International Journal of Agricultural Engineering, Vol. 3 No. 1 (April, 2010) : 171-174

Research Paper :

Application of pulsed electric field in food processing

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Accepted : ***April, 2010***

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ABSTRACT

Among nonthermal treatments, pulsed electric field (PEF) has received special attention on account of its potential use in treating liquid foods and its feasible application in continuous-flow processing. Pulsed electric fields (PEF) is a non-thermal preservation method mainly used in liquid foods to inactivate micro-organisms and enzymes, retaining volatile compounds and nutrients in foods Improving the food quality of milk and dairy products with PEF processing may be a relevant consideration in product development research. It has already been demonstrated that pulsed electric fields (PEF) processing can alternatively be applied to deliver safe and shelf-stable products.

Key words : Pulse electric field, Non-thermal preservation, Electropermeabilization

Pulsed electric field (PEF) treatment involves applying a short burst of high voltage to foods between two electrodes, and can be carried out at ambient or at refrigeration temperatures. It is thought that pulsed high-voltage (40kV/cm) stimulation ruptures microbial cell membranes, and decontamination of liquid or semisolid foods such as juices, milk and potato dextrose agar have been successful, achieving reductions of up to 6 log (Zhang *et al.,* 1994).

The treatment is applied for less than one second, so there is little heating of the food, and it maintains its "fresh" appearance, shows little change in nutritional composition and has a satisfactory shelf-life (Castro *et al.,* 1993, Kozempel *et al.,* 1998). Microbial reductions of up to 9 log have been achieved in laboratory scale systems using treatments of 2 seconds to 300 seconds, and good results have been achieved in liquids such as water, milk and juices (Qin *et al.,* 1995).

METHODOLOGY

Application of Pulsed Electric Fields (PEF)

The exposure of biological cells to an external electrical field of sufficient field strength induces the formation of pores in the cell membrane. This phenomenon, termed electropermeabilization, can be utilized for many operations in food- and bioengineering as shown in Fig. 1. First reported in the 1960s for disintegration of plant or animal tissue, research on the applicability of these gentle membrane permeabilization techniques in food processing has concentrated on microbial inactivation in different liquid food products (Zhang *et al.*, 1995, Grahl and Märkl,1996, Wouters and Smelt, 1997, Barbosa-Cánovas *et al.*, 1999 and engineering aspects.(Barbosa-Cánovas *et al.*, 1999, Heinz *et al.*, 2002) In addition, the electropermeabilization of plant cells, (Brodelius *et al.*, 1988; Aibara and Esaki , 1998; Ho *et al.*, 1997, Hodgins *et al.*, 2002) the effects of PEF on food matrices,(Bendicho *et al.*, 2003) inactivation of enzymes and induction of stress reactions and secondary metabolites production(Bendicho *et al.*, 2003) have been investigated. Even if application of PEF will require an additional input of electrical energy, the subsequent sections show selected examples of beneficial effects on total energy consumption of mass transfer processes such as extraction or pressing, as well as increased sustainability.

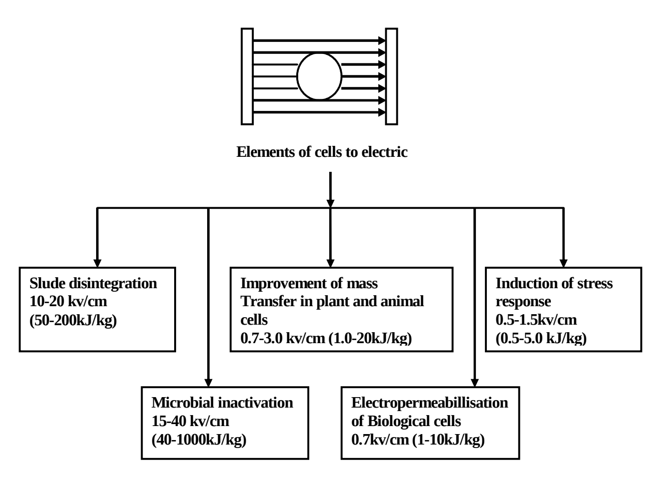

Fig. 1 : Electropermeabilisation of cells after expose to electric field and application in food and waste water processing with typical electric field strength and energy input requirements

RESULTS AND DISCUSSION

The results obtained from the present investigation are summarized below :

Improvement of extraction of intracellular compounds:

Many operations in food and bioengineering, such as extraction, pressing or drying, include either enzymatic, thermal, or mechanical disruption of cellular material prior to recovery of intracellular compounds. These techniques may require a significant amount of mechanical or thermal energy, long holding times and storage tanks for an enzymatic maceration. Apart from the energy point of view, undesirable activities of endogenous or added enzymes and thermal degradation lead to significant losses of nutritionally and physiologically valuable substances. When applying PEF to cellular tissues an increase in mass transfer coefficients could be observed.(An almost total permeabilisation of apple and potato tissue can be achieved with an electrical energy input in the range of 1–5 kJ per kg of product(32) in contrast to 20–40 kJ/kg for mechanical, 60–100 kJ/kg for enzymatic, and above 100 kJ/kg for thermal degradation of plant tissue. For an enzymatic or a thermal disintegration, heating of the raw material and considerable holding time at high temperature is required, heat transfer is slow, and heat recovery is poor as plate heat exchangers can hardly be applied for fruit mashes. A PEF treatment can be performed at ambient temperature and in a continuous operation, and in contrast to enzymatic maceration, no holding time and tank are required. It is noteworthy that the timescale required for a PEF treatment is in the range of seconds. An exemplary flow chart of such a process is shown in Fig. 2.

It has been shown that pressing of PEF-treated apple pieces at a pressure of 3 MPa resulted in an increased yield of 12%. At a pressure of 0.2–0.3 MPa, an increase of 40% was reported in contrast to untreated samples (Bazhal and Vorobiev, 2000). This clearly indicates that PEF treatment provides (in addition to lower energy requirements for disintegration) a possibility to reduce energy required for fruit juice pressing. For carrot juice, an increase of juice yield from 60.1 to 66.4% was found in comparison to an untreated sample, in the same way the dry matter of the pomace was increased from 13 to 15 %, resulting in less efforts for drying (Knorr *et al.*, 1994). For grapes, a juice yield of 87%, similar to that after enzymatic maceration, and an increased content of soluble solids and pigments was reported after cell disintegration by PEF.

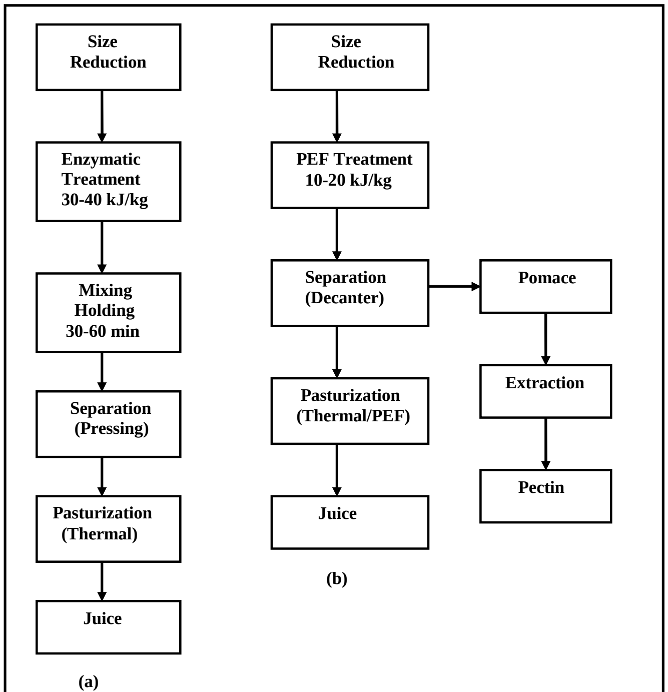

Fig. 2 : Flow chart for fruit juice processing (a) Conventional (b) PEF treated prior to liquid-solid separation

Heat treatment and bench scale PEF processing system:

For heat treatment, an experimental set-up is shown Fig. 3. It consists of pre-heating and holding containers, coils for liquid food passage, a centrifugal sanitary pump to circulate the samples, and thermocouples to record the temperature. For PEF treatment, a bench scale continuous system The schematic diagram of the system is shown in Fig. 3. A trigger generator used to control frequency and pulse width and delay time between opposite polarities. Signals of voltage, current, frequency, and waveform were monitored by a two channel 1 GS/s (60 MHz bandwidth) digital real-time oscilloscope . A typical square-wave bipolar pulse will be generated. Six co-field flow tubular chambers with a 2.92 mm electrode gap and a 2.3 mm inner diameter were grouped in three pairs, and each pair was connected with stainless steel tube with a 2.3 mm inner diameter. After going through each pair of chambers the treated sample was cooled by passing through a coiled tube with a 2.3 mm inner diameter which was submerged in heat exchange bath with cold water varying from 5 to 15 ºC depending on the treatment conditions was used to maintain constant temperatureduring the treatment. The pre and post-PEF exposure temperatures (Tinlet and Toutlet) at the inlet and outlet of the treatment chamber were measured using a Ktype thermocouple. The maximum average elevation temperature (DT = Toutlet -

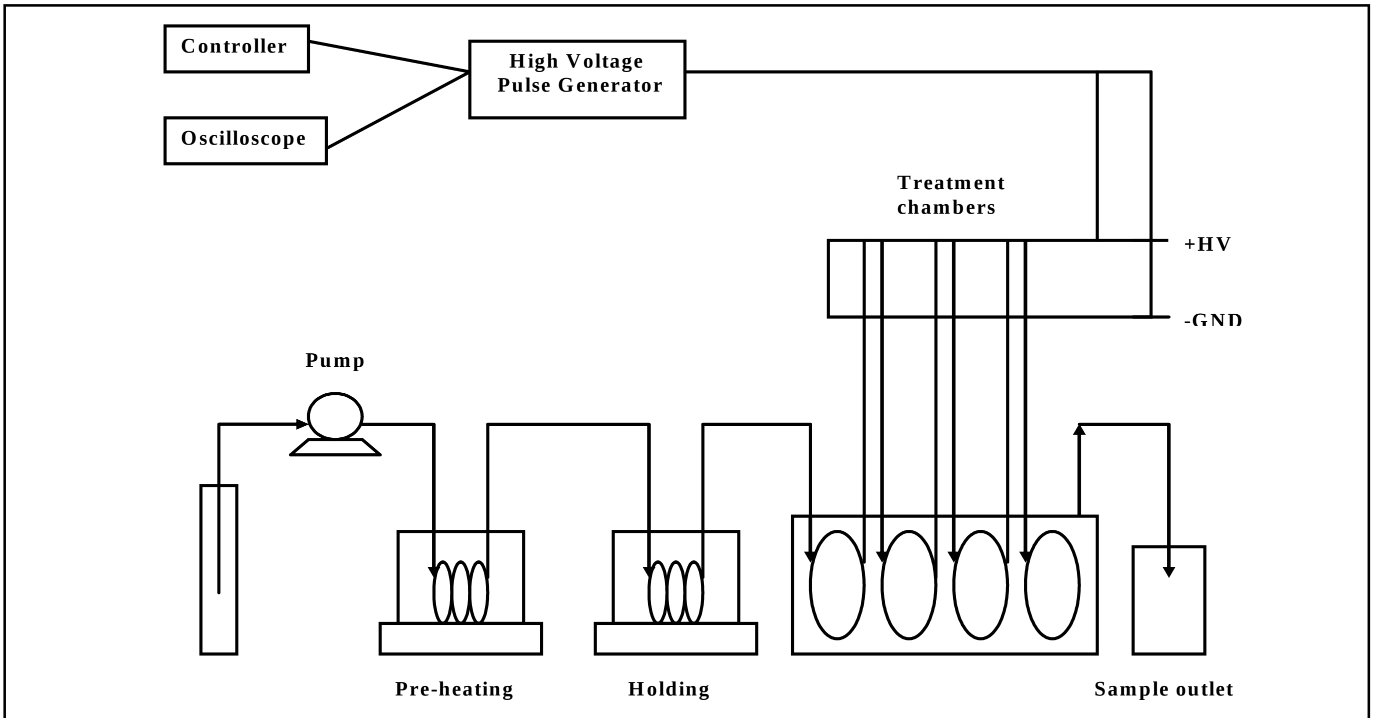

Fig. 3 : Diagram of heat and PEF processing unit

Tinlet) during the PEF treatments was only 3 ± 1^{0}C. The apparatus was thoroughly cleaned with 70% ethyl alcohol and rinsed with steriledistilled water after each experimental run.

Conclusion:

It has been shown that the application of emerging, nonthermal techniques provide a potential to reduce energy requirements for food processing and may contribute to improve energy efficiency in the food industry. It is noteworthy that an application of pulsed electric fields to improve mass transfer rates requires very low energy input in contrast to conventional techniques; Further optimization of processing parameters will help to reduce the costs of operation for pasteurization of liquid food by PEF to approach the low energy requirements for thermal pasteurization where heat recovery rates up to 95% can be reached.

REFERENCES

Aibara, S. and Esaki, K. (1998). Effects of high-voltage electric field treatment on bread starch. *Biosci. Biotech. Biochem.,* **62** : 2194–2198.

Barbosa-Cánovas, G.V., Góngora-Nieto, M.M., Pothakamury, U.R. and Swanson, B.G. (1999). *Preservation of foods with pulsed electric fields*; Academic Press: San Diego,

Bazhal, M. and Vorobiev, E. (2000). Electrical Treatment of apple cossettes for intensifying juice pressing. J. Sci. Food & agric, **80** : 1668–1674.

Bendicho, S., Barbosa-Cánovas, G.V. and Martín, O. (2003). Reduction of protease activity in simulated milk ultrafiltrate by continuous flow high intensity pulsed electric field treatments. *J. Food Sci.,* **68** (3) : 952–957.

Brodelius, P.E., Funk, C. and Shilito, R.D. (1988). Permeabilization of cultivated plant cells by electroporation for release of intracellularly stored secondary products. *Plant Cell Reports,* **7** : 186–188.

Castro, A.J., Barbosa-Cánovas, G.V. and Swanson, B.G. (1995). Microbial inactivation of foods by pulsed electric fields. *J. Food Proc. & Preservation,* **17**: 47-73.

Grahl, T. and Märkl, H. (1996). Killing of microorganisms by pulsed electric fields. *Appl. Microbiol.Biotechnol.,* **45** : 148–157.

Heinz, V., Alvarez, I., Angersbach, A. and Knorr, D. (2002). Preservation of liquid foods by high intensity pulsed electric fields-basic concepts for process design. *Trends. Food Sci. Techno.,* **12**, 103–111.

Ho, S.Y., Mittal, G.S. and Cross, J.D. (1997). Effects of high field electric pulses on the activity of selected enzymes. *J. Food Engg.,* **31** : 69–84.

Hodgins, A.M., Mittal, G.S. and Griffiths, M.W. (2002). Pasteurization of fresh orange juice using low-energy pulsed electrical field. *J. Food Sci.,* **67** (6) : 2294–2299.

Knorr, D., Geulen, M., Grahl, T. and Sitzmann, W. (1994). Food application of high electric field pulses.*Trends Food Sci. Techno.,* **5** : 71–75.

Kozempel, M.F., Annous, B.A., Cook, R.D., Scullen, O.J. and Whiting, R.C. (1998). Inactivation of microorganisms with microwaves at reduced temperatures. *J. Food Protec.,* **61**: 582-590.

Peleg, M. (1995).A model of microbial survival after exposure to pulsed electic fields. *J. Sci. Food agric.*, **67**, 93–99.

Qin, B.L., Pothakamury, U.R., Vega, H., Martín, O., Barbosa-Cánovas, G. V. and Swanson, B.G. (1995). Food pasteurization using high-intensity pulsed electric fields. *Food Technol.,* **49**: 55-60.

Wouters, P.C. and Smelt, J.P.P.M. (1997). Inactivation of microorganisms with pulsed electric fields:Potential for food preservation. *Food Biotechnol.,* **11** : 193–229.

Zhang, Q., Chang, F.-J., Barbosa-Cánovas, G. V. and Swanson, B. G. (1994). Inactivation of microorganisms in a semisolid model food using high voltage pulsed electric fields. *Lebensmittel-Wissenschaft und –Technologie,* **27**: 538-543.

Zhang, Q., Barbosa-Canovas, G.V. and Swanson, B.G. (1995). Engineering aspects of pulsed electric field pasteurization. *J. Food Engg.,* **25** : 261–281.

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