Alternative Verfahren in der Lebensmittelherstellung zur Bekämpfung von Listerien

BfR-Symposium: *Listeria monocytogenes – Aktuelle Herausforderungen für die Lebensmittel-sicherheit und den Verbraucherschutz*

16. – 17. November 2020

Dr. Kemal Aganovic
focus on:

- Pulsed electrical fields (PEF)
- Static high pressure (HPP)
- High pressure homogenisation (HPH)
- Shockwaves
- Light systems (UV, Pulsed light, IR)
- Electron beam
- Ultrasounds
- Supercritical water
- Ohmic heating
PEF is based on electroporation and is suitable for use in a broad range of food and bio-process applications.

Short treatment times: **microseconds**
Total PEF process time: **seconds**.

PEF produces the **electroporation** in bacterial, plant and animal cells.
PULSED ELECTRIC FIELDS
TARGETED TREATMENT

- **0.1 kJ/kg**: Stress response in biotechnology and medicine

- **1.2 kJ/kg**: Softening of solids, fruits, roots, and vegetables

- **3-10 kJ/kg**: Cell permeabilisation for extraction and drying

- **90 kJ/kg**: Cell inactivation for liquid products, juices, smoothies, and dairy

- **150 kJ/kg**: Cell disintegration for sludge treatment
PULSED ELECTRIC FIELDS
STRUCTURE MODIFICATION IN POTATO PROCESSING

Softening of tissue by loss of turgor pressure

Influence of pulsed electric fields on hardness and cutting behaviour
Tissue softening and significant reduction of cutting force

- Smoother cut and less feathering
- Flexible tissue, less breakage
- More even color
- Replacement of thermal preheater, less energy
- Less oil uptake by potato slices/fries
- Less starch in process water
- Longer knife durability

In untreated tissue, the cutting force is significantly higher compared to PEF-treated tissue.
Inactivation of *E. coli*, *L. innocua*, *S. cerevisae* and *B. megaterium* in ringer solution with an electrical conductivity of 1.25 mS cm\(^{-1}\) after PEF treatment with graphite anode and a field strength of 16 kV cm\(^{-1}\)
Inactivation of *Listeria monocytogenes* in Milk by Pulsed Electric Field

Laura D. Reina, Z. Tony Jin; Q. Howard Zhang; Ahmed E. Yousef


https://doi.org/10.4315/0362-028X-61.9.1203

The inactivation of *Listeria monocytogenes* by pulsed electric field (PEF) treatment in a static chamber

Gregory J. Fleischman, Sadhana Ravishankar, V.M. Balasubramaniam

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PULSED ELECTRIC FIELDS
APPLICATION FOR JUICES

FMP

FMP (Fresh Micro Pulse), or pulsed electric field processing, involves treating the juice with high voltage pulses.

The FMP process delivers a series of electric pulses in a treatment chamber filled with fresh juice. This technique lengthens the storage life with no noticeable loss of quality. The juice isn’t heated, so the aroma, color, texture and nutritional value stay intact.

FMP is a safe and reliable method involving no additives, and therefore a clean label technology.

GROM USES ELEA PEF FOR FRUIT PUREE PROCESSING

“Gromart has installed an Elea PEF system for use in the processing of their fresh fruit puree and have been very satisfied with the performance and operation of the system.” – Guido Martinietti, CEO of Gromart Srl

Find out more about Grom and their high quality gelato
**Product:**
- Raw milk
- pH value: 6.9
- Fat content: 3.7 to 5.1 %
- Conductivity: 4mS/cm
- Applied electric field strength: 12 kV/cm

**PULSED ELECTRIC FIELDS**

**MICROBIAL INACTIVATION IN MILK**

**Graph:**
- **Inactivation [log N/N₀]** vs. **specific energy [kJ/kg]**
- **E. coli**
- **L. innocua**

**Graph:**
- **Total viable count [log cfu/g]** vs. **time [d]**
- **time [d]:** 0, 2, 4, 6, 8, 10, 12, 14
- **Energy levels:**
  - **rawmilk**
  - 314 kJ/kg
  - 244 kJ/kg
  - 210 kJ/kg
  - 65 kJ/kg
• For liquid food products
• Capacities from 50 L – 10 000 L/h
HIGH HYDROSTATIC PRESSURE
LOW TEMPERATURE PRESERVATION OF FOOD

With permission Hiperbaric, 2018.
Burgos, Spain
HIGH HYDROSTATIC PRESSURE
GOVERNING PRINCIPLES

1. **Isostatic rule**
   “pressure is equally and instantaneously transmitted through the vessel and product”
   Pressure reduces the volume of the material without changing its shape – altering the distance between the molecules

2. **Le Châtelier’s principle**
   “a system in equilibrium will shift to a new equilibrium, to counteract the impact change in temperature, concentration and/or volume”

3. **Compression heating**
   1st law of thermodynamics (the total energy of an isolated system is constant):
   \[ Q = W + \Delta U \quad \Delta U = Q - W \]

4. **Microscopic ordering**
   increase in pressure at constant temperature increases the degree of ordering of molecules of a given substance
Temperature and pressure during a processing cycle for:

1. **high pressure pasteurization (HP-LT)**
   - $300 \text{ MPa} < P < 600 \text{ MPa}$
   - $4 \degree C < T < 30 \degree C$

1. **high pressure sterilization (HP-HT)**
   - $600 \text{ MPa} < P < 900 \text{ MPa}$
   - $90 \degree C < T < 130 \degree C$

Compression approx. 15%

Temperature increase – adiabatic heating
HIGH HYDROSTATIC PRESSURE
MAJOR INDUSTRIAL APPLICATIONS

With permission Hiperbaric, 2018.
Burgos, Spain
p-T isokineticity diagrams for 5 log inactivation of 3 pathogenic strains of *Listeria monocytogenes* in “Black Forest Prosciutto” (Ham) after 15-240 s.
HIGH HYDROSTATIC PRESSURE
SAFETY OF MEAT PRODUCTS

ESPUÑA (Spain), 1998
CAMPOFRIO (Spain), 2003

More applications:
West Liberty Foods (USA)
Fresh Press (GR)
Zwaneberg (NL)
Maple Leaf (CA)
Rovagnati (IT)
Angst (CH)
...
HIGH HYDROSTATIC PRESSURE EFFECTS ON RAW MEAT PROTEIN

Colour changes in roast beef (*M. longissimus dorsi*) after 3 min. at 0.1 – 600 MPa and 18 °C

Colour changes in pork loin (*M. longissimus dorsi*) after 3 min. at 0.1 – 600 MPa and 18 °C

Colour changes in turkey breast (*M. pectoralis superficialis*) after 3 min. at 0.1 – 600 MPa and 18 °C

Colour changes in chicken breast (*M. pectoralis superficialis*) after 3 min. at 0.1 – 600 MPa and 18 °C
HIGH HYDROSTATIC PRESSURE
MICROBIAL INACTIVATION

• High pressure treated turkey fillet
• 6000 bar, 5min
• Shelf life > 30 days

![Graph showing microbial inactivation over storage time with CFU/g on the y-axis and storage time [d] on the x-axis.](image)
HIGH HYDROSTATIC PRESSURE COMBINATION WITH ANTIMICROBIALS

ALGINATE-FILM WITH OREGANO EXTRACT COMBINED WITH HHP

*L. monocytogenes*-Cocktail:
FMCC-B-129, FMCC-B-131, FMCC-B-133

**HHP:** 500 MPa, 2 min., 20°C

**Film**
Na-Alginate-Film with 1% oregano Essential Oil

**Result**
- Reduction of Listeria through oregano extract
- **HPP:** reduction in the beginning at 1 log CFU/g
  - Synergistic effect during storage

**Graphs**
- **No HHP**
- **4 °C**
- **With HPP**
- **12 °C**
- **With HPP**

Survival curves of *Listeria monocytogenes* cocktail strains in ham stored at 4 °C (I), 8 °C (II) and 12 °C (III), without (a) and after (b) high pressure processing treatment. (♦) Control samples, (■) samples with edible film free from oregano essential oil-OEOF and (▲) samples with edible film supplemented with oregano essential oil-OEOS. Open symbols (◊, □, Δ), indicate absence of *Listeria monocytogenes* after application of the enrichment method.

DECONTAMINATION OF SURFACES
TREATMENT WITH LIGHT

**Pulsed Light**
- Broad spectrum with significant UV-C (180 – 1100 nm)
- (µs) pulses produced by flash lamps

Emitting light and energy:
\[ E = h\nu = \frac{hc}{\lambda} \]

- \( h \) – Planck’s constant
- \( \nu \) - Frequency
- \( \lambda \) – Wavelength
- \( c \) – speed of light in vacuum

**Infrared**
- Infrared light (780 – 1000 nm)
- Short term treatment by lamp or LED

Surface decontamination of packed product

- No toxic substances
- Decontamination using UV, PL
- Contact-free
- Continuous process from all sides
- Treatment in packaging
- Moderate costs
SURFACE DECONTAMINATION
PULSED LIGHT

Ultraviolet energy dose for 1 log destruction of various Microorganisms (mJ/cm²)

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Energy Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Bacillus anthracis</em></td>
<td>4.5</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>4.5</td>
</tr>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td>8.0</td>
</tr>
<tr>
<td><em>Salmonella enteritidis</em></td>
<td>4.0</td>
</tr>
<tr>
<td>Mold Spores</td>
<td></td>
</tr>
<tr>
<td><em>Aspergillus niger</em></td>
<td>132</td>
</tr>
<tr>
<td><em>Aspergillus flavus</em></td>
<td>60</td>
</tr>
<tr>
<td><em>Penicillium roqueforti</em></td>
<td>13</td>
</tr>
<tr>
<td><em>Mucor mucedo</em></td>
<td>70</td>
</tr>
</tbody>
</table>

Photothermal, photochemical and photoelectrical effect
SURFACE DECONTAMINATION
DECONTAMINATION USING ELECTRON BEAM

Treatment of pallets or bulk material
Radio frequency (RF) linear electron accelerator
(LINAC, type CIRCE III from Thomson-CSF/Linac Technologies S. A. (Orsay, France)

- **Acceleration energy:** 5-10 MeV
- **Irradiation power:** max. 10 kW
- **Dose:** 0.25 to 50 kGy (max. dose for food 10 kGy)
- **Dose tracked by:** alanine pellet dosimeters
- **Irradiation direction:** vertical down
- **Irradiation area:** 75x75 cm (tin plate size)
- **Conveyor belt speed:** 1 to 1000 mm/sec

**D-Wert:**
Strahlendosis zur Inaktivierung von 90 %
(1-log)

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>D-Wert kGy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clostridium botulinum</td>
<td>2-3.5</td>
</tr>
<tr>
<td>Salmonella typh.</td>
<td>0.2-1</td>
</tr>
<tr>
<td>Staph. aureus</td>
<td>0.2-0.6</td>
</tr>
<tr>
<td>E. Coli 0157:H7</td>
<td>0.1-0.34</td>
</tr>
</tbody>
</table>

**Strahlungsenergie**
begrenzt auf

<table>
<thead>
<tr>
<th>Strahlungstyp</th>
<th>Energie (MeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gammastrahlung</td>
<td>&lt;1.3</td>
</tr>
<tr>
<td>Röntgen-/ Bremsstrahlung</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Elektronenstrahlung</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>
Log survival fractions on irradiated (4 kGy, 5 MeV) inoculated with different strains and cocktails: Salmonella cocktail (serovars Enteritidis, Gaminara, Oranienburg, Rubislaw, and Typhimurium), E. coli cocktail (E. coli DSM 19206 and DSM 5923), DSM 18039 (E. coli DSM 18039, nonpathogenic), NCCB 86023 (E. faecium NCCB 86023), DSM 20539 (D. radiodurans DSM 20539), and ATCC 7953 (G. stearothermophilus ATCC 7953) spores.

Thank you for your attention!

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