NON-THERMAL PASTEURISATION OF LIQUID FOODS

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Consumers around the world are demanding safe, healthy and almost natural-like products with desirable appearances. This can be achieved by monitoring the process that changes the nutritional and qualitative characteristics, particularly the pasteurisation process.

Fruit juices are usually flash pasteurised; in fact, 98% of all juices are heat pasteurised (NFPA, 1999). This is a type of high-temperature-short-time (HTST) pasteurisation method that utilises rapid heating and cooling steps. Thermal pasteurisation process of fruit juices typically involves heating to 90-95°C for 15-20 seconds (Torlak, 2014). This conventional process is designed to inactivate pertinent microorganisms and unwanted endogenous enzymes that may degrade the fruit juice.

Pasteurisation effectively produces products that are safe and have a longer shelf-life; the synergistic effect of treatment time and temperature is also proportional to the amount of quality and nutritional loses (*Dolatowki et al., 2007*). The high energy treatment involved in thermal pasteurisation usually diminishes vitamins, essential nutrients and food flavours in the product (Barbosa-Canovas & Bermudez-Aguirre, 2011). Various studies prove that thermal pasteurisation causes detrimental effects on the juice quality. Nutritional content, chemical, antioxidant and sensory attributes have been reported to be directly affected by the heat. However, thermal treatments still dominate the industry as these are relatively stable and efficacies are guaranteed. So, any new technology to replace the thermal pasteurisation technique should be able to offer additional advantages, in terms of cost, product quality and value-added functional properties that are not available via thermal treatment alone (*Coutinho et al., 2018*).

This has led to increasing interests in various non-thermal technologies (Figure 1). Ultraviolet (UV-C), pulsed electric field (PEF), ozone (O_3), and cold plasma are the ones chosen for their suitability for liquid food pasteurisation. These technologies have been extensively researched and applied to various fruit juice samples in order to comply with United States Food & Drug Administration (FDA, 2004) regulations that that liquid food processors must achieve a minimum of 5-log reduction of pertinent microorganisms to market their products to the masses. An added advantage is the ability to deactivate spoilage and pathogenic microorganisms, while prolonging shelf-life without compromising the fresh-like quality.

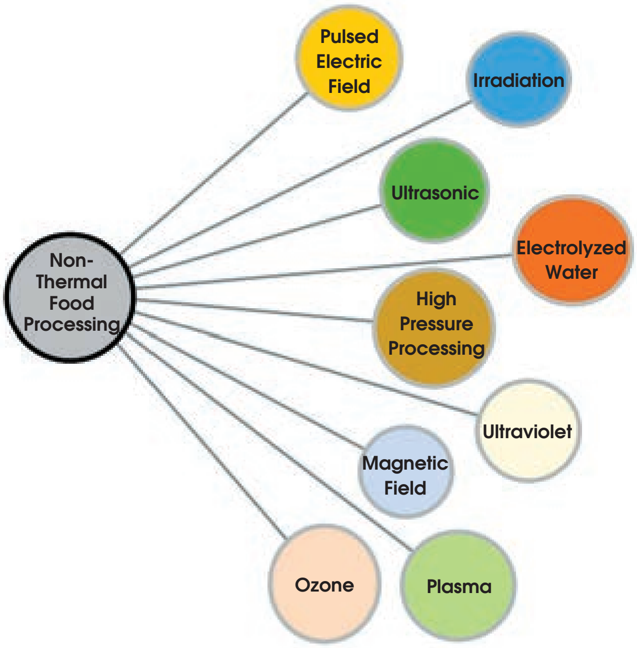
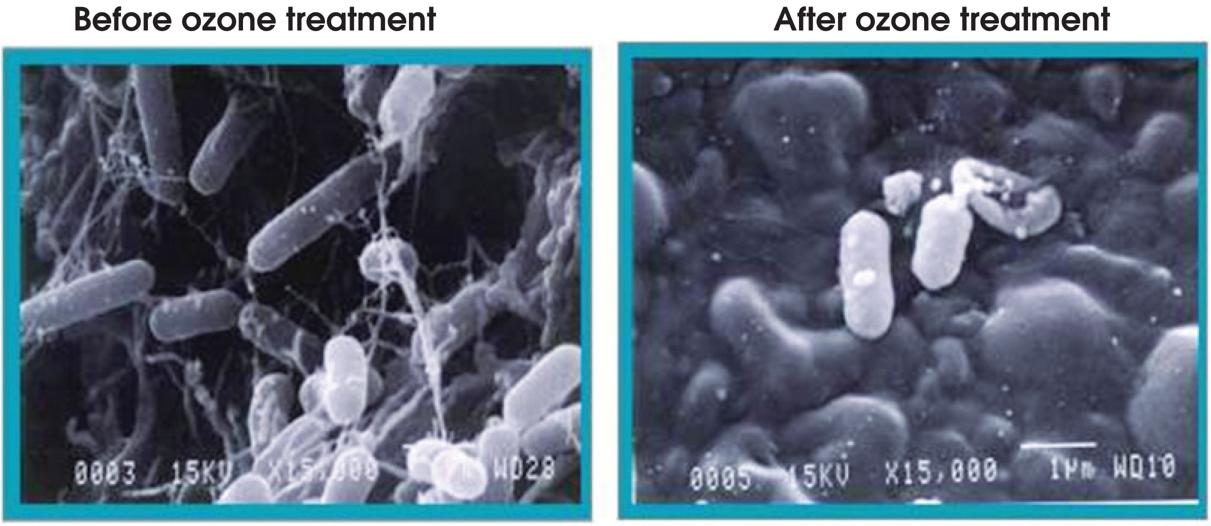


Figure 1: Novel food processing techniques adopted by the food industry in recent times (from Khan et al., 2017)

Ultraviolet (UV-C) utilises light with intense and short-duration pulses of electromagnetic spectrum from 200 to 280 nm with a radiant exposure of at least 400 J/m^2 to inactivate pertinent microorganisms in liquid foods (Li & Farid, 2016). Its bactericidal mechanism is based on the absorption of UV-C light by microbial DNA or RNA structures. The primary mechanism is the creation of pyrimidine dimers to damage microorganism DNA, thus preventing microorganisms from replicating, further rendering them inactive and unable to cause food-borne illness.



Before ozone treatment

After ozone treatment

1. Ozone oxidises cell membrane, causing osmotic bursting
2. Ozone continues to oxidise enzymes and DNA

Figure 2: Microbial inactivation via ozone treatment (Yuan et al., 2000)

With the positive consumer image and low processing cost, the use of UV-C light for water treatment is well established and is currently in use to treat and kill pathogens in drinking water. However, its application in liquid foods presents a relatively new challenge to beverage producers, based on complexities posed by liquid foods which often lead to complications during pasteurisation using non-thermal technologies. This slows down the progress of the use of UV-C in food industry.

Unlike water, liquid foods have a range of optical and physical properties and diverse chemical compositions which may influence UV-C light transmittance, dose delivery, momentum transfer and consequently microbial inactivation (*Shah et al., 2016*). The intrinsic factors of liquid food – its opacity and solid components – are often the barriers to achieving microbial inactivation efficacy. Hence, the ability of juice to absorb the electromagnetic spectrum is important in gauging the technology efficacy against pertinent microbial populations in the juice.

Studies on UV-C are now focused on the development of new reactors with improved hydrodynamics design to induce thin-film flow regime, ensuring full exposure of target microorganisms to UV-C light (Li & Farid, 2016). Furthermore, UV-C does not generate any chemical residue or significant amounts of heat during processing. Positioning UV-C treated juices as premium products with relatively lower investment costs and quicker payback period can be attractive for small scale manufacturers (*Shah et al., 2016*).

Pulsed electric field (PEF) technology has been extensively investigated in recent years for application in food processing. It can be used to process liquids and semi-liquids with minimal qualitative changes.

PEF emits short pulses of high voltage, of between two electrodes (20-80 kV/cm) at short duration (1-100 μs), which causes electroporation in the cell wall of microorganisms, thus inactivating them (Amiali & Ngadi, 2012). When the electric field intensity across the membrane exceeds the threshold, permeabilisation of microbial cells will be irreversible and subsequently result in the leakage of intercellular compounds and cell lysis (*Jaeger et al., 2014*). The efficacy of PEF microbial inactivation depends highly on its process parameters (electric field intensity, power and treatment time), microorganisms parameters (types, growth phase, size and shape of microbes) and medium parameters (pH, solid contents and particle size) – (Li & Farid, 2016).

Its effectiveness in treating high electrical conductivity food products is a concern (Amiali and Ngadi, 2012) because most of the energy input will be converted into heat, thus discounting the advantage of PEF as non-thermal technology. Furthermore, the cost is higher than thermal, since the throughput has a direct effect on the capital cost of the PEF system. According to a study by *Sampedro et al.,* (2014), the total pasteurisation cost of orange juice using PEF is US$3.7 cent per litre or 2.5 times higher than thermal treatment (US$1.5 cent per litre). But despite the high initial cost, PEF is popular and is currently used for commercial scale juice production in The Netherlands and other European countries (*Jermann et al., 2015*).

Meanwhile, ozone (O_3) is a triatomic molecule consisting of three oxygen atoms. It is an allotrope of oxygen that is far less stable than the diatomic O_2. Ozone has attracted great interest with regards to food safety as it is 1.5 times stronger than chlorine and is effective over a wider spectrum of microorganisms (Patil & Bourke, 2012). Figure 2 illustrates the effect of ozone treatment on microbial survivality in water.

Ozone also leaves no chemical residue and it degrades to molecular oxygen upon reaction or due to natural

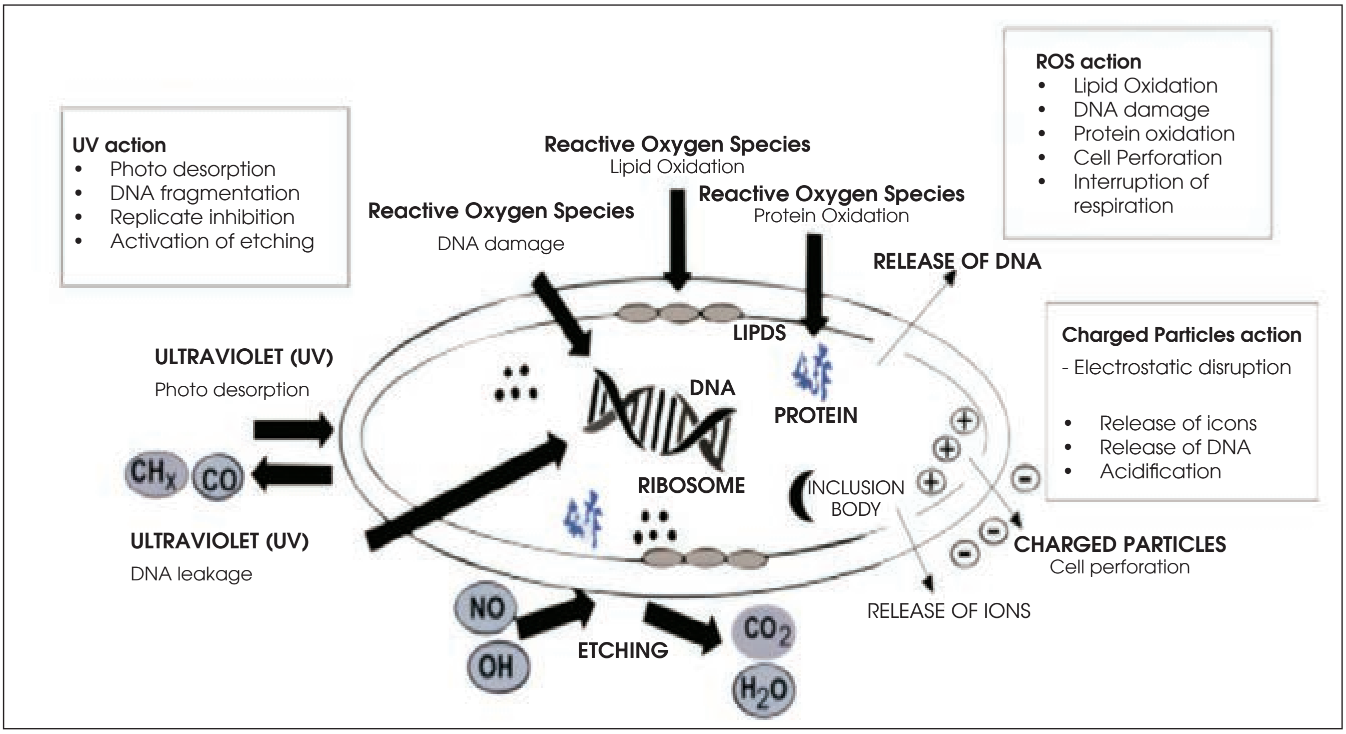


Figure 3: Overview of cold plasma bactericidal mechanisms (Schluter & Frohling, 2014)

degradation. It is a colourless gas that is readily detectable at the range of 0.01 to 0.05 ppm (Patil & Bourke, 2012). When ozone is produced, it will decay rapidly because it is an unstable compound with a relatively short half-life. It quickly degrades to oxygen in pure water and even more rapidly in impure solutions such as fruit juice which contains various soluble and insoluble solids (*Guzel-Seydim et al., 2004*).

In 2001, the USFDA approved the use of ozone in gaseous and aqueous phases as an antimicrobial agent for the treatment, storage and processing of foods (*Khadre et al., 2001*). Ultraviolet radiation (188nm wavelength), corona discharge and cold plasma methods can be used to initiate free radical oxygen formation and thereby generate ozone. The corona discharge method is the most popular type of ozone generator for most industrial and personal uses. It is very cost-effective and does not require an oxygen source other than air. However, due to the highly reactive nature of ozone, it is necessary to understand the key parameters in order to optimise its application for sterilising liquid food products. In a study, *Restaino et al.*, (1995) stated that the effectiveness of ozone against microorganisms depends not only on the concentration of ozone used but also on the residual ozone in the medium and various environmental factors such as medium pH, temperature, humidity, additives such as sugar and the amount of organic matter surrounding the cells. The impact of different compounds such as sugar, fibre, ascorbic acid and other organic matter in the dissolution rate and availability of ozone can create a protective effect in some components.

Meanwhile, cold plasma is a relatively new sterilisation method which has caught the attention of food scientists. It is considered to be a unique "pure" non-thermal method that combines the synergistic effects of UV radiation and oxidation caused by ozone which have been proven to effectively kill microorganisms. The bactericidal effects caused by the mixture of electrons, ions, atomic species, UV photons and charged particle of cold plasma treatment can be achieved through direct or indirect method of food exposure (Li & Farid, 2016).

Cold plasma is generated under atmospheric or reduced pressures which controls its low temperatures of 30-60°C (*Coutinho et al., 2018*). Plasma jets, Dielectric Barrier Discharges (DBD), corona discharges and microwave discharges are common sources for the generation of cold plasma at atmospheric pressure. Cold plasma has great advantages, such as lower water consumption, lower operating temperatures and lower costs, compared to conventional thermal processing. The ability to inactivate spores by cold plasma mainly depends on the types of feed gas. Gas plasma is generated by ionising feed gases through external electric field or other energy sources.

Figure 3 presents an overview of cold plasma microbial inactivation. Three basic mechanisms are triggered by the plasma which contribute to cell death, including etching of cell surfaces induced by reactive species formed during plasma generation, volatilisation of compounds and intrinsic photodesorption of UV photons and destruction of genetic material (*Coutinho et al., 2018*).

CONCLUSION

Novel non-thermal pasteurisation techniques have proved to have significant advantages over thermal treatment. The application of emerging technologies is aimed at preservation with minimal qualitative changes, in addition to the promise to deliver foods which are safe with "fresh-like" quality and a longer shelf-life. A number of issues have been identified which has delayed the commercial/ industrial implementation, especially in Malaysia. High capital cost, lack of expertise, products uniformity and safety regulations, warrants extensive studies to encourage the use of non-thermal technologies in food industries. Active collaborations between scientists and engineers can foster rapid developments to reduce the cost of equipment, while establishing proper standard operating procedures as well as increasing efficiencies with lower operating costs.

Furthermore, a better understanding of the complex physicochemical mechanisms of action of non-thermal processing technologies and their effects on the functional and nutritional properties of liquid foods will also contribute towards reinforcing the presence of these emerging technologies at industrial scales. ■

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