

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/338242355>

Review on Non-thermal Technologies for the Preservation of Fruit Juices

Article in *Journal of Agricultural Science and Technology B* · June 2019

DOI: 10.17265/2161-6264/2019.06.001

CITATION

1

READS

743

3 authors, including:



Erandya Jayawardena

University of Sri Jayewardenepura

9 PUBLICATIONS 10 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:



Study on developing micronutrients enriched spread using fermented cooked rice [View project](#)

Review on Non-thermal Technologies for the Preservation of Fruit Juices

Erandya Jayawardena, Mihiri Vanniarachchi and Jagath Wansapala

Department of Food Science and Technology, University of Sri Jayewardenepura, Gangodawila, Nugegoda 10250, Sri Lanka

Abstract: Liquid food industries use different preservation methods to extend the shelf life of products by reducing both enzymatic and microorganism activities. Emerging non-thermal pasteurization techniques are applied in order to avoid thermal processes maintaining the microbial safety and quality of liquid foods. Non-thermal preservation technologies used in the liquid food industry include high-pressure processing (HPP), pulsed electric field (PEF), ultraviolet light (UV-C) and ultra-sonication (US). HPP is a method to target specific organisms by applying a pressure range of 100-1,000 MPa. PEF uses short pulses of a strong electric field applied to a flowing liquid food which affects the whole cell membrane of the organism. UV-C treatment at 253.7 nm has been proven to be appropriate for maintaining liquid quality and minimal deterioration of nutrients. US is applied to liquid foods in a lower frequency range of 20-100 kHz and a higher sound intensity of 10-1,000 W/cm² to the breakdown of cells. According to scientific literature, those methods have been applied to fruit juices like orange, apple, pear, coconut water, etc. Most of the non-thermal methods achieved the Food and Drug Administration (FDA) requirement of a 5-log reduction of microorganisms without deteriorating the sensory and nutritional attributes of fruit juices. Some of these methods have already been commercialized and others are still in a pilot scale. This study gives a comprehensive overview of published literature regarding the potential for using non-thermal pasteurization methods to extend the shelf life of different fruit juices with minimal deterioration of nutritional and sensory quality.

Key words: Non-thermal pasteurization, high-pressure process, pulsed electric field, UV-C light, ultrasound.

1. Introduction

There is growing consumer demand for fresh, unpasteurized, nutritionally sound and microbiologically safe liquid beverages with extended shelf life. But beverages with high water content are a good transportation system for spoilage microorganisms and a good source for enzymatic activities [1]. Liquid food industries use different preservation methods to extend the shelf life and to assure that products will be microbiologically safe by inactivating enzymatic and microorganism activities. A good preservation technology must maintain the quality of the product while providing convenient shelf life as well as ensuring the preservation of original flavor and nutritional properties of products. The oldest and best developed preservation method is

thermal pasteurization or sterilization technique [2, 3]. In thermal operation, low temperature long time (LTLT) and high temperature short time (HTST) treatments are the most commonly used techniques that have the tendency to induce permanent changes to the nutritional and sensory characteristics of the food. Therefore, today in liquid food industry there is a need to find out a suitable pasteurization method that considerably reduces damage to nutrients and sensory quality of the product [4]. Emerging non-thermal pasteurization methods are applied as substitutions to conventional thermal processes in order to maintain the quality of the product. However, these non-thermal methods should also minimize the microbial content to a safe level so that products can be safe and stable before introducing them to consumers [5].

Corresponding author: Erandya Jayawardena, Ph.D. candidate, research field: food science and technology.

Advantages of non-thermal processes are low operational temperature, low energy utilization, the

enhanced sustainability of the process and the maintenance of flavors and nutrients, while inactivating the spoilage microorganisms and enzymes [6]. These non-thermal preservation methods used in liquid food industry, include high-pressure processing (HPP), pulsed electric field (PEF), ultraviolet light (UV-C) and ultrasound treatment. These emerging techniques are in a developing stage being tested in laboratory scale [7]. Many studies are conducted to scale up and nowadays some techniques are applied to pilot scale processing.

This paper focuses on different non-thermal pasteurization methods and their suitability on the fruit juice industry as alternatives to the thermal pasteurization techniques.

2. High Pressure Processing (HPP)

HPP or pascalization refers as a non-thermal pasteurization technique applying pressure on foods in a range of 100-1,000 MPa [3, 8]. These treatments are able to inactivate microorganisms and endogenous enzymes, while retaining nutrients, flavors and colors

[9]. Initially HPP has been used to extend the shelf-life of milk for 4 d by applying 600 MPa pressure at room temperature [10]. This method is nowadays being used in the liquid food industry to target specific pathogenic organisms such as *Listeria monocytogenes*, *Salmonella* and *Escherichia coli* O157:H7 as post-process action in fruit juices/vegetable juices [7]. Ramaswamy *et al.* [11] had done an experiment applying high pressure (150-400 MPa; 0-80 min at 25 °C) on apple juice, proving that *E. coli* is highly sensitive to the HPP. Many studies have proved that pressure above 200 MPa inactivates several vegetative cells and viruses, but bacterial spores have high tolerance to the pressure even above 1,000 MPa. Also with respect to the type of the microorganism HPP parameters and treatment will differ.

Fig. 1 shows the sketch diagram of HPP equipment. It mainly consists of pressurization cylinder, sample vessel, cooling system, pressure pump and liquid inlets and outlets. In HPP first the liquid/semi-liquid product is filled into the sterilized pressure vessel, then

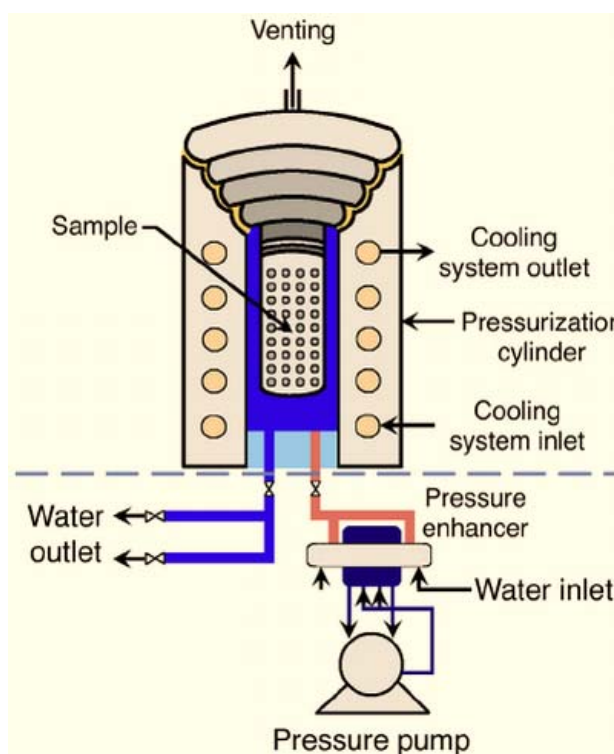


Fig. 1 Representation image of high-pressure processing (HPP) equipment [12].

pressure is applied and the product is held under pressure at desired time. After that the vessel is de-pressurized and processed food is removed. The holding time of pressure is depending on the pressure medium and the food material. Chawla *et al.* [2] said that in a general HHP process, pressure of 680 MPa results in 15% compression of the liquid processed.

The major drawbacks of HPP are high installation cost for the unit and the process becomes semi-continuous for the liquids. Also the microorganism spores and some bacteria species are not inactivated by HPP treatments. The effectiveness of HPP can be increased by combining with antimicrobial constituents or mild heat treatments [6, 13].

3. Ultraviolet-C Radiation (UV-C)

A UV radiation takes account of small range in electromagnetic spectrum from 100 nm to 400 nm. There are three ranges: UV-A (320-400 nm), UV-B (280-320 nm) and UV-C (200-280 nm) [14, 15]. Among these three ranges, UV-C has germicidal effect on microbial cells and no significance changes arise or toxic by-products are produced when applied as a non-thermal preservation or disinfectant method [16]. The good consumer image and low operation cost of the UV-C process have proven to be suitable for ensuring minimum quality of the juice [17]. According to literature UV-C treatment is recommended for juices (by United States Food and Drug Administration (USFDA)) as a non-thermal

pasteurization method without producing toxic compounds and off-flavors and odors [15]. Also no off flavor is formed after the treatment and the energy consumption in UV-C treatment is very low compared to thermal pasteurization methods [15]. According to USFDA and United States Department of Agriculture (USDA), UV-C light wavelength of 253.7 nm has proven to be safe for liquid food processing and it is approved to be used as an alternative method to reduce microorganism load of the food. The disadvantage of this method is the deterioration of ascorbic acid content. About 12%-18% of ascorbic acid is deteriorated using this method. The effectiveness of these treatments is limited by the light wavelength, type of food, types of microorganism and processing parameters. Torkamani and Niakousari [5] proved that bacteria cells were more sensitive to UV-C treatment than fungi by conducting an experiment on orange juice. Structure of cell wall, pigmentation and the presence of the restoration system of microorganisms were reasons for the variation of the sensitivity of UV-C light. Tran and Farid [16] experimented and observed 12% of vitamin C and 70% of enzymatic activities were degraded by 73.8 mJ/cm² of UV dose applied on orange juice and no significant changes occurred on pH and color after the treatment.

Fig. 2 represents a pilot scale UV-C system. According to Keyser *et al.* [15], the pilot scale UV system generally consists of a stainless steel inlet and outlet chambers, a stainless steel corrugated spiral tube

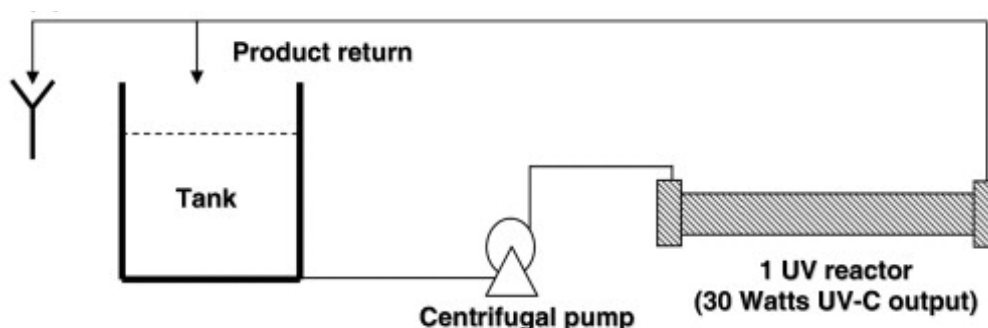


Fig. 2 Representation image of pilot scale UV system [15].

and the UV germicidal lamp which is connected inside the spiral tube. The quartz sleeve is used to protect the UV-C lamp. Therein, the liquid product flows through the corrugated spiral tube in between the tube and the quartz sleeve. Velocity and turbulence created inside the inlet chamber drive the liquid through the spiral tube to contact with UV-C radiation.

4. Pulsed Electric Field (PEF)

PEF is one of the most advanced technologies in liquid pasteurization. The cells and spores of microorganisms in a liquid are destroyed by applying short pulses of a strong electric field which is formed in between two electrodes [18]. Fig. 3 shows the representative electromagnetic field of PEF. It creates a high voltage to liquid which placed between the electrodes. The targeted microorganisms in this operation are yeast and mold, due to their ability to grow in acidic conditions (low pH values) [19]. Since yeast and molds are the major spoilage microorganisms in fruit juices many studies were conducted for PEF. PEF affects the whole cell membrane of the organism by electroporation which

causes outflow of cytoplasmic materials from cells [1]. The two species of molds *Byssochlamys fulva* and *Neosartorya fischeri* are reported as major spoilage organisms of fruit juices in literature [8]. These organisms produce heat resistant spores called Coniospores. Those spores resist in thermal pasteurization and HPP. According to the findings of Raso *et al.* [8] mold Coniospores can be inactivated by a small amount of PEF intensity. The PEF equipment is still in developing stage and new designs and comprehensive studies needed to scale up the PEF system. The effectiveness of the process depends on the electrical conductivity of the liquid food. Effectiveness of PEF can be increased with combining with hurdle technology or with mild heat treatments [20].

5. High Power Ultra-Sonication (US)

US is one of the non-thermal pasteurization techniques used for liquid food processing, especially in juices, purees and smoothies. The researches prove that US improves the flavors, stabilizes and preserves the quality of juices/purees [22]. This method is applied

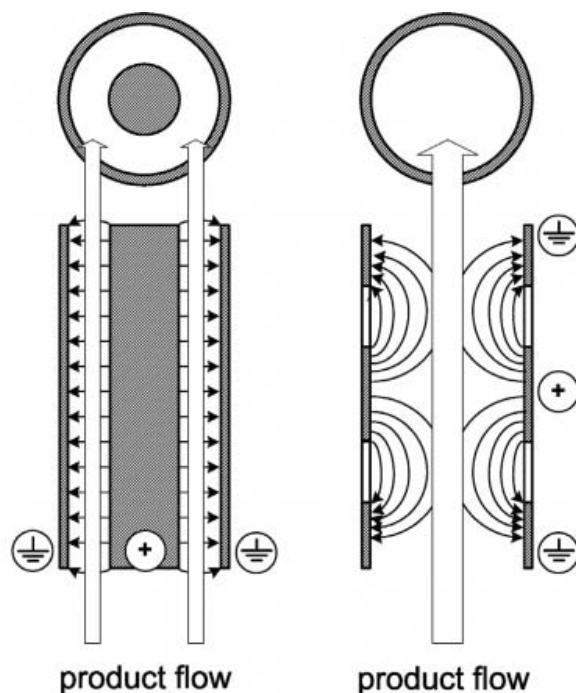


Fig. 3 Representative image for pulsed electric field (PEF) [21].

to liquids as the individual or combined technique to inactivate or disrupt the activity of microorganisms and enzymes. The power applied in low frequency (10-1,000 W/cm²) is the technique that involves power US [23]. High power ultrasounds are applied to liquid foods to induce the formation of cavitation bubbles, which cause the breakdown and destruction of microorganism cells [24].

Fig. 4 shows the representative image of ultrasonic processor. It consists of ultrasonic generator, ultrasonic converter with horn and counter tool. Ultrasonic generator converts power to electrical energy and then it is converted into mechanical oscillation. In the US process, two phases are identified, compression and rarefaction. In compression stage, wave micro-bubbles are formed of different nucleation locations in the fluid. In rarefaction stage, the bubbles are growing quickly and flop onto a different compression phase, by releasing a shock wave [20]. This causes to collapse the micro bubbles brutally in the compression phase of circulated ultrasonic waves resulting in localized high temperature inside the cell up to 5,000 K and pressures up to 50,000 kPa. Because of the shearing effects on cell walls, cell membranes will be disrupted and damage DNA sequence of microorganisms [2].

Protein denaturation, fat oxidation and valuable enzyme inactivation are the major disadvantages of this method.

O'donnel *et al.* [23] reviewed that US used with mild heat treatment was effective against *E. coli* and *L. monocytogenes* in apple cider. Also, ultrasound combined with pressure or heat and pressure combination was effective against the activity of spoilage enzymes.

6. Quality Changes of Different Fruit Juices after Applying HPP, PEF, UV-C Radiation and US

Table 1 represents the review comparison of quality changes of different fruit juices after applying HPP, PEF, UV-C radiation and US. According to scientific literature (Table 1), HPP, PEF, UV-C radiation and US were applied to fruit juices like orange, apple, pear, tender coconut water (TCW) etc. As an example, HPP (550 MPa), PEF (35 kV/cm), UV-C (230 J/L) and US (500 kHz) were applied in orange juice to achieve FDA requirement of a 5-log reduction of microorganism. After processing, 2% and 12% of vitamin C was lost by HPP and UV-C. Significant changes of vitamin C and cloud value were found by US. About 8% of vitamin A and 1% of citric acid was

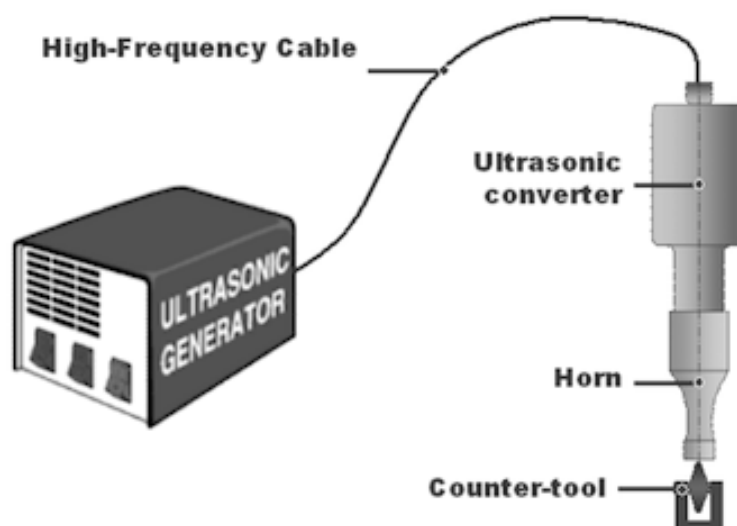


Fig. 4 Representative image of ultrasonic processor [25].

Table 1 Quality of different fruit juices after applying different non-thermal pasteurization methods.

Method	Fruit juice	Target microorganism	Treatment parameters	Log reduction	Quality change	Source
HPP	Orange juice	<i>Escherichia coli</i> O157:H7	500 MPa, 25 °C, 5 min	> 5	2% loss of vitamin C No Brix, pH and color change	Rupasinghe and Yu [26] Aneja <i>et al.</i> [1]
			400 MPa, 40 °C, 1 min		5%-8% loss of vitamin C No Brix, pH and color change	Pivarnik and Worobo [7] Deliza <i>et al.</i> [10]
	Apple juice	<i>E. coli</i> , <i>Listeria</i> and <i>Salmonella</i>	400-600 MPa 15 min	5	Shelf life increased to 14-21 d No Brix, pH and color change	Daher <i>et al.</i> [3]
PEF	Orange juice	<i>E. coli</i>	35 kV/cm, 4 μS, 40 °C	5	8% loss of vitamin A 1% loss of citric acid Brix, pH, vitamin C and viscosity of orange juice unaffected	Rupasinghe and Yu [26] Vega-Mercado <i>et al.</i> [20] Aneja <i>et al.</i> [1]
	Cranberry juice	<i>Byssoschlamys fulva</i> conidiospores	36.53 kV/cm, 3.3 μS, 22 °C	6	No pH change	Raso <i>et al.</i> [8]
UV-C	Orange juice	<i>E. coli</i>	> 230 J/L	2-3	Maximum aroma and color of the treated fruits being maintained 11% loss of vitamin C	Abdul Karim Shah <i>et al.</i> [27] Kaoutchma [17] Rupasinghe and Yu [26]
	TCW	<i>E. coli</i> W1485 <i>Listeria monocytogenes</i>	254 nm, R _e level 397.7	5	Slight change in pH (5.1-5.4) No significant changes in aroma & flavor	Gautam <i>et al.</i> [28]
US	Orange juice	Total aerobic plate count	500 kHz, 240 W, 15 min, 60 °C	3-4	No significant changes in Brix and titratable acidity Significant changes in juice pH, color, non-enzymatic browning, cloud value and ascorbic acid	Zoran <i>et al.</i> [22] Aneja <i>et al.</i> [1]
	Cactus pear juice	<i>E. coli</i>	90% amplitude for 5 min	Non-detectable level	pH, titratable acidity and soluble solids unaffected after storage of 2 d	Cruz-Cansino <i>et al.</i> [24] Aneja <i>et al.</i> [1]

HPP: high-pressure processing; PEF: pulsed electric field; UV-C: ultraviolet-C radiation; US: ultra-sonication; TCW: tender coconut water.

lost by PEF. No significant changes in aroma, color, Brix, pH and titratable acidity were found by non-thermal processing compared to the traditional thermal preservation methods. After applying 400-600 MPa of HPP on apple juice *E. coli*, *Listeria* and *Salmonella* were inactivated and no significant changes were observed in pH, Brix and color during the storage period of 14-21 d. UV-C was applied on TCW and slight changes of pH occurred and aroma and flavor were unaffected. Cactus pear juice was preserved using US at 90% amplitude for 5 min and led to inactivate *E. coli* into undetectable levels without effect on pH, total acids and soluble solids.

7. Applications of Non-thermal Preservation Methods for Liquid Food Industry

In some countries, HPP liquid food is produced and commercialized, including fruit & vegetable juices (citric juices, organic juices, low citric juices and vegetable juices), guacamole and Mexican sauces [10]. The shelf life of the HPP product is increased up to 14-28 d by applying high hydrostatic pressure with a range 100-700 MPa [3].

Since the other methods are still in pilot scale, additional pilot studies need to make those methods become actual substitutes for thermal processing.

8. Conclusions

Today the consumer perception is high for fresh, minimally processed liquid foods with high nutrient content. The best preservation technology must maintain the quality of the product while providing convenient shelf life as well as ensuring the flavor and nutritional property.

Emerging non-thermal pasteurization methods are applied as substitutions to conventional thermal processes in order to maintain the safety of food products and also maintain their qualities.

HPP, PEF, US and UV-C light treatments are better alternative methods for the thermal pasteurization methods.

High installment cost, limited on type of food & type of micro flora, deterioration of some nutrients (vitamin C, protein) & some valuable enzymes are the major drawbacks of these methods.

Acknowledgment

The authors thank the University of Sri Jayewardenepura, Sri Lanka for the financial assistance (Grant No.ASP/01/RE/SCI/2017/51).

References

- [1] Aneja, K. R., Dhiman, R., Aggarwal, N. K., and Aneja, A. 2014. "Emerging Preservation Techniques for Controlling Spoilage and Pathogenic Microorganisms in Fruit Juices." *International Journal of Microbiology* 201-4.
- [2] Chawla, R., Patil, G. R., and Singh, A. K. 2011. "High Hydrostatic Pressure Technology in Dairy Processing: A Review." *Journal of Food Science and Technology* 48 (3): 260-8.
- [3] Daher, D., Le Gourrierc, S., and Pérez-Lamela, C. 2017. "Effect of High Pressure Processing on the Microbial Inactivation in Fruit Preparations and Other Vegetable Based Beverages." *Agriculture* 7 (9): 72.
- [4] Awuah, G. B., Ramaswamy, H. S., and Economides, A. 2007. "Thermal Processing and Quality: Principles and Overview." *Chemical Engineering and Processing: Process Intensification* 46 (6): 584-602.
- [5] Torkamani, A. E., and Niakousari, M. 2011. "Impact of UV-C Light on Orange Juice Quality and Shelf Life." *International Food Research Journal* 18 (4): 1265-8.
- [6] Toepfl, S., Mathys, A., Heinz, V., and Knorr, D. 2006. "Potential of High Hydrostatic Pressure and Pulsed Electric Fields for Energy Efficient and Environmentally Friendly Food Processing." *Food Reviews International* 22 (4): 405-23.
- [7] Pivarnik, L. F., and Worobo, R. 2014. "Non-thermal or Alternative Food Processing Methods to Enhance Microbial Safety and Quality." *USDA-NIFA* 1-2.
- [8] Raso, J., Calderón, M. L., Góngora, M., Barbosa-Cánovas, G., and Swanson, B. G. 1998. "Inactivation of Mold Ascospores and Conidiospores Suspended in Fruit Juices by Pulsed Electric Fields." *LWT-Food Science and Technology* 31 (7-8): 668-72.
- [9] Tauscher, B. 1995. "Pasteurization of Food by Hydrostatic Pressure: Chemical Aspects." *Z Lebensm. Unters. Forsch.* 200: 3-13.
- [10] Deliza, R., Rosenthal, A., Abadio, F. B. D., Silva, C. H., and Castillo, C. 2005. "Application of High Pressure

- Technology in the Fruit Juice Processing: Benefits Perceived by Consumers.” *Journal of Food Engineering* 67 (1): 241-6.
- [11] Ramaswamy, H. S., Riahi, E., and Idziak, E. 2003. “High-Pressure Destruction Kinetics of *E. coli* (29055) in Apple Juice.” *Journal of Food Science* 68 (5): 1750-6.
- [12] Barba, F. J., Zhu, Z., Koubaa, M., Sant’Ana, A. S., and Orlie, V. 2016. “Green Alternative Methods for the Extraction of Antioxidant Bioactive Compounds from Winery Wastes and By-Products: A Review.” *Trends in Food Science & Technology* 49: 96-109.
- [13] Yıkımsı, S. 2016. “New Approaches in Non-thermal Processes in the Food Industry.” *International Journal of Nutrition and Food Sciences* 5 (5): 344-51.
- [14] Guerrero-Beltrán, J. A., and Barbosa-Cánovas, G. V. 2004. “Advantages and Limitations on Processing Foods by UV Light.” *Food Science and Technology International* 10 (3): 137-47.
- [15] Keyser, M., Müller, I. A., Cilliers, F. P., Nel, W., and Gouws, P. A. 2008. “Ultraviolet Radiation as a Non-thermal Treatment for the Inactivation of Microorganisms in Fruit Juice.” *Innovative Food Science & Emerging Technologies* 9 (3): 348-54.
- [16] Tran, M. T. T., and Farid, M. 2004. “Ultraviolet Treatment of Orange Juice.” *Innovative Food Science & Emerging Technologies* 5 (4): 495-502.
- [17] Koutchma, T. 2009. “Advances in Ultraviolet Light Technology for Non-thermal Processing of Liquid Foods.” *Food Bioprocess Technol.* 2: 138-55.
- [18] Barrett, D. M., and Lloyd, B. 2012. “Advanced Preservation Methods and Nutrient Retention in Fruits and Vegetables.” *Journal of the Science of Food and Agriculture* 92 (1): 7-22.
- [19] Raso, J., and Barbosa-Cánovas, G. V. 2003. “Non-thermal Preservation of Foods Using Combined Processing Techniques.” *Critical Reviews in Food Science and Nutrition* 43 (3): 265-85.
- [20] Vega-Mercado, H., Martín-Belloso, O., Qin, B. L., Chang, F. J., Góngora-Nieto, M. M., Barbosa-Cánovas, G. V., and Swanson, B. G. 1997. “Non-thermal Food Preservation: Pulsed Electric Fields.” *Trends in Food Science & Technology* 8 (5): 151-7.
- [21] New Food. 2007. “Pulsed Electric Field Processing of Foods.” *New Food magazine*. Accessed August 20, 2018. <https://www.newfoodmagazine.com/article/1594/pulsed-electric-field-processing-of-foods/>.
- [22] Zoran, H., Jambrak, A. R., Vukušić, T., and Stulić, V. 2016. “Effects of the High Power Ultrasound on Microorganisms in Fruit.” *MOJ Food Process Technol* 2 (5): 00052.
- [23] O’donnell, C. P., Tiwari, B. K., Bourke, P., and Cullen, P. J. 2010. “Effect of Ultrasonic Processing on Food Enzymes of Industrial Importance.” *Trends in Food Science & Technology* 21 (7): 358-67.
- [24] Cruz-Cansino, N. D. S., Reyes-Hernández, I., Delgado-Olivares, L., Jaramillo-Bustos, D. P., Ariza-Ortega, J. A., and Ramírez-Moreno, E. 2016. “Effect of Ultrasound on Survival and Growth of *Escherichia coli* in Cactus Pear Juice during Storage.” *Brazilian Journal of Microbiology* 47 (2): 431-7.
- [25] DECOUP+. “Our Ultrasonic Technology”, DECOUP.com. Accessed August 23, 2018. <http://www.decoup.com/ultrasonic-technology/>.
- [26] Rupasinghe, H. V., and Yu, L. J. 2012. “Emerging Preservation Methods for Fruit Juices and Beverages.” In *Food Additive*, InTech.
- [27] Abdul Karim Shah, N. N., Shamsudin, R., Abdul Rahman, R., and Adzahan, N. M. 2016. “Fruit Juice Production Using Ultraviolet Pasteurization: A Review.” *Beverages* 2 (3): 22.
- [28] Gautam, D., Umagiliyage, A. L., Dhital, R., Joshi, P., Watson, D. G., Fisher, D. J., and Choudhary, R. 2017. “Non-thermal Pasteurization of Tender Coconut Water Using a Continuous Flow Coiled UV Reactor.” *LWT-Food Science and Technology* 83: 127-31.