

2015 International Nonthermal Processing Workshop

Sustainable innovation based on science and applied research of nonthermal technologies

PROCEEDINGS



Athens, Greece
2015

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*Sustainable innovation based on science and applied research
of nonthermal technologies*

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Editors

Petros Taoukis
Nikolaos Stoforos
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ATHENS, GREECE
2015

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The Nonthermal Processing division is a global organization with members from food processors, equipment manufacturers, ingredient suppliers, regulatory agencies, research institutions, and universities in North and South America, Europe, Asia, and the rest of the world.

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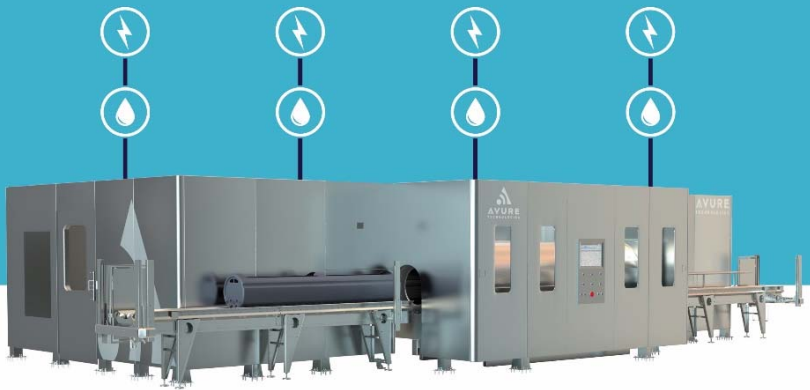
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PREFACE

The International Nonthermal Processing Workshop is a yearly event organized by the Nonthermal Processing Division of the Institute of Food Technologists (IFT) and the European Federation of Food Science and Technology (EFFoST).

The 2015 International Nonthermal Processing Workshop with the theme “*Sustainable innovation based on science and applied research of nonthermal technologies*” took place in Athens, Greece on 12-13 November 2015, organized by the Laboratory of Food Chemistry and Technology, School of Chemical Engineering, National Technical University of Athens (NTUA). The Workshop served as a global meeting point and forum for experts in the field of nonthermal processing of food from academia and research, food professionals, equipment manufacturers and students. The objective was the exchange of state of the art knowledge on developments on research and applications and the enhancement of progress in the field via interaction and synergism.

The Workshop highlighted original research results and developments arising both from the deeper understanding of the phenomena and mechanisms of nonthermal processes based on basic science and engineering and from applied studies on food components and systems targeting sustainable innovations. The scientific program included 56 oral and 58 poster presentations presented in 3 plenary sessions, 8 thematic oral sessions and a poster session. The 2015 International Nonthermal Processing Workshop joined the 29th EFFoST International Conference on the 12th of November by sharing 2 oral sessions with the theme: *Advances in research and applications of nonthermal technologies for food processing and preservation*.

The Organizing Committee was honoured and pleased to welcome more than 150 participants from 34 countries, experts in the field that enjoyed a stimulating two days of science and Greek hospitality in Athens the birthplace of congresses.

Petros Taoukis



*Chairman of the Organizing Committee
2015 International Nonthermal Processing Workshop*

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Non-thermal technologies for *Alicyclobacillus acidoterrestris* inactivation in apple juice

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ABSTRACT

Non-thermal processes have been applied to food products with the purpose of eliminating spoilage and microorganisms. Ultraviolet-C (UV-C) radiation and ultrasound (US), combined or not with less severe temperature conditions, are giving promising results. In fruit juices, namely apple juices, *Alicyclobacillus acidoterrestris* is a concern, because it is responsible for quality degradation while being a spore-forming bacterium, able to grow at low pH (2.5–6.0) and high temperature (25–70 °C) conditions. The main objective of this work was to study the influence of UV-C radiation, ultrasounds and combinations of both treatments on *A. acidoterrestris* inactivation in apple juices. Ultrasounds were also tested at 60 °C (thermosonication). Commercially available juices were artificially inoculated with the bacterium, with initial loads around 10⁷ CFU/mL. The juices were then exposed to the following treatments, for different times: (i) UV-C radiation with 13.44 W/m² of intensity; (ii) ultrasonication (US) with frequency of 35 kHz and power level of 120–480 W; (iii) thermosonication at 60 °C and (iv) combination of UV-C and US (testing both orders of treatments). The inactivation rate was estimated by fitting a linear model to log-survival data obtained from each treatment. Results showed that ultrasounds had no significant effect on *A. acidoterrestris* inactivation. When UV-C radiation was applied, the number of spores decreased drastically (around 5-log reduction, which attains US Food and Drug Administration requirements) after 8 min of treatment. The combined treatment US followed by UV-C resulted in higher inactivation (around 6-log reduction) after 25 min of exposure. Inverting the order of treatments, *i.e.* UV-C followed by US, inactivated approximately 4-log of initial microbial load, after 30 minutes of treatment. Overall it can be concluded that UV-C radiation and combination of US with UV-C are promising treatments with a drastic impact on the loads of *A. acidoterrestris* in apple juices.

Keywords: Ultraviolet-C radiation; ultrasound; apple juices; *Alicyclobacillus acidoterrestris*; inactivation

INTRODUCTION

Alicyclobacillus acidoterrestris is a thermoacidophilic, non-pathogenic, spore-forming bacterium that grows at pH values ranging from 2.5 to 6.0 and temperatures of 25 to 70 °C (Yamazaki et al., 1996). Such thermoacidophilic properties constitute the main obstacle to the inactivation of this organism (Bae et al., 2009; Baysal et al., 2013). Spores are able to survive at high temperatures (Splittstoesser et al., 1998) and can germinate and grow in low pH ranges, leading to the spoilage of acidic fruit juices (Walker and Phillips, 2008).

Thermal pasteurization is efficient in reducing the number of viable microorganisms in foods. However, excessive heat exposure may generate undesirable off-flavours, particularly for apple juice (Splittstoesser et al., 1996; Lu et al., 2010). To reduce the negative impacts of high temperature processes, alternative non-thermal technologies as efficient as thermal pasteurization ones, but with minor impacts on the products quality features, are promising fields of investigation.

Among non-thermally based processes, ultraviolet (UV-C) radiation and ultrasound (US) are technologies that have been applied to inactivate harmful microbes in liquid foods (Lu et al., 2010; Keyser et al., 2008; Franz et al., 2009; Caminiti et al., 2012). Microorganisms that are exposed to UV-C light are affected at DNA (deoxyribonucleic acid) level (Terry and Joyce 2004; Perkins-Veazie et al. 2008), which compromises their survival. Power ultrasound is capable of inducing cavitation to inactivate microorganisms in foods (Piyasena

et al., 2003). Cavitation is the process whereby micro bubbles are grown and collapsed within a liquid medium (Gabriel 2012; Gao et al., 2014). This action results in hot spots and microbial cell disruptions because of increased temperature and pressure (Bermudez-Aguirre and Barbosa-Canovas 2012; Mohideen et al., 2015). However, as a preservation method, application of ultrasound alone is not efficient enough to kill all microorganisms. If high power levels of US are used, nutritional and sensorial properties of foods may be adversely affected (Ferrario et al., 2015). Therefore, combination of ultrasound with other stressing conditions is often applied: ultrasound with high-pressure conditions (manosonication) or ultrasound with high temperature (thermosonication) are examples (Chemat et al., 2011). Combining ultrasound with a heat treatment may decrease the time needed for microbial inactivation. However, it depends on the ultrasound waves amplitude, exposure time, composition and volume of food to process and temperature selected (Lee et al., 2009; Chemat et al., 2011).

In this context, the aim of this work was to study the influence of UV-C radiation, ultrasounds and combinations of both treatments on contaminated apple juices with *A. acidoterrestris*. Thermosonication at 60 °C was also tested. The inactivation behaviour of the microorganisms was assessed and the impacts of each treatment were compared.

MATERIALS & METHODS

Spores suspension

The growth of viable *A. acidoterrestris* CCT 4384 cells was carried out in four slant tubes containing potato dextrose agar (PDA), pH 3.5, incubated at 44 °C for 3 days. The biomass obtained was added to 10 mL AAM broth (*Alicyclobacillus acidocaldarius* medium) formulated according to Murakami et al. (1998) and incubated at 45 °C for 24 hours. The enrichment broth was spread over Petri dishes containing AAM medium supplemented with MnCl₂.4H₂O of 0.05% and 1.5% agar (pH 4) and incubated for 10 days at 45 °C. After microscopic confirmation of spores per staining using Malachite Green, 10 mL of water was added to each plate followed by scraping. The spores obtained were centrifuged five times at 3500 rpm (2000 xg) for 15 minutes. The supernatant was then removed, re-suspended in sterile water and kept in refrigerated conditions until further use.

Spores were enumerated according to methodology reported by Silva et al. (2000). The medium was composed by three solutions mixed after sterilization (at 121 °C for 10 min): (i) BAT medium: CaCl₂.7H₂O, 0.25 g; MgSO₄.7H₂O, 0.5 g; (NH₄)₂SO₄, 0.2 g; yeast extract, 2 g; glucose, 5 g; KH₂PO₄, 3 g; and distilled water, 500 mL, adjusted to pH 4.0 with H₂SO₄; (ii) trace elements solution: 1 mL of trace elements solution (ZnSO₄.7H₂O, 0.1 g; MnCl₂.4H₂O, 0.03 g; H₃BO₃, 0.3 g; CoCl₂.6H₂O, 0.2 g; CuCl₂.2H₂O, 0.01 g; NiCl₂.6H₂O, 0.02 g; Na₂MoO₄.2H₂O, 0.03 g; distilled water, 1 L); (iii) agar, 15 g; distilled water, 500 mL.

Incubation of the inoculated plates was at 45 °C for 2 days. Concentration of spores' suspension was 2×10^7 CFU/mL.

Fruit juice samples

Pasteurized apple juice available in the market was used in the experiences. The pH values of the juices were measured by a pH meter (Crison GLP22, Switzerland) and soluble solid content (°Brix) was determined by a refractometer (Atago, China). The juice pH averaged 3.2 and soluble solid content was approximately 10.5 °Brix.

Each juice sample was a volume of 25 mL of apple juice artificially inoculated with 0.05 mL of spores suspension (2×10^7 CFU/mL) placed in a single layer in a Petri dish (90 mm). The samples were then submitted to inactivation treatments.

Inactivation treatments

UV-C treatments were conducted in a camera containing four germicidal lamps (TUV 15W/G15 T8, Philips, Holland), emitting at 254 nm. Prior to use, UV-C lamps were stabilized by turning them on for 30 minutes. Juice samples in Petri dishes were placed 30 cm below the lamps. A constant stirring (magnetic agitation) was imposed during treatment in order to ensure equal distribution of UV dose through the sample.

The tested UV-C intensity was measured by a photo-radiometer (DELTA OHM LP9021 UVC), giving corresponding dose of 13.44 W/m². At a given dose of radiation, samples of 1 mL were taken after different exposure times.

Sonication was carried out in ultrasonic bath (BANDELIN, Germany) with 35 kHz frequency and 120-480 W power levels. Apple juice was placed in an Erlenmeyer flask and bacterial culture was inoculated at the initial stage of treatment. A constant stirring (magnetic agitation) was imposed during treatment in order to

ensure equal distribution of the sample. Samples of 1 mL were taken after different exposure times. Thermosonication was performed in the same way, imposing a temperature of 60 °C to the ultrasonic bath water.

Two combined treatments were also tested: (i) US+UV - the juice was exposed for 15 min at US with 35 kHz frequency and 120-480 W power levels and then for 10 min at UV-C radiation with intensity of 13.44 W/m²; (ii) (UV+US) - the juice was exposed for 5 min at UV-C radiation with intensity of 13.44 W/m² and then for 30 min at US with 35 kHz frequency and 120-480 W power levels. Samples of 1 mL were taken after different exposure times of each combined treatments.

A thermal treatment in a thermostatic water bath at 95 °C was used as a control of the non-thermal treatments efficiency.

After each treatment, microbiological analysis of the juices were carried out.

Microbiological analysis

After inactivation treatments, survival spore in juice samples were determined by spread plating the diluted samples onto *Bacillus acidoterrestris* (BAT) agar (pH 4). The plates were incubated at 45 °C for 2–3 days. Microbial counts were performed in triplicate and expressed as CFU/mL.

Data analysis

If log-survival of microorganisms varies linearly with time due to a treatment exposure, the following model can express the kinetic tendency:

$$\log\left(\frac{N}{N_0}\right) = -kt \quad (1)$$

where N_0 is the initial microbial load of the juice (CFU/mL), N the microbial load (CFU/mL) at a given treatment time t (min), and k the inactivation rate (min⁻¹).

The model presented in equation 1 was fitted to experimental data of *A. acidoterrestris* inactivation and the model parameter k for each treatment was obtained by regression analysis procedures using IBM SPSS® Statistics® 20 for Windows® (SPSS Inc., Chicago, USA).

RESULTS & DISCUSSION

Experimental inactivation data of *A. acidoterrestris* in apple juice applying UV-C radiation, ultrasounds, and combinations of treatments testing both orders (UV+US and US+UV) are in Figure 1. Results obtained from a thermal treatment at 95 °C are also included. All data are expressed in terms of $\log(N/N_0)$ to avoid the influence of the initial microbial loads. The magnitude of N_0 used in all the experiments was around 10⁵ CFU/mL.

Food and Drug Administration (FDA) reported a primary performance standard for non-thermal processing methods of a minimum of 5 log-reduction of spoilage and potentially pathogenic bacteria for fruit juices (Tiwari and Muthukumarappan, 2012). Industrial requirements are not so restricted, this meaning that 2 log-reductions are accepted for an antimicrobial agent (Tiwari and Rice, 2012). These requirements allow understanding the achievements based on the experimental results obtained in this work.

Our results showed that ultrasounds had a minor effect on *A. acidoterrestris* inactivation, reducing only 0.6-log after 30 minutes of treatment. Djas et al. (2011) reported less than a 0.12 log reduction of *A. acidoterrestris* spores after the application of single US (10 min, 330 W) in concentrate apple juice. Ferrario et al. (2015) investigated the effect of ultrasound (600 W, 20 kHz and 95.2 mm wave amplitude; 10 or 30 min at 20, 30 or 44 ± 1 °C) on the inactivation of *A. acidoterrestris* ATCC 49025 spores and *Saccharomyces cerevisiae* KE162 inoculated in commercial and natural squeezed apple juices. They reported that US treatment was unable to inactivate *A. acidoterrestris* spores, as no reductions were observed after 30 min of sonication.

Thermosonication (ultrasounds tested at 60 °C) had an impact similar to the one observed by US alone (data not shown) and was not effective in the inactivation of *A. acidoterrestris* in apple juice.

When UV-C radiation was applied, the number of spores decreased drastically (around 5-log reduction, which attains FDA requirements) after 8 min of treatment. Baysal et al. (2013) studied the effect of short wave ultraviolet light (UV-C) on the inactivation of *A. acidoterrestris* DSM 3922 spores in commercial pasteurized white grape and apple juices. The inactivation of *A. acidoterrestris* spores in juices was evaluated at different radiation intensities (3.8, 7.1 and 13.1 W/m²) and exposure times (till a maximum of 15 min), at a constant depth (0.15 cm). The best reduction (5.5 log-cycles) was achieved in grape juice when

the UV intensity was 13.1 W/m². For apple juice and under the same conditions, the maximum inactivation was approximately 2 log-cycles, lower than the ones obtained in our work.

The combined treatment US followed by UV-C resulted in higher inactivation (around 6-log reduction) after 25 min of exposure. Inverting the order of treatments, *i.e.*, UV-C followed by US, a decrease of approximately 4-log of initial microbial load occurred after 30 minutes of treatment. These results are similar to the ones obtained with a thermal treatment at 95 °C.

Based on the results, it can be concluded that the combination of US+UV treatments have an additive effect on spores inactivation. This means that when a treatment is applied first and then followed by a second one, the impact is the same if each of the treatments are applied alone for the same time period, and no synergetic effects are observed. For each treatment and combination of treatments, inactivation rates (*k*) were estimated by fitting the model presented in equation 1 to experimental data (Table1). It is possible to verify that inactivation rates were similar when US were applied alone (0.025±0.005 min⁻¹) or when US were applied before UV treatment (0.019±0.002 min⁻¹).

However, a synergetic effect was observed when UV was applied before de US treatment. In such situation, the US treatment applied resulted in a higher inactivation rate when compared to the US treatment applied alone. When applied alone, US treatment resulted in an inactivation rate of 0.025±0.005 min⁻¹; when applied after UV-C radiation, the US treatment showed an inactivation rate of 0.091±0.014 min⁻¹, which was significantly higher.

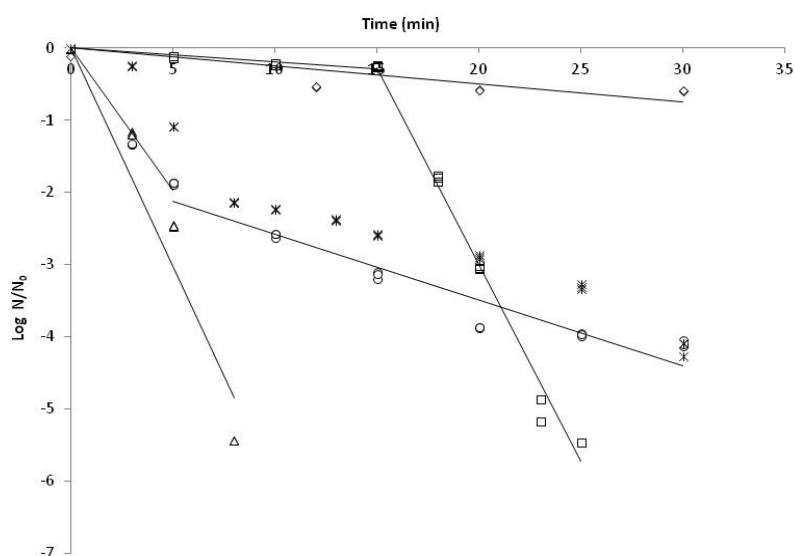


Figure 1. *A. acidoterrestris* inactivation in apple juice applying different treatments: (Δ) UV-C, (◇) US, (□) US+UV, (○) UV+US and (×) 95 °C. Lines represent model fits for each treatment individually (eq. 1).

Table 1. Inactivation rates of *A. acidoterrestris* spores in apple juices obtained for each non-thermal treatment; confidence intervals at 95% (CI_{95%}) and correlation coefficients (R) are included

Treatment	First treatment		Second treatment	
	$k(\text{min}^{-1}) \pm \text{CI}_{95\%}/2$	R	$k(\text{min}^{-1}) \pm \text{CI}_{95\%}/2$	R
UV-C	0.606±0.069	0.97	-	-
US	0.025±0.005	0.76	-	-
UV+US	0.393±0.025	0.99	0.091±0.014	0.96
US+UV	0.019±0.002	0.96	0.546±0.035	0.99

Some published works studied spore inactivation by the combination of ultrasound and other technologies (Sagong et al., 2013; Lopez-Malo et al., 2005; Coronel et al., 2011). Such combinations can be considered good alternatives to thermal treatments. Char et al. (2010) applied two non-thermal techniques to inactivate *E. coli* ATCC 35218 present in some fruit juices: high-intensity ultrasound (USc) and short-wave ultraviolet radiation (UV-C). In apple juice, UV-C radiation resulted in higher microbial inactivation than USc

treatment. In orange juice, the single effect of UV-C light was enhanced by the combination with USc. Combined treatments were more effective in simultaneous rather than in a series of USc+UV-C arrangement.

Overall our results allow concluding that UV-C radiation and combined treatments of UV-C followed by US technologies could be used as good non-thermal alternatives for apple juice pasteurization.

CONCLUSION

It can be concluded that UV-C radiation and combined treatments of UV-C followed by US are promising treatments with a drastic impact on the loads of *A. acidoterrestris* in apple juices. UV-C applied prior to US resulted in a synergetic effect on inactivation rates. Ultrasounds applied alone had no significant impact on spores inactivation.

UV-C radiation and combinations of the treatment with ultrasounds could be used as an alternative to thermal treatments for apple juices.

This research opens new opportunities of investigation that embrace studies on quality characteristics of the products and safety standards.

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REFERENCES

- Bae Y.Y., Lee H.J., Kim S.A. & Rhee M.S. 2009. Inactivation of *Alicyclobacillus acidoterrestris* spores in apple juice by supercritical carbon dioxide. *International Journal Food Microbiology*, 136, 95–100.
- Baysal A.H., Molva C. & Unluturk S. 2013. UV-C light inactivation and modeling kinetics of *Alicyclobacillus acidoterrestris* spores in white grape and apple juices. *International Journal Food Microbiology*, 166, 494–498.
- Bermudez-Aguirre D. & Barbosa-Cánovas G.V. 2012. Inactivation of *Saccharomyces cerevisiae* in pineapple, grape and cranberry juices under pulsed and continuous thermo-sonication treatments. *Journal of Food Engineering*, 108, 383–392.
- Caminiti I.M., Palgan I., Muñoz A., Noci F., Whyte P., Morgan D.J., Cronin D.A. & Lyng J.G. 2012. The effect of ultraviolet light on microbial inactivation and quality attributes of apple juice. *Food Bioprocess Technology*, 5, 680–686.
- Char C.D., Mitiliniaki E., Guerrero S.N. & Alzamora, S.M. 2010. Use of high-intensity ultrasound and UV-C light to inactivate some microorganisms in fruit juices. *Food Bioprocess Technology*, 3, 797–803.
- Chemat F., Huma Z. & Khan M.K. 2011. Applications of ultrasound in food technology: processing, preservation and extraction. *Ultrasonics Sonochemistry*, 18, 813–835.
- Coronel C., Jimene M., Lopez-Malo A. & Palou E. 2011. Modelling thermosonication inactivation of *Aspergillus flavus* combining natural antimicrobial at different pH. *Procedia Food Science*, 1, 1007–1014.
- Djas M., Bober M. & Henczka M. 2011. New methods for inactivation of *Alicyclobacillus acidoterrestris* spores in apple juice concentrate. *Challenges of Modern Technology*, 2, 46–49.
- Ferrario M., Alzamora S.M. & Guerrero S. 2015. Study of the inactivation of spoilage microorganisms in apple juice by pulsed light and ultrasound. *Food Microbiology*, 46, 635–642.
- Franz C.M., Specht I., Cho G.S., Graef V. & Stahl M.R. 2009. UV-C inactivation of microorganisms in naturally cloudy apple juice using novel inactivation equipment based on dean vortex technology. *Food Control*, 20, 1103–1107.
- Gabriel, A.A. 2012. Microbial inactivation in cloudy apple juice by multi-frequency *Dynashock* power ultrasound. *Ultrasonics Sonochemistry*, 19, 346–351.
- Gao S., Lewis G.D., Ashokkumar M. & Hemar Y. 2014. Inactivation of microorganisms by low-frequency high-power ultrasound: Effect of growth phase and capsule properties of the bacteria. *Ultrasonics Sonochemistry*, 21, 446–453.
- Keyser M., Muller I.A., Cilliers F.P., Nel W. & 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, 348–354.
- Lee H., Zhou B., Liang W., Feng H. & Martin S.E. 2009. Inactivation of *Escherichia coli* with sonication, manosonication, thermosonication and manothermosonication: microbial responses and kinetics modeling. *Journal of Food Engineering*, 93, 354–364.

- Lopez-Malo A., Palou E., Jimenez-Fernandez M., Alzamora S.M. & Guerrero S. 2005. Multifactorial fungal inactivation combining thermosonication and antimicrobials. *Journal of Food Engineering*, 67, 87-93.
- Lu G., Li C., Liu P., Cui H., Xia Y. & Wang J. 2010. Inactivation of microorganisms in apple juice using an ultraviolet silica-fiber optical device. *Journal of Photochemistry and Photobiology B: Biology*, 100, 167–172.
- Mohideen F.W., Solval K.M., Li J., Zhang J., Chouljenko A., Chotiko A., Prudente A.D., Bankston J.D. & Sathivel S. 2015. Effect of continuous ultra-sonication on microbial counts and physico-chemical properties of blueberry (*Vaccinium corymbosum*) juice. *LWT Food Science and Technology*, 60, 563–570.
- Murakami M., Tedzuka H. & Yamasaki K. 1998. Thermal resistance of *Alicyclobacillus acidoterrestris* spores in different buffers and pH. *Food Microbiology*, 15, 577-582.
- Perkins-Veazie P., Collins J.K. & Howard L. 2008. Blueberry fruit response to postharvest application of ultraviolet radiation. *Postharvest Biology and Technology*, 47, 280-285.
- Piyasena P., Mohareb E. & McKellar R.C. 2003. Inactivation of microbes using ultrasound: A review. *International Journal of Food Microbiology*, 87, 207–216.
- Sagong H., Cheon H., Kim S., Lee S., Park K., Chung M., Choi Y. & Kang D. 2013. Combined effects of ultrasound and surfactants to reduce *Bacillus cereus* spores on lettuce and carrots. *International Journal of Food Microbiology*, 160, 367-372.
- Silva F.M., Gibbs P. & Silva C.L.M. 2000. Establishing a new pasteurisation criterion based on *Alicyclobacillus acidoterrestris* spores for shelf-stable high-acidic fruit products. *Fruit Processing*, 10, 138–141.
- Splittstoesser D.F., McLellan M.R. & Churey J.J. 1996. Heat resistance of *Escherichia coli* O157:H7 in apple juice. *Journal of Food Protection*, 59, 226–229.
- Splittstoesser D.F., Lee C.Y. & Churey, J.J. 1998. Control of *Alicyclobacillus* in the juice industry. *Dairy, Food and Environmental Sanitation*, 18, 585–587.
- Terry L.A. & Joyce D.C. 2004. Influence of growing conditions on efficacy of acibenzolar and botryticides in suppression of *Botrytis cinerea* on strawberry fruit. *Advances in Strawberry Research*, 23, 11-19.
- Tiwari B.K. & Muthukumarappan K. 2012. Ozone in fruit and vegetable processing. In: O'Donnell C., Tiwari B.K., Cullen P.J., Rice R.G. (Eds.), *Ozone in Food Processing*. Wiley-Blackwell, West Sussex, England, 55–80.
- Tiwari B.K. & Rice R.G. 2012. Regulatory and Legislative Issues. In: O'Donnell C., Tiwari B.K., Cullen P.J. & Rice R.G. (Eds.). *Ozone in Food Processing*. Blackwell Publishing Ltd, Oxford, 7-17.
- Walker M. & Phillips C.A. 2008. *Alicyclobacillus acidoterrestris*: an increasing threat to the fruit juice industry? *International Journal of Food Science and Technology*, 43, 250–260.
- Yamazaki K., Tedzuka H. & Shinano, H. 1996. Isolation and identification of *Alicyclobacillus acidoterrestris* from acidic beverages. *Bioscience, Biotechnology and Biochemistry*, 60, 543–545.