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Mapping trends in novel and emerging food processing technologies around the world

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A B S T R A C T

This paper discusses novel technologies and their applications in the world. Two surveys were independently designed and conducted by a North American (Survey 1) and by a European group (Survey 2). The respondents were food professionals from industry, academia and government. The questions sought to identify novel technologies either applied now or with the potential to be commercialised in 5–10 years, commercialisation factors, associated regulations and limitations. In Survey 1, HPP (80%), microwave (88%) and UV (84%) were the main technologies applied now and anticipated in the next 5 years. PEF was third instead of UV in Survey 2. The main drivers were higher quality products (94%), product safety (92%) and shelf life (91%). HPP and microwaves were identified as main technologies now and in the next 10 years. There were geographical differences with North America finding UV and radiation, and Europe finding PEF of more importance now. Cold plasma and PEF were anticipated to be more important in Europe in 10 years' time while HPP, microwave and UV remained more important to North America.

Industrial relevance: The emerging technologies mentioned in the survey have been developing since the early 20th century or before. However, they are not adopted on any large scale such as canning or heat pasteurisation. This study was conducted on a worldwide scale to determine current uses for emerging technologies in different food sectors. Some technologies are deemed of more commercial importance in certain countries than others. HPP and microwave heating are the two main technologies currently on commercial applications. PEF is more popular in Europe, especially the Netherlands where a commercial scale unit exists. On the contrary, microwave technology seems to be popular in all countries but the Netherlands. UV and radiation are more important in North America than Europe. Pressure and CO_2 is only deemed to be of commercial importance in North America.

1. Introduction

Growing industrialisation of food production, globalisation and trade of food supply make food safety and extended shelf-life products perhaps the most important issues for food and equipment manufacturers, retailers and consumers around the globe. More than two decades ago, novel food processing technologies that were based on high tech or cutting edge advances started to emerge to address productivity issues, extending product shelf life without affecting the nutritional content, organoleptic attributes and product specifications. Despite some of the technological advancements developing since the early 20th century, their applications for foods are still in a phase that needs a substantial amount of research to prove their pragmatic feasibility. Current limitations related to high investment costs, incomplete control of variables associated with the process operation and lack of regulatory approval have been delaying a wider implementation of these technologies on an industrial scale. The readiness and commercialisation level of novel and emerging technologies varies both geographically and among more than 20 available techniques.

Two surveys were independently designed and conducted to collect opinions about commercial applications of novel and emerging technologies, their development potential and to compare the level of technology development around the globe in different countries and continents.

In this article, the survey responses of food experts from different parts of the world will be discussed and analysed with the aim of having a better understanding of modern trends in food processing, the level of commercialisation and the role that novel and emerging technologies play in various geographical locations.

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The principles of the various technologies encountered in the surveys are explained below. They include high pressure processing, pulsed electric fields, ultraviolet light, microwave heating, radiation, infrared heating, ohmic heating, ozone, pressure and CO_2, power ultrasound, cold plasma and electrolysed water.

- High pressure processing (HPP) (Barba, Grimi, & Vorobiev, 2014; Barbosa-Cánovas, Medina-Meza, Candoğan, & Bermúdez-Aguirre, 2014; Mújica-Paz, Valdez-Fragoso, Samson, Welti-Chanes, & Torres, 2011; Rendueles et al., 2011; Ros-Polski, Koutchma, Xue, Defelice, & Balamurugan, 2015) is also called high hydrostatic pressure processing, pascalisation or high pressure pasteurisation. It effectively inactivates vegetative bacteria, yeast and moulds using pressures up to 600 MPa at ambient temperature and can inactivate spores when combined with high temperature (High Pressure Thermal Processing (HPTP)). HPP retains most of the sensory and nutritional quality of a liquid or solid, or chilled products. Its effect on enzymes is variable.
- Pulsed electric field (PEF) (Barba et al., 2014; Huang, Tian, Gai, & Wang, 2012; Martín-Belloso & Sobrino-López, 2011; Singh, Kumar, Kumar, & Bhat, 2012; Terefe, Buckow, & Versteeg, 2015; Zhao, Tang, Lu, Chen, & Li, 2014) involves the application of high voltage (typically 20 to 80 kV/cm) to foods placed or circulating between two electrodes. It can be applied for different purposes, one of them being as a preservation technology. Similar to HPP, it destroys vegetative bacteria, yeast and moulds but not spores and not many enzymes.
- Ultraviolet light (UV) (Abida, Rayees, & Masoodi, 2014; Falguera, Pagán, Garza, Garvín, & Ibarz, 2011; Gayán, Condón, & Álvarez, 2014; Koutchma, 2009) produces a non-ionising radiation with germicidal properties at wavelengths in the range of 200–280 nm. It can be used for surface treatment and as a non-thermal alternative for fluid foods and ingredients.
- Microwave heating (MWH) (Barba et al., 2014; Barbosa-Cánovas et al., 2014; Chandrasekaran, Ramanathan, & Basak, 2013; Datta & Rakesh, 2013; Kim et al., 2012; Ros-Polski, Schmidt, Marsaioli-Junior, Vitali, & Raghavan, 2014; Venkatesh & Raghavan, 2004, 2005) refers to the use of electromagnetic energy at the particular frequencies of 915 and 2450 MHz to generate heat in a food material. Contrary to conventional thermal techniques, heat is generated volumetrically throughout the product at faster rates. It can be used on solid and pumpable foods. This includes fluids containing large particles.
- Radiation (Alam Khan & Abrahem, 2010; Otto et al., 2011) includes irradiation by any of the three sources: gamma-rays, X-rays or electron beams. They are often also referred to as ionising radiations. Gamma-rays can penetrate the food but electron beams have limited penetration depth.
- Infrared heating (IR) (Raghavan et al., 2005) refers to the heating of materials by electromagnetic radiation having a wavelength of 1.3 to 4.0 μm (infrared radiation). It is based on the ability of materials to absorb a certain part of the spectrum of such radiation. Deep or superficial heating of the irradiated body, as well as local drying without heating the entire object, may be accomplished with appropriate selection of the emission spectrum of infrared radiation.
- Ohmic heating (OMH) (Sakr & Liu, 2014; Varghese, Pandey, Radhakrishna, & Bawa, 2012), also known as Joule heating or resistive heating, is a process where an alternating electric current is passed through the food product. The electrical resistance of the food promotes rapid generation of heat directly inside the food. Contrary to conventional thermal techniques, heat is generated volumetrically throughout the product. It can be used on solid and pumpable foods. This includes fluids containing large particles.
- Ozone (O_3) (Guzel-Seydim, Greene, & Seydim, 2004; Khadre, Yousef, & Kim, 2001; Perry & Yousef, 2011) is a powerful broad-spectrum antimicrobial with high oxidation potential. It has the potential to be used instead of chlorine. Fruits and vegetables may be processed either by dipping in ozonated water, washing in bubbling ozone water, or by the application of gaseous ozone. It is approved by the US FDA as a direct additive to food.
- Pressure and CO_2 (Martín-Belloso & Sobrino-López, 2011; Otto et al., 2011) is also called dense phase carbon dioxide (DPCD or DP-CO_2), liquid CO_2, supercritical CO_2 ($SCCO_2$) or high pressurised carbon dioxide (HPCD). It is a continuous, non-thermal processing system for liquid foods that utilises pressure in combination with carbon dioxide to destroy microorganisms as a means of food preservation.
- Power ultrasound (Abbas, Hayat, Karangwa, Bashari, & Zhang, 2013; Barba et al., 2014; Chandrapala, Oliver, Kentish, & Ashokkumar, 2013; Deora et al., 2013; Otto et al., 2011; Warning & Datta, 2013) is a versatile technique using high power sound waves at low frequency (about 20 kHz). Its various uses include emulsification, homogenisation, viscosity and texture modification, crystallisation seeding, microbial decontamination, cleaning and extraction. It is mainly used in fluids and fluids containing particles.
- Cold atmospheric plasma (Misra, Tiwari, Raghavarao, & Cullen, 2011; Otto et al., 2011; Smeu & Nicolau, 2014) (also known as cold plasma, non-equilibrium, non-thermal plasma) have different electron, ion, and neutral species temperatures. Such plasmas are good sources of highly reactive oxidative and reductive species and plasma electrons. Via these species, one can direct electrical energy into favourable gas chemistry (like decomposing pollutants or fragmenting larger hydrocarbons into smaller, more-easily combustible ones). It is researched for use to decontaminate foods not suitable for chemical treatment or with fragile surfaces.
- Electrolysed water (Koseki & Isobe, 2007) (known as electrolysed oxidising water, electro-activated water or electro-chemically activated water solution) is produced by electrolysing a weak salt solution. This produces sodium hypochlorite, a disinfectant. Acidic electrolysed water also exists and can be more efficient. This water can be used to clean food preparation surfaces or decontaminate fruit and vegetables.

2. Material and methods

The two surveys were independently designed and conducted, i.e., the respondents were not necessarily the same in both studies. Survey 1 (conducted by North America) and Survey 2 (conducted by Europe) are described in this section.

2.1. Survey conducted in North America—Survey 1

The Food Safety Working Group (FSWG, http://www.cigr.org/governance_work.html#FoodSafety) of CIGR in collaboration with Guelph Food Research Centre of Agriculture and Agri-Food Canada (AAFC) developed a survey to collect the answers and opinions of food professionals in terms of the role that novel and emerging food processing technologies and innovations can play to address global food safety issues and challenges. The survey consisted of a total of 18 questions. Part of the survey contained questions to better understand the level of the existing knowledge in combination with the factors that may accelerate or slow down development of novel food processing. In this survey eleven processing technologies were included in the list of emerged or emerging processing techniques that during the last decade have been tested for different food applications: High Hydrostatic Pressure (or HPP), Pulsed Electric Field (PEF), Ultraviolet Light (UV), Microwave heating (MWH), Radiation, Infrared heating (IR), Ohmic heating (OMH), Ozone (Oz), Pressure and CO_2, Power ultrasound (US) and Cold Atmospheric Plasma.

The 18 questions were:

Q1: What processing technology has commercial application or emerged in food production in your country?