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APPLICATIONS OF PULSED ELECTRIC FIELD TECHNOLOGY FOR THE FOOD INDUSTRY

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Titill / Title	Applications of pulsed electric field technology for the food industry - Notkun rafpúlsa til að bæta nýtingu sjávarafurða		
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Ágrip á íslensku:	Tilraunir með rafpúlsa hafa verið gerðar á ýmsum matvælum, t.d. í framleiðslu ávaxtasafa og til að auka vatnsheldni kjöt afurða. Aðalmarkmið þessa verkefnis var að auka vatnsheldni fisks (þorskur, ýsa og ufsi) og auka mýkt skelfisks afurða eins og beitukóngs og kúskeljar með því að nota rafpúlsatækni. Notkun pækilvéla með nálar sem voru 4 mm að þvermáli reyndist ekki vel. Fyrir viðkvæmar vörur eins og fisk þá þarf að nota minni nálar, <1mm. Rafpúlsarnir höfðu greinileg áhrif á uppbyggingu vöðvans í fiskinum með því að sjáanleg göt urðu fleiri. Áhrif þess þarf að skoða nánar. Ekki fengust marktækar niðurstöður m.t.t. aukinnar mýktar skelfisksins		
Lykilorð á íslensku:	*Rafpúlsar, Rafgötun, fiskur*		
Summary in English:	Experiments using pulsed electric field (PEF) have been carried out on food products, i.e. in juice production to facilitate cell breakdown and to increase the water holding capacity of meat. The aim of this project was to improve the water holding capacity of fish cod, haddock and pollock and tenderization of shellfish products such as, common whelk and Iceland cyprine using PEF treatment technique. Injecting brine with commercial injection machine proved to be unsuitable, since it was equipped with needles 4 mm in diameter. For delicate products such as fish, they can't be more than 1 mm in diameter. Treating the fish muscle with PEF gave a more porous structure which implications need to be studied further. Studies on tenderization resulted in no significant results.		
English keywords:	*Pulsed electric field, electroporation,fish*		

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1. INTRODUCTION

When biological cells are exposed to an electric field it can influence the permeability of cell membranes and may induce structural changes and local membrane breakdown. This phenomena, called electroporation, has lead to studies into the applications in food- and bioprocessing. This technique has been used for microbial genetics to introduce foreign material, such as DNA into cells [1].

The mechanism of action can be seen schematically in figure 1.

The electric breakdown is reversible if the pores induced are small in comparison to the membrane area. Increase of electric field strength (E) and treatment intensity by increasing pulse width and/or number will promote formation of large pores and the reversible damage will turn into irreversible breakdown, associated with mechanical destruction of the cell membrane and cell death.

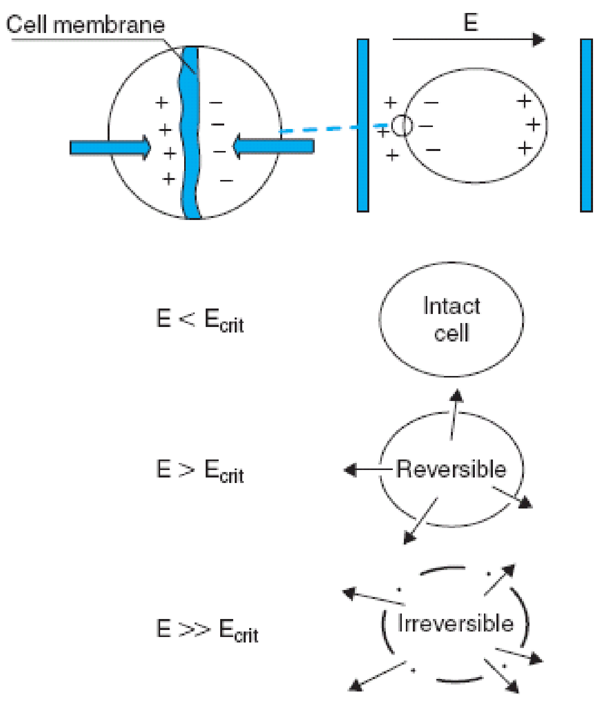

Figure 1. Schematic depiction of mechanism of membrane permeabilization by electrocompressive forces induced by an external electric field. Increasing treatment intensity will lead to formation of large irreversible membrane pores. E = Electric field strength, E_{crit} = Critical electric field strength [2].

Some attempts have been made to use pulsed electric field (PEF) in food production, but no products have been marketed. PEF has two important effects on products, although both are because of the same phenomena, one is the microbial inactivation and the other is the disintegration of biological tissues. This disintegration is often a key step in food processing prior to winning of intracellular compounds. PEF can be applied continuously and in a time-scale of seconds, and can therefore easily be implemented into existing processing lines.

This method has been tried in juice processing, to treat microalgae, seaweed and other aquatic species. It has been used in plant oil extraction, drying enhancement, sugar processing and meat and fish treatments.

Disintegration of animal cellular tissue is of interest to enhance processes where an uptake of substance is required, such as marination or curing of fish or meat products.

The latest unpublished results on PEF treatment of ham (done by Berlin University of Technology) [3] shows changes in tissue structure leading to weight increase after brine injection and first of all to greater water holding capacity and less loss during cooking. The explanation of swelling and higher water holding capacity in ham tissue is that PEF treatment causes porous, swamp- like structure (capillary force) which holds injected brine better then untreated ham. The other very important change after PEF treatment was improved tenderness of ham. The PEF treated ham was significantly softer and tender then untreated samples.
IFL has a special interest to investigate how the structure of fish and shellfish will respond to PEF treatment. The construction of fish tissue is much weaker that the animal tissue. The question is: will the PEF treatment destroy the cell membranes as in case of fruit or vegetable or will it make as porous as in the case of animal meat?

The aim of this preliminary project was to improve water holding properties of fish and to improve tenderization of shellfish products such as common whelk and Iceland cyprine using PEF treatment technique. The other aim was to establish deeper cooperation between Berlin University of Technology and IFL.

2. MATERIALS AND METHODS

A high voltage pulse modulator (Berlin University of Technology, Germany), internally equipped with a power supply (20 kV), a capacitor bank (3 µF) and a high voltage switch was used to generate exponential decay pulses (see figure 2).

Figure 2. A high voltage pulse modulator (TU Berlin)

The repetition rate was varied from 1 to 4 Hz. The samples were placed between two parallel stainless electrodes (A = 1125 cm^2) in tap water, the electrode gap was 8 cm (see figure 3.). The samples were treated with different intensities, by variation of the pulse number n (20, 40, 80 or 120) and the electric field strength E (1.2 kV/cm or 2.0 kV/cm). The pulse width (to a decay to 37 %) was 400 microseconds. Samples were weighed before and after PEF treatment.

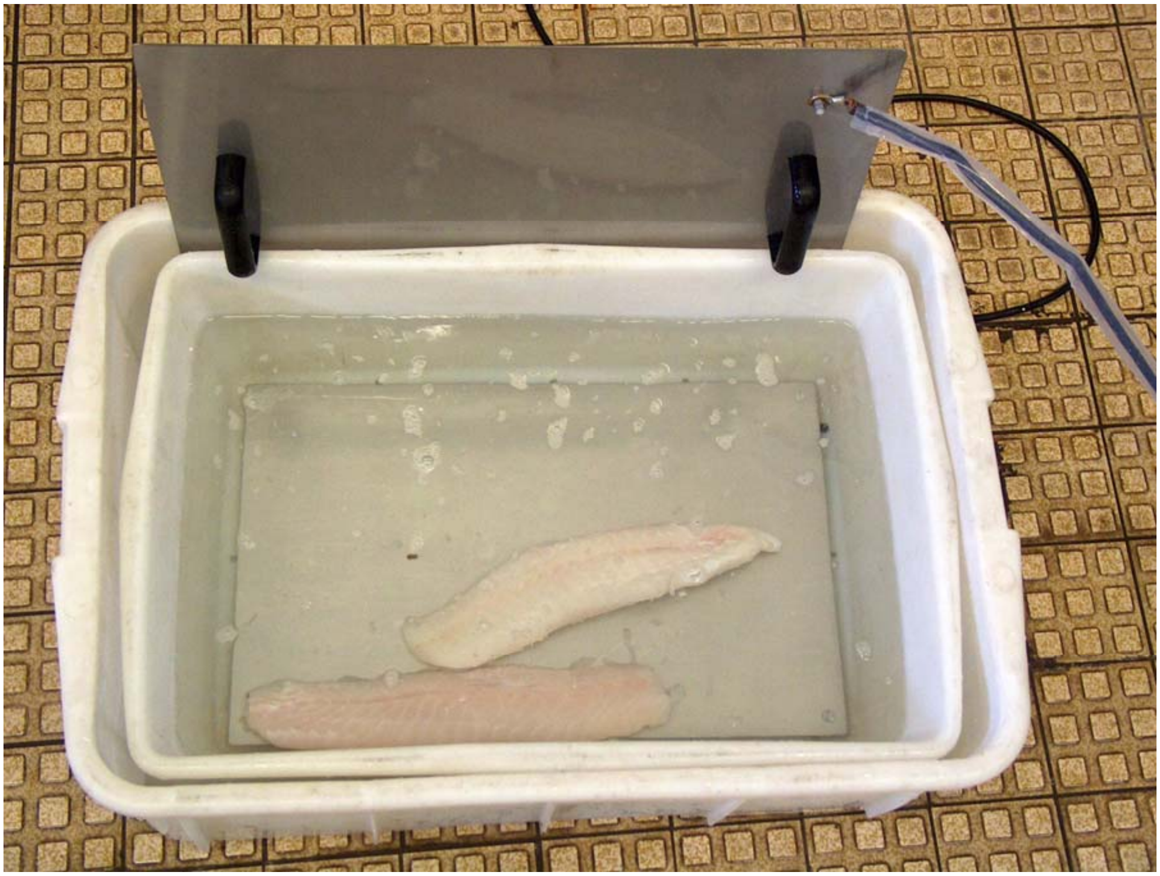

Figure 3. Samples of cod in container between two parallel stainless electrodes

After treatment the salt brine (approx. 10 %) was manually injected by using syringes with a volume of 20 ml, or using a commercially available injection machine IR 28 of Ruehle, Germany. After injection the fish samples were packed in vacuum bags, stored at 4°C for 1 to 4 h and cooked in a water bath at 95°C. After cooking the water loss was evaluated.

After PEF treatment of scallops a tumbling step was performed to investigate its impact on textural properties, a Ruehle MKR 150 tumbler was used. Texture analysis was performed using a texture analyser (Stable Microsystems).

Fish samples: Pollock fillets, cod loins frozen, cod fresh fillets, haddock loins frozen, Iceland cyprine and common whelk

Cook-out

Evaluation of cook-out was performed by steam cooking/heating the vacuum packed loins and fillets (n=3) at 95-100°C for 10 minutes in boiling water. The loins and fillets were cooled under running water for 10 min prior to weighting. The total weight of the vacuum packed loins was recorded, then the package was cut open and the cooked-out liquid pored away. Then weight of the fish and packing material was recorded and finally only the packaging material was weighted. The values obtained were used to calculate the cook-out, which was expressed as percent of the weight loss due to cooking.

$$Cook-out\% = 100 \times \frac{Weight\ of\ sample\ in\ packaging - (weight\ of\ drained\ sample + packaging\ material)}{Weight\ of\ sample - packing\ material}$$

All the experiments were carried out at the Department of Food Biotechnology and Process Engineering at the Berlin University of Technology.

Table 1. PEF treatment of fish and shellfish

Sample	Treatment	Initial weight (kg)	PEF Parameters	Injection	Weight after injection	Injection weight increase	Weight after storage	Cooked weight	water	water loss during cooking
Fresh cod skinless fillet	PEF + Injection	0,911	2 kV/cm, 90 Pulses	manual, 200 g brine	1,031	13,17	1,022	0,730	0,277	19,87
	Injection	0,905		manual, 200 g brine	1,021	12,82	1,013	0,709	0,278	21,66
Frozen haddock loins	PEF + Injection	0,612	2 kV/cm, 90 Pulses	manual, 150 g brine	0,680	11,11	0,675	0,498	0,166	18,63
	Injection	0,602		manual, 150 g brine	0,685	13,79	0,682	0,480	0,190	20,27
Frozen cod loins	PEF +Injection	0,838	2 kV/cm, 90 Pulses	manual, 200 g brine	0,949	13,25	0,946	0,643	0,284	23,27
	Injection	0,840		manual, 200 g brine	0,931	10,83	0,931	0,614	0,298	26,90
Scallops	PEF + Injection	0,554	2 kV/cm, 270 Pulses	2.5 bar, 30 /min	0,575	3,79	0,557			
	Injection	0,694		2.5 bar, 30 /min	0,701	1,01	0,681			

3. RESULTS

After adjustment of the PEF equipment, a full scale experiment was carried on. It was important to keep the number of pulses above 90 and the field strength above 2.0 kV/cm. Water loss is an important parameter when evaluating the performance and the effect of PEF treatment.

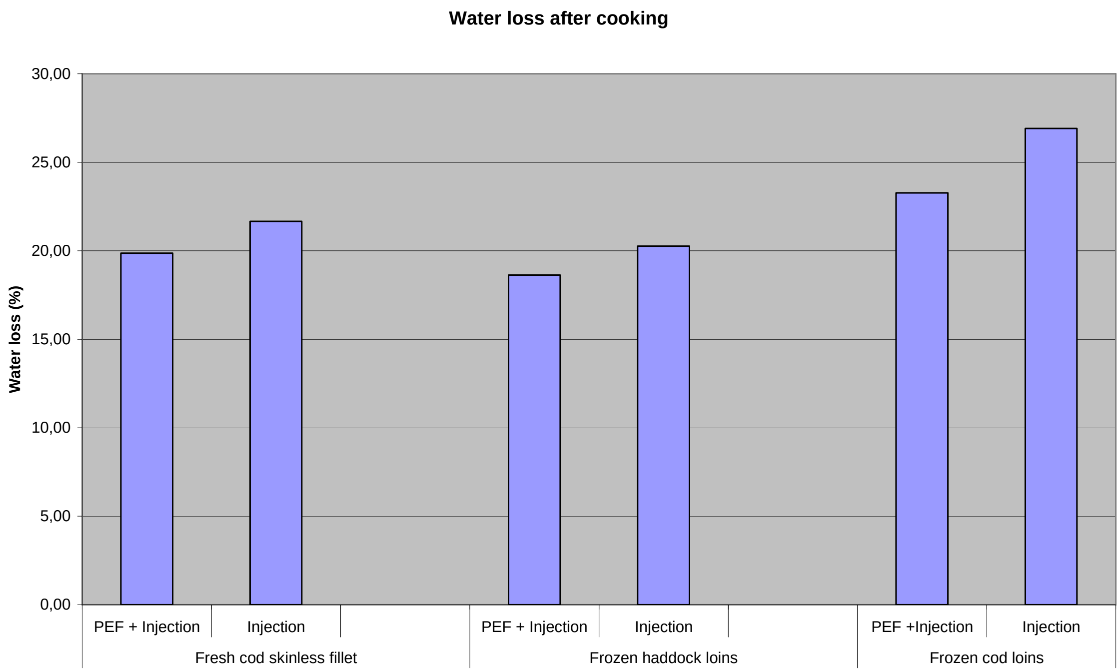

Figure 4. Water loss after cooking, cook-out of cod and haddock

In figure 4 the cook-out for fresh cod fillets, frozen cod loins and frozen haddock loins was evaluated. All the samples were injected with brine manually, 200 g for cod and 150 for haddock. PEF treatment resulted in less water loss than in samples only injected with brine. It has to be noted that the trend in less water loss in all samples after cooking was observed both for fresh and frozen fish. It would be expected that frozen fish will loose more water because the tissue structure of fish is damaged during the freezing process which results in worse water holding properties. The parameters for the PEF treatment were 2.0 kV/cm and 90 pulses/min.

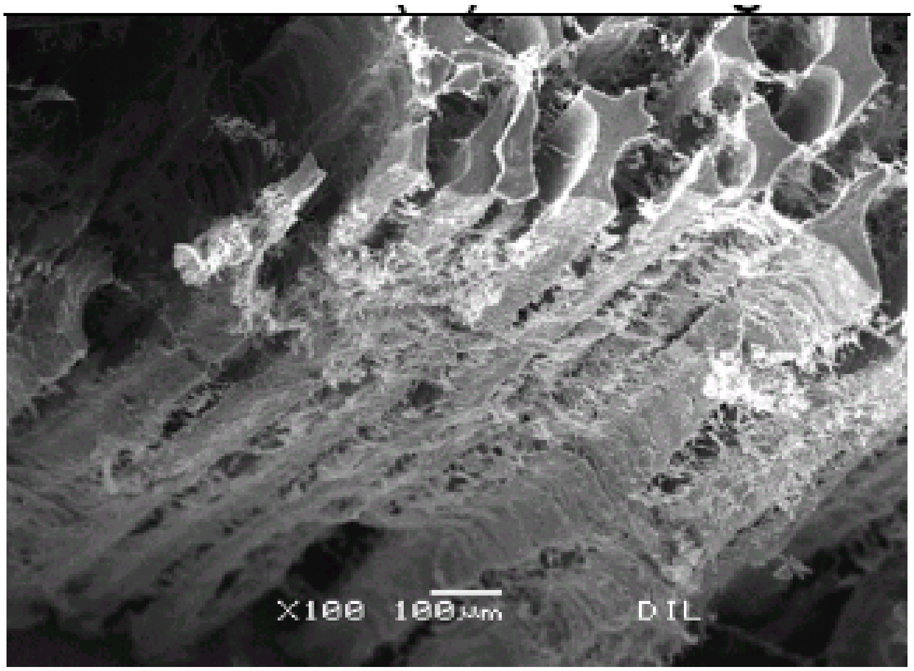

Figure 5. Longitudinal section of cod injected with brine manually

Figure 5 shows the cod muscle tissue on a microscopically level non PEF treated after the injection of brine.

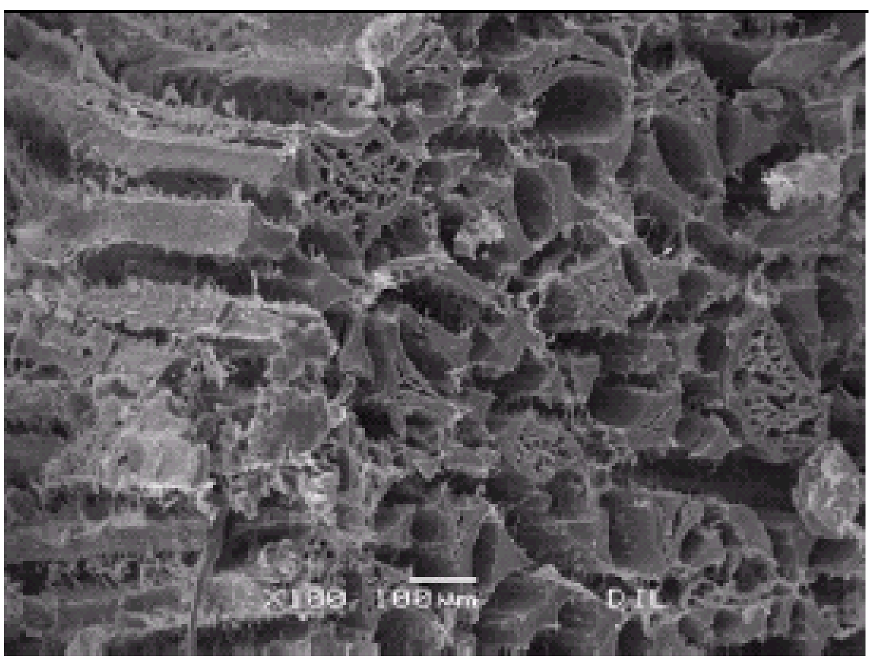

Figure 6. . Longitudinal section of cod injected with brine manually and PEF (2.0 KV/cm,; 90 pulses)

Figure 6 shows the affect of PEF treatment on the structure of the muscle tissue. The structure becomes more porous.

4. DISCUSSION & CONCLUSIONS

The PEF treatment of shellfish products such as common whelk and Iceland cyprine had no pronounced effect on improved tenderness of the products. The variation within the group was larger then between treated and untreated samples.

PEF treatment was not effective with less than 90 pulses and field less than 2.0 kV/cm. Injection with the commercial injection machine was not suitable; since it was equipped with needles which were 4 mm in diameter. For delicate products as fish, the diameter of needles should be 1 mm. To increase the water holding properties in fish the soaking in brine method should be tested.

Treating the fish muscle with PEF makes the structure porous. Implications and properties of this structure change needs to be addressed.
Optimisation of the PEF process need to be done and below are two possible examples that need to be developed further:

1. To establish correct treatment parameters as the strength of the field and number of pulses to create optimal structure (hole size), which will increase the capillary force and hold water to a greater extent.

2. To enlarge the porous structure of a tissue, in order to accelerate the drying process by facilitating the leaking of water from cells.

3. To increase the porous structure more pulses can be applied higher strength or combination of both.

The influence of the different brining methods should be investigated further, e.g. injection vs. soaking. The injection methods could disrupt mechanically the structure of the fish muscle, but soaking is a more gently treatment. Soaking does take longer time and is not a continuous process as injection is.

It would also be of interest to test the injection of a mixture of brine and phosphate, as it is practiced in fish processing for higher water uptake.
For meat tissue it has been shown by TU Berlin that a combination of electroporation and phosphate addition provides a highly synergetic effect on water binding capacity.

PEF treatment has the potential to increase the water uptake and water holding properties which makes it very interesting technology in fish processing industry.
The other interesting application of PEF treatment is using the technology for fish drying.

5. ACKNOWLEDGEMENTS

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