Documented shelf-life of food products with PEF treatment

Food matrix	PEF application goal	PEF treatment conditions	Results on shelf-life	Reference
Liquid whole egg	Inactivation of *Salmonella* Typhimurium and *Staphylococcus aureus*	Electric field intensities: 20, 25, 30, 35, 40 and 45 kV/cm. Specific energies per pulse: 8.3, 12.9, 18.6, 25.4, 33.1 and 41.9 kJ/kg. Frequency: 0.5 Hz Final temperature: below 35 ºC	Maxima inactivation levels of *S.* Typhimurium: 4 Log_{10} by applying 45 kV/cm, 30 µs and 419 kJ/kg Maxima inactivation levels of *S. aureus:* 3 Log_{10} by applying 40 kV/cm, 15 µs and 166 kJ/kg In order to achieve higher inactivation levels, it is necessary to combine with other preservation technologies	[1]
	PEF treatment + heat	Electric field intensity: 25 kV/cm Specific energy: 75 kJ/kg Flow rate: 2 L/h Final temperature after PEF treatment: 38 ºC Heat treatment of PEF-treated samples: 52 ºC / 3.5 min; 55 ºC / 2 min; 60 ºC / 1 min Triethyl citrate was added to the sample at a concentration of 2 %	Maintenance of color, foaming and emulsifying capacity	[2]

Food matrix	PEF application goal	PEF treatment conditions	Results on shelf-life	Reference
Strawberry juice	Pasteurization	Electric field intensity: 35 kV/cm Treatment time: 27 µs Storage: 4 ºC / 42 days	Extended shelf life at least 28 days while heat treatment with the heat treatment was 42 days Better retention of phenolic contents and higher antioxidant activity	[3]
Beer	Inactivation of *Saccharomyces cerevisiae* ascospores	Electric field intensity: 45 kV/cm Frequency: 800 Hz Number of pulses: 46 Treatment time: 70 µs Flow rate: 4.34 mL/s Final temperature: 43 – 53 ºC Alcohol contents ranging from 0.05 to 7% alc/vol Degassing prior to pulse application	The higher % alc/vol, the greater the inactivation At 53 ºC and 7 % alc/vol, yeast Log_{10} reductions of 3.3 Some PEF-treated beer developed undesirable light-struck character	[4]
Apple juice	Inactivation of spoilage microorganisms	Electric field intensity: 30 kV/cm Number of pulses: 200, 300 and 400 Cycle of 50 pulses Final temperature: < 35 ºC	72h shelf-life at 4ºC after 400 pulses of PEF treatment No effect neither in the content of vitamin C or polyphenols	[5]
Whole milk	Mild pasteurization	Electric field intensity: 35 kV/cm Pulse width: 2.3 µs Flow rate: 72 L/h Heat treatment: 65 ºC / < 10 s	Shelf-life of PEF-treated milk was up to 24 days at 4 ºC No negative effect on sensory properties	[6]

Food matrix	PEF application goal	PEF treatment conditions	Results on shelf-life	Reference
Cranberry juice	Mild pasteurization	Electric field intensity: 32 kV/cm Frequency: 500 Hz Treatment time: 47 µs Energy per pulse: 2.0 J Flow rate: 100 L/h Heat treatment: 60 ºC / 32 s	Extended shelf-life up to 197 days at 4 ºC No effect on juice color	[7]
Pomegranate juice	PEF pasteurization + antimicrobial bottle coating	Electric field intensity: 35 kV/cm Frequency: 2000 Hz Treatment time: 72 µs Flow rate: 7.2 L/h Final temperature: 55 ºC Antimicrobial: potassium sorbate and sodium benzoate	Shelf-life of PEF-treated packaged in antimicrobial bottled juices was 84 days while that of PEF-treated juices alone was 21 days at 4 ºC No significant differences in total phenolic and antioxidant compounds, pH, and total soluble solid were observed in treated juices	[8]
Fruit juices (apple, pear, tomato, strawberry, orange)	Microbial inactivation combined with antimicrobials	Electric field intensity: 35 kV/cm Frequency: 100 – 235 Hz Treatment time: 72 µs Flow rate: 90 – 110 mL/min Final temperature: 55 ºC Antimicrobials: citric acid (0.5 -1.5 %) and cinnamon bark oil (0.05 – 0.1 %)	Combining PEF treatment with antimicrobial in all juices prolonged the shelf life by 91 days at 4 ºC, the same with heat treatment Addition of antimicrobials affected juice acceptability	[9]

Food matrix	PEF application goal	PEF treatment conditions	Results on shelf-life	Reference
Fresh milk	Inactivation of *Pseudomonas*	Electric field intensity: 31 kV/cm Frequency: 200 Hz Treatment time: 19.6 µs Flow rate: 60 mL/min Final temperature: 55 ºC	Extended shelf life to 8 more days at 4ºC when PEF is applied (total days: 13)	[10]
Apple–strawberry–banana smoothies	Inactivation of yeast and moulds	Electric field intensity: 13.5-24.0 kV/cm Frequency: 100 – 290 Hz Initial temperature: 40 ºC Flow rate: 130 L/h Total energy: 52-55 kJ/kg Final temperature: 59 ºC	PEF-treated smoothies increased their shelf life by 25-75 % when stored at 4 and 7 ºC, respectively	[11]

For questions about this table, please contact:

Ignacio Álvarez (ialvalan@unizar.es)
Guillermo Cebrián (guiceb@unizar.es)
Leire Astrain (astrain@unizar.es)

References

1. Monfort, S.; Saldaña, G.; Condón, S.; Raso, J.; Álvarez, I. Inactivation of *Salmonella* Spp. in Liquid Whole Egg Using Pulsed Electric Fields, Heat, and Additives. *Food Microbiol* **2012**, *30*, 393–399, doi:10.1016/j.fm.2012.01.004.
2. Monfort, S.; Mañas, P.; Condón, S.; Raso, J.; Álvarez, I. Physicochemical and Functional Properties of Liquid Whole Egg Treated by the Application of Pulsed Electric Fields Followed by Heat in the Presence of Triethyl Citrate. *Food Research International* **2012**, *48*, 484–490, doi:10.1016/j.foodres.2012.04.015.
3. Yildiz, S.; Pokhrel, P.R.; Unluturk, S.; Barbosa-Cánovas, G.V. Shelf Life Extension of Strawberry Juice by Equivalent Ultrasound, High Pressure, and Pulsed Electric Fields Processes. *Food Research International* **2021**, *140*, 110040, doi:10.1016/j.foodres.2020.110040.
4. Milani, E.A.; Alkhafaji, S.; Silva, F.V.M. Pulsed Electric Field Continuous Pasteurization of Different Types of Beers. *Food Control* **2015**, *50*, 223–229, doi:10.1016/j.foodcont.2014.08.033.

5. Dziadek, K.; Kopeć, A.; Dróżdż, T.; Kiełbasa, P.; Ostafin, M.; Bulski, K.; Oziembłowski, M. Effect of Pulsed Electric Field Treatment on Shelf Life and Nutritional Value of Apple Juice. *J Food Sci Technol* **2019**, *56*, 1184–1191, doi:10.1007/s13197-019-03581-4.
6. Sepulveda, D.R.; Góngora-Nieto, M.M.; Guerrero, J.A.; Barbosa-Cánovas, G.V. Shelf Life of Whole Milk Processed by Pulsed Electric Fields in Combination with PEF-Generated Heat. *LWT - Food Science and Technology* **2009**, *42*, 735–739, doi:10.1016/j.lwt.2008.10.005.
7. Akdemir Evrendilek, G.; Dantzer, W.R.; Streaker, C.B.; Ratanatriwong, P.; Zhang, Q.H. Shelf-Life Evaluations of Liquids Foods Treated by Pilot Plant Pulsed Electric Field System. *IFST* **2007**, *25*, 283–297, doi:9443/10.1111/j.1745-4549.2001.tb00461.x.
8. Jin, T.Z.; Guo, M.; Yang, R. Combination of Pulsed Electric Field Processing and Antimicrobial Bottle for Extending Microbiological Shelf-Life of Pomegranate Juice. *Innovative Food Science & Emerging Technologies* **2014**, *26*, 153–158, doi:10.1016/j.ifset.2014.07.011.
9. Mosqueda-Melgar, J.; Raybaudi-Massilia, R.M.; Martín-Belloso, O. Microbiological Shelf Life and Sensory Evaluation of Fruit Juices Treated by High-Intensity Pulsed Electric Fields and Antimicrobials. *Food and Bioproducts Processing* **2012**, *90*, 205–214, doi:10.1016/j.fbp.2011.03.004.
10. Craven, H.M.; Swiergon, P.; Ng, S.; Midgely, J.; Versteeg, C.; Coventry, M.J.; Wan, J. Evaluation of Pulsed Electric Field and Minimal Heat Treatments for Inactivation of Pseudomonads and Enhancement of Milk Shelf-Life. *Innovative Food Science & Emerging Technologies* **2008**, *9*, 211–216, doi:10.1016/j.ifset.2007.11.002.
11. Timmermans, R.A.H.; Nederhoff, A.L.; Nierop Groot, M.N.; van Boekel, M.A.J.S.; Mastwijk, H.C. Effect of Electrical Field Strength Applied by PEF Processing and Storage Temperature on the Outgrowth of Yeasts and Moulds Naturally Present in a Fresh Fruit Smoothie. *International Journal of Food Microbiology* **2016**, *230*, 21–30, doi:10.1016/j.ijfoodmicro.2016.04.014.