Moderate Intensity Pulsed Electric Fields (PEF) as Mild Preservation Technology for High and Low Acid Juices

R.A.H. Timmermans[1], H.C. Mastwijk[1,2], L.B.J.M. Berendsen[1], A.L. Nederhoff[1], A.M. Matser[1], M.A.J.S. Van Boekel[3], M.N. Nierop Groot[1]

[1] Wageningen Food & Biobased Research, Wageningen University & Research, Wageningen, The Netherlands.

[2] present address: Kruislaan 3, 3721 AL Bilthoven, The Netherlands.

[3] Food Quality & Design Group, Wageningen University & Research, Wageningen, The Netherlands.

Introduction

Pulsed Electric Fields (PEF) can be used as alternative preservation technology applicable to liquid food products, such as high acid fruit juices. The aim of the PEF treatment is to pasteurise at milder temperatures to obtain a safe food product, while retaining fresh characteristics.
Typical process conditions for mild preservation use high intensity PEF, with pulses at electric field strength (E) ~ 20 kV/cm and pulse width (τ) in the range of 2 – 20 µs, for a short period of time to minimise the heat load. Limitations of these conditions are that they are not applicable on neutral pH juices and that there are large differences between micro-organisms, especially *Listeria monocytogenes* is difficult to inactivate (Timmermans et al. 2014).

The use of moderate intensity PEF, with E = 0.5 – 5.0 kV/cm has been extensively studied as a pre-step in mass transfer processes in food- and biotechnology to disintegrate plant cells, and in the field of biology to cause electroporation of micro-organisms, but has not been exploited to achieve inactivation of micro-organisms.

Objective

The aim of the work was to evaluate PEF at moderate intensity for pasteurisation of high- and low-acid juices.

Material & Methods

PEF conditions used:

- Continuous flow system (1 L/h)
- Preheating 36 °C
- Variable frequency
- Fixed pulse conditions (E, τ)

  (Variable frequency and fixed pulse conditions: Resulting in variable T_{max} or specific energy *(w)*)
- Temperature increase as a result of the ohmic heat generated by the PEF condition
- Directly cooling (within 2.3 s)
- Two co-linear treatment chambers (PEI, Ultem™) with titanium electrodes.

High intensity PEF
E = 10 – 20 kV/cm
τ = 2 µs, monopolar pulses

Moderate intensity PEF
E = 0.9 – 2.7 kV/cm
τ = 1000 µs, biopolar pulses

Fruit juice was inoculated with micro-organisms (10^8 – 10^9 cfu/mL), treated with PEF and samples were plated to determine efficiency of the PEF condition.
Inactivation was modelled using Gauss-Eyring model (Mastwijk et al. 2017).

A detailed description of Material & Methods used can be found in Timmermans (2018).

Results

Effect moderate vs. high intensity PEF conditions

Fig 1. shows the inactivation of *Escherichia coli* and *Listeria monocytogenes* in orange juice (pH=3.8). Increase of the E results in more inactivation, both at high intensity PEF and moderate intensity PEF conditions.
E=0.9 kV/cm was used as a reference for thermal inactivation at continuous flow, as shown previously (Timmermans, 2018). Inactivation at moderate condition of E=2.7 kV/cm, τ=1000 µs was more effective than a thermal reference. In addition, this condition of E=2.7 kV/cm, τ=1000 µs was more effective to obtain a 5 log reduction than E=10 kV/cm, τ=2 µs, implying that inactivation can be obtained at low E when a large pulse width is applied.
Results are confirmed for *Lactobacillus plantarum, Salmonella* Senftenberg and *Saccharomyces cerevisiae* in orange juice.

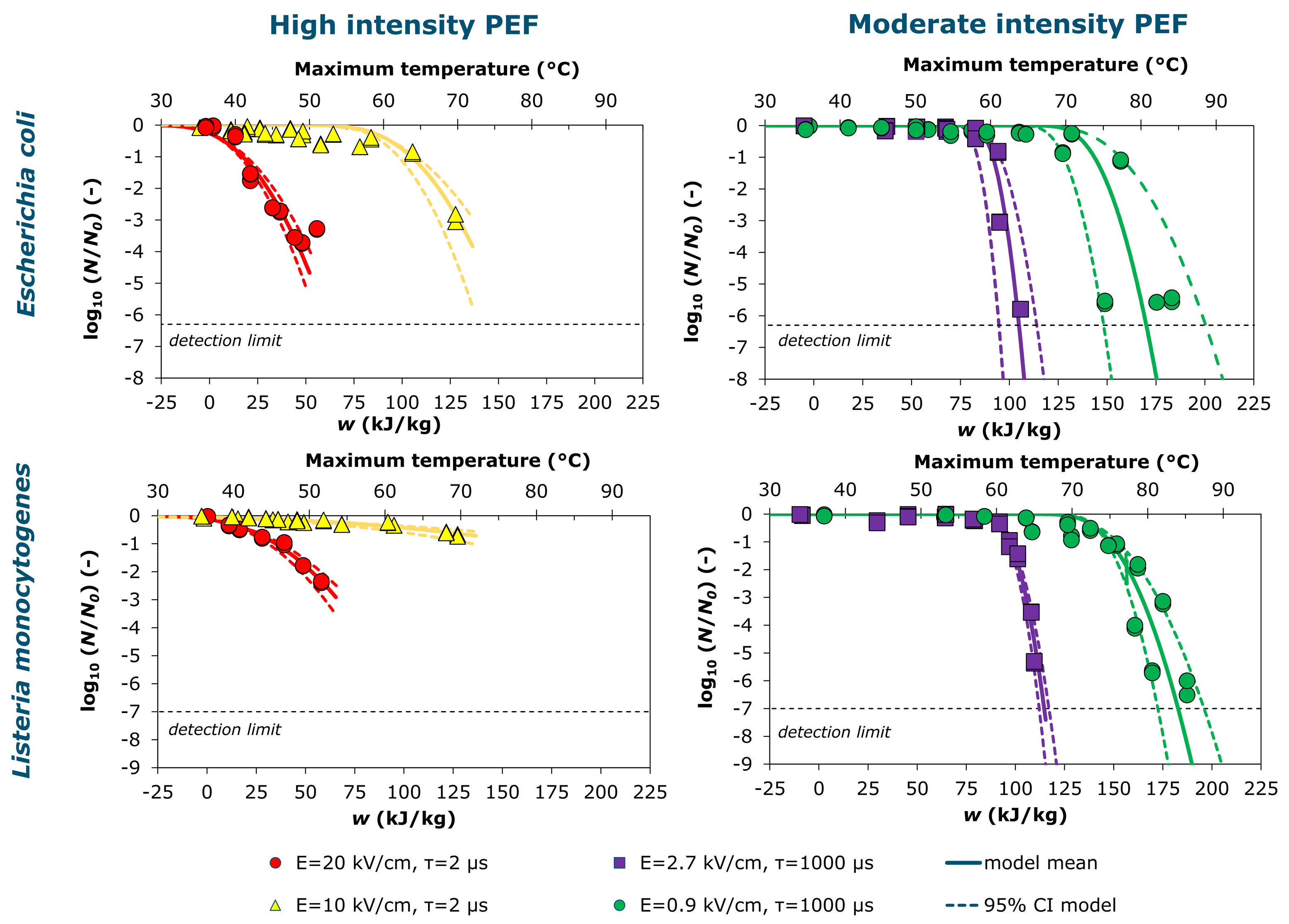

Figure 1. Reduction of viable counts of *E. coli* and *L. monocytogenes* in orange juice after PEF treatment. Symbols represent measured data, continuous lines represent the mean value estimated by Gauss-Eyring model and dashed lines the 95% confidence interval. Horizontal dotted line represents the detection limit.

Effect of high acid and low acid matrix

PEF processing at high intensity conditions (E= 20 kV/cm, τ=2 µs) effectively inactivated *E. coli* at high acid juices (pH 3.5-3.7), but lost its efficacy at moderate acidic values in watermelon juice (pH=5.3). The same pH dependency was also observed for other tested species, where no inactivation was observed at pH=5.3 for *L. monocytogenes* (Timmermans et al. 2014).
Fig 2. shows that at moderate intensity conditions (E=2.7 kV/cm, τ=1000) inactivation of *E. coli* and *L. monocytogenes* in different fruit juices is pH-independent. Interestingly, no effect of the matrix pH was observed, and the moderate conditions also effectively inactivated *L. monocytogenes.*

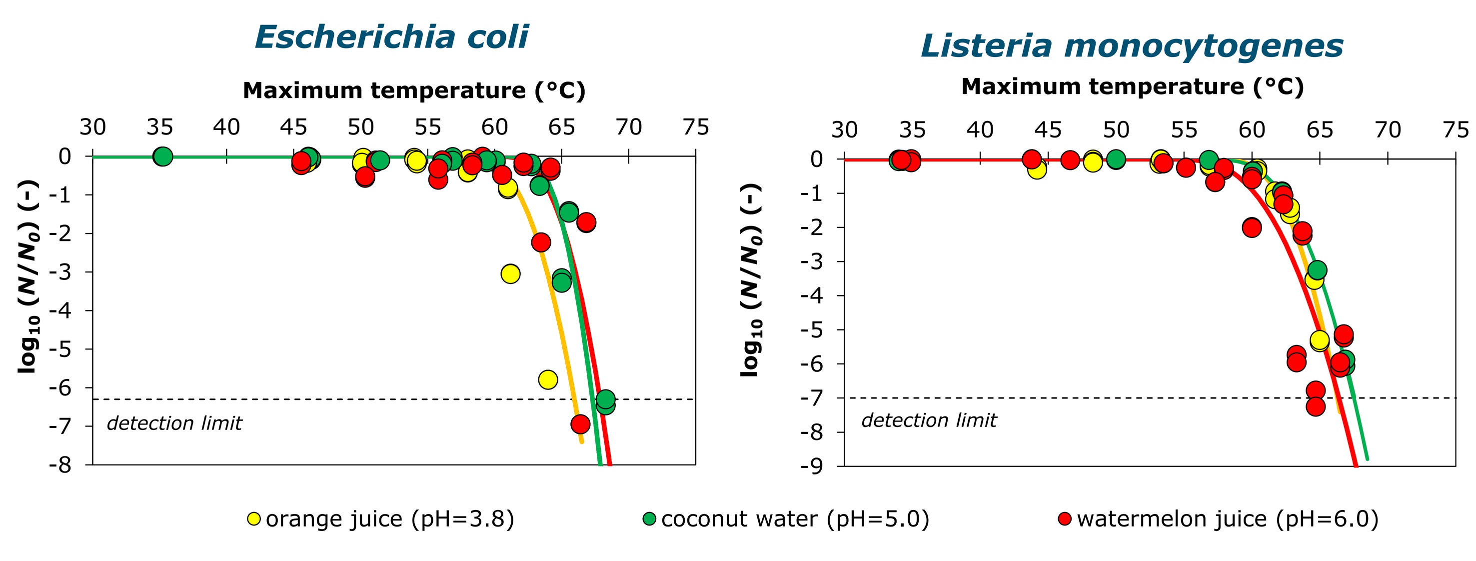

Figure 2. Reduction of viable counts of *E. coli* and *L. monocytogenes* in different fruit juices with variable pH after PEF treatment at E=2.7 kV/cm, τ=1000 µs. Symbols represent measured data, continuous lines represent the mean value estimated by Gauss-Eyring model.

Conclusions

- Moderate intensity PEF (E=2.7 kV/cm, τ=1000 cm) is applicable to both high- and low-acid juices.
- Moderate intensity PEF is effective in inactivation of *Listeria monocytogenes,* also in neutral pH juices.
- Moderate intensity PEF is milder than heat pasteurisation and applicable to a wider range of products than high intensity PEF.

- Mastwijk, Timmermans, Van Boekel (2017). Food Chemistry, 237, 331-341
- Timmermans, Nierop Groot, Nederhoff, Van Boekel, Matser, Mastwijk (2014). International Journal of Food Microbiology, 173, 105-111
- Timmermans (2018). PhD-thesis Wageningen University. DOI:10.18174/426533

Wageningen University & Research
P.O. Box 17, 6700 AA Wageningen, The Netherlands
Contact: rian.timmermans@wur.nl
T + 31 (0)317 48 13 05
www.wur.nl/wfbr

This research is part of the PPS Mild Preservation, which was co-financed by the Dutch Ministry of Economic Affairs, project number TKI-AF-12148.