Functional and rheological properties of liquid whole egg after pulsed electric field treatment

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Summary

The aim of the work was determination of functional and rheological properties of liquid whole egg (LWE) after pulsed electric field (PEF) treatment. LWE was obtained from eggs of 27 weeks old layer hens Tetra SL. Parameters of PEF treatment were chosen according earlier experiment results where significant reduction of microflora was observed (32,89 kV/cm and 20, 60, 100 pulses). It was concluded that functional properties of liquid whole egg after PEF were not worse than control sample. Furthermore foam ability and emulsifying capacity of LWE after PEF were significantly better with increasing of amount of impulses than control. Viscosity of LWE at shear rate 250 [1/s] was higher for samples after PEF treatment: 112 mPa s after 20 pulses, 106 mPa s after 100 pulses. Apparent viscosity for control was 102 mPa s. Obtained results indicate that pulsed electric fields could be useful methods of liquid whole egg preservation especially in the context of functional and rheological properties. Another problem is the improvement of microbiological safety which should be the main assessment criteria of that method.

Introduction

Most conventional food processing efforts aim towards reduction or inactivation of microbial populations which can be achieved by thermal processing (i.e. blanching, pasteurization, sterilization) using water, steam, electrical, light or microwave energy as a means for heat transfer (Knorr, 1998). The most important in food preservation is inactivation of undesirable microorganisms what could be also obtained with help of new technologies at lower economical costs. Non-thermal methods allow the processing of food below temperatures used during thermal pasteurization, so flavours, essential nutrients and vitamins undergo minimal or no changes (Butz and Tauscher, 2002). In the past years such preservation methods like aseptic processing, ionizing energy, modified atmospheres, oscillating fields, pulsed electric fields (PEF), microwave energy became more and more popular (Cardello, 2003). Many studies indicate microbiological effectiveness of these methods at good level of sensory characteristics of products (Sitzman, 1995; Knorr, 1998). Success of the food product depends on both product and consumer factors including these social, cultural, contextual and attitudinal ones. Consumers are afraid of some new technologies more than others. Within this context the application of novel food processing technologies to commercial foods creates high levels of consumer concern. The highest level of consumers' concern is connected with addition of bacteriocins, genetic engineering, pulsed X-rays, and irradiation. The lowest levels of consumers' fear of food preservation concerns old technologies like heat pasteurisation, cold preservation, thermal energy but also some new technologies like radio-frequency heating, microwave radiation, pulsed electric fields, ultrasounds and oscillating magnetic field (Cardello, 2003).

One of the non-thermal alternatives to traditional heat pasteurisation of food liquids is method of pulsed electric fields (PEF) where the main purpose is to inactive pathogenic bacteria (Manas *et al.*, 2001; Oziemblowski and Trziszka, 2003). PEF processing involves the application of pulses of high voltage (typically 20 - 80 kV/cm) to foods placed between 2 electrodes. The effect of PEF is related to the application of high voltage for very short periods of time (in the range of nano- or microseconds). Exposure of bacterial cells to the field changes of the sufficient amplitude affects the electrical properties of the cell membrane, reflecting in the decrease in its resistance and the increase in

conductance. Consequently, permeability of the membrane is altered, which is known as electroporation (Knorr *et al.*, 2001; Heinz *et al.*, 2002).

That method is usually used to liquid foods like orange juice, liquid whole egg, milk, yoghurt. PEF preservation of liquid food helps also to extend shelf-life of product. Liquid whole egg (LWE) with 0,15% addition of citric acid and after PEF treatment (E=30 kV/cm, t=489 μs, W=6331 J/ml) has durability of 20 days at 4°C. The same LWE but with 0,50% addition of citric acid and after a little different PEF treatment (E=30 kV/cm, t=55 μs, W=357 J/ml) is characterized by 30 days shelf-life at temperature of 4°C (Gongora-Nieto *et al.*, 2003). Above example shows that skilful connection of combined preservation methods result in safer product with extended shelf-life.

Although some studies have concluded that PEF preserves the nutritional components of the food, effects of PEF on the chemical and nutritional aspects of specific foods should be good understood before it is used in food processing (Qin *et al.*, 1995).

Aim

The aim of the study was to investigate the effect of pulsed electric field on functional and rheological properties of liquid whole egg (LWE).

Materials and methods

Studies were performed on LWE from eggs obtained from commercial farm of 27 weeks old Tetra SL laying hens, kept in cage system and fed standard feed (11,3 MJ/kg of energy and 16% protein). LWE was obtained from yolk and albumen in the ratio 1:2 (w/w) after 2 s treatment in Buchi homogenisator. Homogenised LWE was filled into stationary cell (10 ml) placed in PEF generator SU-1. Samples were exposed to different number (20, 60 and 100) of PEF pulses (voltage 25 kV, i.e. 32,89 kV/cm). Pulses were performed every 1 second and average energy of single pulse was 78,1 J. Temperature changes of LWE were also monitored after PEF treatment.

Foam ability (ΔVp) of LWE was determined according equation:

$$\Delta Vp = 100\% \frac{Ma - Mf}{Mf}$$

where:
Ma – mass of 100 ml of LWE
Mf – mass of 100 ml of LWE foam

Stability of foam (SF) was calculated according equation:

$$SF = 100\% \frac{Va - Vd}{Va}$$

where:
Va – volume of LWE
Vd – volume of leakage from LWE foam after 30 min

Emulsifying capacity (EC) was calculated as amount of emulsified oil [ml] by investigated sample.

Rheology properties were studied on rotational viscometer HAAKE RS 50. Shear stress [Pa] and apparent viscosity [Pa s] of LWE after PEF were investigated in function of shear rate [1/s].

Results and discussion

The most important problem in food products connected with use of PEF is safety. Product should be safe from microbiological point of view after use of pulsed electric field (or together with other combined methods). This study is based on our previous microbiological results where it was proved the significant reduction of microflora: the reduction of *Escherichia coli* at 32,89 kV/cm for 20, 60 and 100 pulses were 1,33; 2,02 and 2,77 log CFU x ml^{-1} for PCM 2057, respectively (Malicki *et al.*, 2004).

Increasing of temperature of LWE after PEF treatment was observed, but it was no significant preservation factor. Liquid whole egg before PEF treatment was cooled to 10°C and temperature of LWE was increasing of 2,5°C, 6,3°C and 14,9°C after 20, 60 and 100 pulses at 32,89 kV/cm, respectively.

Emulsifying capacity of LWE after PEF was statistically significant better ($p<0,05$) for samples after 60 and 100 pulses (21,8 ml and 22,2 ml, respectively). There was no statistically difference between LWE control sample (20,5 ml) and sample after 20 pulses (20,6 ml). It means that increase of PEF pulses had slight positive effect on emulsifying capacity of LWE.

Foam ability (ΔVp) of LWE was significantly depended on amount of PEF pulses. It was $\Delta Vp=663,31\%$ for control sample and 707,33%, 730,86% and 760,75% for samples after 20, 60 and 100 pulses, respectively. Similar results were observed also for stability of foam, where the best stability was for sample after 100 pulses (95,47%). For lower amount of pulses (20 and 60) stability was worse (95,06% and 95,26%, respectively). The worst stability of foam was for control sample: 94,90%. All results both for foam ability and stability of foam were statistically different, so there were 4 homogenous groups for each parameter (Table 1). Obtained results indicate positive role of PEF treatment on foam parameters of LWE.

Rheological parameters (Table 2) of LWE like apparent viscosity [mPa s] and shear stress [Pa] were also depended on PEF treatment, but it was no linear relationship like for foam parameters. The highest values of apparent viscosity (112,3 mPa s) and shear stress (26,8 Pa) were observed for LWE sample after treatment of 20 pulses of PEF. Values of apparent viscosity were 110,3 mPa s and 105,8 mPa s for 60 and 100 pulses respectively. Apparent viscosity for control was 102,4 mPa s. Shear stress of LWE after PEF was also lower for samples after 60 and 100 pulses (26,4 Pa and 24,9 Pa), but the lowest value was for control sample (23,2 Pa). All values of apparent viscosity and shear stress was determined at shear rate of 250 [1/s]. Liquid whole egg is usually described as Newtonian, Bingham, Herschel-Bulkley or thixotropic rheological models (Ahmed *et al.*, 2003). On our diagram Bingham curve was shown together with experimental data of LWE (Figure 1).

Conclusions

1. Functional properties of liquid whole egg (i.e. foam ability, stability of foam and emulsifying capacity) were not worse after pulsed electric field treatment than control samples.
2. The best parameters of foam ability (760,75%) and stability of foam (95,47%) were for LWE after 100 pulses of PEF at 32,89 kV/cm.
3. The highest values of apparent viscosity (110,3-112,3 mPa s) and shear stress (26,4-26,8 Pa) were determined for LWE after 20 and 60 pulses at 32,89 kV/cm.
4. Pulsed electric fields can be useful method of liquid whole egg preservation especially in the context of functional and rheological properties, but the main assessment for that methods is always microbiological safety.

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Table 1 Parameters of functional properties of liquid whole egg (LWE) after pulsed electric field treatment at 32,89 kV/cm (n=3, p<0,05).

Samples of LWE	Foam ability (%)	Stability of foam (%)	Emulsifying capacity (ml)
Control LWE	663,31[a]	94,90[a]	20,5[a]
LWE after 20 pulses	707,33[b]	95,06[b]	20,6[a]
LWE after 60 pulses	730,86[c]	95,26[c]	21,8[b]
LWE after 100 pulses	760,75[d]	95,47[d]	22,2[b]

Table 2 Parameters of rheological properties (for shear rate 250 [1/s]) of liquid whole egg (LWE) after pulsed electric field treatment at 32,89 kV/cm (n=3, p<0.05).

Samples of LWE	Apparent viscosity (mPa s)	Shear stress (Pa)
Control LWE	102,4[a]	23,2[a]
LWE after 20 pulses	112,3[b]	26,8[b]
LWE after 60 pulses	110,3[b]	26,4[b]
LWE after 100 pulses	105,8[a]	24,9[a]

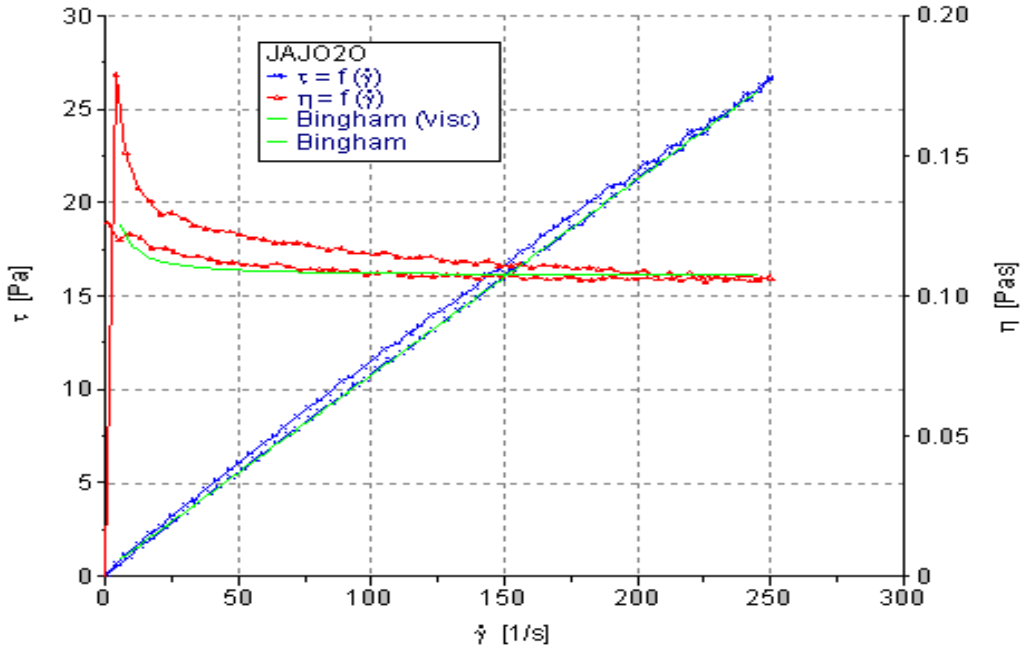

Figure 1 Example of diagram with curves of apparent viscosity [Pa s] and shear stress [Pa] in function of shear rate [1/s] for liquid whole egg after treatment of pulsed electric field (20 pulses at 32,89 kV/cm).