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

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New Technologies Specialist
Overview

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

What not to expect

Cold blood

Cosmetic cream
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.
• 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.
Cold plasma
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)

- Plasma can immobilise bioactive compounds onto the surfaces of packaging

- Applying active packaging to fresh fruits and vegetables
Equipment decontamination

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
Food treatments

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/
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.

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
Feasibility experiments at Campden BRI
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
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
Plasma chemistry

- Different plasma parameters significantly affect the plasma chemistry.
## Inactivation results

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

• Three plasma conditions which generated the greatest log reduction with the longest exposure time
Chlorine Inactivation

<table>
<thead>
<tr>
<th>Chlorine wash (200 ppm pH 7.0)</th>
<th>Wash log reduction (cfu/g)</th>
<th>Mean log reduction (cfu/g)</th>
<th>Overall mean log reduction (cfu/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>1.73</td>
<td>1.15</td>
<td>1.16</td>
</tr>
<tr>
<td>2</td>
<td>0.99</td>
<td>0.98</td>
<td>1.00</td>
</tr>
<tr>
<td>3</td>
<td>0.71</td>
<td>0.99</td>
<td>0.87</td>
</tr>
</tbody>
</table>

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

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

Designed by the University of Liverpool
Stainless Steel surface

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

<table>
<thead>
<tr>
<th></th>
<th><em>Salmonella</em></th>
<th><em>Listeria</em></th>
<th><em>E. coli</em></th>
<th><em>S. aureus</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low soil</td>
<td>Low soil</td>
<td>Low soil</td>
<td>No soil</td>
</tr>
<tr>
<td><strong>control (log)</strong></td>
<td>4.98</td>
<td>4.12</td>
<td>5.05</td>
<td>4.81</td>
</tr>
<tr>
<td><strong>2 mins treatment</strong></td>
<td>&gt;3.98</td>
<td>&gt;3.42</td>
<td>&gt;2.66</td>
<td>&gt;2.91</td>
</tr>
<tr>
<td><strong>5 mins treatment</strong></td>
<td>&gt;4.28</td>
<td>&gt;3.42</td>
<td>&gt;4.35</td>
<td>&gt;4.11</td>
</tr>
<tr>
<td><strong>10 mins treatment</strong></td>
<td>&gt;4.12</td>
<td>&gt;3.12</td>
<td>&gt;4.35</td>
<td>&gt;4.11</td>
</tr>
</tbody>
</table>

Low soil = 0.3 g/L Bovine serum Albumin (BSA)
No soil = No addition of protein
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.
Future challenges

• Greater understanding about the reactive plasma species.

• Scalability of the technology to industrial applications.
Thank you for your attention!

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