Ref. Ares(2015)4649712 - 28/10/2015

European Commission

Business Innovation Observatory

Sustainable, Safe and Nutritious Food

Food processing technologies

Case study 53

Internal Market, Industry, Entrepreneurship and SMEs

Sustainable, Safe and Nutritious Food

Food processing technologies

Business Innovation Observatory
Contract No 190/PP/ENT/CIP/12/C/N03C01

Authors: Laurent Probst, Laurent Frideres, Bertrand Pedersen & Federica Amato, PwC Luxembourg.

Coordination: Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Directorate F "Innovation and Advanced Manufacturing", Unit F1 "Innovation policy and Investment for Growth".

European Union, September 2015.

Table of Contents

1. Executive summary

The competitiveness of the European food industry is being challenged by the increasing competition from emerging markets, low R&D expenditure and little innovation in products and processes. Novel food processing technologies are thus required to boost manufacturing efficiency and contribute to food security.

Food processing entails a series of steps (unit operations) that turn raw ingredients into products fit for human consumption. The efficiency and sustainability of these steps can be improved by two broad sets of innovative technologies, namely non-thermal pasteurisation and nano/micro technologies. The former include high-pressure processing (HPP), microwave volumetric heating (MVH) and pulsed electric field (PEF). Because these do not involve significant heating, they extend the shelf life of foods without altering their nutritional benefits and taste. The latter include a particular type of membranes known as microsieves, used for diverse applications including fractionation/filtration of various liquids, the formation of emulsions and microencapsulation of ingredients.

The economic potential of trend is very promising. The number of HPP industrial installations is predicted to rise to over 350 by the end of 2015, reaching a market value of EUR 0.53 billion by 2018. Consumer demand for HPP-processed food products will also increase, resulting in a global HPP food market size of EUR 10.5 billion by 2018. The global fruit juice industry is valued at EUR 120 billion by 2018, whereas the global dairy processing equipment market is expected to reach EUR 9.2 billion by 2019. Namely, pasteurising equipment is estimated to provide a EUR 720 million market potential for MVH and PEF. The global food encapsulation technology market is predicted to be worth EUR 23 billion by 2018, with microencapsulation and nanoencapsulation being projected to reach EUR 7.7 billion by 2020 and EUR 6.2 billion by 2018, respectively.

Novel food processing technologies also have important socio-environmental repercussions. From an environmental standpoint, their integration in the food value chain entails substantial water and energy savings, as well as a more efficient use of packaging material. Most importantly, the extended shelf life of the processed products allows a significant reduction of food waste, thus contributing to environmental protection. From a public health perspective, the overall improvement of both the quality and nutritional value of processed food products can alleviate the burden of obesity.

The uptake of the trend is driven by two main factors. Firstly, the increased consumer demand for healthy food with the same nutritional benefits as the unprocessed counterpart. Namely, the demand for fresh juices as a result of the "cleanse craze" (i.e. an excessive consumer excitement about the detoxifying effects of fresh juices) has been identified as a major driver for non-thermal pasteurisation. Secondly, national initiatives launched within the context of the EU Salt Reduction Framework have supported the adoption of novel preservation and microencapsulation techniques.

However, the widespread integration of innovative processing technologies is held back by several obstacles. The fragmentation of the EU food industry, particularly with regard to the high number of SMEs and the heterogeneity of tastes and recipes across different countries, was identified as a main difficulty. Furthermore, the limited understanding of how to successfully turn research ideas into commercially viable solutions has resulted in customer and investor mistrust about innovative technologies.

To overcome these issues, various measures could be adopted at the EU level. Firstly, the EU food market could be harmonised across Member States from a product and process perspective, by enforcing more stringent regulations as to the salt and fat content of processed foods. Secondly, initiatives and subsidies should be implemented to actively encourage knowledge transfer from the university level to the commercial scale. Thirdly, better initial support should be given to innovative food technology start-ups, in the form of technical and commercial advice and financial incentives.

2. Food processing technologies

The present case study is one of the three that make up the trend "Sustainable, Safe and Nutritious Food", which addresses the latest developments across the food industry. In particular, this case study focuses on the processing step of the food value chain, exploring emerging technologies that have the potential to transform the food processing industry.

2.1. Trend presentation

The development and adoption of new food processing technologies is a crucial factor for boosting the competitiveness of the European food and drink sector. The globalisation of markets has resulted in increased competition from Asia and South America, whose market share is growing due to their generally lower costs, thus leading to a decline in Europe's food exports. Furthermore, compared to other industries, innovation in the food industry is sluggish, still relying on traditional products and processes. In fact, research and development expenditures only accounted for between 1% and 2% of its net sales in 2014, classifying it as a medium-low intensity R&D sector[1]. These intrinsic industry-specific weaknesses, coupled with broader socio-environmental factors such as the staggering projected increase in the world's population and resource scarcity, constitute a serious threat to food security.

Food processing entails the transformation of raw ingredients into products fit for human consumption, in order to improve their digestibility, nutrient uptake, energy content, taste, appearance and safety, among others. The main steps involved are known as unit operations, and consist of pre-treatment and separation, conversion, structure formation, stabilisation and packaging, as shown in Figure 1 (on page 4). Within this context, the introduction of innovative technologies will result in more efficient manufacturing and better food products.

The present case study focuses on two broad categories of novel processing techniques, namely non-thermal pasteurisation and nano/micro technologies. Non-thermal pasteurisation intervenes at the stabilisation stage, whereas nano/micro technologies can be used for both separation and structure formation.

Non-thermal pasteurisation technologies include high pressure processing (HPP), advanced heating techniques such as Microwave Volumetric Heating (MVH), and pulsed electric field (PEF). Traditional preservation technologies use heat to enhance the shelf life of foods, but this can often affect the taste, texture and nutrient integrity of the product.

On the contrary, because mild non-thermal pasteurisation does not involve significant heating, the sensory and nutritional quality of the processed product is comparable to that of the unprocessed counterpart, thus allowing the preservation of its 'fresh-like' taste whilst successfully destroying bacteria and other microorganisms.

Pasteurisation through HPP is achieved by subjecting food to pressures ranging between 150 and 600 megapascal (MPa) at room temperature for a certain time, usually less than 5 minutes. HPP treatment is suitable for a variety of products, from juices and beverages to vegetables and meat. It is important to notice that the high pressure is applied to already packaged products. Hence, when processing involves HPP, the packaging unit operation takes place immediately after the conversion step, before structure formation and stabilisation (Figure 2 on page 4).

MVH uses electromagnetic energy to rapidly and homogeneously heat food. Although not strictly a non-thermal technique, microwave heating does not damage the quality of the product compared to conventional heat pasteurisation, due to the speed of the treatment process. Unlike HPP, microwave processing is carried out prior to packaging).

In PEF pasteurisation, food is pumped between a pair of electrodes and subjected to a pulsed high voltage field for less than a second. This technique is suitable for homogeneous products with low salt content, such as juices, liquid dairy products, beer and wine.

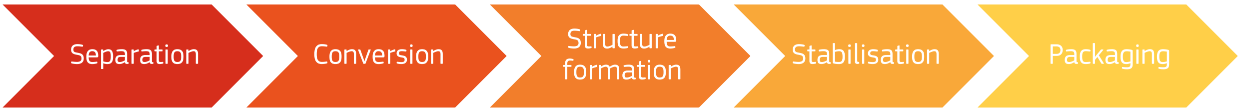
Nano/micro technologies are deemed to be a key breakthrough in the food industry, having a promising role in both advanced food processing and in the development of nano/microencapsulation systems that can carry, protect and deliver food ingredients. The most promising are microfluidic techniques, which process or manipulate small volumes of fluids using features (channels, structures, and microdevices) of micrometric dimensions. These technologies include particular types of membranes known as microsieves, which can be used for a broad variety of processing applications, including fractionation/filtration and emulsification.

Microsieve fractionation and filtration consist in the separation of microparticles in certain foods such as milk, which are made of suspended proteins, fat droplets and bacteria. Through this process, protein components such as casein can be separated and recovered for other uses, and the number of bacteria in the food reduced.

Microsieves are also useful for the formation of high quality stable emulsions, in a process known as membrane emulsification. Emulsions are dispersions of liquid droplets into another liquid, where the two are immiscible. They are an important component of foods such as dressings (mayonnaise, vinaigrette, sauces), artificial milks, margarine and low-fat spreads. Membrane emulsification relies on low pressure to force the liquid to be dispersed (dispersed phase) through a membrane (the microsieve with very small pores) into the other liquid (continuous phase), and is more energy-efficient compared to conventional emulsification techniques. Membrane emulsification is the pre-step for microencapsulation, whereby the emulsion droplets can encapsulate flavours and nutrients such as omega-3, menthol and vitamins, covering their less desirable attributes (e.g. the bad taste of omega-3 fish oil) and protecting the ingredients from oxidation and degradation during ingestion.

The physical and chemical processes on which these technologies are based have been known for some time. However, they are only recently being turned into practical commercial applications for the food industry. Pioneering companies responsible for these advances are presented below.

Figure 1: Sequence of unit operations in conventional food processing



Source: PwC Analysis

Figure 2: In food processing using HPP technology, packaging precedes structure formation and stabilisation

Source: PwC Analysis

2.2. Overview of the companies

Table 1: Overview of the company cases referred to in this case study

Company	Location	Business innovation	Signals of success
Hiperbaric	Spain	Hiperbaric is the leading manufacturer of High Pessure Processing (HPP) machinery	- First company to take the HPP technology from the research level to the industrial level - In 2004, it obtains the "ASME VIII Division 3 Certification" for manufacturing HPP equipment in North America - Installations in Europe, North and South America, Oceania and Asia - Winner of the 2006 "FEMEBUR AWARD" - In 2008, awarded the "IFT INNOVATION AWARD" for the development of the world´s biggest and most productive HPP machine: Hiperbaric 420
Advanced Microwave Technologies (AMT)	United Kingdom (Scotland)	AMT develops and commercialises equipment for the delivery of microwaves through Microwave Volumetric Heating (MVH)	- In 2012, winner of the 'Interface Excellence Awards' for 'Innovation of the year' and 'Sustained Partnerhsip' - Represented in Europe (France, Germany, Benelux and Denmark) by its distributor DymoWave - Extensive participation in international conferences and events
Elea	Germany	Elea manufactures and markets Pulsed Electric Field (PEF) technology for the food and beverage sectors	- First company to take the PEF technology from the laboratory to the industrial level - Numerous industry partners, including the German Institute of Food technologies - Numerous research partners across Europe, North America, Asia and Africa
Aquamarijn	The Netherlands	Aquamarijn develops innovative micro and nano technologies for a variety of applications and industries	- In 2004, Small Times finalist 'Innovator of the year' - Extensive press coverage in trade magazines and publications - Pioneers in microsieves development
Pervatech	The Netherlands	Pervatech develops cutting-edge membranes for the separation of water and small organic substances from larger ones	- In 2015, partnership with Philips Ceramics for membrane development - Sales in over 40 countries across Europe, Brazil, China, India and North America - Ongoing negotiations with over 80 countries

Problem 1 – Food scares in the developed world calls for the need to innovate food preservation to guarantee an advanced level of consumer protection.

Innovative solution 1 – Hiperbaric was founded in 1999 in Spain, to address a Listeria food contamination crisis at the end of the 1990's. This event pushed the company to develop a new food processing technology based on High Pressure Processing, which was then only know at the laboratory level. Hiperbaric was therefore the first company to adapt HPP to the requirements of the food industry.

The company manufactures a broad range of HPP machines, varying in size so as to suit both smaller and larger customers. The size of the vessel starts from 55 litres (for the Hiperbaric 55 machine), up to a capacity of 525 litres with a throughput of over 3,000kg of product per hour. HPP allows the effective destruction of pathogens, whilst keeping key nutrients intact.

HPP can be used to treat a wide range of substrates, from fruit juices to meat and dairy products. The effectiveness of this technology has resulted in the installation of over 100 Hiperbaric machines across 25 countries worldwide. The company plans to quadruple its turnover within the next 4 years and employ up to 200 people.

Hiperbaric 55 High Pressure Processing machine: with its 55 litre vessel, it is suitable for small food producers

Source: Hiperbaric[2]

The bacteria Listeria untreated (left) and treated with HPP (right)

Source: Hiperbaric[3]

Problem 2 – Conventional thermal processing of food relies on conduction and convection to transfer the heat from hot surfaces to the product. However, this method does not treat the food uniformly, also damaging it through direct contact with the heated walls of the vessel.

Innovative solution 2 – AMT was established in 2007 in Scotland, with the aim of commercialising Microwave Volumetric Heating (MVH), an innovative process to deliver microwaves deeply and uniformly into the entire volume of the material.

At the heart of AMT's MVH equipment is a treatment chamber made of a range of microwave transparent materials, through which food is pumped and treated. The energy is continuously delivered through small microwave sources (magnetrons), whose number, size and spacing can be adjusted so as to create a variety of energy conditions. The microwaves can penetrate to a depth of 42 millimetres, compared to the 3-4 millimetres of standard microwave systems.

MVH treatment allows the processing of food without fouling, burning or affecting the flavour and nutritional benefits of the substrate. Furthermore, it efficiently kills bacterial spores at lower temperatures compared to conventional thermal methods. Furthermore, the absence of hot surfaces in the system enables the processing of difficult liquids such as honey and syrups, preventing them from sticking to the walls of the treatment chamber.

AMT's MVH machine

Source: AMT[4]

AMT is the winner of two Interface Excellence Awards

Source: AMT[5]

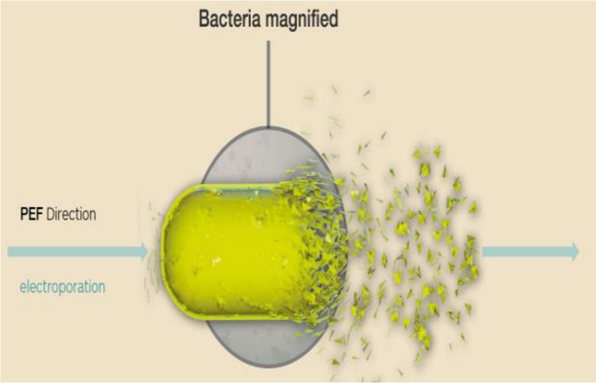
Problem 3 – Consumer health and sustainability awareness is pushing for alternative pasteurisation methods, which are able to extend food shelf life, while at the same time preserving the integrity of nutrients.

Innovative solution 3 – Elea was established in 2012 in Germany as a spin-off of the German Institute of Food technologies, with the aim of developing, manufacturing and commercialising PEF equipment. It was the first company to successfully bring the PEF technology from the laboratory to the industrial level.

PEF destroys pathogens by making their membranes permeable, a process known as electroporation. Exposure of the microorganism to a pulsed electric field punctures its membrane and killing the pathogen. This ensures the targeted and effective inactivation of bacteria, thus achieving pasteurisation of food products.

PEF achieves a significant increase in shelf life (up to 240%), as well as greater yields, energy savings and lower operational costs. In addition, since the process does not involve significant heating, pigments, vitamins and antioxidants are not damaged, and the food retains its sensorial and functional value.

Electroporation of a bacterial cell through PEF



Source: Elea[6]

Elea's logo

Source: Elea[7]

Problem 4 – Traditional techniques for the fractionation, filtration and emulsification of liquid foods are often very prone to fouling and not suitable for scaling up.

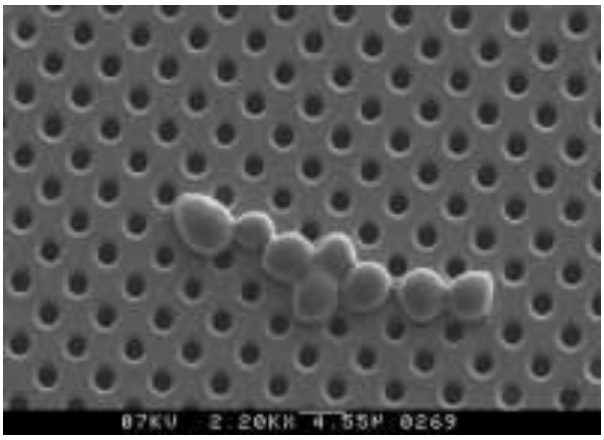
Innovative solution 4 – Aquamarijn is a nano and micro engineering company, founded with the aim of developing innovative and performant membranes for a variety of applications, including microfiltration and emulsification.

Aquamarijn engineered a novel microfiltration membrane, the microsieve®, characterised by many well defined pores of controllable size and geometry. Contrary to traditional membranes, the microsieve does not suffer from fouling. In fact, the company developed a technology to continuously clean it during filtration, by breaking up the cake layer on the membrane. This results in a longer filtration cycle with lower power consumption, without requiring the use of cleaning chemicals.

Microsieves can therefore achieve process fluxes that are 50 to 100 times higher. In addition, a 1 to 10 million-fold reduction in the number of bacteria in liquids filtrated through microsieves can be achieved, compared to only a standard 1,000-fold decrease with conventional methods. This makes microsieves ideal for sterile microfiltration of dairy products like skimmed and fat milk, as well as clarification of beer.

Furthermore, microsieves enable the formation of droplets of the same size, making the resulting emulsion more stable. This is allows for cost-effective scaling up of emulsions and their application at the industrial level.

The microsieve's well-defined pores allow accurate separation of particles at the micrometric scale



Source: Aquamarijn[8]

Aquamarijn is the Small Time "Innovator of the year" finalist

Source: Aquamarijn[9]

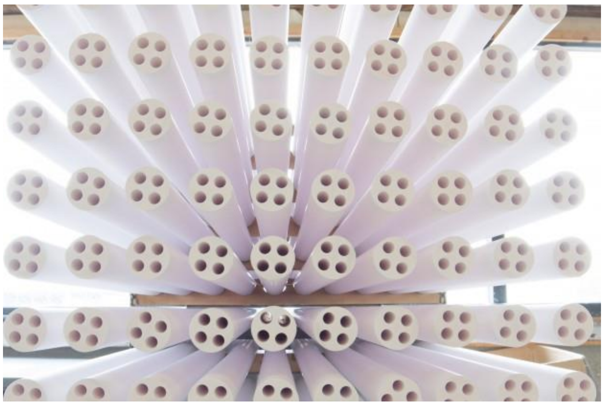
Problem 5 – Conventional technologies for the separation of organic components are often associated with low yields, high energy consumption, waste streams and suboptimal efficiency.

Innovative solution 5 – Pervatech is a nanotechnology high-tech company that develops, produces and commercialises ceramic membranes for the separation of water and small organic molecules from mixtures of organic substances, and for the dehydration of organic solvents like alcohols.

Separation is achieved through pervaporation. In this process, the substrate to be separated is first heated and then brought into contact with the pervaporation membrane. The component with the best permeability passes through the membrane and is removed in the form of vapour. The continuous removal of the vapour creates a difference in concentration on the two sides of the membrane, and this gradient acts as a driving force for the process.

Pervaporation membranes allow to obtain important energy savings (between 25% and 75%), higher efficiency and higher quality final products. They can be used in a variety of industries. In food applications, Pervatech's membranes are involved in the recovery of unwanted alcohols such as ethylic alcohol from wines and beer, as well as in juice and alcohol production. Furthermore, their hydrophobic character repels water and allows the efficient recovery of esters, the compounds that are responsible for aromas in many foods. This process thus enables the effective recovery and concentration of aromas.

Pervatech's ceramic pervaporation membranes



Source: Pervatech[10]

Pervatech is widely used in the food industry

Source: Pervatech[11]

3. Impact of the trend

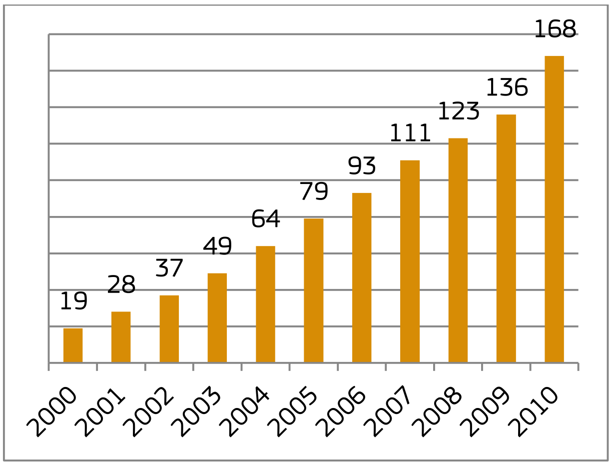
The food and drink industry is Europe's largest manufacturing sector in terms of turnover (over EUR 1 trillion in 2012, representing 14.6% of the total EU manufacturing turnover) and employment (4.25 million people employed in 2012, accounting for 15.5% of employment in the EU manufacturing sector)[12].

Furthermore, despite the economic crisis, it remains stable, non-cyclical and robust, with increasing sales of processed foods both in high-income and in more developing countries. However, it is lagging behind in terms of innovation and R&D compared to other manufacturing sectors. The potential of novel food processing technologies is discussed below, both from a market perspective and a social standpoint.

3.1. The market potential of the trend

The market for HPP technology is expected to experience a remarkable growth over the next years, both in terms of HPP equipment and HPP-treated products. The number of HPP machines installed worldwide at the beginning of 2011 was 168 (Figure 3), with North America leading the way with 88 machines, and Europe following with 44. This represents almost an 89% increase from 2000, when only 19 HPP processors were commercialised globally[13].

Figure 3: Number of HPP machines installed worldwide



Source: adapted from R. Sharma[14]

According to recent studies, the total number of HPP industrial installations will be in excess of 350 by the end of 2015, with a market value of EUR 0.29 billion[15]. By 2018, this is predicted to reach EUR 0.53 billion[16], with 56% of installations in North America and 24% in Europe[17]. Consumer demand for HPP-processed food products that have natural attributes has also increased. This is particularly true for meats and fresh juices, resulting in a global HPP food market size of EUR 8.6 billion in 2015[18]. This is forecasted to hit EUR 10.5 billion by 2018, with North America representing the strongest market[19].

PEF and advanced heating technologies such as MVH have particular potential in the fruit juices/smoothies and liquid dairy subsectors. The global juice industry experienced a 2% yearly growth between 2006 and 2010, reaching a value of EUR 74 billion in 2010. This is predicted to exceed EUR 81 billion by 2015 (EUR 35 billion in Europe alone) and EUR 120 billion by the end of 2018[20], with 100% fruit juice representing the leading market segment. The market potential for MVH and PEF is closely linked to that of HPP, since these technologies address some of the same subsectors.

However, since MVH is not suitable for the processing of solid foods, its addressable market is estimated to be about half of that of HPP, approximately equal to EUR 0.27 billion[21]. As for the dairy drink sector, the global market for dairy processing equipment is expected to grow at 5.3% annual rate between 2014 and 2019, reaching EUR 9.2 billion by 2019. Namely, pasteurising equipment is estimated to account for 8% of this value, thus providing a EUR 720 million market potential for MVH and PEF[22]. Currently, there are about 70 PEF machines installed globally, but their number will increase rapidly as a result of the market opportunities[23].

The change in consumer trends, namely increased health awareness, are also the driving force behind the increased demand for functional and fortified foods, which in turns boosts the food encapsulation market. In fact, the global food encapsulation technology market is predicted to experience a 6.2% annual growth between 2013 and 2018, reaching EUR 23 billion by 2018[24]. In particular, micro and nanoencapsulation will be leading the encapsulation market, since they allow to more effectively control the release of ingredients in the food matrix and protect active ingredients. While microencapsulation technologies have been widely used in areas such as the pharmaceutical sector for many years, their application has only recently been extended to the food industry. Indeed, the global microencapsulation market is projected to reach EUR 7.7 billion by 2020, according to a recent study[25], with food applications gaining increased market share. Furthermore, the market for nanoencapsulated food ingredients and additives is also booming, valued at EUR 6.2 billion by 2018. The North-American market is currently dominant, whilst the European one is expected to be the fastest-growing, with a projected annual growth rate of 8.3%[26].

3.2. The social potential of the trend

The adoption of novel food processing technologies entails clear social benefits, ranging from sustainability and environmental protection, to the relief of certain health burdens as a result of improved nutrition.

The technologies explored in this case study can significantly improve the sustainability of the food industry across several areas.

Firstly, they will reduce energy and water consumption, both during product processing and storage. In fact, non-thermal pasteurisation can be carried out without significant heating at much lower temperatures compared to traditional pasteurisation procedures, which are estimated to account for about 29% of the total energy consumption in the food industry. Studies have shown that PEF pasteurization results in 100% savings in natural gas savings, since thermal processing is avoided. Electricity savings can also be up to 20%, compared to the electricity consumption of conventional heat pasteurisation. This is estimated to potentially create in annual savings of 791–1,055 terajoules of fossil fuel-equivalents, thus contributing to the reduction of CO_2 emissions[27]. Similarly, HPP processing allows an energy recovery rate of up to 50%, corresponding to a 20% reduction

in total energy requirements[28]. Furthermore, the low temperatures associated with non-thermal pasteurisation reduce the need for cooling systems, which are usually responsible for 50% of the total energy usage in food processing. Because of the high quality of non-thermal treatment, storage of processed foods under chilled or frozen environments may no longer be required to the same extent, being instead replaced with ambient conditions and reducing the energy and water impact.

Secondly, novel processing technologies enable a more efficient use of packaging material and decrease the need for repacking. As previously mentioned, processing through HPP and microwave heating takes place after the product has been packaged. Therefore, re-packing is not necessary, cutting down on the volume of packaging and greatly reducing the risk of food recontamination. Studies have shown that the environmental impact of products is strongly influenced by the type of packaging and materials. Namely, the plastic wrappings used for high pressure processing are preferable from an environmental perspective, since they are light in composition and therefore decrease the impact of transport on the overall sustainability of the product.

Thirdly, novel pasteurisation techniques play a crucial role in the reduction of food waste, which is currently a major environmental burden in the developed world. In fact, it is estimated that about 100 million tonnes of food were disposed of in the EU in 2014, with per capita waste generation amounting to 95-115 kg per year[29]. Within this context, PEF processing has been proved to extend the shelf life of juices and other products by up to 240%, from 8-9 days to 3 weeks[30]. Similarly, MVH has been shown to achieve a 6-8 week shelf life for citrus and apple juices[31]. These results imply that fewer losses are incurred across the entire production chain and most importantly at the consumer level. In fact, about 40% of the total food wastage occurs at the retail and consumer level in developed economies, and extending product shelf life can contribute to solving this issue. A further consideration on environmental protection is related to the fact that novel pasteurisation and sterilisation technologies do not require the use of additional agents, thus resulting in the reduction of chemicals in the water effluents from food processing facilities.

Another significant impact of emerging food technologies is undeniably the overall improvement of the quality and nutritional value of processed food products, and the public health benefits that ensue. As previously mentioned, the beneficial properties of nutrients can be preserved and enhanced through nano/microencapsulation technologies, and the characteristics of vitamins and proteins maintained by mild pasteurisation. Moreover, membrane emulsification is emerging as an important player in the production of low-fat products such as spreads, cheese and chocolate. This is achieved by encapsulating a low-fat internal phase such as water in an oil emulsion (fat phase) surrounding it. This can allow to obtain low-fat cheese with up to 35% water content, whilst preserving the creamy consistence and taste.

These technological advances have considerable repercussions on certain public health issues, namely obesity. It is estimated that, in Europe alone, 52% of the population is obese or overweight, costing the EU healthcare system EUR 59 billion yearly. This represents 7% of the total health expenditure[32]. The widespread introduction of low-fat products as a result of technology developments can therefore contribute to alleviating this burden and generally help tackle the broad issue of food security in the EU and worldwide.

4. Drivers and obstacles

Innovation in food processing is driven by the general increase in demand for better and healthier products, as supported by initiatives at the national level. However, the heterogeneity of the European food market, as well as some legislative hindrances and overall lack of trust, are slowing down the commercialisation and widespread adoption of novel technologies, as discussed below.

4.1. Consumer demand for fresh and healthy food - the "cleanse craze"

A main driver behind the uptake of non-thermal pasteurisation and microencapsulation is the current increase in customer demand for products that retain the same "freshness" and nutritional benefits the day they are consumed as the day they were packaged.

In particular, all the showcased companies confirmed that the marketing hype around the premium juice sector, a phenomenon referred to as the "cleanse craze", constitutes a major boost to the adoption of their novel processing technologies (Figure 4). These non-conventional juices (namely vegetable or mixed juices) are currently being marketed as a therapeutic way to detox and "cleanse" the body from toxins. Consequently, the demand for juices that have been minimally processed is soaring. Hiperbaric reported that many of its HPP machines are being sold specifically for this application.

"Consumers are willing to pay USD 8-9 for a bottle of HPP juice...Incredible!"– ***Hiperbaric***

Similarly, AMT explained that consumer preferences are increasingly shifting away from conventional thermally pasteurised juices also because of their artificially-added fructose content. In fact, in all current vegetable juices other than fresh ones, the pH is modified to prevent the growth of bacterial spores. This is commonly achieved by adding lemon juice, which creates a more acidic environment. This increases the sugar content and may therefore offset the health benefits of juices. For the removal of lemon juice to be possible, new technologies to destroy spores are needed, and this represents a great opportunity for companies like Hiperbaric, Elea and AMT.

Figure 4: the demand for fresh juices is a driver for new technologies

Source: The Fix[33]

4.2. The EU 'Salt Reduction Framework'

European initiatives aimed at the reduction of salt content in foods were identified by the showcased companies as being an important driver for the commercialisation of their technologies.

As part of the European Commission's Strategy for Europe on Nutrition, Overweight and Obesity related Health Issues, a common EU Framework on Salt Reduction was created in 2008. The Framework sets a minimum target of 16% salt reduction over 4 years for all food products[34]. Member States participation is voluntary, giving them the flexibility to adopt different timelines and targets so as to tailor initiatives to the respective national context. As a result of the Framework, all Member States currently have salt reduction initiatives in place. Namely, the UK reported an average decrease of 0.5 grams per person, from 8.6 grams to 8.1 grams, during the implementation period[35].

*"The differences between the European and American markets are starting to narrow down, but Europe is still lagging behind" – **Hiperbaric***

Since salt plays a role in the preservation of foods, its reduction implies that alternatives are required, thus broadening the opportunities for novel technologies, as confirmed by Hiperbaric. For instance, food processed through AMT's MVH technique was found to acquire a saltier taste compared to the untreated product. This could have represented a hindrance for the uptake of MVH if the salt content of the unprocessed food had been too elevated, but salt reduction initiatives have contributed to averting this issue. Similarly, because high-salt foods are not suitable for PEF processing, such initiatives are beneficial to the diffusion of PEF, potentially expanding the range of possible substrates that can be treated.

Moreover, reduction of salt content generates the need to enhance the flavour of foods trough alternative means. This can further boost the adoption of microencapsulation, which allows the preservation and controlled release of flavouring agents.

4.3. Fragmentation of the EU food market and impact on innovation

One of the main obstacles identified by the showcased companies is the heterogeneity of the European food market, which creates an environment that is unconducive to innovation in food technologies.

The EU food and drink industry is highly fragmented, both in terms of number of players and consumer preferences. With the exception of a few multinationals, it consists predominantly of SMEs, which make up 99.1% of Europe's 287,000 food and drink companies[36]. These are active mainly at the national level and thus have only a relatively limited market reach. In addition, the cultural diversity of the Member States is reflected in their different culinary preferences and consumption patterns. Recipes and products are therefore adapted to the local market and tastes, thus further contributing to the heterogeneity of the industry.

This fragmentation has several implications for the development and commercialisation of new technologies. Firstly, obtaining the same market success across the various Member States can be challenging. Hiperbaric explained that better penetration was achieved in southern Europe (namely Spain, Italy, France and Greece) compared to countries like Germany. This was attributed to the difference in food spending as a result of the cultural importance of higher quality food in these countries.

Secondly, since the heterogeneity of the EU food industry leads to a slower growth of the market for novel food technologies, European companies shift their business focus to other markets, namely the North American. Hiperbaric confirmed that 70-80% of its sales are in the US, because the more homogeneous and global food industry allows a faster uptake of innovative food technologies. Indeed, the best-selling HPP machines in the US are the ones with a 525 litre capacity (costing about EUR 2.5 million), whereas European clients invest in smaller ones (55 litre capacity costing around EUR 500,000).

4.4. The 'Novel Foods Regulation' and food technologies

The Novel Foods Regulation was also reported as being an additional hindrance to innovation in the food sector. In particular, there is confusion as to how to develop new products under it, since it is not clear whether new food technologies and the products treated with them are classified as Novel Foods. In addition, the resources required for the assessment and evaluation of potential health issues related to food products are a further obstacle, especially for smaller companies.

In practical terms, the lack of a joint position as to the classification of new technologies across all Member States hampers their widespread commercialisation in Europe. For instance, in countries like Spain, products treated with HPP could be sold without major complications. However, their export and sale in France was subject to a series of legal and political procedures, which slowed down the business of companies like Hiperbaric. Currently, HPP no longer falls under the Novel Foods classification, which has alleviated the burden for the concerned companies. However, many years of opportunities have been missed in the meantime. In fact, Hiperbaric reported that many customers in countries like France have been lost until recently because of the confusion related to the Novel Foods regulation. Conversely, continuous support from the North American authorities, namely the Food and Drug Administration, further contributed to boosting the adoption of innovative technologies in the US compared to Europe.

4.5. Lack of understanding of commercial applications

Another obstacle identified by the showcased companies is related to the poor understanding of how novel processes can be turned into viable practical applications.

Some progress in this regard was achieved through the EU-funded NovelQ project, a consortium of 32 partners comprising large multinationals, SMEs and universities. Its aim was to solve some of the R&D issues that might hinder the integration of novel technologies in the food industry and provide practical guidelines for the transition between laboratory-scale research and industrial development.

However, the current rate of commercial success of new product developments in the food industry is only about 5 to 15%[37]. According to Elea, this is due to the lack of knowledge of many start-ups as to how the initial innovative idea can be transferred from the research level to the commercial scale. For this reason, the high rate of failures has brought about a general feeling of mistrust about innovation in the food sector.

This has two main implications for businesses trying to develop and bring to market new technologies. Firstly, recruiting skilled workforce is a great challenge, as confirmed by Elea. Experienced professionals lack the confidence in food technology start-ups and are not willing to take the leap. This creates a vicious cycle, since it is the people who convert ideas into concrete marketable solutions which can generate profit.

*"People are the greatest strength in a start-up. If we have no talented people, we cannot turn our ideas into money" – **Elea***

Secondly, larger food producers which could integrate emerging technologies into their value chain are often cautious, preferring instead to avert the risk and rely on traditional well-established processing techniques. Indeed, Aquamarijn confirmed that the market potential for its microsieves is enormous, but it is very difficult to fully exploit because customers prefer to invest in technologies that already have between 5 and 10 years of proven track record.

Similarly, Pervatech reported that, due to the novelty of their technology, there is still negligible competition from other similar companies in the market. This further contributes to the aversion of potential customers towards riskier investments in new technologies.

*"We are a small, new company, with no major competitors. But if there is no competition, clients are reluctant to invest in your technology" – **Pervatech***

5. Policy recommendations

The previous chapter highlighted the fragmentation of the European food market and the general lack of confidence as the main issues that hinder innovation in this sector. The ensuing stagnation of the EU market is therefore pushing companies to seek more fertile ground for expansion in North America.

In order to boost the uptake of novel technologies in Europe, several actions can be taken by policy makers to create an environment that is better suited to the inception and development of innovative SMEs, as discussed below.

5.1. Equalising the EU food market

The heterogeneity of the European food industry ultimately results in the lack of a strong voice to represent the interest of SMEs and of a solid unified position against larger corporations and retailers. This constitutes a barrier to the adoption of new technologies by big food producers, since often their individual interests are not aligned with sustainability, efficiency and innovation. For instance, longer shelf life, as achieved through novel pasteurisation techniques, implies less waste, which in turn reduces the quantities bought by the consumer, thus affecting the sales of big retailers and food producers. Indeed, AMT confirmed that penetration into the juice market is challenging due to the dominance of the well-established chill supply chain.

For this reason, EU policy makers should be aiming to harmonise the food market between Member States, both from a product and technological point of view, so as to promote the adoption of novel technologies and ultimately improve the sustainability of food processing. This could be achieved through enforcing more stringent and binding regulations as to the content of salt or fats in processed foods across all European countries. This would contribute to equalising the recipes and the products, implying in turn that the technologies to process such foods would have to be used equally and to a broader extent across Member States.

5.2. Encouraging knowledge transfer

The lack of confidence in innovation in the food industry is a major obstacle to the uptake of emerging technologies. This is particularly relevant given the current times of economic downturn, where food companies are more reluctant to invest in novel equipment, despite their efficiency and sustainability advantages.

One way to address this issue could be by fostering better knowledge transfer from university and research centres to food companies, through common initiatives and better subsidies at the EU level. In fact, as expressed by companies like Pervatech, the EU funding mechanism for projects aiming to enable the transition from the research to industrial level is not tailored to start-ups and SMEs. Indeed, these companies are required to contribute significantly to the capital, but often cannot afford to do so. Adapting the structure of the funding process would therefore be beneficial for innovative food technology SMEs, since it would allow them to develop commercially sound solutions and showcase their financial viability to potential clients, a key step in securing their trust.

*"You need to assess and understand your obstacles before you start" – **Elea***

A further step for policy makers could be to encourage large food processing companies to actively market their own technologies. In fact, the R&D departments of big corporations are extremely secretive as to their technological developments, often avoiding their commercialisation on the grounds of intellectual property protection. This results in the fact that innovation taking place within the R&D branches of these larger players often remains concentrated at the company level, and does not reach other industry players, further preventing the widespread adoption of innovation across the entire European food sector.

5.3. Better support to food technology start-ups

Another way policies could help tackle the general feeling of mistrust in the food industry is by putting in place better support mechanisms for food technology start-ups from the very early stages.

*"We need funds to move from research to technological development: EU subsidies could make a change" – **Aquamarijn***

In fact, some of the showcased companies advocated the need for a tougher screening of new start-ups, so as to immediately identify the flaws in their business plans and anticipate ensuing hindrances. To this end, joint commercial and technical expertise should be made available to emerging companies with the aim of providing advice on the concrete market opportunities open to them and ensuring that funds are optimally spent.

Additional support from policy makers to promising start-ups could come in the form of initiatives to attract skilled and experienced workforce, as well as financial incentives such as advantageous tax rates. Indeed, current tax regimes are often a burden for new start-ups. This was confirmed by Elea, which reported a tax expenditure of about EUR 350,000 in the first year of its operation.

6. Appendix

6.1. Interviews

Company	Interviewee	Position
Hiperbaric	Andres Hernando Saiz	Managing Director
AMT	Stephen Roe	CEO
Elea	Nickolas Speakman	Director
Aquamarijn	Cees van Rijn	Managing Director
Pervatech	Frans Velterop	Managing Director

6.2. Websites

Company	Web address
Hiperbaric	www.hiperbaric.com
AMT	www.advancedmicrowavetechnologies.com
Elea	www.elea-technology.eu
Aquamarijn	www.aquamarijn.nl
Pervatech	www.pervaporation-membranes.com

6.3. References

[1] European Commission, 2014, The 2014 EU Industrial R&D Investment Scoreboard
http://iri.jrc.ec.europa.eu/scoreboard14.html

[2] Hiperbaric, 2015, Hiperbaric 55
http://www.hiperbaric.com/en/hiperbaric55

[3] Hiperbaric, 2015, HPP Technology
http://www.hiperbaric.com/en/hpp

[4] AMT, 2015, Equipment
http://www.advancedmicrowavetechnologies.com/products-services/

[5] AMT, 2015, AMT Heritage
http://www.advancedmicrowavetechnologies.com/company/

[6] Elea, 2015, Elea PEF
http://www.elea-technology.eu/elea-pef

[7] Elea, 2015, About us
http://www.elea-technology.eu/about

[8] Aquamarijn, 2015, Microsieve filtration technology
http://www.aquamarijn.nl/ms_filtration.php

[9] Aquamarijn, 2015, Microsieve filtration technology
http://www.aquamarijn.nl/ms_filtration.php

[10] Pervatech, 2015, Membranes
http://pervaporation-membranes.com/products/membranes/

[11] Pervatech, 2015, Membranes
http://pervaporation-membranes.com/products/membranes/

[12] FoodDrinkEurope, 2014, Data & Trends of the European Food and Drink Industry 2013-2014
http://www.fooddrinkeurope.eu/uploads/publications_documents/Data__Trends_of_the_European_Food_and_Drink_Industry_2013-2014.pdf

[13] R. Sharma, 2011, Market trends in high pressure processing (HPP) food
http://www.promatecfoodventures.com/doc/HighPressureProcessingMarketTrends2011.pdf

[14] R. Sharma, 2011, Market trends in high pressure processing (HPP) food
http://www.promatecfoodventures.com/doc/HighPressureProcessingMarketTrends2011.pdf

[15] Visiongain, 2015, The Food High Pressure Processing (HPP) Technologies Market Forecast 2015-2025
https://www.visiongain.com/Report/1406/The-Food-High-Pressure-Processing-%28HPP%29-Technologies-Market-Forecast-2015-2025

[16] MarketsandMarkets, 2013, HPP (High Pressure Processing) Market by Equipment Type, Application, Product Type & Geography - Forecast to 2018
http://www.marketsandmarkets.com/PressReleases/hpp.asp

[17] FoodProduction Daily, 2014, Hiperbaric 'can't complain' about growth in HPP market
http://www.foodproductiondaily.com/Processing/Hiperbaric-can-t-complain-about-growth-in-HPP-market

[18] Visiongain, 2015, The Food High Pressure Processing (HPP) Technologies Market Forecast 2015-2025
https://www.visiongain.com/Report/1406/The-Food-High-Pressure-Processing-%28HPP%29-Technologies-Market-Forecast-2015-2025

[19] MarketsandMarkets, 2013, HPP (High Pressure Processing) Market by Equipment Type, Application, Product Type & Geography - Forecast to 2018
http://www.marketsandmarkets.com/PressReleases/hpp.asp

[20] MarketLIne, 2014, Global Juices industry profile
http://store.marketline.com/Product/global_juices?productid=MLIP1367-0008

[21] AMT, 2015, AMT market sizing

[22] Research and Markets, 2015, Global Dairy Processing Equipment (Pasteurizers, Homogenizers, Separators, Evaporators & Dryers, Membrane Filters & Others) Market 2015-2019
http://www.researchandmarkets.com/research/r92vcv/dairy_processing

[23] Elea, 2015, personal communication

[24] MarketsandMarkets, 2014, Food Encapsulation Technology Market worth $26,208.3 Million by 2018
http://www.marketsandmarkets.com/PressReleases/food-encapsulation.asp

[25] Grand View Research, 2015, Microencapsulation Market Analysis By Application (Pharmaceuticals, Agrochemicals, Household Products, Food Additives) And Segment Forecasts To 2020
http://www.grandviewresearch.com/industry-analysis/microencapsulation-market

[26] Companies and Markets, 2013, Nanoencapsulation market driven by the increase in demand for functional foods
http://www.companiesandmarkets.com/News/Food-and-Drink/Nanoencapsulation-market-driven-by-the-increase-in-demand-for-functional-foods/NI8235

[27] R.N. Pereira, A.A. Vicente, 2010, Environmental impact of novel thermal and non-thermal technologies in food processing
http://repositorium.sdum.uminho.pt/bitstream/1822/11276/1/Pereira_Food%20Research%20International.pdf

[28] S. Toepfl, 2006, Pulsed electric fields (PEF) for permeabilization of cell membranes in food- and bioprocessing-applications. Process and equipment design and cost analysis

[29] European Commission, 2015, Stop food waste
http://ec.europa.eu/food/safety/food_waste/stop/index_en.htm

[30] Elea, 2015, Elea Pulsed Electric Field
http://www.elea-technology.eu/elea-pef

[31] AMT, 2015, Fruit and vegetable juices
http://www.advancedmicrowavetechnologies.com/food-and-drink/fruit-and-vegetable-juices/

[32] EU Observer, 2006, Obesity epidemic costs EU €59 billion a year
https://euobserver.com/news/21720

[33] The Fix, 2015
http://www.thejuicefix.com.au/

[34] European Commission, 2012, Survey on Members States' Implementation of the EU Salt Reduction Framework
http://ec.europa.eu/health/nutrition_physical_activity/docs/salt_report1_en.pdf

[35] European Commission, 2012, Survey on Members States' Implementation of the EU Salt Reduction Framework
http://ec.europa.eu/health/nutrition_physical_activity/docs/salt_report1_en.pdf

[36] FoodDrinkEurope, 2015, Small and Medium Sized Enterprises
http://www.fooddrinkeurope.eu/our-actions/topic/small-and-medium-sized-enterprises-smes/

[37] European Parliament, 2013, Technology options for feeding 10 billion people: options for sustainable food processing
http://www.europarl.europa.eu/RegData/etudes/etudes/join/2013/513533/IPOL-JOIN_ET%282013%29513533_EN.pdf