Pulsed Electric Field technology offers new potential for New Zealand potato processing and winemaking industries

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PEF industry trial at a potato processing plant. Left to right: Katy Bluett (FIET board member), John Jackson (McCain Foods), Gordon Gillies (McCain Foods), Jimmy Kinsella (Elea, Germany), Prof. Indrawati Oey (University of Otago – UO), Chris Claridge (Potatoes New Zealand), Dr. Sze Ying Leong (UO), Zhihao Hu (UO), Ian Ross (UO), Pat Silcock (UO) and Prof. Phil Bremer (UO).

How does Pulsed Electric Field technology (PEF) work?

PEF technology uses brief (microseconds) pulses of high voltage electricity to disrupt the cell membranes of microorganisms, plant material or animal products [1]. It can be used to modify the structural integrity and microstructure of plant and animal tissues, with the goal of improving mass transfer processes [2]; enhancing the extraction yield and quality of pigments or bioactive compounds [3]; reducing cutting force required [4]; and inactivating micro-organisms (vegetative cells) [5] as an alternative to the pasteurisation of bulk liquids, such as fruit juices.

The heterogeneous nature of plant material makes evenly delivering high voltages with very short electric pulses a challenge [6]. Throughout the years, advances in equipment and generator design for PEF technology have improved the feasibility of applying brief electric pulses through solid plant tissue and increased the application of PEF to a very broad range of food products.

The effectiveness of PEF processing to achieve cell electroporation varies depending on the processing parameters applied as well as the physical characteristics of the plant material (e.g. electrical conductivity, particle size, size and type of cells, chemical composition, pH, temperature, etc.) placed between the conducting electrodes [7]. Key PEF processing parameters to achieve specific food applications or to obtain desired quality improvement in the final product include electric field strength, specific energy input, pulse duration or pulse width, number of pulses, treatment time, pulse repetition rate or pulse frequency, pulse shape and pulse polarity [8]. Many of these processing parameters are interdependent; for example, the specific energy input varies according to the applied electric field strength, pulse frequency, pulse width, pulse number and treatment time.

Scope of research

PEF has a wide variety of applications across many food processing industries and has been used as a processing step internationally in potato, sugar beet industries and in winemaking. Research carried out by students, researchers and food companies using pilot plant scale PEF equipment (batch and continuous mode, HVP ELCRACK 5 from German Institute of Food Technologies) in the Food Science

PEF industry trial at a local winery. Left to right: Dr. Martin Sack (KIT), Prof. Indrawati Oey (UO), Martin Hochberg, Prof. Georg Muller (KIT), Lily Liu (UO), Pat Silcock (UO), Megan Treadwell (UO), Ian Ross

Department at the University of Otago over the last 7 years has demonstrated the wide ranging benefits that PEF can offer to a broad range of New Zealand products [9-11].

Funding provided by the Ministry of Business, Innovation and Employment (MBIE) through the Food Industry Enabling Technology (FIET) programme is enabling us to translate our laboratory-based research into commercial reality. We are currently conducting industrial scale trials using high-throughput PEF equipment to assess the potential advantages of PEF for two very different New Zealand products, namely wine and deep-fried potato products (e.g. French fries and crisps).

Wine trial

In winemaking PEF is applied immediately after destemming, before the grapes enter the maceration/fermentation tank (Figure 1). Consequently, this process affects the structure and permeability of the grape skin cells, which facilitates better release of bioactive molecules (e.g. anthocyanins and phenolic compounds) and flavour compounds important for wine (Figure 2). The process shortens the maceration time to achieve the desired colour and profile of bioactives, flavour. This application also provides the winemaker with the ability to tailor sensory properties by modulating phenol and tannin release, to reduce biological or seasonal variation and to increase varietal expression. PEF processing conditions need to be optimised for each grape variety and wine making style.

To date, we have carried out two trials with a New Zealand wine company. In the first trial, a continuous PEF system (KEA-WEIN developed by the Karlsruhe Institute of Technology) was used at a commercial winery to process 10 tonnes of grapes, which were subsequently processed by experienced winemakers according to their standard commercial winemaking practices. The final wines produced from PEF-treated grapes were characterised for their phenolic and volatile profiles using HPLC and headspace GC-MS analysis respectively. Sensory descriptive analysis (Figure 3) was used to describe and characterise the red wine's flavour, odour, taste and

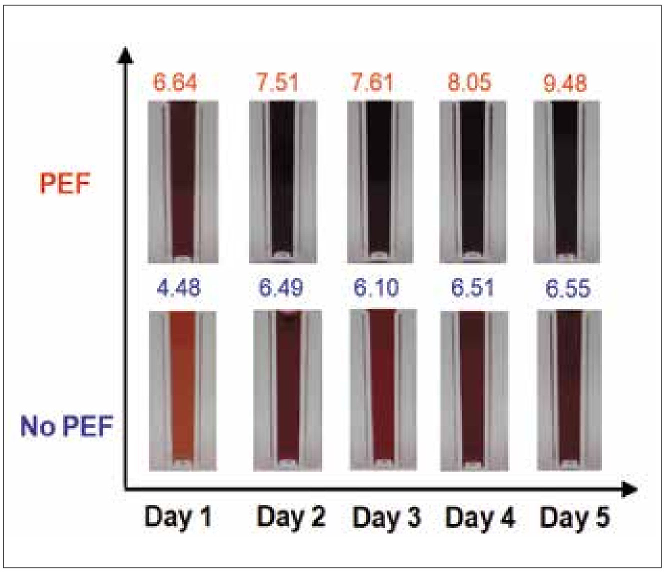

Figure 2. A PEF treatment on grapes accelerated the release of anthocyanins from skin cells into the must

Figure 3. Setup for the sensory descriptive analysis to profile wines vinified with untreated and PEF-treated grapes

aftertaste. Sensory descriptive analysis used a 10-person trained panel and involved a total of 24 h training using product and sensory attribute references. In addition to the red wine trial, the effect of PEF treatment on Sauvignon Blanc is currently being investigated for the first time.

Deep-fried potatoes

In the deep-fried potato industry, PEF is applied after the sorting, washing and peeling step immediately prior to cutting. The delivery of short electric pulses through the uncut (whole) potatoes during PEF processing alters the potato's microstructure, which results in a more controlled release of sugar, a more uniform brown colour formation and less oil absorption during frying (Figure 4). It also improves processing efficiency as the softer texture makes the potatoes more flexible and easier to cut which increases the durability of the cutting knifes, results in fewer broken chips leading to less waste, and creates an opportunity to develop new cut shapes. Factors such as potato

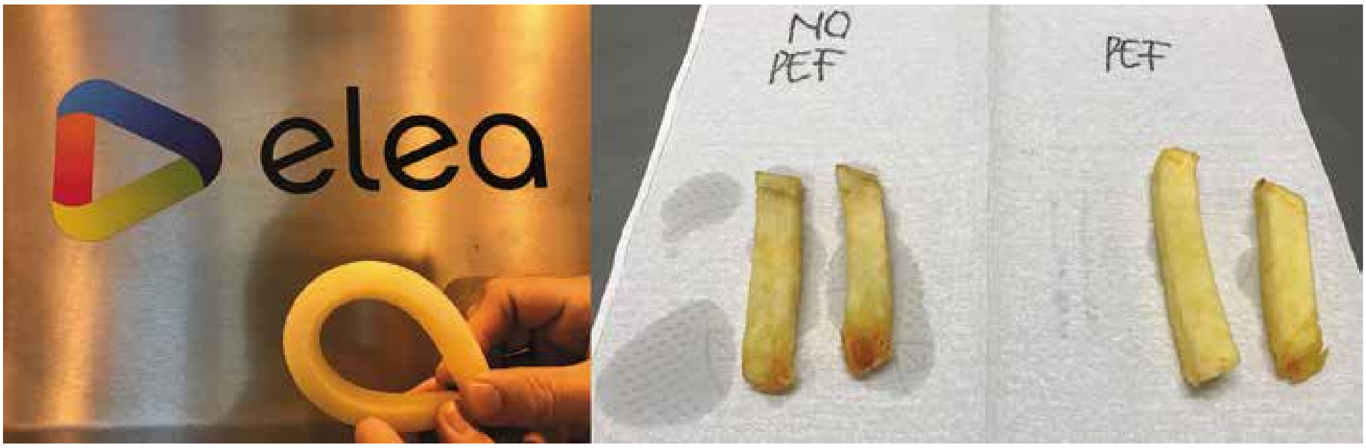

Figure 4. A PEF treatment on potatoes led to the production of French fries with flexible structure (left) and a reduction of oil uptake (right)

cultivar and the impact of starch to sugar conversion during the storage of potatoes prior to processing need to be considered. We are currently carrying out a three-month industrial scale trial with a large New Zealand based French fries producer, which is supported by Potatoes New Zealand and Elea (Germany, PEF unit provider).

Future perspective

The use of PEF technology for French fries production is promising and the research will be pursued on other popular deep-fried potato products in New Zealand, e.g. potato crisps. Another wine trial is also planned to be conducted in the next harvest season using a large transportable PEF machine to undertake industry trials on different grapes and growing conditions at vineyards throughout New Zealand.

Team

Otago research team members: Indrawati Oey, Pat Silcock, Phil Bremer, Sze Ying Leong, David Burritt, Graham Eyres, Biniam Kebede, Stephanie Then, Nerida Downes, Ian Ross, Zhihao Hu. Students: Mylene Arcena and Jessica Schueller (MSc students).

In collaboration with Mohammed Farid (University of Auckland), Samantha Baldwin (Plant and Food Research), Elea (Germany) and Karlsruhe Institute of Technology (Germany).

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FIET Food Industry Enabling Technologies

Food Industry Enabling Technologies (FIET) is funded by the Ministry for Business, Innovation and Employment and its purpose is to support new process developments that have the potential to add significant value to our national economy. The programme has six partners, Massey University (the host), Riddet Institute, University of Auckland, University of Otago, Plant and Food and AgResearch. Funding is $18m over six years (2015-2021) and targets pre-commercialisation activities. If you are interested in more information, then please contact either Ross Holland (R.Holland1@massey.ac.nz) or Professor Richard Archer, Chief Technologist, (R.H.Archer@massey.ac.nz).