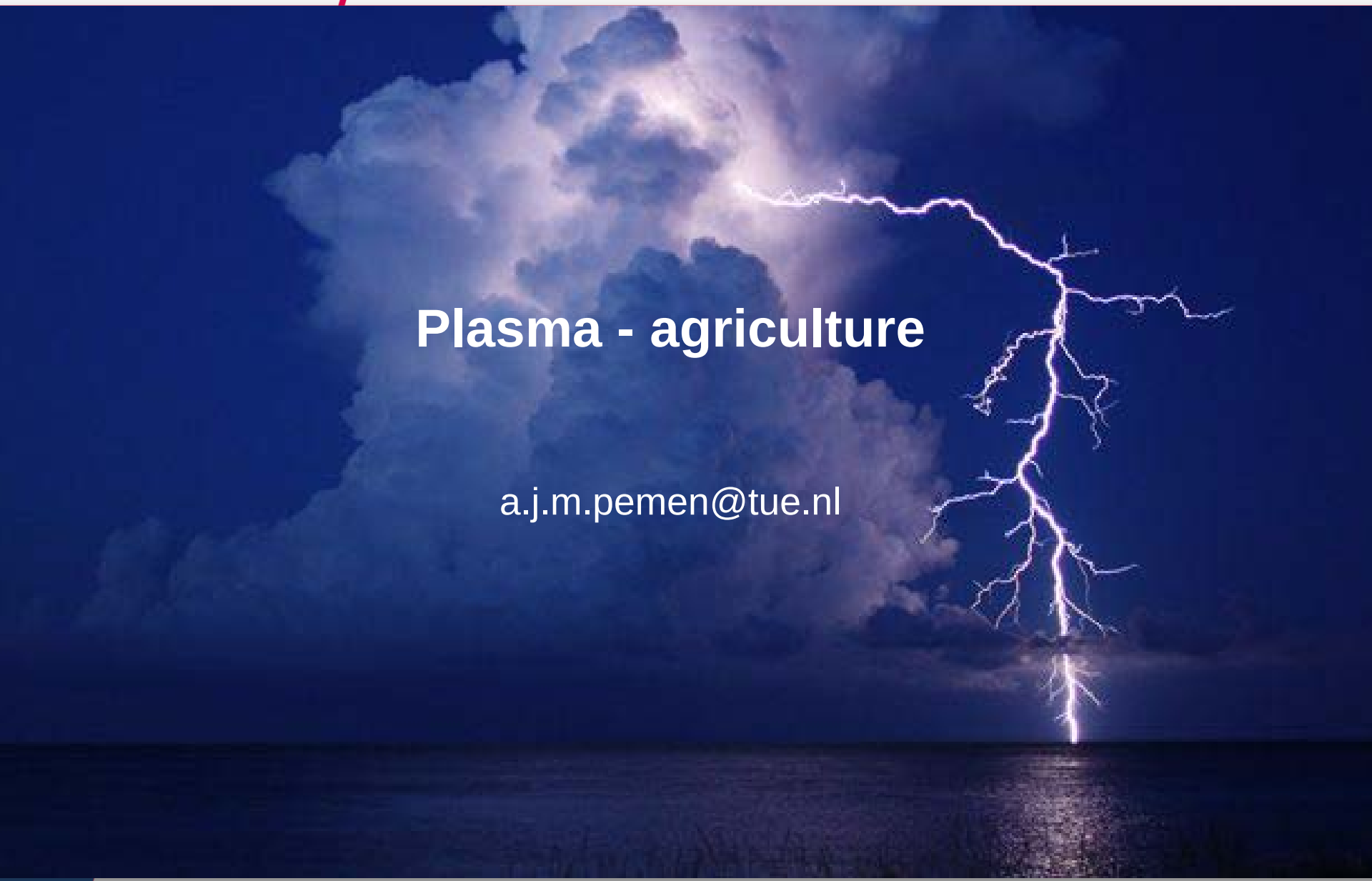
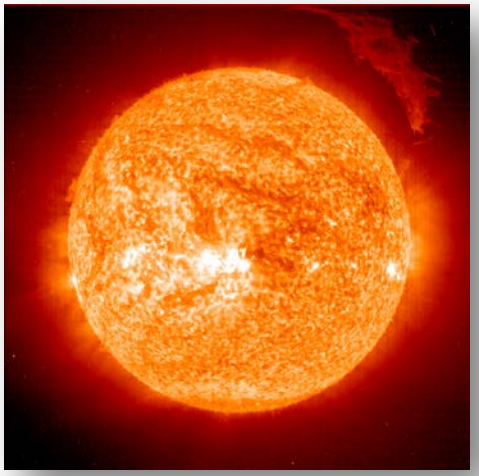


Plasma - agriculture

a.j.m.pemen@tue.nl

Plasma in nature

- Almost everything…..

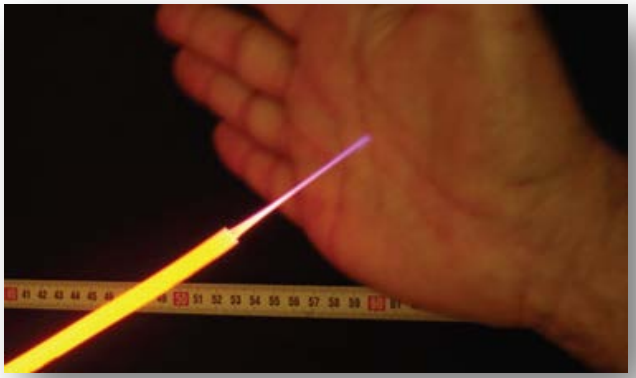


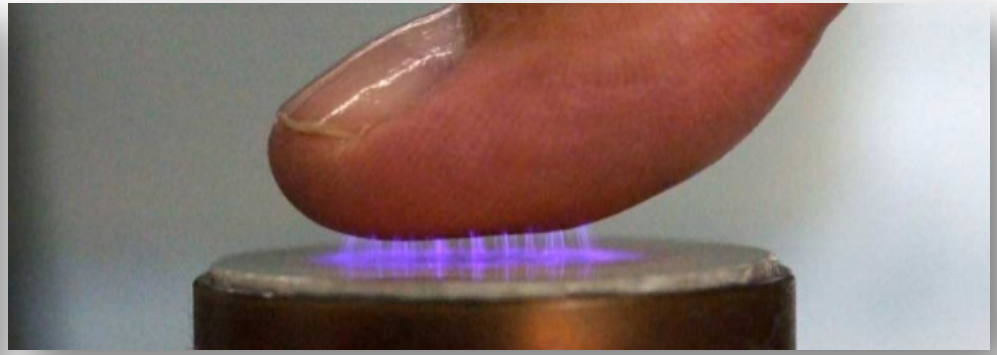
the sun

lightning

northern light

Man-made plasma





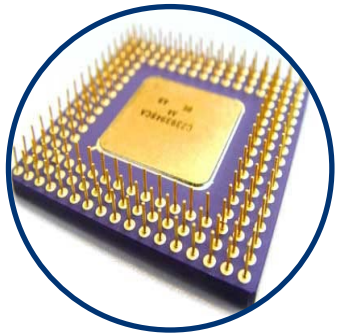
Applications of plasma

Renewable energy

- Efficient lighting
- New chemistry
- (liquid) Fuels
- Solar cells

Air and water

- Air and water purification
- Clean combustion
- Waste treatment



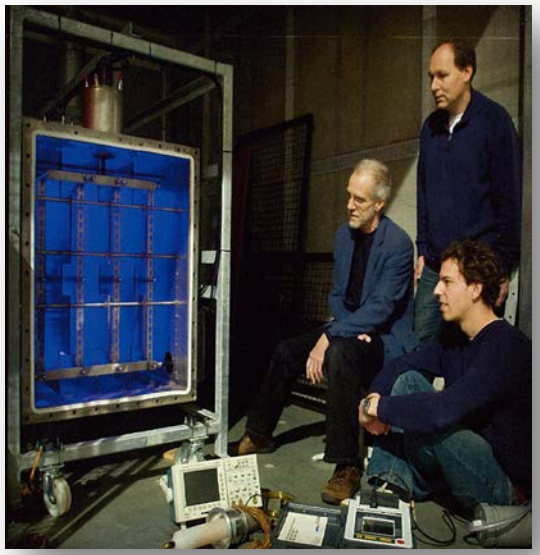
High tech systems

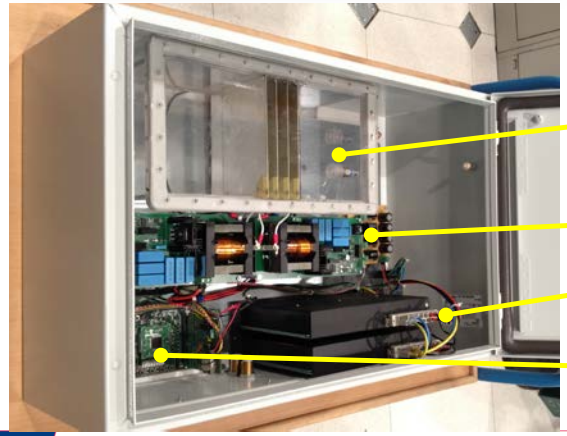
- Semiconductor
- Nanotech
- Surfaces, polymers
- Textile

Health

- Wound healing
- Biocompatibility
- Sterilization
- Cancer treatment

Spin-offs from TU/e-EES



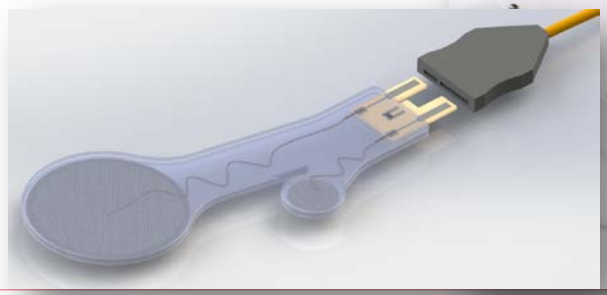


Patented plasma/cat reactor

4-channel power modulator

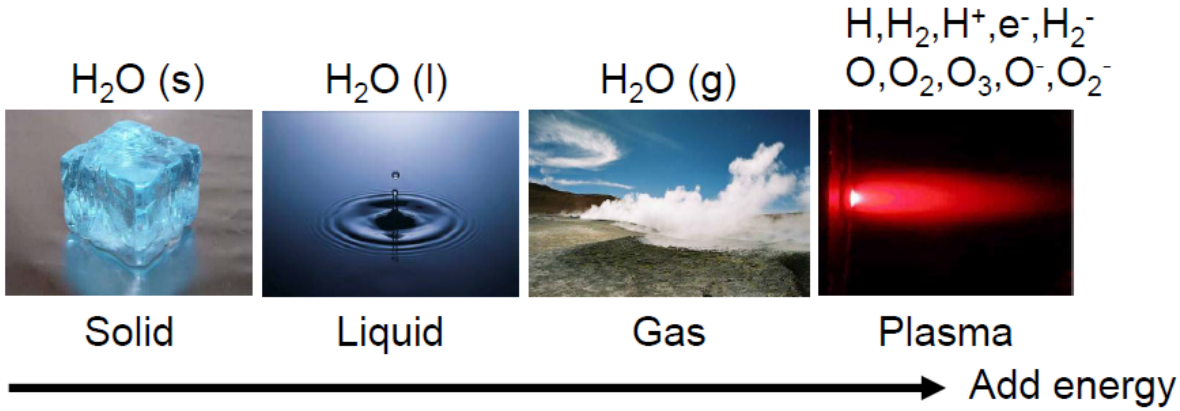
Power supply

Interface and controller



What is plasma?

- Plasma is an ionized gas, consisting of free electrons, ions, reactive atoms, neutral molecules and photons

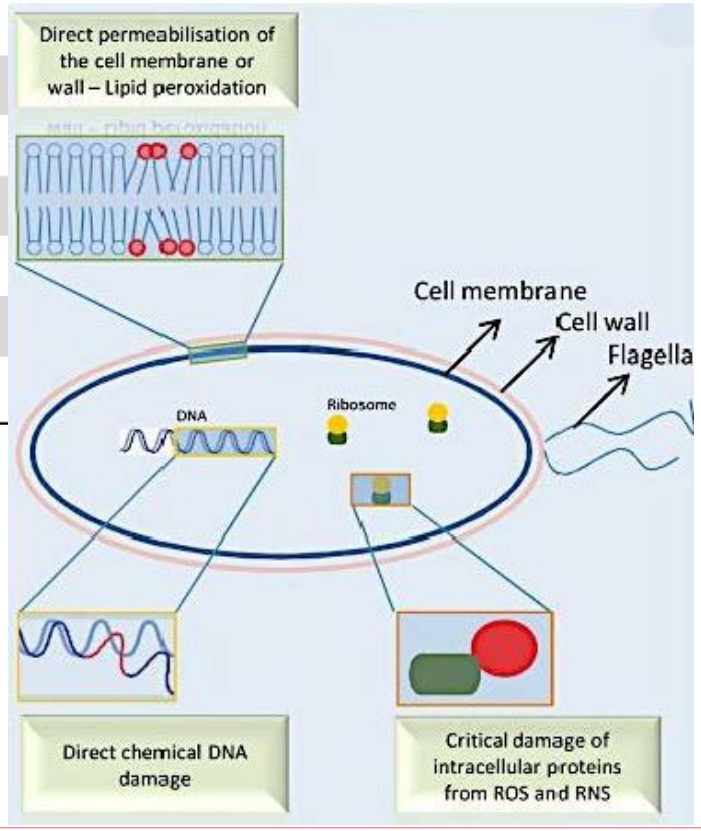


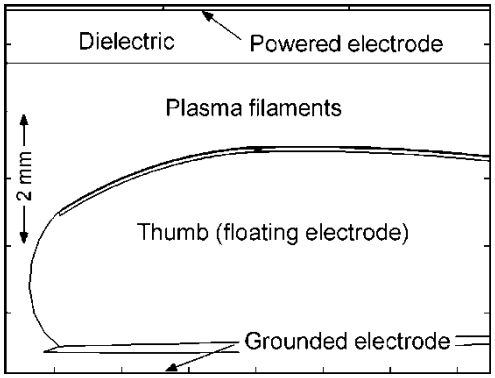
- The plasma state can be reached by supplying sufficient high electric field to a gas or mixture of gases.
- Plasmas can be operated in a wide range of conditions and gasses

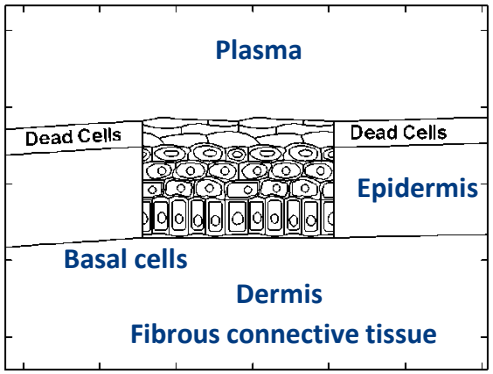
What is plasma ?

	Plasma Generated Species	Density (cm^{-3})
Reactive oxygen species	Superoxide ($O_2^{\bullet -}$)	10^{10}–10^{12}
	Hydroxyl ($OH^{\bullet}$)	10^{15}–10^{17}
	Hydrogen Peroxide (H_2O_2)	10^{14}–10^{16}
	Singlet Oxygen ($^1O_2$)	10^{14}–10^{16}
	Ozone (O_3)	10^{15}–10^{17}
Reactive nitrogen species –	Nitric Oxide (NO)	10^{13}–10^{14}
	Electrons (e^-)	10^9–10^{11}
	Positive Ions (M^+)	10^{10}–10^{12}

UV radiation, energetic ions, charged particals etc.

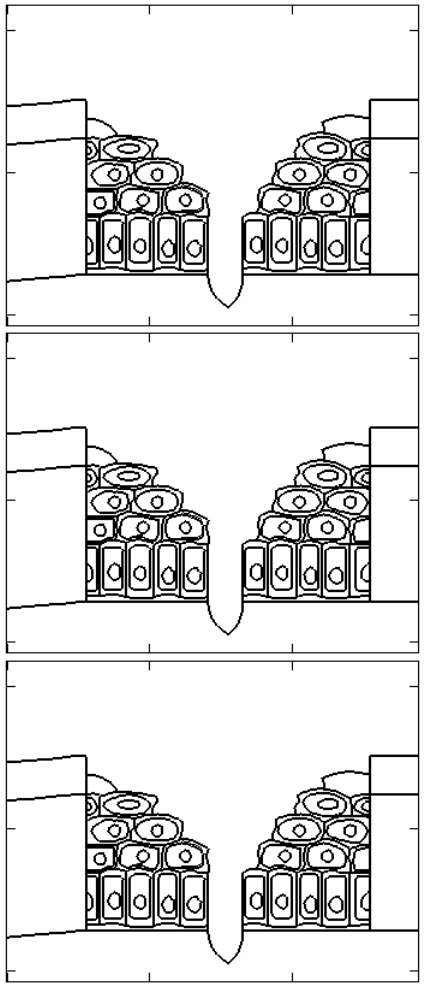


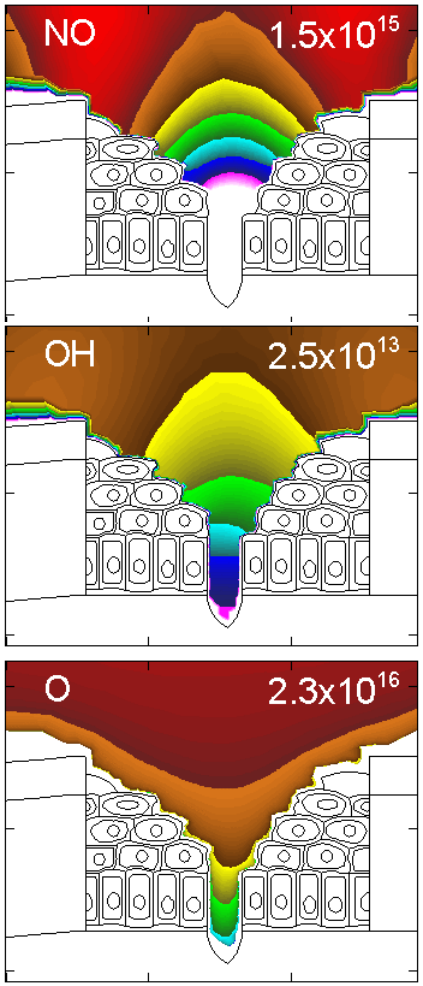




0.25 to 0.5 ns

0.01 to 0.4 ms





MIN MAX

Log scale

Plasma generation

Direct exposure

Plasma jet

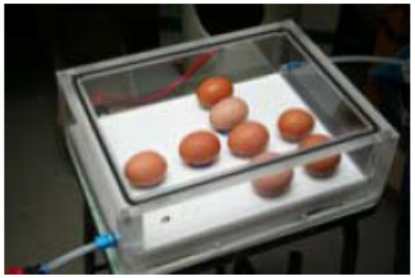
Indirect exposure

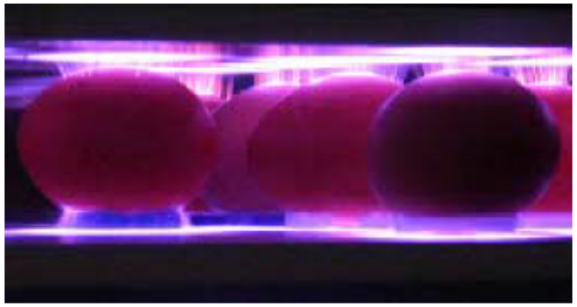
Exposure via water

Plasma treatment of eggs

- EU project on egg sterilization
- Development of new technology for killing Salmonella on egg shells
- Nofima

- “99.5% of all bacteria on the egg shell have been removed. This is a gentle method: the egg yolk and white are unaffected.”





Uncooked poultry and other meat products

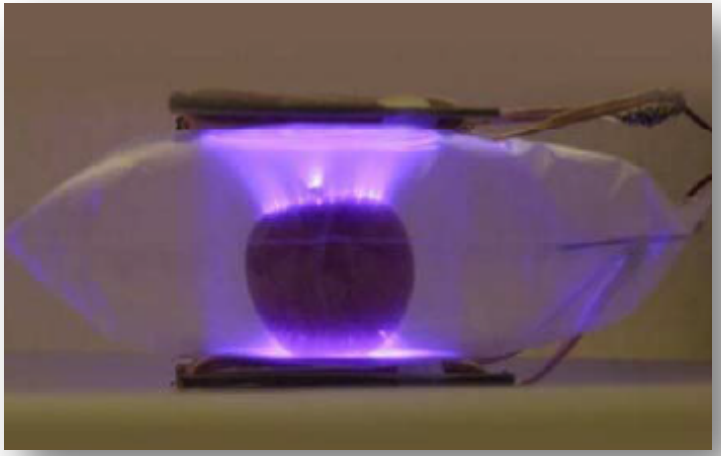
- *Campylobacter* and *salmonella* are found on as much as 70 % of chicken meat tested.

- Drexel University, Journal of Food Protection, Jan. 2012:
- “Plasma can be an effective method for killing pathogens on uncooked poultry”.
- “The treatment either entirely eliminated *salmonella enterica* and *campylobacter jejuni* from skinless chicken breast and chicken skin”.

In-pack decontamination of food products

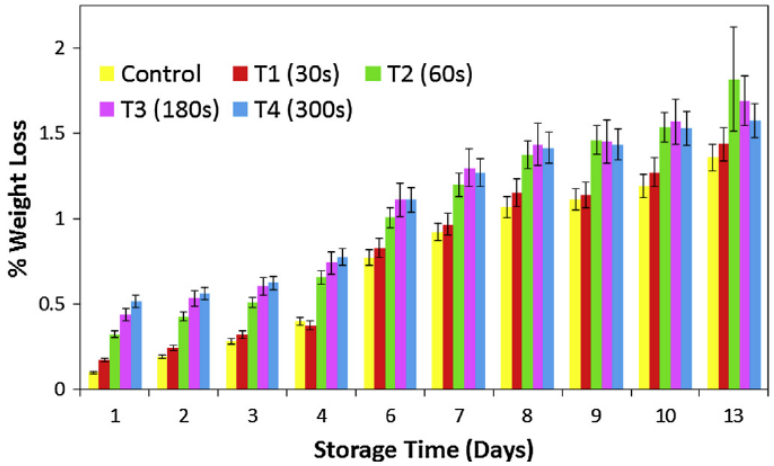
- EU SAFE-BAG project (Dublin Institute of Technology)

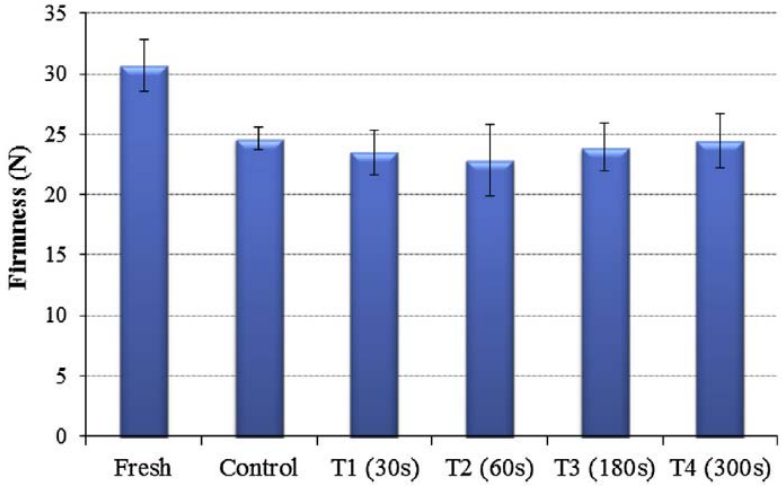
- Aims at developing a novel continuous in-pack decontamination system for fresh produce,
- that is in line with market trends and consumer demands to move away from e.g. chlorine washing



In-package atmospheric pressure cold plasma treatment of cherry tomatoes

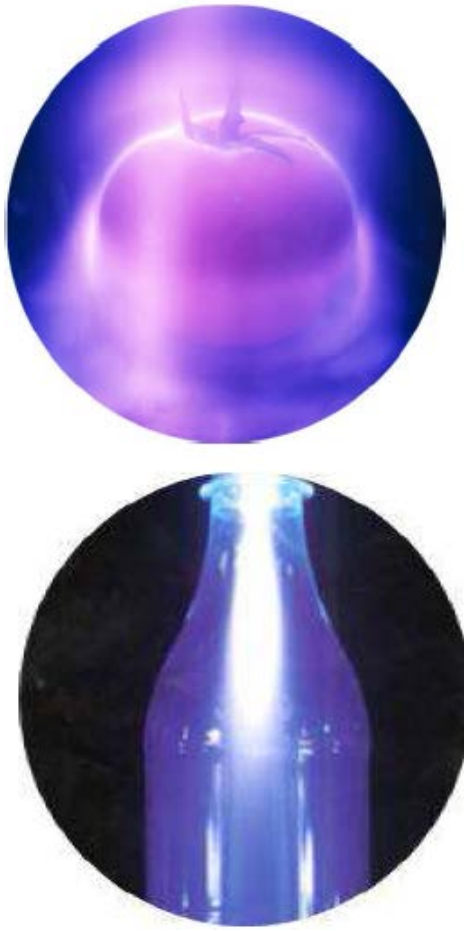
- EU SAFE-BAG project (Dublin Institute of Technology)
- Misra et.al, J. BIOSCI. BIOENG., Vol. 118, 2014
- “The plasma treatment of cherry tomatoes does not adversely affect critical quality parameters of colour, firmness, pH and weight loss”.



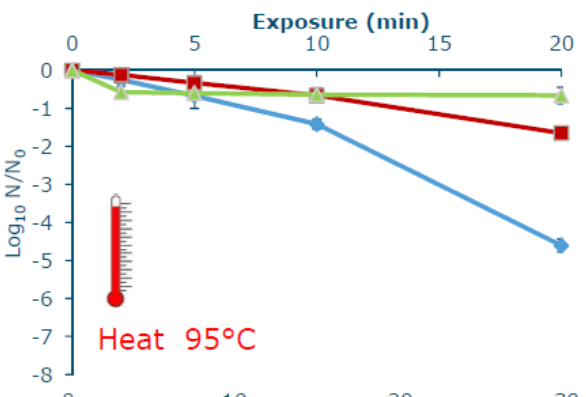


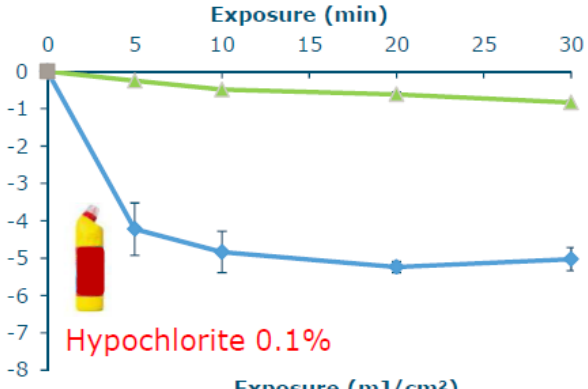
Non-thermal surface decontamination

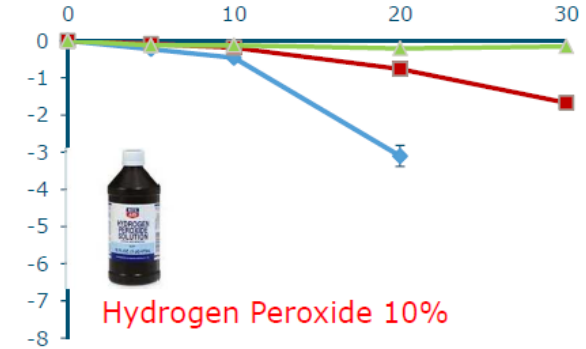
- Wageningen UR, food and biobased research
- “Effective against vegative cells and heat and chemical resistive spores (including pathogens)”.
- To further develop plasma technology and provide supporting data for industrial application on food or its packaging material
  - Packaging material (e.g. PET)
  - Food surfaces
  - Up-scaling of plasma system
  - Mechanism of microbial inactivation
  - Insight in opportunities and constraints for application on food

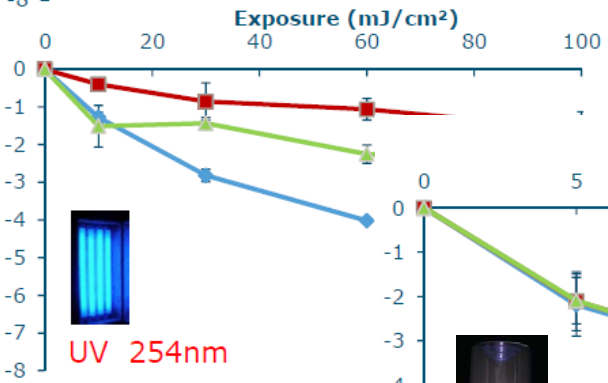


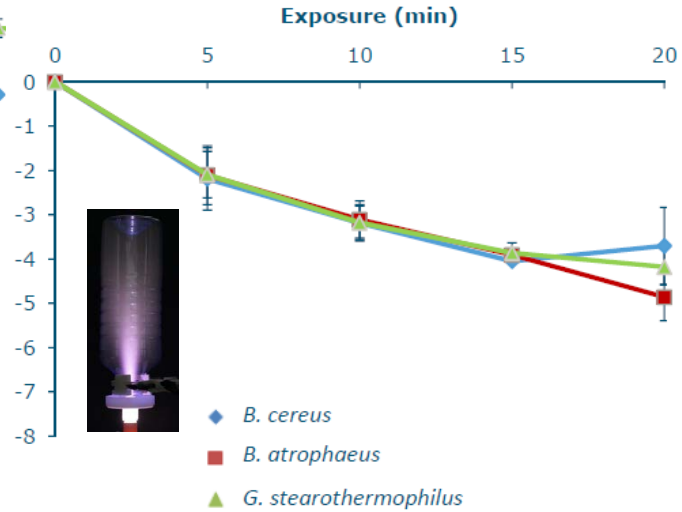
Non-thermal surface decontamination





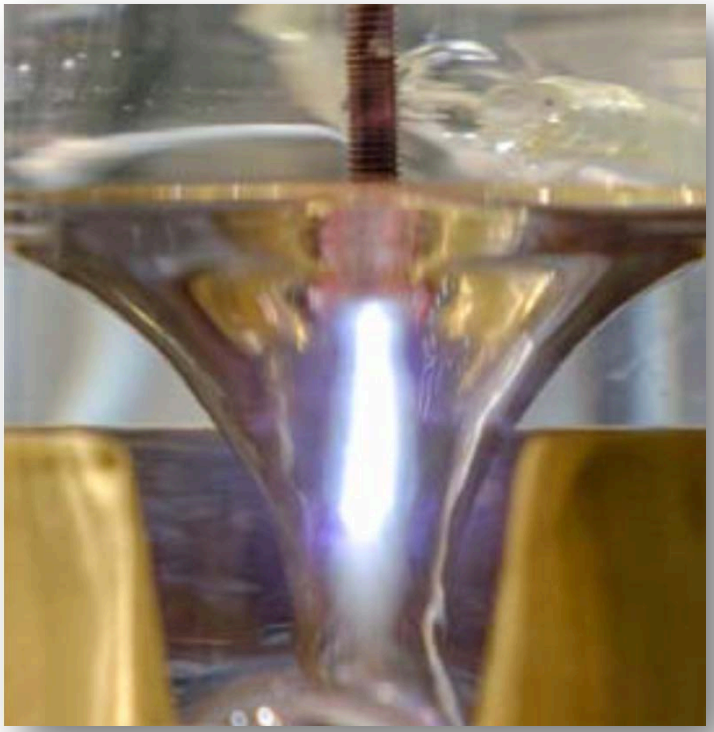


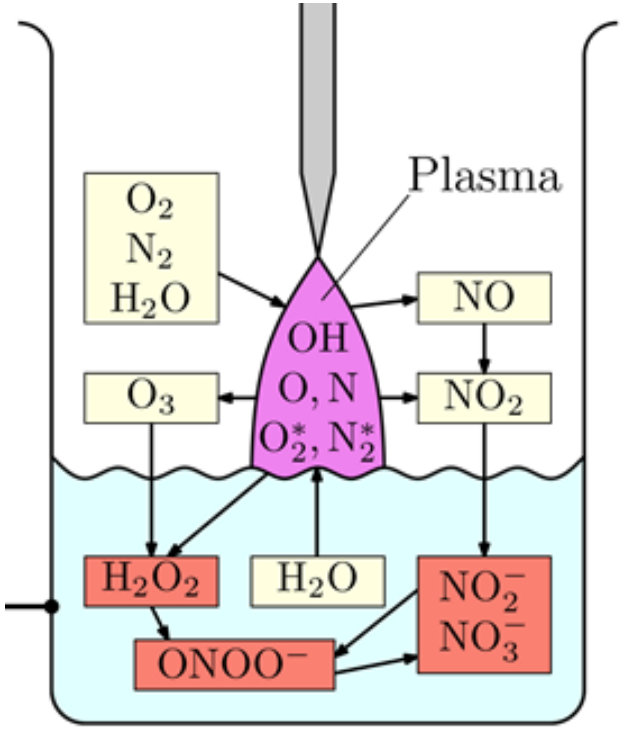




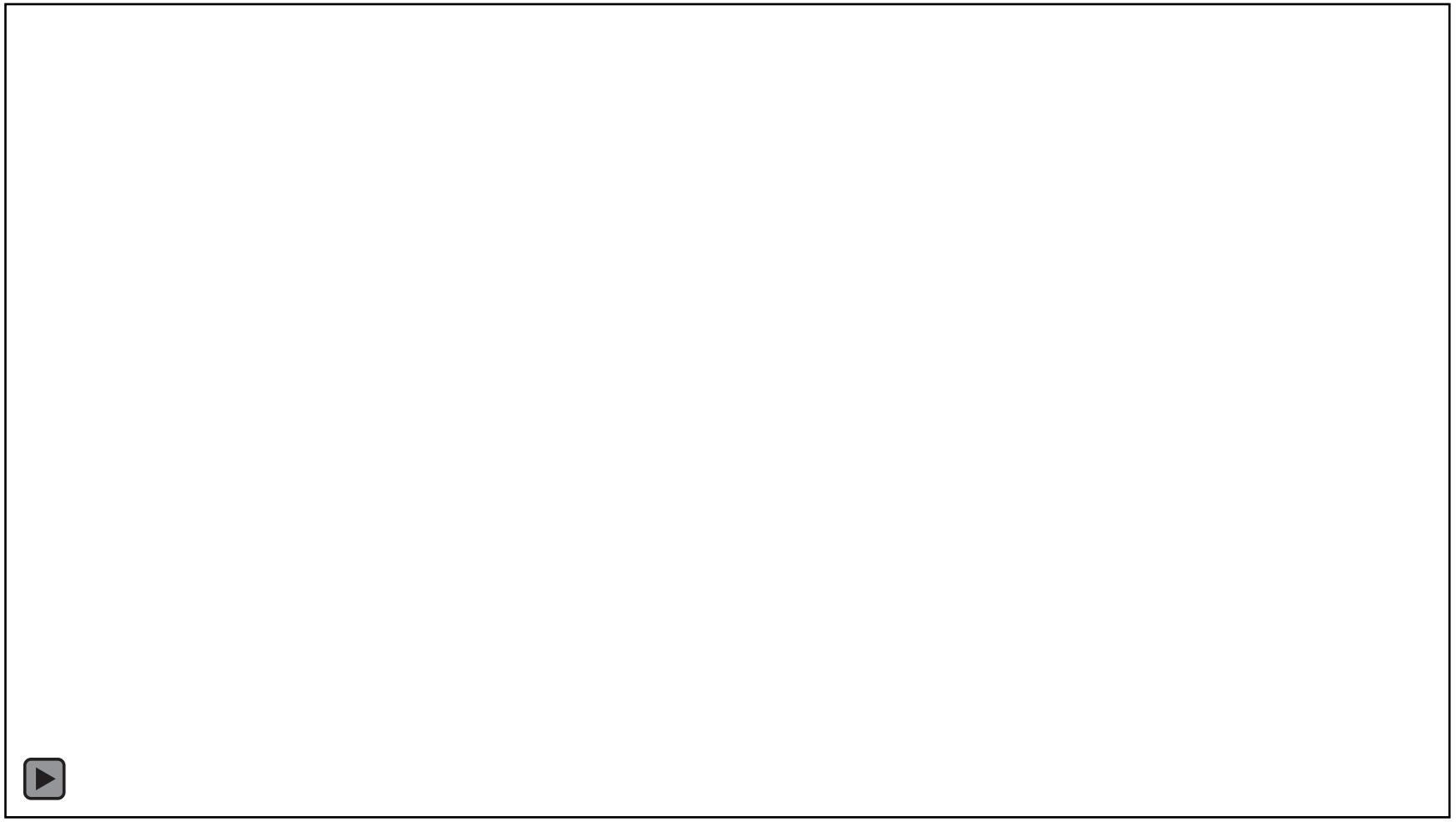
WAGENINGEN UNIVERSITY & RESEARCH

Plasma activated water



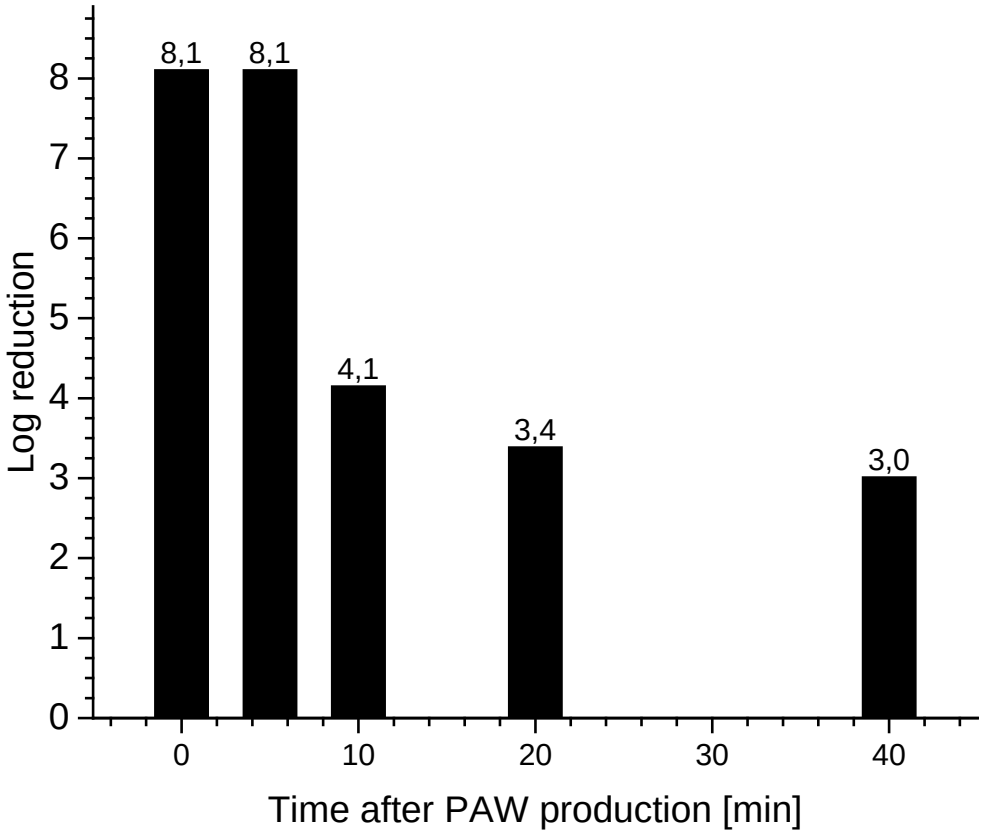


Plasma source for PAW production – 2/2




VitalFluid

Reduction of S. Epidermides -



- The log reduction of S. Epidermides versus the time after which the PAW has been produced.

Ontwikkeling van toepassingen met plasmawater in de glastuinbouw

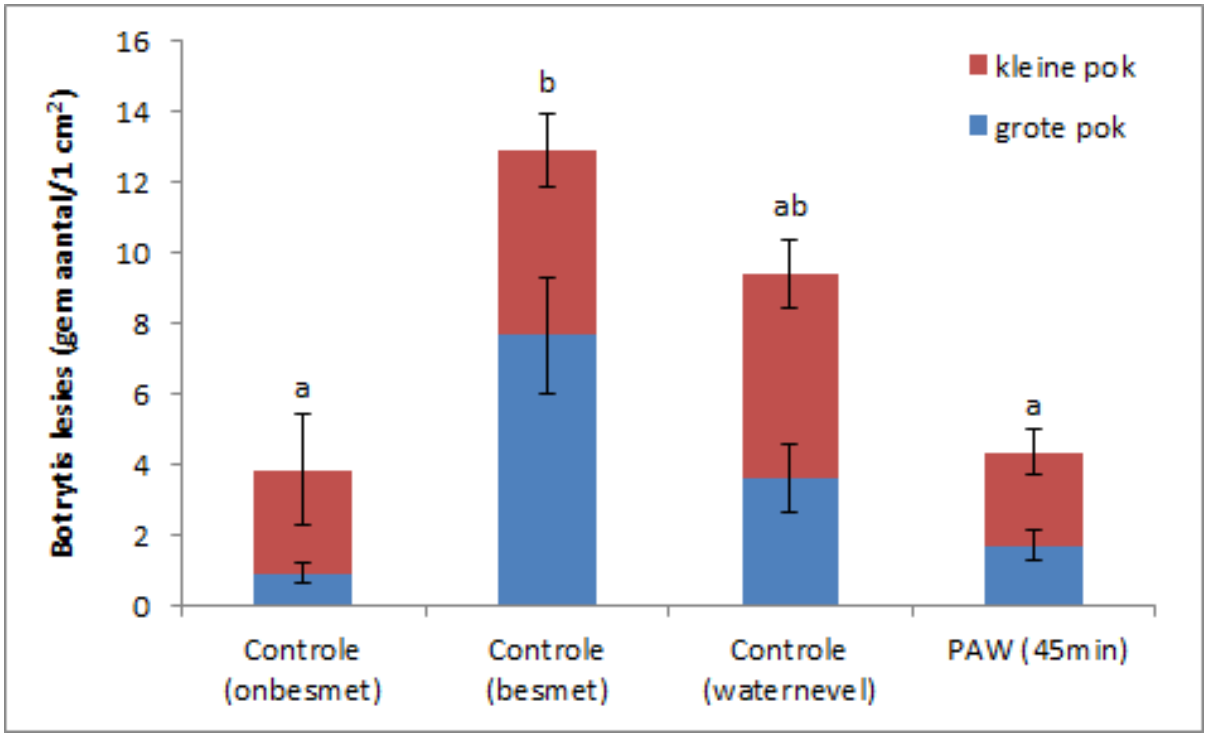
William Quaedvlieg, Jantineke Hofland-Zijlstra (red.), Trees Hollinger, Marianne Noordam, Casper Slootweg, Rob van den Broek, Jan-Paul van der Kolk, Jim van Ruijven en Ineke Stijger

Rapport GTB-1391

WAGENINGEN UR
For quality of life

TOPSECTOR

Gelderland & Overijssel


Botrytis lesies (gem aantal/1 cm²)
16
14
12
10
8
6
4
2
0
kleine pok
grote pok
a
b
ab
a
Controle (onbesmet)
Controle (besmet)
Controle (waternevel)
PAW (45min)


Controle


PAW 15 min mild

Fertilizer

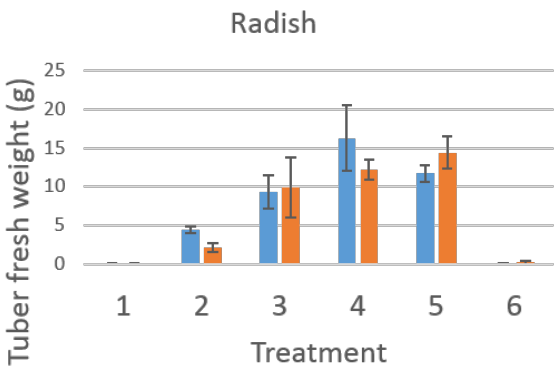
- Cucumber fertilization

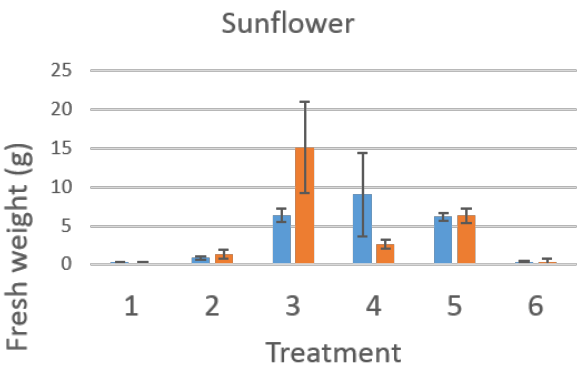
1 2 3 4 5 6

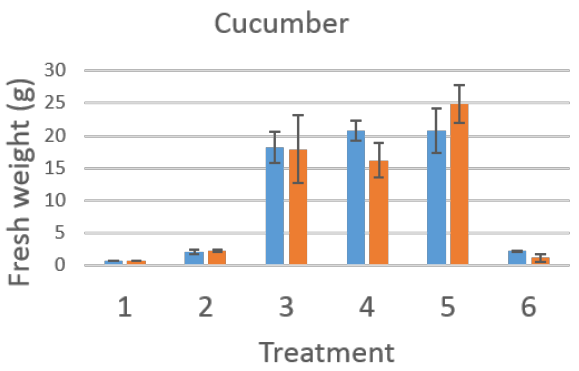
1. Untreated water
2. PAW
3. Fertilizer (tap water)
4. ***PAW, with minerals***
5. PAW treated fertilizer solution
6. PAW/fertilizer solution

Fertilizer

- Fresh weight, various crops





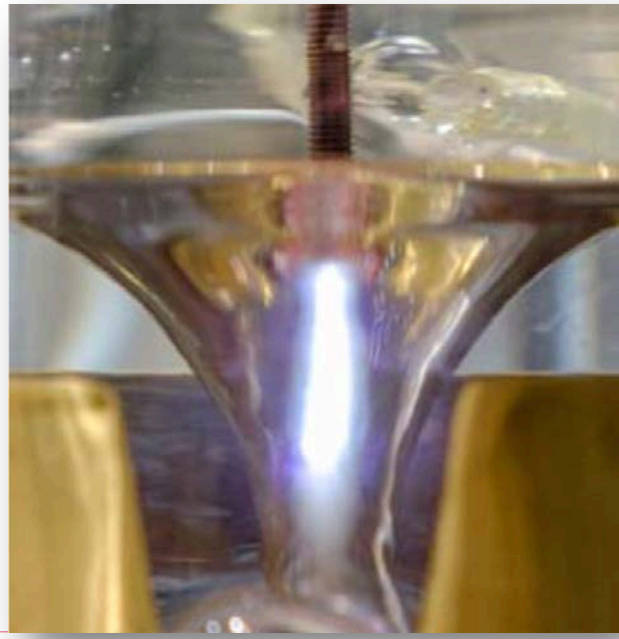


1. Untreated water
2. PAW
3. Fertilizer (tap water)
4. ***PAW, with minerals***
5. PAW treated fertilizer solution
6. PAW/fertilizer solution

Fertilizer

- 40% of world population would not have anything to eat without it
- State-of-the-art Haber-Bosch process:
  - 2 % of the total global energy consumption (7.8 EJ)
  - 300 million ton CO_2/year (3.2 %)
  - Best performance 29 GJ/tN

- Transient plasma assisted N_2 fixation:
  - Zero-emission of CO_2
  - Only air, water and (renewable) electricity
  - Eliminates use of fossil fuels
  - Estimated energy yield 20-30 GJ/tN
  - Decentral, on-site production



Samenvatting

- Plasma water is rijp voor grootschalige praktijk proeven en demonstraties.
- Solide kennisbasis; uitdagingen zijn schaalgrootte en verkorten behandeltijd.
- Plasma technologie voor toepassing in de levensmiddelenindustrie is volop in ontwikkeling.
- Diverse consortia werken aan ontwikkeling van grote schaal industriële plasma behandeling op voedsel producten.