Pioneering with pulsed electric field

Number of PEF food applications are growing

Pulsed electric field (PEF) technology has shown that it is more than just a promising, novel food processing method. In the last few years the technology has definitely found its way to the food manufacturing market. However, implementation is not as straightforward as conventional processing techniques.

Thousands of liters of fresh fruit juices have been treated by the hour with pulsed electric fields (PEF) at the Hoogesteger facility in Zwanenburg, the Netherlands, since 2012. With processing temperatures set below 50 degrees Celsius, PEF treated juices look and taste like fresh juice and retain their nutritional value whereas the imposed field strength of 15-20 kV/cm effectively kills spoilage organisms and pathogens present in the raw materials through the electroporation of their cell membranes. As PEF does not inactivate most enzymes, the treated juices still have to be refrigerated. Nevertheless, PEF treatment extends refrigerated shelf life from 6-7 days fresh juice to 21 days, and this has enabled Hoogesteger to increase its market share in the Netherlands as well as in Europe. "The excellent product quality and increased export possibilities are benefits that far outweigh the investment, imple-

This prototype of the Nutri-Pulse e-Cooker has three compartments.

PEF pilot plant of Wageningen UR Food & Biobased Research.

mentation and running costs," says Hoogesteger's manager of operations, Frank Janssen. Even though the targeted production capacity has not yet been reached, as a result of which the production costs are still relatively high, Hoogesteger is very positive about its investment in PEF technology. "We went for the best quality for our customers and chose the technology best suited to meet that goal. In this we succeeded," Janssen says. "In late 2013 we doubled our capacity by installing a second pulse generator. To further cut production costs, we have been applying lean production principles."

Market introductions

In addition to Hoogesteger, the Dutch fresh juice producer Fruity Line has recently implemented PEF technology in its facility in Ochten. While Hoogesteger bought its PEF equipment from Elea, a spin-off of the German Institute of Food Technologies (DIL), Fruity Line works with the PureePulse technology of the Dutch PEF specialist Cool Wave Processing, a subsidiary of the technology and product development company TOP specializing in PEF for mild preservation.

In addition to the abovementioned juice producers, other Dutch food manufacturers are also investing in pulsed electric field technology. "We have installed several PEF units in the Netherlands since 2011," says Elea's business development manager, Jan Kasten. These installations include machines for shelf life extension of fresh juices, such as used by Hoogesteger, as well as installations for potato and sugar beet treatment which have resulted in process, product and yield improvement.

Raw material treatment

PEF processing promotes cell disintegration in raw materials which in turn enhances all kinds of processes particularly mass transport processes such as extraction, drying and marinating but also cutting and peeling. Senior scientist Ariette Matser from Wageningen UR Food & Biobased Research expects that the use of PEF for extraction processes will increase in the coming years. Though, the exact advantages of various raw materials in comparison with conventional techniques still have to be assessed. According to Mark de Boevere of the Dutch PEF equipment manufacturer Pulsemaster, "PEF treatment of potatoes has many advantages." Electroporation of potato cells softens the raw material which improves cut quality, reduces French fry breakage and frying times and reduces fat uptake. Water and energy consumption are reduced as well. "PEF systems are an excellent alternative for traditional preheaters in potato processing," says De Boevere.

De Boevere's company Pulsemaster supplies a range of industrial-scale PEF equipment under the brand name Conditioner, for both raw material treatment and mild food preservation. "For example, we offer 80 kW systems that can handle 50 tons of potato per hour but also smaller installations. Depending on the potato variety, appropriate field strengths range from 0.8 to 3.0 kV/cm and expected costs are 1 euro per ton."

One of the key players in the Dutch agri-food sector, Royal Cosun has worked closely with AVEBE, provider of starch based ingredients, on a feasability study on PEF by the Carbohydrate Competence Center (CCC). According to AVEBE's chief technology officer Marco Giuseppin: "PEF has proven to be a very promising technique for the French fry industry. However, the technology is not yet sufficiently developed to become a technical alternative for our conventional extraction techniques."

'PEF has proven to be a very promising technique for the French fry industry'

**** What is PEF?***

PEF fuses a high voltage electric pulse to perforate the cell wall of raw materials. This breakdown of the cell's barrier function enables the structure of the material to be modified or micro-organisms to be killed.

A chef demonstrates how the e-Cooker works.

Pulsemaster supplies a range of industrial-scale PEF equipment

Dairy applications

Wageningen UR Food & Biobased Research is currently measuring inactivation kinetics of micro-organisms in food matrices, other than fruit juice, particularly in milk and dairy products. The dairy segment also has the attention of Cool Wave Processing's technology and product development partner TOP. TOP wants to bring PEF treated milk as 'raw milk' to the consumer. The company has formed a consortium with dairy farmers and retailers to accomplish this.

An important obstacle for PEF treated milk in supermarkets is, however, the strict Dutch food safety legislation for dairy products which demands certain minimum treatment temperatures to ensure food safety. As PEF is mostly a non-thermal process

Challenges of Pulsed Electric Fields

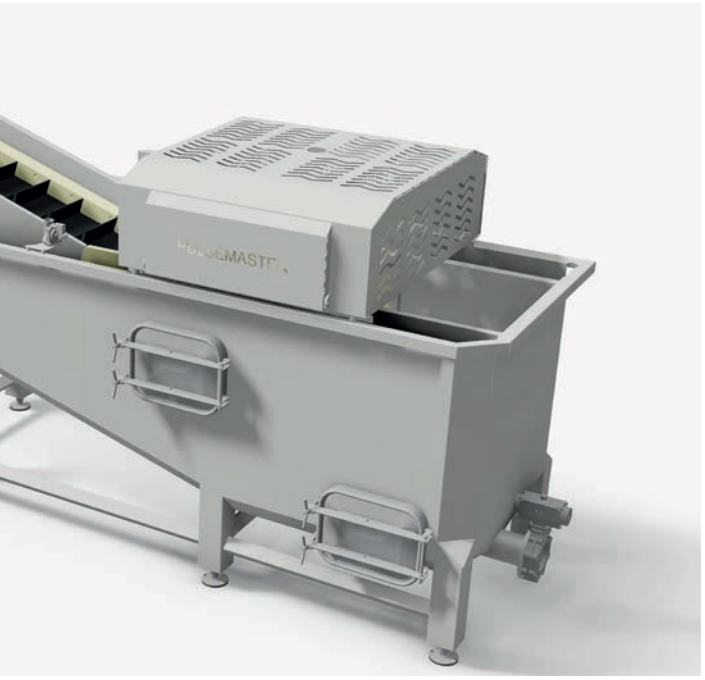
PEF for raw material treatment requires significantly less field strengths than PEF for mild preservation of liquids, allowing much higher treatment capacities. More-over, raw material treatment is not a critical step for food safety. At the moment, the treatment capacity difference between (single) systems for raw material treatment versus systems for mild preservation is roughly tenfold: 5,000 l/h for microbial inactivation versus 50,000 kg/h for raw material treatment. The differences in cost are in the same order of magnitude.

In practice, achieving capacities of 5,000-10,000 liters an hour for mild preservation is still a major challenge. "I am curious whether this problem will be solved in the next few years," says Ariette Matser, from Wageningen UR Food & Biobased Research. She was former coordinator of the EU-funded project NovelQ on novel food processing methods such as PEF. Wageningen UR Food & Biobsed has worked closely with Hoogesteger on PEF applications. Matser points out that the extremely high field strengths and the ultrashort microsecond pulses are difficult to achieve reliably in high capacity systems. Single semiconductor pulse switches are not yet available for these voltages; to reach the proper voltage these switches must be connected in series; making high capacity systems more complex.

"But why would you try to scale up production to larger volumes with a single unit?" asks researcher Bart Roodenburg from the Delft University of Technology. "From a scientific and a technological point of view there is no reason for building high capacity systems with only one treatment chamber."

By splitting the treatment chamber into several parallel chambers the total power rating for the system can be reduced for a given total flow rate.

In addition to capacity limits, PEF preservation faces other challenges, as it is a critical process step requiring considerable operator skills and knowledge. Furthermore thorough knowledge of inactivation kinetics of relevant food spoilage organisms as well as food pathogens is needed to ensure food safety of PEF treated products. The NovelQ project has provided an important breakthrough by demonstrating the microbial safety of PEF treated fresh juices. "For the type of PEF systems used at Hoogesteger this safety data is now available," says Matser. "But for various other PEF systems and products, product safety still needs to be assessed."*



Potato interlaced with PEF treatment

– the PurePulse system aims for temperatures below 40 degrees Celsius. Legislation would have to be changed. "We are trying to get dispensation from the Netherlands Food and Consumer Product Safety Authority," says TOP's creative director Dennis Favier, "but much testing and validating is needed to build up the required food safety dossier."

According to Favier, low treatment temperatures and high inactivation rates are typical features of Cool Wave's PurePulse technology. Since 2008 technology partner TOP has put a lot of effort in treatment chamber design to get optimal flow patterns for inactivation at relatively low temperatures. For mild preservation purposes, temperatures below 50 degrees Celsius are desirable, in order to fully achieve the benefits of PEF, namely, preserving freshness, color, taste and nutritional value. Cool Wave offers capacities of 3000 l/h and has a pilot facility of 300 l/h.

High speed cooking

Pulsed electric fields can also be used for high speed cooking such as in the e-Cooker invented by IXL Netherlands. According to IXL's innovation director Hans Roelofs, the Nutri-Pulse e-Cooker is now almost ready to be launched on the market for both restaurant and home use, following five years of research, testing and prototype development. In contrast to mild preservation, e-Cooking does require heat development within the treated food products, called ohmic heating. At the same time electroporation of cell membranes facilitates and speeds up the cooking process. Compared to traditional cooking, baking and frying, e-Cooking temperatures are relatively low (below 100 degrees Celsius), improving taste, texture, tenderness, juiciness and nutritional value. Within seconds to a few minutes, foods such as meat and fish can be prepared. "The technique of e-Cooking also holds promise for industrial applications but this is still uncharted territory," says scientist Ariette Matser. As a first step, Wageningen UR Food & Biobased Research is now working with IXL in a public-private partnership on applying e-Cooking technologies for mild preservation. Last year the cooking device won a Global Food Industry Award.

> *'Food manufacturers currently investing in PEF technology may still be considered pioneers'*

One of the frontrunners

Home to several food manufacturers using PEF technology, two industrial-scale PEF equipment suppliers, a company that has invented a unique e-Cooking device and a renowned applied research institute generating knowledge on PEF, the Netherlands is one of the frontrunners in pulsed electric field innovations. Despite the growing practical experience with PEF application, food manufacturers currently investing in PEF technology may still be considered pioneers. "It is a high risk investment," says Favier. "Food manufacturers using PEF may be confronted with more production line disruptions or early replacement of certain machine parts. On the other hand, if a company decides not to invest in PEF at this early stage, competitors might take the lead and gain market share. This is the choice manufacturers have to make but first of all they have to be convinced of the opportunities PEF is offering them."

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