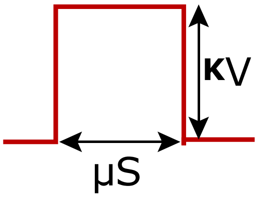
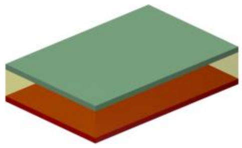
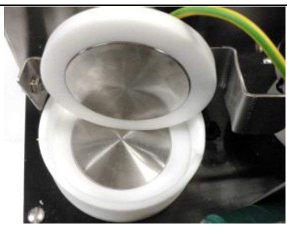
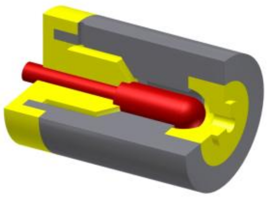
Sterilization & Extraction
by **Pulsed Electrical Fields (PEF)**:

Advantages:



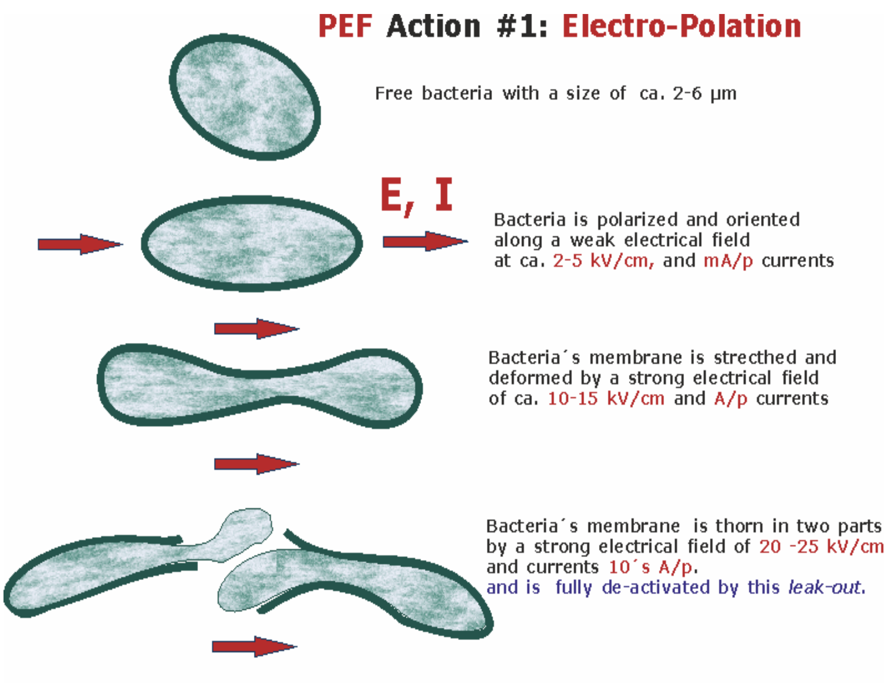
- works <u>uniformly</u> on an flowing liquid, cream-jell or grinded mash,
- *has no wearing parts*,*
- keeps the product temperature almost unchanged,
- *has no dependence on optical properties,*
- does not degrade nutrient properties of a treated media,
- *does not produce harmful or any by-products,*
- cost-effective because uses the latest advances in pulsed power technology,
- *can be integrated into production lines,*
- No labeling in contrast to "radiation and heat" sterilization.

PEF sterilizes *<u>stretching</u>* all bacteria to its disruption (electro-polation) in high electrical fields of 20 to 35 kV/cm applied between two evenly distances electrodes. A gap between electrodes is usually from 5 to 15 mm and pulsed voltage is 20 to 40kV:

			
parallel electrodes is for still samples	Parallel PEF cell used in Steribeam systems	Coaxial cells: for moving liquids/creams	Coaxial PEF cell used in Steribeam systems

All bacteria have a thin membrane ("a skin bag"), filled with a fluid substance, containing DNA and other live-materials, water and some minerals. This complex fluid (like a jell) is a bit conductive which allows to polarize it along an applied electrical filed. It is sufficient a few (3- 5 V) volts across bacteria to polarize it. When it is polarized, it orients itself along the applied electrical field.

With a bacteria size of a few micron, (1-5)x10^{-4} cm, a few volts across it translates to the strength of an electrical field of 5-15kV/cm. Stronger electrical fields (20-40 kV/cm) stretch bacteria cells so much that its membrane breaks-up. The rapture of membrane releases a liquid content out into a treated media making bacteria no longer active.



PEF action is not for a fully dielectric media - where no current flows through!

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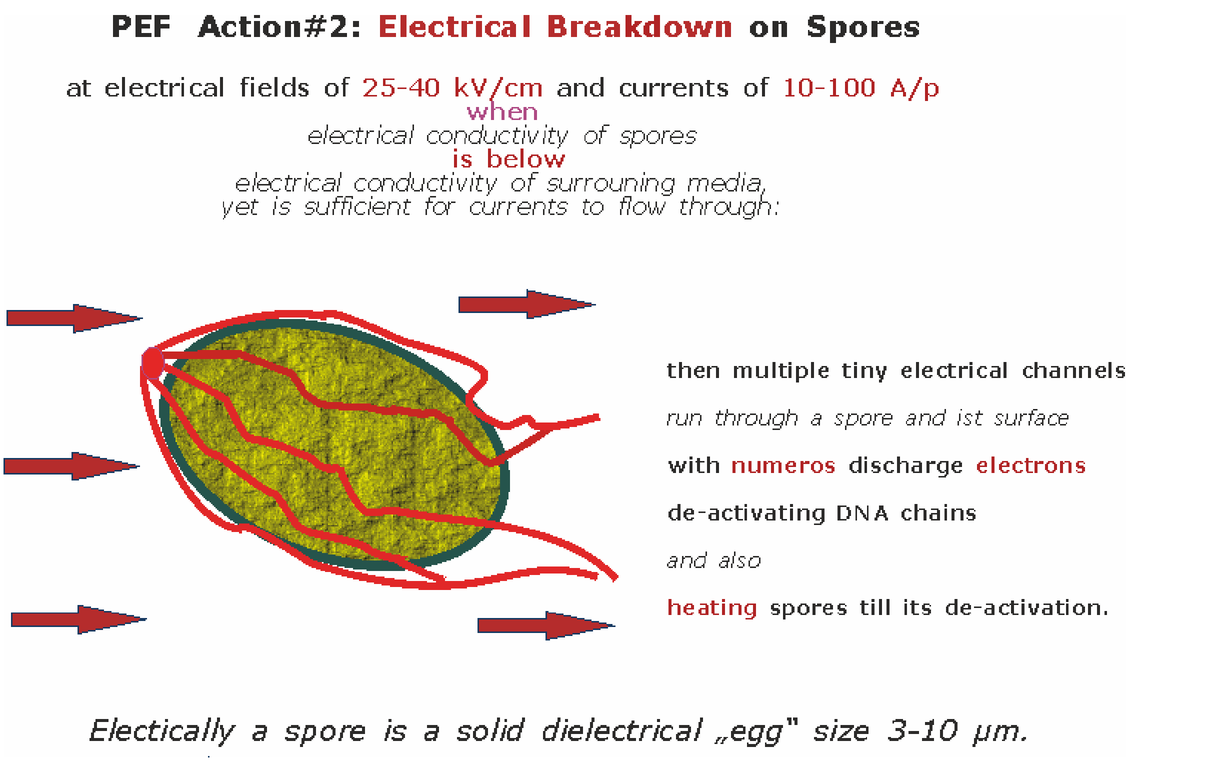
PEF sterilization by impacts of freed electrons

released during micro-discharges over bacteria (or over a spore) in a treated media. This condition is a sort of "a cold plasma" (also known as a barrier discharge) in a poor-conductive media with an electrical field strong enough to cause numerous electrical streams of a very short durations (in a fractions of µsec). These el streams do not create direct breakdowns between electrodes.

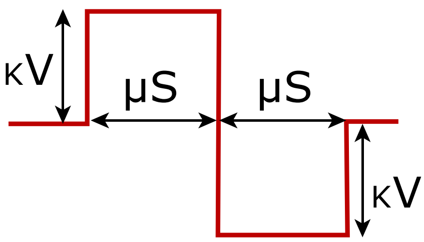


This mechanism is not so well studied as the first one, yet it is the only one to explain why PEF method works on spores and fungi in a treated media.

It also deactivates bacteria by electron impacts of the same origin, yet its effect on bacteria evidently much weaker than the electro-polation.

Bi-Polar pulsing enhances a break-up of a membrane:

Stretching bacteria in one direction can be immediately followed by its stretching in the opposite direction by a pulse with the same parameters but of the opposite polarity. This causes an additional mechanical stress - a wearing by an alternating load known e.g. for metal parts in equipments.



This advantage is offset by three drawbacks:

#1: It requires up to twice as much electrical energy,
#2: Physical limitation: a free floating in juice bacteria will just turn around in the new direction of the switched E-filed to be exposed to the same stretching as before.
#3: it increases costs of the HV block by 3 three times as much.

Because of above, we do not offer Bi-Polar pulsing - instead we offer double stage PEF systems with each stage having different HV parameters.

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Energy consumption for these two PEF processes in a treated liquid
for 1 sec pulsing and 2 to 3 logs reduction in micro-organisms concentration:

PEF #1: 1-4 cal/cm³ (4-16 w/cm³),
PEF #2: (for breaking spores) – is up to 35 cal/cm³ (up to 150 w/cm³).

A much higher energy deposition for the #2 PEF process causes a treated liquid to heat up to possibly 40 to 80°C. To off-set this heating, a treated liquid has to be cooled.

Conditions for PEF process:

- a direct contact of PEF electrodes with a treated media,
- *applied el pulses have to have sharp fronts of about 50-200 ns and to have a rectangular square shape,*
- pulse durations have to be from 2 to 40 μsec, depending on a treated media and sterilization goals,
- *a treated media has to have a small electrical conductivity which allows small el. currents flowing through a treated media during pulsing. No conductivity makes it act as a capacitor, whereas a very good el. conductivity results in heating of a media,*
- a shape of electrodes is also important,
- *electrode materials must assure minimal losses due to its erosion.*

The PEF sterilization method is well known since quite a few decades
yet up to recently it is mostly used for small scale processes because:

- it depends on a treated media,
- *some electrode erosion in large systems,*
- former high costs of HV sub-systems and components for required square pulses.

Note: sin-wave electrical fields used in original PEF works decades ago, because it was only equipment available that time, mostly heated treated media, and greatly reduced effects of the electro-polation.

Unless the application is known, any other product has to be evaluated on its applicability to PEF treatment. This is done with evaluation tests by finding an optimal pulsed voltage, a gap between electrodes, a fluid throughout (l/h), a pulse duration and the Pulse Forming Network (PFN). Since PEF sterilization is media dependent, it requires a regulatory (FDA or EFSA) approval for each new usage in production.

Limitations for PEF process:

PEF will not work on a conductive media, neither on a fully insulated media (like in a liquid enclosed in a plastic bag).
A small current has to flow through a treated media to allow PEF to work by either of two mechanisms described above.

PEF sterilization /extraction is driven by restrictions of gamma, heat and other invasive sterilization techniques, which create harmful by-products and considerably degrade nutrients in treated foods.

Details on known applications you can find e.g. in the FDA-Review-on-PEF copied from the FDA website (dated 2009) to our database.

Sterilization & Extraction
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COLD EXTRACTION
of Juices and colors
with PEF in brief:

A cold pressing does not allow a rupture of all plant cells to obtain a high extraction yield. The application of PEF pre-treatment before pressing significantly increases the extraction yield and increases its quality.

PEF can be also used for the recovery of specific substances (proteins, vitamins, antioxidants) from targeted cells without the use of chemical or thermal treatments known to degrade such substances.

PEF is used to enhance a cold extraction of up to 80% for juices, proteins, nutrients, vitamins and natural colors *from* -- *roots,* -- fruits, -- *vegetables,* -- grass and leafs , -- *protein rich original products.*

PEF extraction keeps original properties of nutrients unchanged plus can simultaneously sterilize it.

Prior to the PEF processing natural products have to be converted to a mash unless. This is to assure a uniform flow through a PEF treatment chamber, where having air bubbles or large solid pieces can lead to local electrical breakdowns.
Step-by-step PEF extraction: - electrical fields polarize and stretch bacteria cells up to a break-up of its membranes. (bacteria get from 3V to 5V across its length (ca. 1-3 µm), sufficient for this process). - - resulting rapture of cell walls releases a liquid content of cells. PEF fields of 5 to 10 kV/cm are sufficient for the extraction.

Advantages and limitations of PEF extraction are just the same as for PEF sterilization and are listed above.

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