Reductions of *Listeria monocytogenes* on cold-smoked and raw salmon fillets by UV-C and pulsed UV light

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Criteria for *Listeria* mitigation strategies on salmon

- Effect on *L. monocytogenes* (kill + inhibition)
- Robust effect under industry conditions
- Suitable for high throughput processing
- Approved for use
- Consumer acceptance
- No negative sensory effects
- Provide cost-benefit

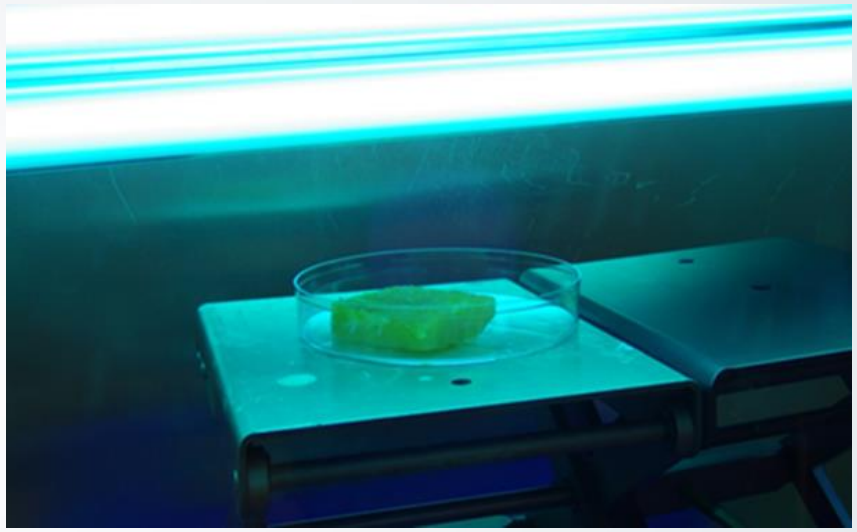
Holck et al. IFSET 2018
Heir et al. IJFM 2019

Interventions for salmon

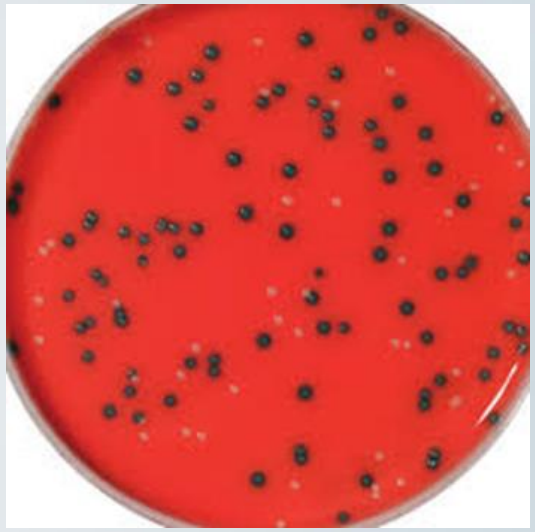
Interventions/technologies	Reported effects on *Listeria* (kill/growth inhibition)	Salmon of relevance for treatment
Chemical		
Organic acids/salts	Growth inhibition	Fresh, smoked
Oxidative compounds	Kill: 0-99% reduction	Fresh
Lauryl arginate	Kill: 0-99% reduction	Smoked
Epsilon polylysine	Kill: 90% reduction	
Liquid smoke	Kill + Growth inhibition	Smoked
Biological		
Bacteriophages	Kill: 50-99.9%	Fresh, smoked
Protective cultures/ bacteriocins	Growth inhibition (Protective cultures) Kill (Bacteriocins)	Fresh, smoked
Physical		
Ultraviolet light (UV-C)	Kill: 0-99% reduction	Fresh, smoked
Pulsed UV Light	Kill: 90-99% reduction	Fresh, smoked

Testing for reduction of *L. monocytogenes* by UV light

Spreading of *Listeria* on salmon



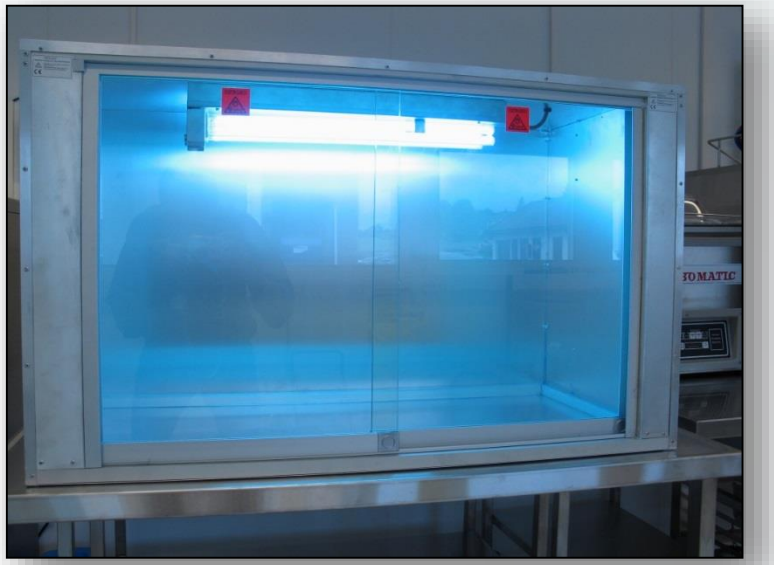
UV treatment



Surviving *Listeria* quantified on petri dishes

UV-light sources

Continuous UV-C light



254 nm

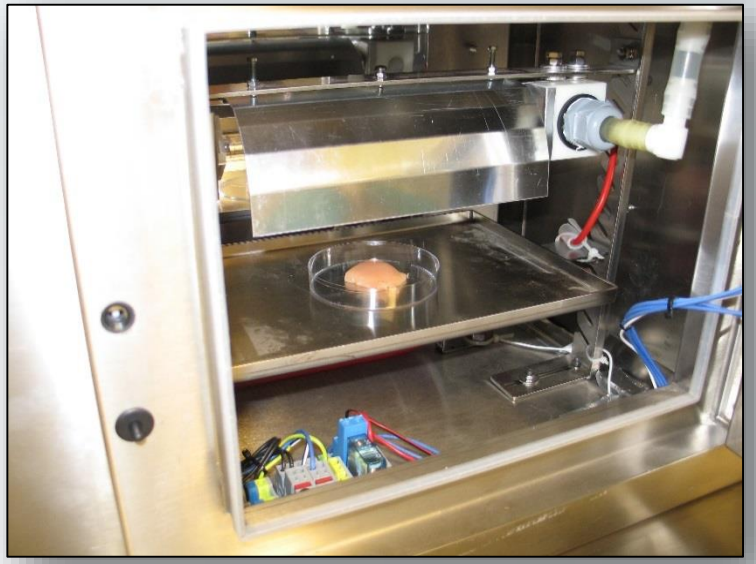
6 cm from light source 10 mW/cm^2

5 s, 10 s, 30 s, 1 min, 5 min

↓ ↓ ↓ ↓ ↓

0.05 0.1 0.3 0.6 3.0 J/cm^2

High intensity pulsed UV light



200-1100 nm 54% in UV spectrum

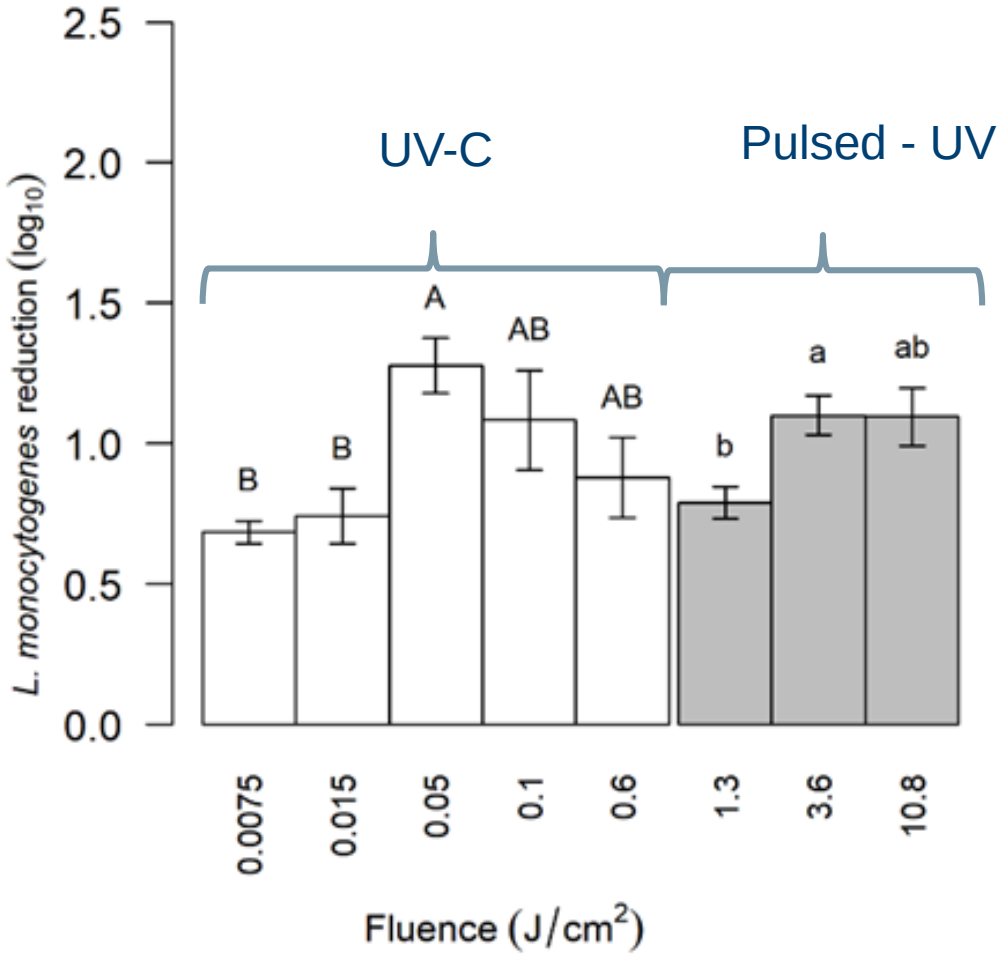
Single pulse 6.5 cm from light source

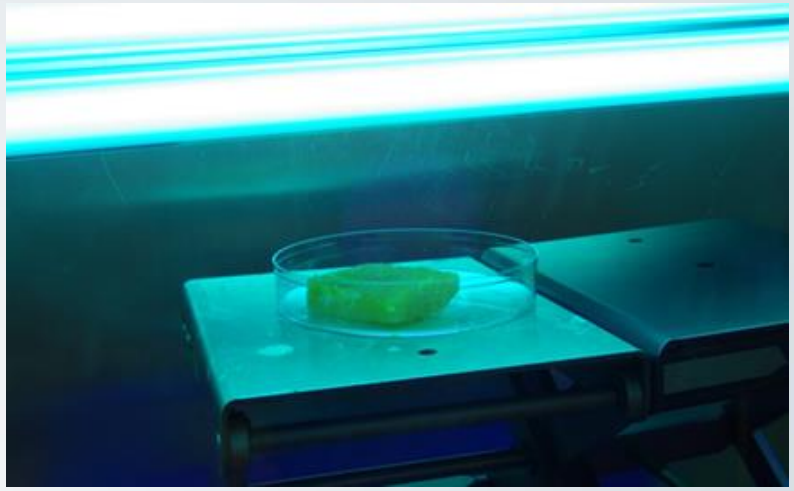
Low pulse (L), High pulse (H), H x 3, H x 5

↓ ↓ ↓ ↓

1.25 3.6 10.8 18.0 J/cm^2

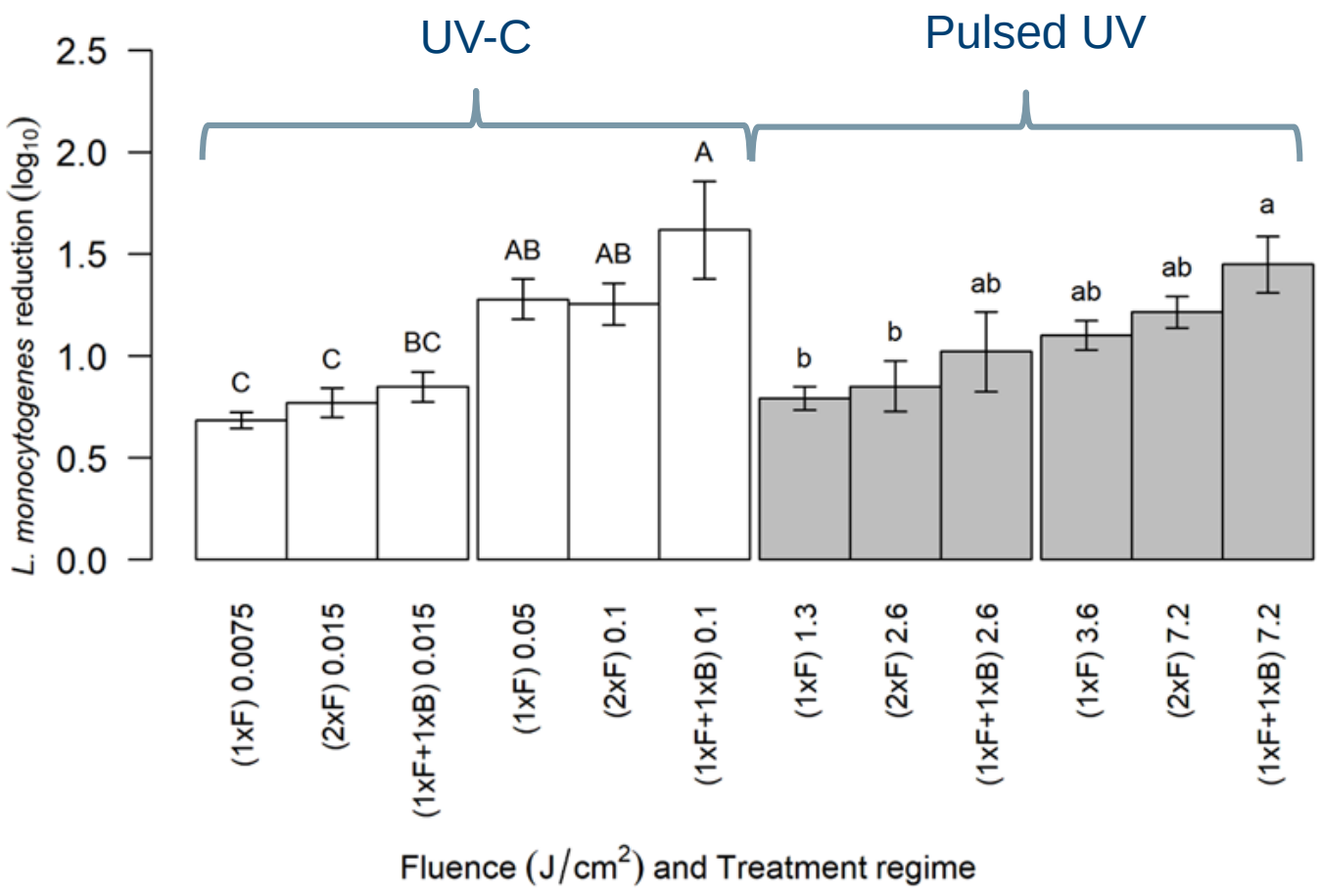
Reductions of *L. monocytogenes* by UV-C and pulsed UV light on smoked salmon





- 0.7 – 1.3 log reduction
- Approx. same reduction for UV-C and pulsed UV
- High UV-doses provided no increase in *Listeria* killing

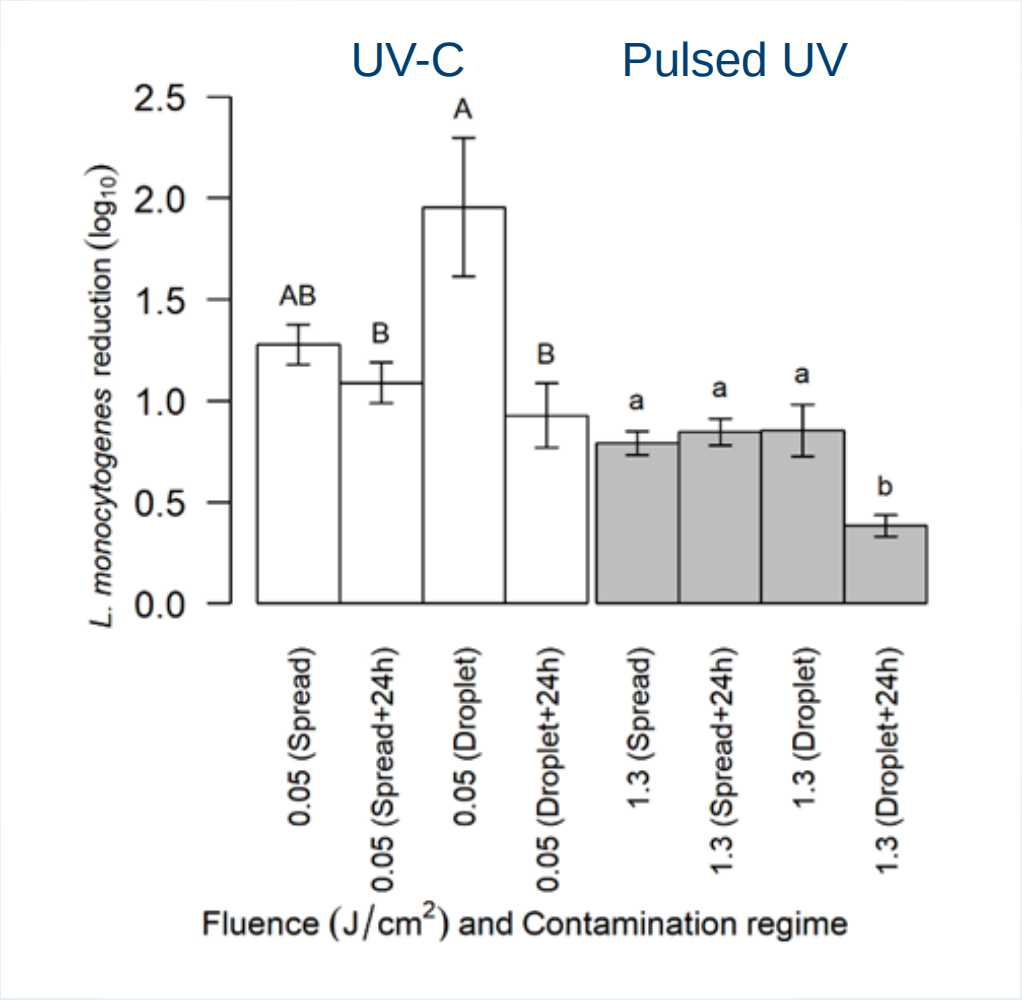
Reductions of *L. monocytogenes* by UV-C and pulsed UV light on smoked salmon, flat and bent pieces



F: flat, B: bent pieces

- Better access to surface crevices on bent pieces?
- No, same results as when flat.

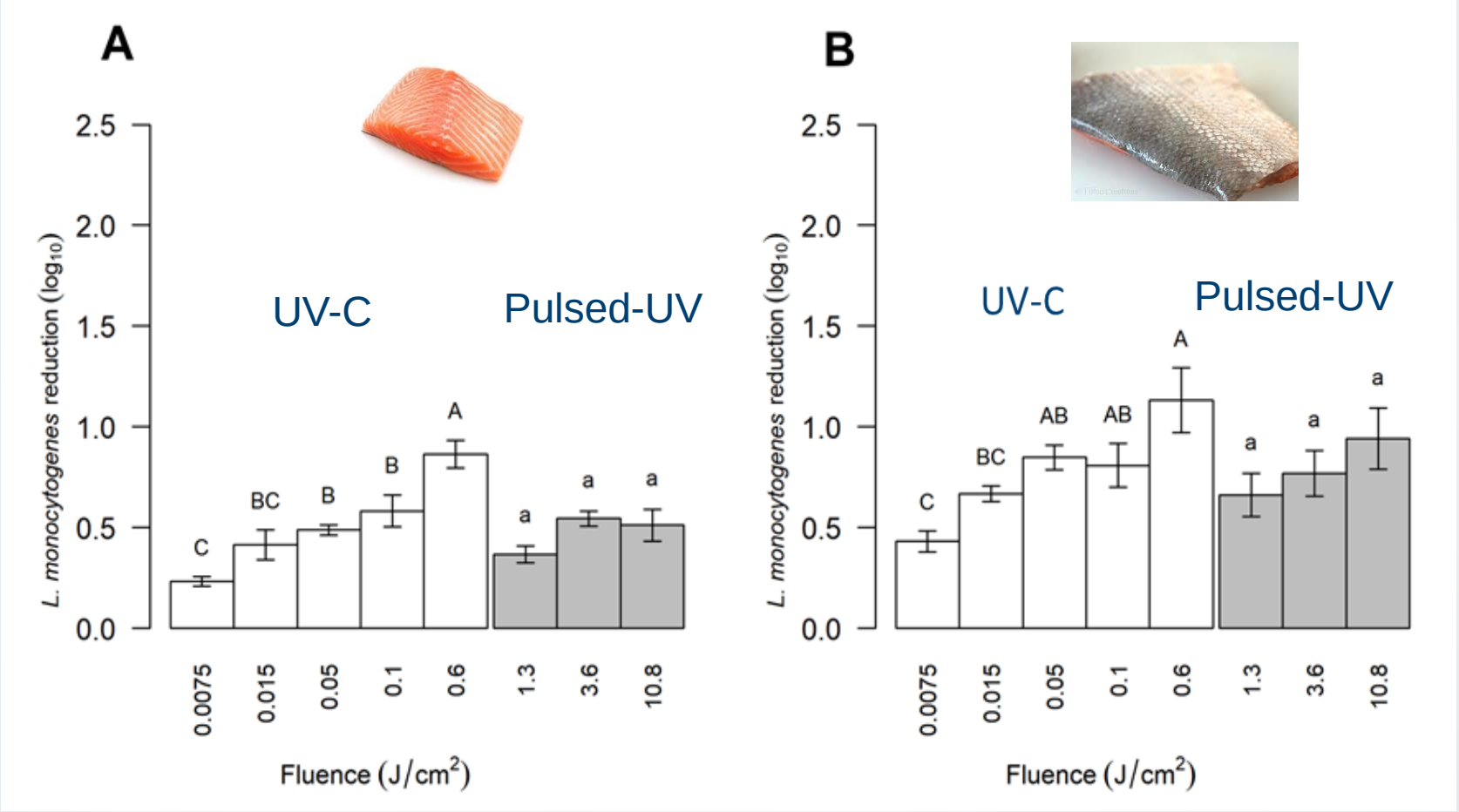
Reductions on smoked salmon of *L. monocytogenes* applied in droplets and after 24 hour attachment



- Importance of *Listeria* remaining on surface (mimicking contamination at slaughterhouse and transport to smoking facility)
- Better kill if *Listeria* suspended in water droplets? (mimicking aerosol contamination)

- Same killing for cells remaining on fish for 24 h
- Better killing in droplets immediately than after 24 h

Reductions of *L. monocytogenes* by UV-C and pulsed UV light on raw salmon

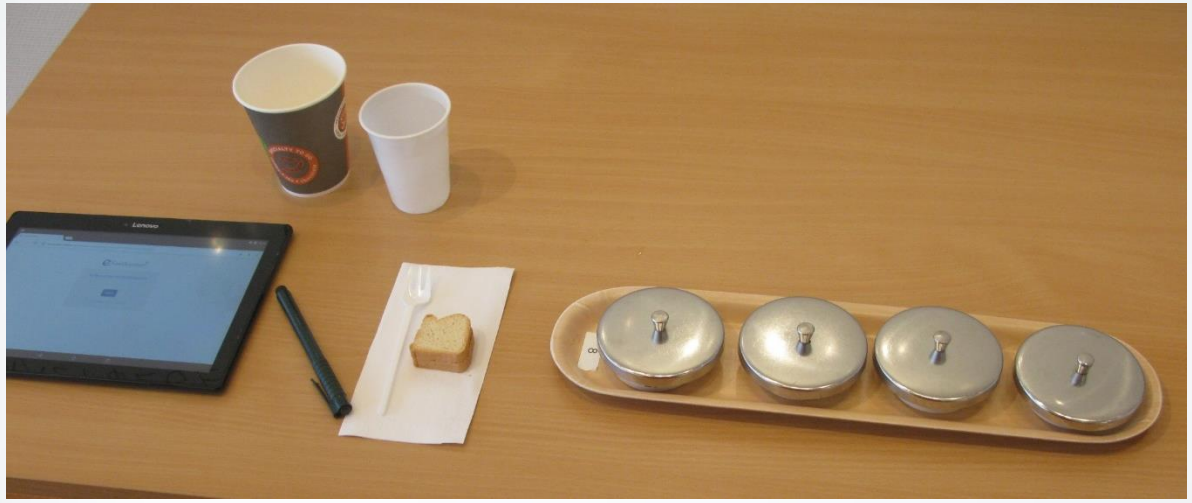


- Up to1 log (90%) reduction
- Small differences UV-C vs. pulsed UV
- Less reduction on raw muscle than skin side

Muscle surface

Skin side

Sensory analyses of UV-C and pulsed UV treated smoked salmon



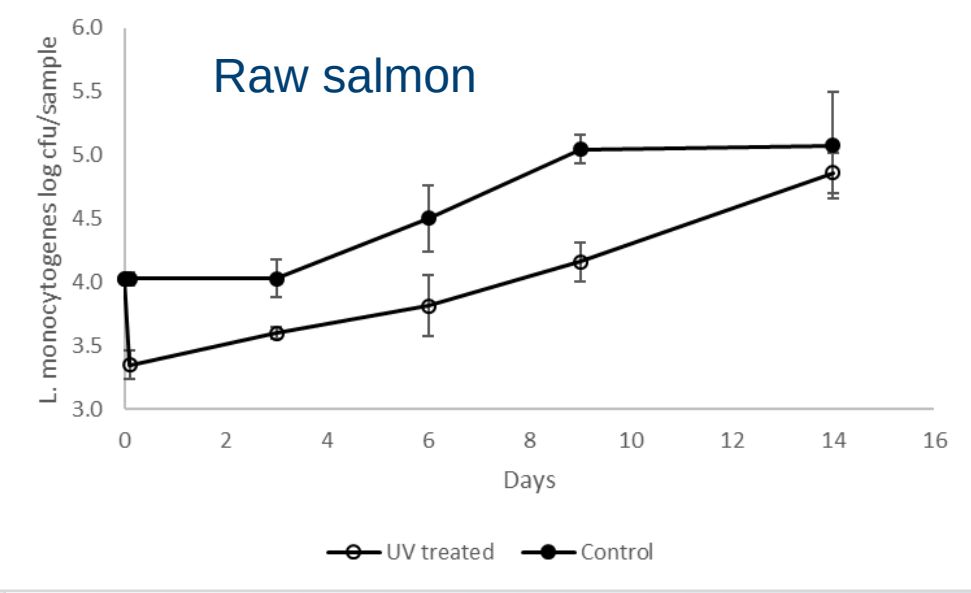
Consumer test

- 40 consumers
- UV-C and pulsed UV
- Odor and appearance
- No sensory changes

Descriptive test

- Trained sensory panel
- 9 panelists
- UV-C
- 22 attributes
- Insignificant changes

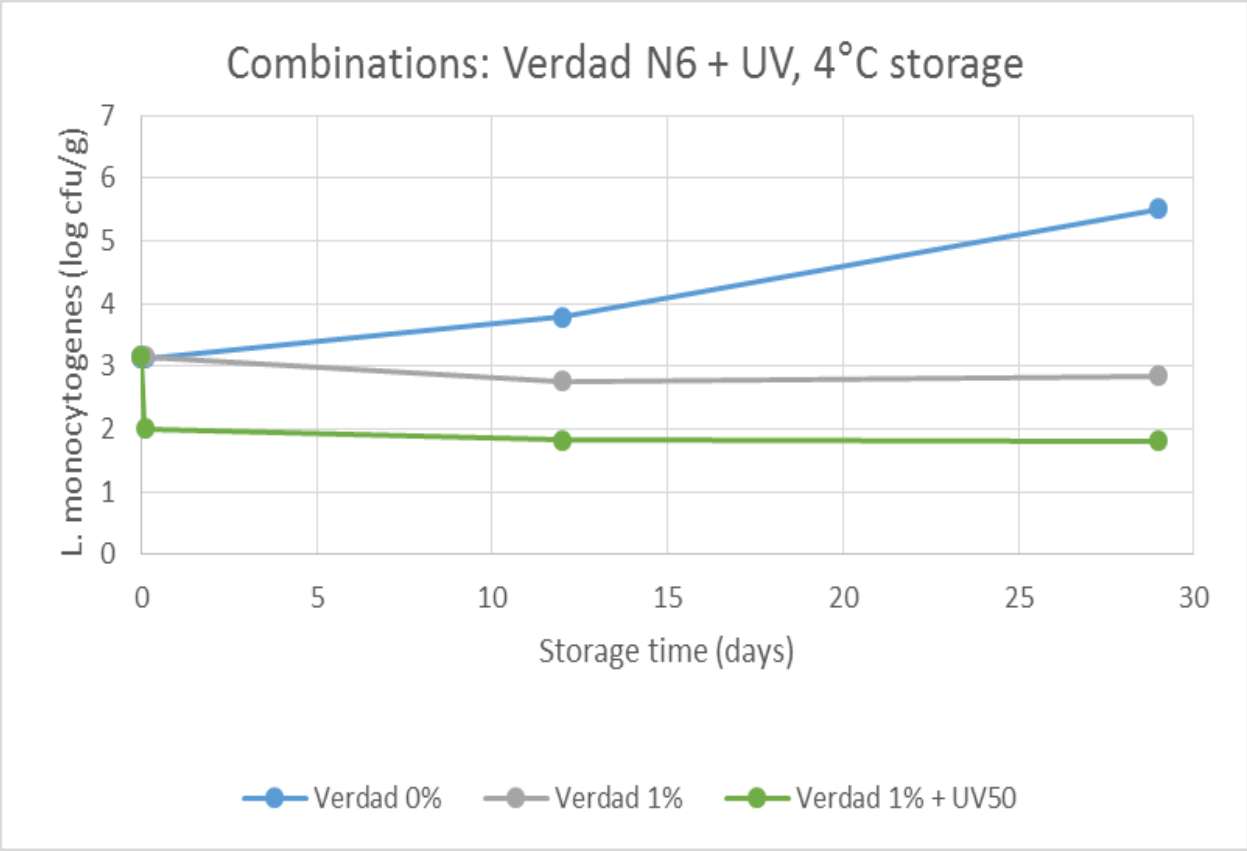
Growth of *L. monocytogenes* on salmon muscle after UV-C treatment



0.050 J/cm^2 UV-C, vacuum packed, stored at 4°C

- 0.7 - 0.9 log reduction
- Similar growth rate of UV surviving cells as control cells
- UV treatments => Large extension of shelf life
- Need of growth inhibition in addition to killing

Killing and growth inhibition by combining Verdad and UV-light (50 mJ/cm^2) on unsliced cold-smoked salmon



For unsliced salmon

- 1 log (90%) reduction in *L. monocytogenes* obtained by UV-C treatment (50 mJ/cm^2)
- Complete growth inhibition with 1 % Verdad N6

Regulations on the use of UV light in EU and USA on foods

EU UV-C

- Regulated as novel food (new production process after may 15,1997, with changes in nutritional value, metabolism or undesirable compounds)
- Approved: milk, bread
- When we asked EU: No UV-C legislation, can be used freely
- UV-C restrictions in Germany: only water, fruit, vegetable products and hard cheeses

EU Pulsed UV (Unclear situation, novel food??)??

USA UV-C

- Limited to high fat containing food, water, juice, milk, baking yeast

USA pulsed UV

- Approved up to 12 J/cm^2 on food surfaces (FDA)

Possible uses of UV light in the salmon industry

Decontamination of production area

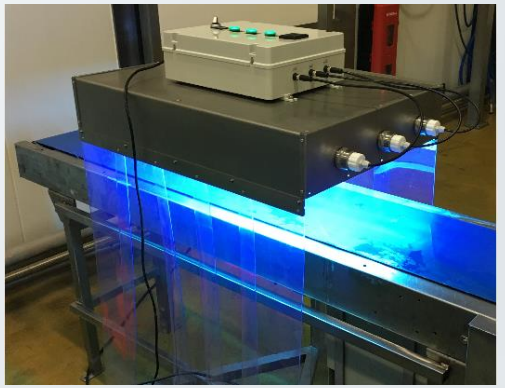
- Air disinfection
- Whole room disinfection

UV-C in cheese factory, Portugal

- Disinfection of equipment
  - Conveyor belts, slicing machines,..

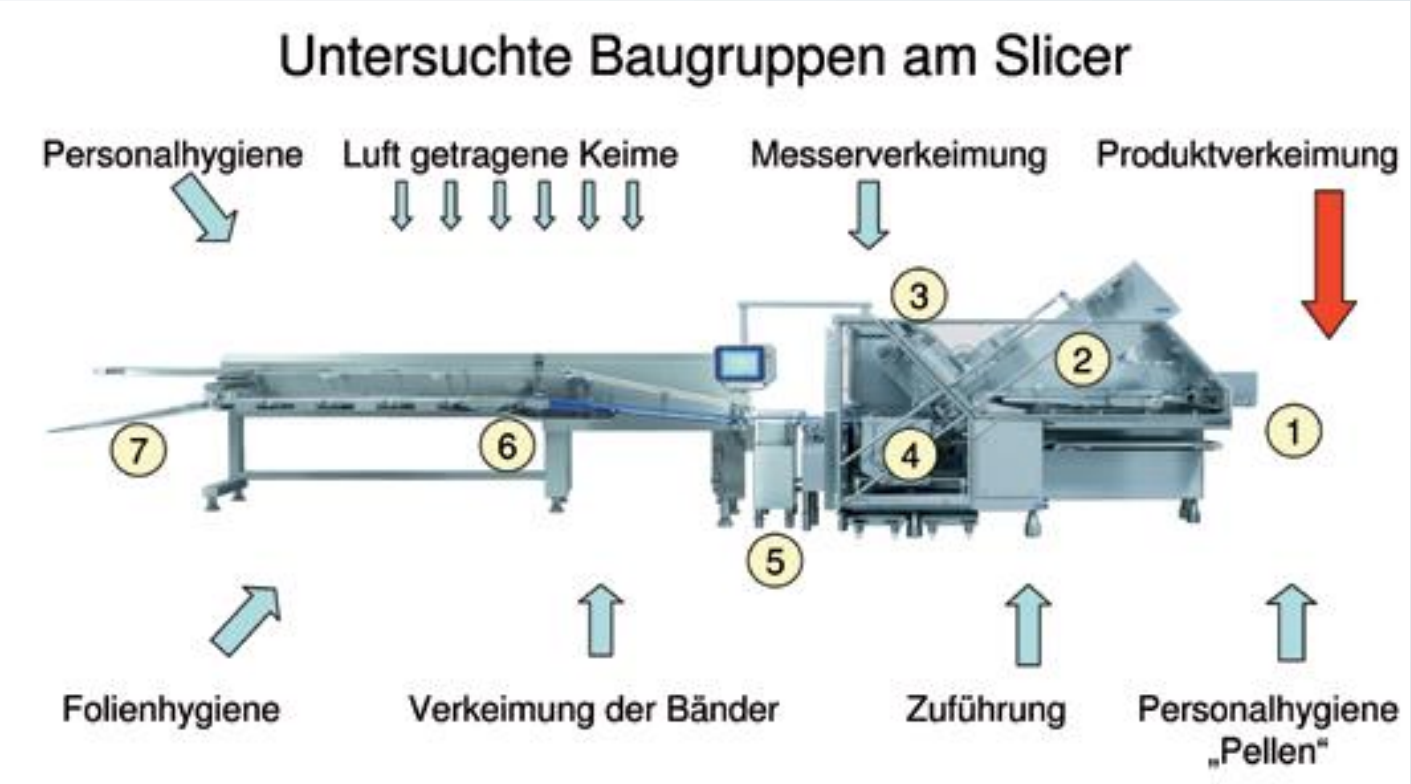
UV lamp for conveyor belts

Decontamination of food surfaces



Conveyor for UV treatment of food

Slicer with UV light at ten positions to reduce cross-contamination of foods



Arrows indicate where the slicer may be contaminated.
UV lights mounted to continuously decontaminate conveyor belts

SterilAir GmbH, Germany

Conclusions

- Listeria is often found on smoked salmon products
- UV light can contribute to *Listeria* reduction
- UV light gives limited reduction, but contamination levels are often low (~1 cfu/g), so UV light leads to reduction in risk
- UV light gives extended shelf life
- UV kills, surviving bacteria may grow
- Growth depends on processing (smoking and temperature)
- UV light (killing) can be used in combination with other growth inhibition strategies

Thank you for your attention