MNF Report

Statement on the Treatment of Food using a Pulsed Electric Field

*Opinion of the Senate Commission on Food Safety (SKLM) of the German Research Foundation (DFG)**

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The working group "Food technology and safety" of the DFG Senate Commission on Food Safety (SKLM) discussed the food safety aspects associated with new technologies that are being developed and used for processing food. One of these newly developed processes uses a pulsed electric field, which is currently being used only on a pilot-scale in Europe. Key objectives of this treatment include the gentle and efficient extraction of cellular constituents as well as gentle pasteurisation of fruit juices. However, the associated electrochemical processes are still insufficiently understood. The SKLM issued the following opinion on 13th March 2007, the English version was agreed on 30th March 2008.

1 Introduction

Processing with a pulsed electric field (PEF) is a new method in food technology still being in the testing and pilot stage. It is used for inactivation of microorganisms in food or for the efficient extraction of cellular constituents.

PEF-treated food products may only be placed on the market in the European Union (EU), after having examined whether they fall within the scope of Regulation (EC) No. 258/97 [1] concerning novel foods and novel food ingredients that came into force on 15th May 1997. To be considered as novel – and thus subject to authorisation according to Article 4 of Regulation (EC) No. 258/97 – are

"Foods and food ingredients to which has been applied a production process not currently used, where that process gives rise to significant changes in the composition or structure of the foods or food ingredients which affect their nutritional value, metabolism or level of undesirable substances."

Placing on the market of high pressure-treated food had already demonstrated the necessity of extensive investigations in order to decide whether the thus-treated products fall within the scope of Regulation (EC) No. 258/97 [2].

If the PEF-process leads to significant changes with effects on nutritional value, metabolism or levels of undesirable substances in the food, a safety assessment must be carried out as part of the authorisation procedure in accordance with Regulation (EC) No. 258/97 (see ANNEX 1, available online as Supporting Information).

No PEF-treated foods have been authorised so far in the EU. Initial trials on the pilot scale have demonstrated prospects for possible applications, *e.g.* gentle pasteurisation of fruit juices or increases in product yields (juices, sugar extraction, oil yield) [3–6].

2 Process engineering aspects

Pulsed electric field processing involves a sudden discharge of a capacitor to generate high-voltage pulses, which are transmitted to the food via electrodes. The configuration and geometry of the electrodes determine the course of the field

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lines and thus the homogeneity of the electric field. In cases of electrodes that are in direct contact with the food being treated, the selection of the electrode material and/or its coating is of considerable significance [7]. However, the specifications given on the design of different installations and the process parameters used are generally insufficient to obtain reliable information allowing the assessment of literature data [8, 9]. Such parameters include the electric field strength, the pulse shape, pulse duration, number of pulses and the repetition rate of the specific energy input as well as heating of the product and temperature distribution within the treatment cell. Additionally, in many cases it is not possible to differentiate between electrochemical effects and local thermal effects. The electrical conductivity of the product to be treated is also affected by the field distribution, which is influenced *e. g.* by the liberation of dissolved gases [10] or by the product's composition and consistency [11]. According to existing studies, the electric field strength as well as the specific energy input in combination with the process temperature appear to be suitable parameters in a comparative evaluation of the treatment intensity of various PEF processes. (Process engineering aspects, see ANNEX 2, available online as Supporting Information)

3 Microbiological aspects

The inactivation kinetics have been studied for a wide range of microorganisms in various products. Vegetative cells can be inactivated by high-voltage pulses, whereas spores remain virtually unaffected [4]. The geometry of microorganism cells influences the inactivation behaviour: smaller cell diameters exhibit a greater resistance [9, 11]. The results indicate that the inactivation mechanisms are essentially membrane-mediated.

An electromechanical model has been used to describe the processes occurring in the microorganism cells during PEF-treatment. Detailed models of electropermeabilisation also account for factors such as enlargement of already existing membrane defects and opening of protein channels by the pulsed electric field respectively. It is assumed that an initial reversible induction of pores is promoted by already existing statistically distributed membrane defects. In a second step, irreversible pores arise, which are stabilised, thus causing a permanent loss of semi-permeability of the cell membrane. Such reorganisation and permeabilisation of the membrane can take up to 20 seconds and leads to a loss of cell vitality [12–16].

Fractions of vegetative cells resistant to PEF have not yet been observed; however, sub-lethal damages have been described in single cases. The combination of PEF with other processes/process parameters can be used to achieve synergistic effects on the inactivation of microorganisms [3, 17–20].

In contrast to the electroporation process used in molecular biology for transferring genetic material into cells, a PEF-mediated transformation of vegetative microorganisms in foods is unlikely. On the one hand, the density of competent cells is too low, and on the other, there is hardly any replicative DNA present. Furthermore, there is no selection pressure. Transformation of plant or animal cells in food is not relevant on account of their low survival rate or lack of regenerability.

4 Chemical aspects: Modifications of food constituents

To date, only few results of impact studies on high-voltage pulses on food constituents are available. PEF-processes are accompanied by electro-chemical reactions/conversions and electrolysis of water. The resulting direct/indirect changes may influence the composition of the food and thus its quality. However, the occurrence of undesirable chemical reactions cannot be excluded, particularly in cases of adverse processing conditions (see Annex 3, available online as Supporting Information).

Thus, as a matter of principle, the intense electric fields occurring during PEF-treatment are expected to produce reactive decomposition products of water as well as reactive oxygen species [21]. Furthermore, direct or indirect formation or release of toxic substances from electrode material is possible. Impairment of food quality, *e. g.* by degradation of quality determining constituents or by formation of undesirable substances cannot be excluded.

Initial investigations on the modification of quality determining constituents and of sensory properties by PEF-treatment are available for fruit and vegetable juices. PEF-treated orange juice contained higher concentrations of flavors and vitamin C compared to heat-treated juice [22]. In contrast, carotinoid and flavanone concentrations in orange juice were not affected by PEF [23]. Improved colour and sensory properties have been described for tomato juice treated with PEF compared to a heat treatment [24]. Apple juice, which had been subjected to pulsed electric fields during production, showed no differences compared with conventionally produced juices with respect to the investigated quality parameters, such as phenol concentration, total acid concentration and cloud stability [25]. Substantial equivalence, as defined in Regulation (EC) 258/97, can be assumed.

Results on the inactivation of enzymes by PEF are inconsistent [16, 26–33]. The causes for enzyme inactivation are not yet understood. An effect of external electric fields on the protein structure as well as electrochemical reactions are being discussed. A 62% reduction of a *Bacillus subtilis* protease activity in simulated milk ultrafiltrate by PEF was observed [34]. In contrast, the activities of lipoxygenase, polyphenol oxidase, pectin methyl esterase and peroxidase at room temperature were only slightly reduced by PEF-treatment [35]. Inactivation of these enzymes observed in liquid milk products, fruit juices and vegetable juices was attributed to thermal effects [36].

It has been shown that PEF-treatment did not significantly change the gelling properties of chicken protein. Also, PEF-treatment did not cause aggregation or unfolding of β-lactoglobulin and ovalbumin [37].

To date, there have only been a few investigations on the shelf-life of PEF-treated foods [24, 38].

5 Allergenicity aspects

The allergenicity of food constituents can be influenced by technological processes: it is frequently lowered and rarely increased [39–41]. Heat treatment generally leads to significantly greater modifications of food constituents than PEF-processes [42, 43]. No increase in allergenicity due to processing procedures was found in foods with a high proportion of water, *e.g.* fruit and vegetables. On the assumption that, compared to cooking, the PEF process leads to relatively insignificant changes in food proteins, its influence on the allergenicity can be expected to be slight, at most. Studies carried out on celery point in this direction. The allergenic potential of celery after treatment with high-voltage pulses lay between that of untreated raw samples and that of samples that had been boiled or cooked in the microwave [44].

If cells are not lethally injured by the PEF-process, a stress-induced production of secondary metabolites and pathogenesis-related proteins (PR) by the defence system of the plants cannot be excluded [45]. Since PR proteins are of high allergenic potential, the process must be designed in a way to avoid their formation as a result of PEF-treatment.

However, given the lack of scientifically substantiated studies, general statements on the modulation of the allergenic potential by PEF-treatment are not possible at present.

6 Safety aspects/evaluation criteria

At present, the knowledge of the implications of the PEF-process on different food matrices is insufficient to perform a general safety assessment of the process. Therefore, products or product groups treated by the PEF-process must be assessed on a case-by-case basis.

The technical parameters of the PEF-process must be described in a way that a reliable assessment of the product safety of the treated foods is possible. On the one hand, this applies to the process itself (electric field strength, specific energy input, duration, temperature, pH, design of the high-voltage cell, *etc*.). On the other hand, the most complete profile possible must be developed regarding PEF-induced chemical/biochemical/microbiological changes in the food to allow a scientific comparison with traditional and/or authorised food treatment processes.

In particular, studies should focus on the extent of detrimental process-related changes caused by electrolysis of water or by generation of reactive oxygen or other species.

Further issues that should be addressed include possible impacts on the allergenicity of foods and undesirable effects on proteins in terms of generation/stabilisation of proteolysis-resistant conformations.

7 Final comments

The PEF-process promotes permeabilisation of cell membranes thus allowing the efficient extraction of cellular contents and the inactivation of microorganisms in food. This opens up new possibilities with respect to utilisation of raw materials and reduction of microbial contaminants.

The number of substantiated studies is limited in all areas, and a consistent evaluation of the PEF-process is hindered due to the lack of standardisation of process parameters. Development of criteria to assess the process or PEF-treated foods requires, among other things, characterisation of suitable indicator substances and measuring parameters. According to the assessment criteria given in chapter 6, products treated with the PEF-process require a case-by case assessment.

The authors have declared no conflict of interest.

8 References

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