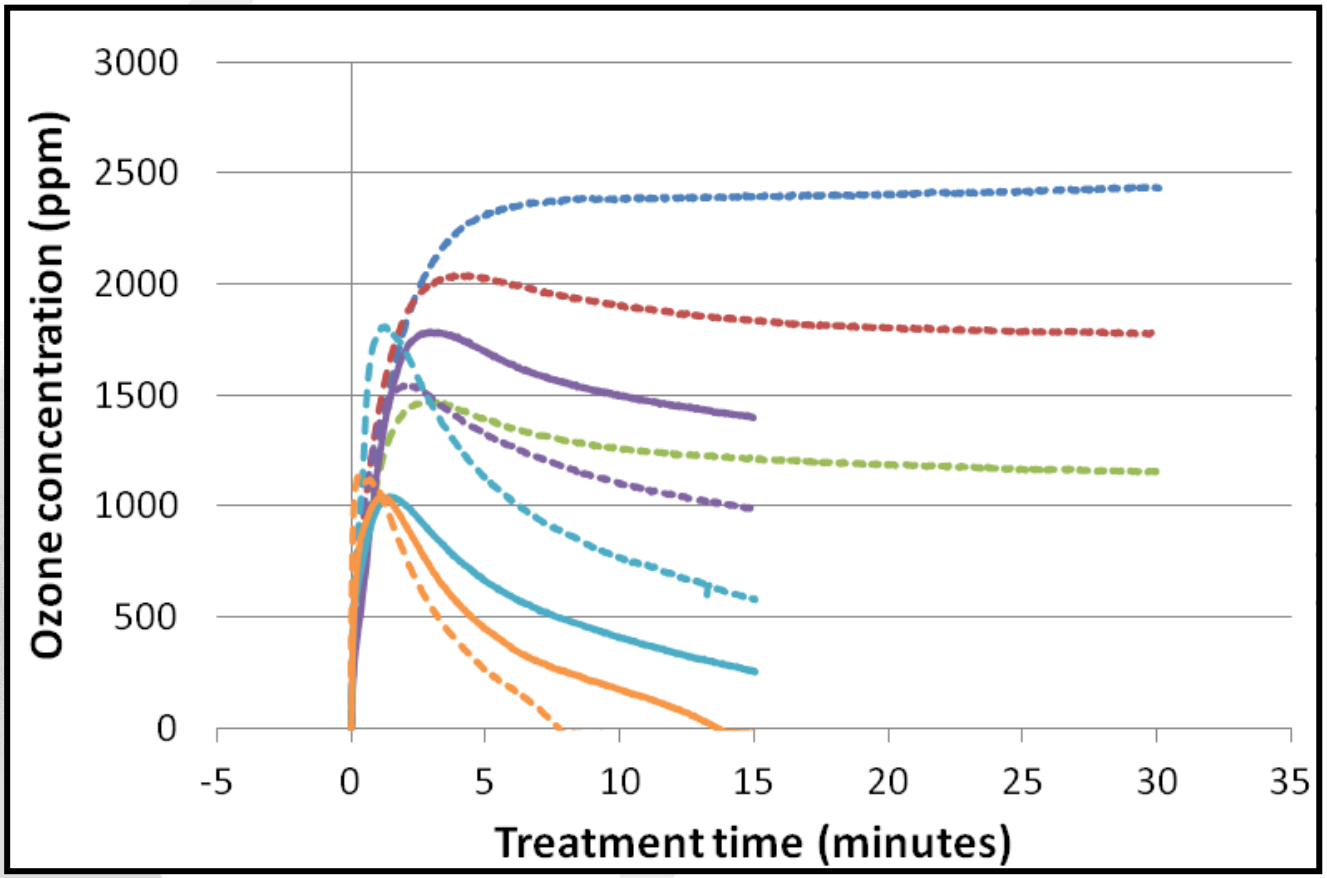
Plasma chemistry



- Different plasma parameters significantly effect the plasma chemistry

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Inactivation results

Treatment condition	Average Power (W)	Duty cycle (%)	Treatment time (min)	Mean log reduction (cfu/g)
2.5 (50%)	2.5	50	10	**0.29**
			20	**0.73**
			30	**1.07**
7.0 (100%)	7	100	5	**0.59**
			10	**0.69**
			15	**0.91**
7.0 (50%)	7	50	5	**0.38**
			10	**0.41**
			15	**1.05**

- Three plasma conditions which generated the greatest log reduction with the longest exposure time

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Chlorine Inactivation

Chlorine wash (200 ppm pH 7.0)	Wash log reduction (cfu/g)			Mean log reduction (cfu/g)	Overall mean log reduction (cfu/g)
	1	2	3		
1	1.73	1.15	1.16	**1.35**	**1.06**
2	0.99	0.98	1.00	**0.99**	
3	0.71	0.99	0.87	**0.85**	

- The plasma inactivation was comparable to a 30 min chlorine wash with 200 ppm Chlorine.

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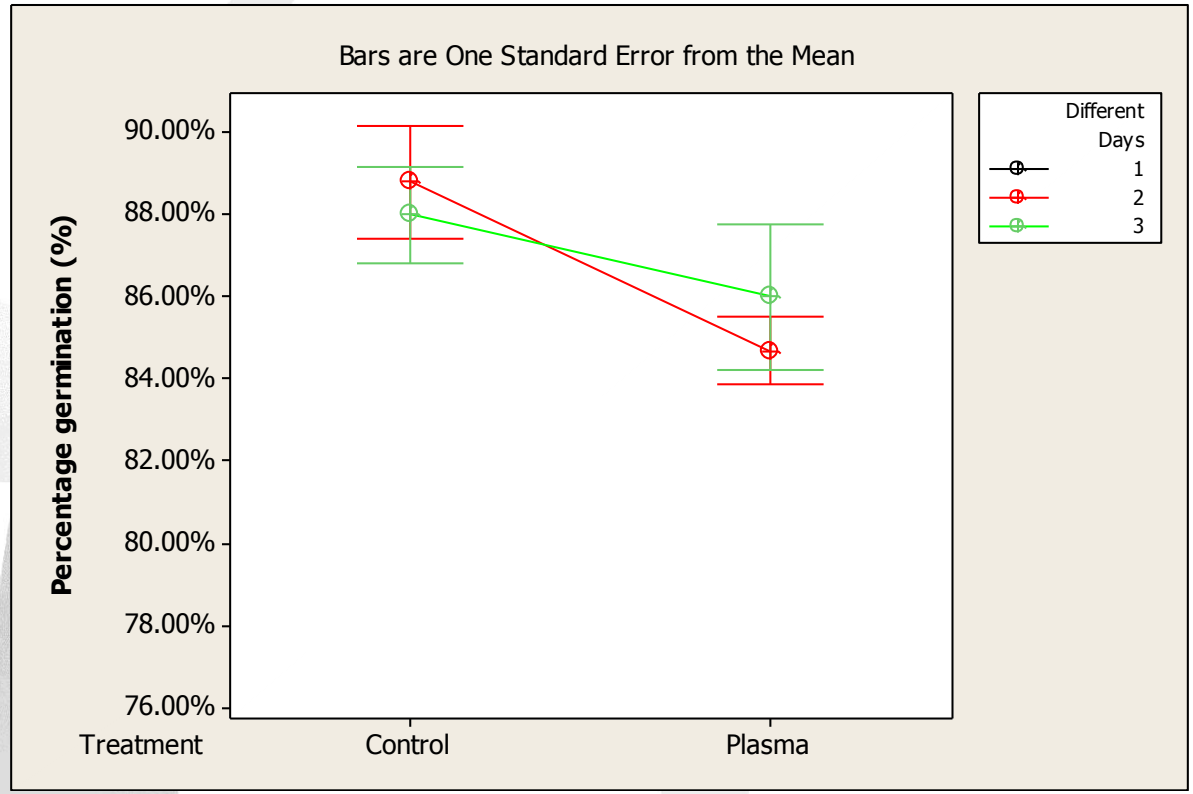
Seed Germination



- 2.5 (50%) plasma condition negatively effected germination.
- 3% Reduction in seed germination

- Most likely due to long exposure to high ozone levels

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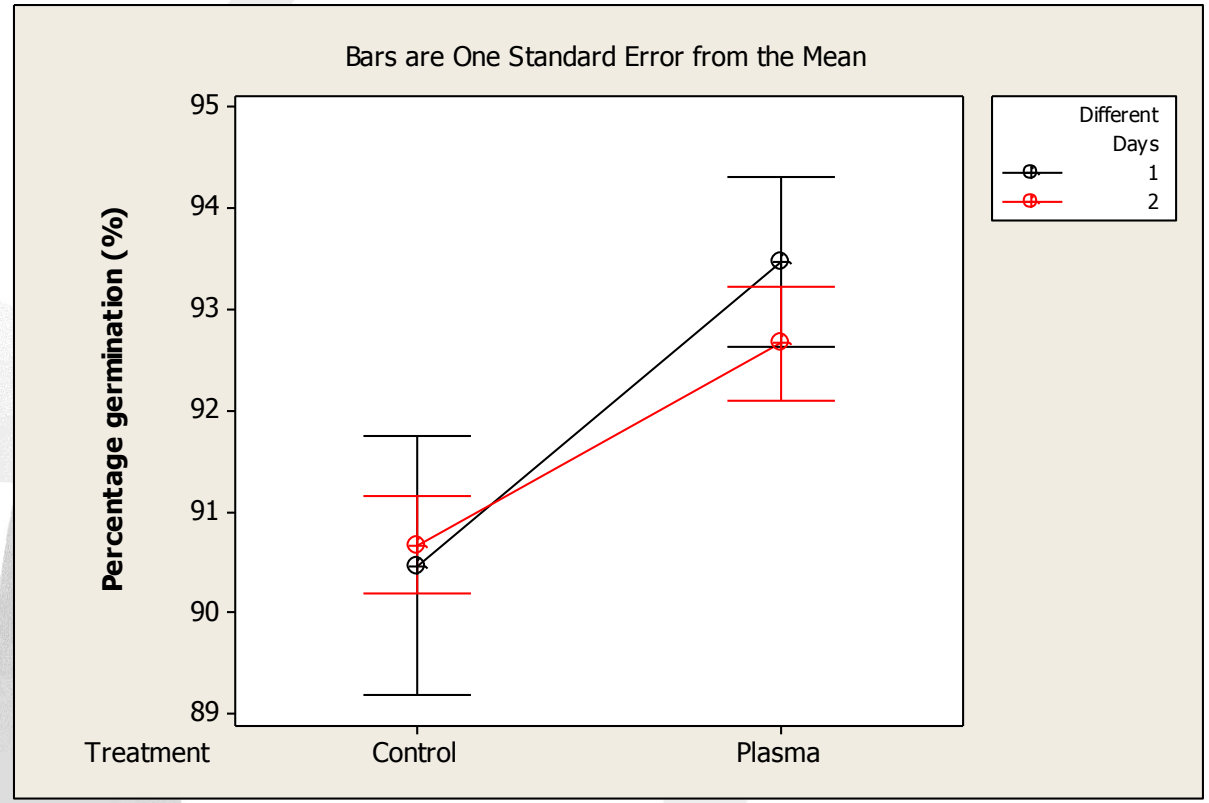
Seed Germination



- 7 (50%) plasma condition had a positive impact on the seed germination.
- 2.5% Increase in seed germination

- Could possibly modify the seed coat to allow better water absorption

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Colour and texture

- The quality of sprouted seeds were assessed after seed treatments with Chlorine washing or plasma treatment by colour and texture measurements.

- Results showed that the large variation within a treatment group (Plasma treated or Chlorine washed) masked and changes brought about by the different treatments.

Campden BRI member funded project

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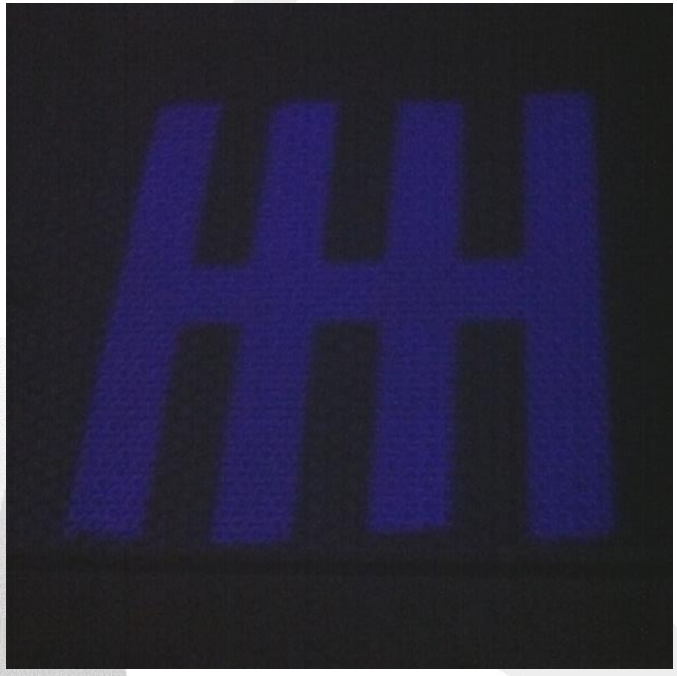
Plasma system



Designed by the University of Liverpool

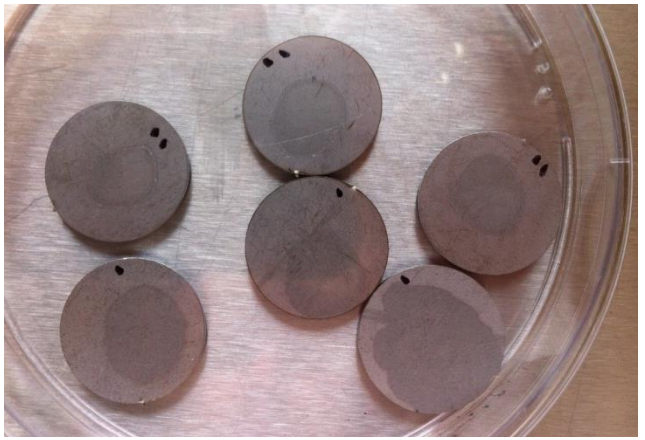
System Benefits

Operates in open air (no need for expensive gases)

Low power (~60 W average input power)

Scalable to larger surface areas and geometries

Stainless Steel surface



EN Standard 1.4301 (SAE grade 304) with a 2B surface finish in accordance with EN 13697

	Salmonella	*Listeria*	*E. coli*		*S. aureus*	
	Low soil	Low soil	Low soil	No soil	Low soil	No soil
control (log)	4.98	4.12	5.05	4.81	6.81	6.41
2 mins treatment	>3.98	>3.42	>2.66	>2.91	1.54	1.14
5 mins treatment	>4.28	>3.42	>4.35	>4.11	1.93	2.11
10 mins treatment	>4.12	>3.12	>4.35	>4.11	1.71	2.19

Low soil = 0.3 g/L Bovine serum Albumin (BSA)

No soil = No addition of protein

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Plasma spoilage impacts

- Day 14

Summary

- Very versatile technology with great potential to benefit areas of the food industry.
- Plasma parameters need to be optimised for the application (e.g. Food vs. Contact surfaces)
- Closer to being a commercial surface decontamination technology
- Great potential for food decontamination and shelf life extension but more work is needed to understand the quality impacts.

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Future challenges

- Greater understanding about the reactive plasma species.
- Scalability of the technology to industrial applications.

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Thank you for your attention!

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