Biointerface Research in Applied Chemistry
Platinum Open Access Journal (ISSN: 2069-5837)

Review
Volume 11, Issue 4, 2021, 11553 - 11561
https://doi.org/10.33263/BRIAC114.1155311561

High-Pressure Processing in Food

Shakiba Narjabadi Fam [1], Kianoush Khosravi-Darani [2], Ramona Massoud [3,*], Armita Massoud [4]

[1] Department of Food Science and Technology, Science and Research Branch, Islamic Azad University, Tehran, Iran; sh.narjabadi@yahoo.com (S.N.F.);
[2] Research Department of Food Technology, National Nutrition and Food Technology Research Institute, Faculty of Nutrition Sciences and Food Technology, Shahid Beheshti University of Medical Sciences, Tehran, Iran; kiankh@yahoo.com (K.K.D.);
[3] Department of Food Science and Technology, Iran Standard Organization Tehran, Iran; rm8059@yahoo.com (R.M.);
[4] Department of medicine, Tehran medicine university, Tehran, Iran; armitamassoud@yahoo.com (A.M.);
* Correspondence: rm8059@yahoo.com;

Scopus Author ID 57038566400
Received: 27.10.2020; Revised: 30.11.2020; Accepted: 5.12.2020; Published: 12.12.2020

Abstract: Thermal processing has been the most common method in food processing technology, but it has eliminated the quality of fresh type food (nutritionally and sensorial). Therefore, the non-thermal methods emerged, and High-Pressure Processing (HPP), applying 100 to 1000 MPa for a short period, is the most popular one due to maintaining the food's nutritional and sensory characteristics extending the shelf-life well as eliminating the level of the microorganism. HPP is an environmentally friendly technology that helps to decrease energy consumption. It can be used in nearly all food industries, from milk to meat, as a novel preserving method. This article reviews the effects of this innovative processing technology on food quality. The microbial effects in some food categories and extending the shelf life are explained. HPPs' advantages and limits compared to thermal processing are highlighted.

Keywords: high pressure; processing; microorganism; food; quality.

1. Introduction

High-pressure processing (HPP) is a way to process foodstuffs where food goes under high pressures up to 900 MPa. It can be used in the food industry alone or with some other conventional techniques [1]. HPP is a novel non-thermal process to stop pathogenic spoilage related to food [2]. In High-pressure processing, known as high hydrostatic pressure, liquids and solid foods are subjected to 100 to 900 MPa pressure, which is a high pressure and would be so specialized for preventing certain enzymes' growth microorganisms in food. By the HPP processing, foods will remain more fresh and desirable than the other thermal processes [3].

Nowadays, there is an increasing trend for more fresh and nutritious food around the world. HHP processing does not affect the physical, chemical, and sensory properties of foodstuffs [4]. For preventing microbial and chemical changes in food, it should be treated with processing technologies so the food products would suit the customers' needs while keeping the main quality [5]. A number of the assorted techniques that can be used for preserving food are as follows: heat adding or removing, dehydration, freezing, and applying salt, sugar [6]. For having food in distant markets, they should be converted to more stable forms. In this way, the most important issue is the shelf life. The unwanted changes in food products' quality would be prevented by controlling the enzymatic, physiochemical, and microbiological activities [5].

Applying heat treatment is so common and easy. However, it also affects the sensory properties and physicochemical characteristics of foodstuff and sensory evaluations. So there was a need for some substituted methods, non-thermal treatments [1]. Amongst non-thermal processing methods such as HPP, pulsed lights, pulse electric field pasteurization, pulsed magnetic field, and ozone treatment, HPP is popular in food processing not only due to its' capacity in food preservation but also the potential of having functional effects [7].

There are small changes during HPP processing, it may affect the non-covalent bonds like hydrogen and also hydrophobic bonds. However, it has no effects on small molecules like amino acids and flavor compounds [1]. Because of the presence of covalent bonds in vitamins, minerals, and flavor compounds, they are rarely influenced by HPP processing; therefore, there are small changes in food qualities like color, flavor, and nutritional value [8]. The application of foods processed with HPP has been improved enormously. It has been applied as an effective commercial process for different food industries like dairy, meat, juices, seafood, jams, fruit, and vegetables [7].

2. HPP Technology

HPP puts high hydrostatic pressure into food through an internal vessel for a specified period of time to inactivate noxious spoilage microorganisms and enzymes. The pressure range from 100 to 1000 MPa, while the atmospheric is nearly 0.1 MPa [9]. This methods' temperature differs from 0 to 100°C. The lower temperatures are used for sensitive heat products that needed to be preserved [7].

HPP is a helpful technique for preserving foods from unwanted enzymes and also harmful microorganisms but, at the same time, keep safe useful compounds like probiotics, antioxidants, and lactoferrin [10-12]. Applying HPP is so interesting and fruitful to the food researchers due to the advantages and opportunities to make new products. The growing trend of this process in the food industry is because of its' other name as the "cold" pasteurization technique, which helps to inactivate the harmful microorganisms without any changes in nutritional values [13].

HPP is generated through three ways [14]: Direct compression by dynamic pressure in pistons; Indirect compression by static pressure seals; Through heating the pressure medium.

The HPP operation is similar to a thermal retort and consists of compression, loading, protecting, and decompression. The foodstuff is put into a vessel and then compressed to the required pressure level and held for the needed time period and after that decompress-ed. Usually, products are held at 300 -600 MPa for 3-5 min. HHP strain vessels are geared up that can be easily used in a short time for loading [15]. HPP process's main factors are pressure, time, temperature, required stress, and decompression time. The product pH, water activity, and packaging material are also important [1].

In this method, the pressure is uniformly and continuously passed through the food samples that depend on the sample's shape and size, which is HPPs' priority to thermal processing [4]. No heat in this processing provides nearly no changes; in the end, nutritional and sensory properties [16]. Therefore, the effect of this unique method on the quality of foodstuffs is describing in this article.

3. HPP Effect On Some Food Quality

3.1. Physiochemical properties.

HPP processing has great impacts on the number of food products [7]. HPP eliminates the physiochemical changes, preserving the color, texture, flavor, and freshness [17]. Some beneficial effects of HPP on food components are mentioned:

3.1.1. Lipids.

HPP treatment (400 – 600 MPa) on canned fish showed a reduction of FFA content (around 50%) during 6-15 months of the frozen storage period, so HPP's inhibitory effect on lipid hydrolysis has been proved in canned fish. Also, the lower peroxide formations have been described in different kinds of canned fish species treated with HPP ($p < 0.05$). These effects were observed to be higher by raising the level of pressure during frozen storage [18]. FFAs accumulation through lipid hydrolysis in fish has no nutritional value. During the frozen fish storage, their presence leads to changes in texture, increases in lipid oxidation, and therefore off-flavor and taste in canned fish [19].

3.1.2. Vitamin C.

HPP protects the ascorbate molecules better than thermal treatments in food products. By this treatment, only less than 5% of vitamin C in orange juice was reduced and lower than 10% of the initial vitamin C content in different fruit products [20-22]. This result would be related to the enzymes (peroxidase, ascorbate oxidase) inactivation through pressure. Also, it shows that the stability of vitamin C juices treated with HPP depends on the food matrix, fruit variety, juicing procedure, and the HPP parameters (orange variety) [20]. Amazingly the vitamin C retention in HPP treatments (200-400 MPa) was greater than 90% [23]. By increasing pressure, the amounts of lactic and acetic acids increase [24].

3.1.3. Health-promoting compounds.

HPP has a positive effect on the number of flavonoids. HPP (200-400) showed a significant increase of total flavonoids (34%) in orange juice ($p < 0.05$). This effect has been attributed to the increasing of the membrane permeability and cell walls disruption. Then, bioactive compounds release and increase their extractability [20]. The effect of HPP depends on the food matrix, processing characteristics, and geographical fruit origin. Therefore, the HPP can produce high-quality orange juices with higher flavonoids as this treatment would increase the extraction of valuable flavonoids [25].

As compared with the other extraction techniques, HPP method showed higher efficiency (90%) in lycopene extraction from tomato waste using high pressure (500 MPa for 1 min) [24, 26].

The two common food wastes with valuable phenolic compounds are olive pomace and grape marc. Olive pomace is made from the solid residual pulp and seeds of olive during its' oil production. Grape marc extracting from seeds and skins is nearly 25 kg in each hundred kg of grape [27, 28]. It is reported that using HPP for extraction of olive pomace and grape marc showed higher yield. Also, Corrales et al. discovered that using the high pressure for anthocyanin extraction from red grape skin ended in better antioxidant levels (nearly 3 times) compare to other extraction methods [29]. Some other studies showed indicated less extreme pressure, about 300 MPa, is needed for phenolic and antioxidant content extraction from citrus peel [30].

3.1.4. Mycotoxin.

HPP is a potential tool in reducing mycotoxin contents in foodstuffs such as HPP treated (400-600 MPa) patulin (PAT) in different fruit juices. It was reported that the most effective pressure level was 600 MPa for 300s that decreased the PAT from 200 to 60 μg/L in sample juices [31], and the possibility of PAT (100 μg/L) degradation in apple juices by HPP and pulsed HPP process was reported as 60 and 72% respectively [32].

The reduction of Aflatoxins (AFs) in HPP treated peanuts after 30 days of storage period. The AFs value after treatment was 0.26 μg/g, respectively. These values were reported to be much lower than the control sample (9.08 μg/g) [33]. Additionally, Deoxynivalenol (DON) and Zearalenone (ZEA) reduction were reported in maize samples after HPP treatment (550 MPa for 20 min), which was almost 100% [34].

3.1.5. Starch Gelatinization-Balakrishn 2020.

Some studies have suggested that using HPP results in reducing the gelatinizing temperature of starch. The higher the pressure, the greater the reduction in [35]. Starch swells up and loses its structure and crystallinity after heating in water. In contrast, the structure of the starch granules is maintained by HPP gelatinization [36].

After HPP treatment, starch gels showed better stability after storage compared to the thermally treated ones, and pressure treatment acted on more stable crystallites. HPP makes denser gels with a lower grade of retrogradation. HPP (100 – 500 MPa) treated starch has shown better emulsion stabilization properties and higher digestibility [37].

3.1.6. Sensory attributes.

HPP can protect the quality of fresh fruit cuts (color, smell, texture, and nutritional value) through inactivating microorganisms and enzymes [38]. It was reported that there was a decrease in the total plate count (about 3 log) in pineapples' fresh-cut by using a pressure treatment (340 MPa) for 15 min [39]. Similarly, the browning in mango cuts was regulated by the application of 800 MPa for 5 min [40]. HPP has been proved to preserve fruit juices and fruit drinks at an industrial scale with an amazing shelf-life. By applying HPP (350 MPa) at 30°C for 1 min, the orange juice shelf life was increased for more than 2 months in the refrigerator [41]. Many types of research have been done on the HPP influences on the quality of meat and its' products, like; the color of beef [42], structural changes in pork [43], microbial inactivation in beef [44], and the oxidation of lipids in beef and poultry [45, 46].

3.2. Microbial properties.

HPP is an effective, preserving method for food products. HPP's important factors in microorganisms' inactivation are pressure, temperature, and holding time [47]. The HPP conditions for the inactivation of some microorganisms in various foodstuffs are mentioned [44]. HPP inactive the microbial cells completely by damaging the microbial cells and destabilizing the cell membrane under the effect of high pressure. HPP also affects the proteins and enzymes that resulted in the inactivation of microorganisms [48]. The inactivation of pathogenic microorganisms in meat by HPP relates to some parameters like pH, water activity, salt content, pressure, processing time, and temperature [49]. In General, it is reported that gram negatives in their growth phase are weaker than gram positives. The 10 to 50 MPa pressure can reduce the growth rate, and the higher pressure levels would cause the microorganism inactivation [48]. HPP causes the cell walls disruption and, therefore, the intracellular constituents' leakage. High pressure (more than100 MPa) makes the cells unable to attach together again after the pressure release. The amount of destruction depends on the membrane structure and bacterial strains [50].

Escherichia coli, the indicator pathogen, needs to at least a 5-log reduction with the combination of time and pressure to ensure the food safety issue [51]. In fruit juices and vegetable products, HPP treatment can make a 5-log reduction of Ecoli, which is needed for pasteurized juices' safety requirements as mentioned in Hazard Analysis and Critical Control Point (HACCP) regulation [52]. In HPP treated acai juice at 400 MPa for 3 min, over 6 log reductions in *E. coli*, *Salmonella,* and *L. monocytogenes* were observed. The most sensitive pathogen among the microorganisms in acai juice was *L. monocytogenes* that successfully a decrease of 6 log was reported at 400 MPa was 1 min [53]. The HPP (600 MPa) for 3 min is needed to effectively reduce Listeria monocytogenes in ready-to-eat meat products [51]. HPP (400 MPa for 1 min) at 20 °C declined over 6 logs of *L. innocua,* but *E. coli* needed 10 min to be reduced the same at the same pressure conditions [33].

Also, HPP is a potent tool in fungi spores inactivation and delay their growth rate. Applying HPP (600 MPa) along with ultrasound (24 kHz) for 30 min on strawberry pureé inactivated the ascospores of Byssochlamys Nivea, a thermal resistant mycotoxins-producing mold, effectively [54]. In addition, some researchers reported that HPP (600MPa) and ultrasound (24 kHz) together inactivated spores of Neosartorya fischeri, another thermal resistant mycotoxin-producing mold on apple juice samples [55]. HPP treatment (600-800 MPa) was observed to inhibit the growth of mycotoxigenic fungi *A. flavus* in peanuts [33].

Amazingly using HPP improved the probiotic bacteria's viability in probiotic products, which is an important issue. Using HPP, positive results were found in probiotic yogurt production with the desired viability of probiotic bacteria. In a study, the milk for yogurt production homogenized at 100, 150, and 200 MPa. Viability of *L actobacillus acidophilus* and *Bifidobacterium lactis* increased during storage ($P < 0.05$) [56].

4. HPP advantages and disadvantages

HPP has some advantages over the other processings as reducing process time and decreasing the heat damage problems, maintaining the color, flavor, and freshness of food products. Also, there is no loss in vitamin C, and other functional changes are diminished compared to the traditional thermal methods [57].

HPP would extend the shelf lives, apply less energy, and have the best processing efficiency for pumpable foodstuffs than other technologies. HPP process can be managed in final packaging that prevents post-processing contamination. The processing time would eliminate and interestingly the inactivation of microorganisms and enzymes that occurred at low temperatures whilst the nutritious materials like vitamins, antioxidants, colors, and flavors, are unaffected [58].

HPP also decreases the need to use chemical preservatives due to avoiding microbial contaminations. Therefore, the food products using HPP technology have an appeal in consumers these days [59]. Table 1 represents the inactivation of some microorganisms by HPP in some foodstuffs.

There are some challenges with this technology, like HPP's incapability for inactivating spores [60]. Applying the combination of heat and HPP (pressure-assisted temperature sterilization or high-pressure sterilization) would be a solution for this problem [61]. Other challenges are the lack of practical knowledge about the interaction between several food constituents, packaging issues, shelf life, and high pressure [61-63]. The most significant limitation of this technology is the high cost; the HPP equipment is expensive and needs high investment depending on the equipment types [64, 65].

Table 1. Inactivation of some microorganisms by HPP.

Microorganism	**Media**	**Inactivation rate (log CFU)**	**HPP condition**			**Ref.**
			P (MPa)	T (°C)	t (min)	
L. monocytogenes	Beef	1.2	550	12	2	44
Salmonella		6.8				
E. coli		4.4				
E. coli	Poultry meat	3	600	20	15	45
S. aureus		3				
C. jejuni	Pork	6	300	25	10	43
Y. enterocolitica		6				
E. coli	Shrimp	1.5	435	20	25	7
S. aureus		1.1				
S. typhimurium	Yogurt	-	300	25	9	56
E. coli	Mango juice	6	250	20	8	40
E. coli	Apple juice	6	400	10	5	55

5. Conclusions

As a novel technology in preserving food, HPP has achieved success in the food industry and consumers' demand for fresh processed foods. HPP is likely to be applied widely due to being a natural alternative for other food industry processing. Compared with thermal processing, HPP maintains more nutrients, color, and flavor compounds. The consumers ask for more natural, healthier food. There are still some issues with this valuable technology, the lack of sufficient knowledge about food constituents' interaction, and the between high pressure. There is still also a need for more researches on this food due to high consumer acceptance.

Funding

This research received no external funding.

Acknowledgments

This research has no acknowledgment.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Abera, G. Review on high-pressure processing of foods. *Cogent Food Agric.* **2019**, *5*, 1-10, https://doi.org/10.1080/23311932.2019.1568725.

2. Pérez-Andrés, J.M.; Charoux, C.m.M.; Cullen, P.; Tiwari, B.K. Chemical modifications of lipids and proteins by non-thermal food processing technologies. *J. Agric. Food Chem.* **2018**, *66*, 5041-5054, https://doi.org/10.1021/acs.jafc.7b06055.
3. Balasubramaniam, V.B.; Martinez-Monteagudo, S.I.; Gupta, R. Principles and application of high pressure–based technologies in the food industry. *Annu. Rev. Food Sci. Technol.* **2015**, *6*, 435-462, https://doi.org/10.1146/annurev-food-022814-015539.
4. Bevilacqua, A.; Campaniello, D.; Speranza, B.; Altieri, C.; Sinigaglia, M.; Corbo, M.R. Two Nonthermal Technologies for Food Safety and Quality—Ultrasound and High Pressure Homogenization: Effects on Microorganisms, Advances, and Possibilities: A Review. *J. Food Prot.* **2019**, *82*, 2049-2064, https://doi.org/10.4315/0362-028X.JFP-19-059.
5. Daher, D.; Le Gourrierec, S.; Pérez-Lamela, C. Effect of high pressure processing on the microbial inactivation in fruit preparations and other vegetable based beverages. *Agriculture* **2017**, *7*, 72-78, https://doi.org/10.3390/agriculture7090072.
6. Ramaswamy, H.S.; Tessema, A. Achieving food security through reduction in postharvest losses of indigenous foods and enhancing manpower training opportunities: Canada-Ethiopia experience. In: Proceedings of Food Innovation Asia conference 2010: Indigenous food research and development to global market, as a part of ProPak Asia 2010, BITEC, Bangkok, Thailand, **2010**.
7. Chauhan, O. *Non-thermal processing of foods*. 1st ed.; CRC Press: USA, **2019**; pp. 16-88, https://doi.org/10.1201/b22017.
8. Barba, F.J.; Terefe, N.S.; Buckow, R.; Knorr, D.; Orlien, V. New opportunities and perspectives of high pressure treatment to improve health and safety attributes of foods. A review. *Food Res. Int.* **2015**, *77*, 725-742, https://doi.org/10.1016/j.foodres.2015.05.015.
9. Niakousari, M.; Gahruie, H.H.; Razmjooei, M.; Roohinejad, S.; Greiner, R. Effects of innovative processing technologies on microbial targets based on food categories: Comparing traditional and emerging technologies for food preservation. In: *Innovative technologies for food preservation*. 1st ed.; Academic Press: Cambridge, Massachusetts, United States, Volume 1, **2018**; pp. 133-185, https://doi.org/10.1016/B978-0-12-811031-7.00005-4.
10. Matser, A.M.; Krebbers, B.; van den Berg, R.W.; Bartels, P.V. Advantages of high pressure sterilisation on quality of food products. *Trends Food Sci. Technol.* **2004**, *15*, 79-85, https://doi.org/10.1016/j.tifs.2003.08.005.
11. Penna, A.; Barbosa-Cánovas, G. High hydrostatic pressure processing on microstructure of probiotic low-fat yogurt. *Food Res. Int.* **2007**, *40*, 510-519, https://doi.org/10.1016/j.foodres.2007.01.001.
12. Da Cruz, A.G.; Faria, J.d.A.F.; Saad, S.M.I.; Bolini, H.M.A.; Sant, A.S.; Cristianini, M. High pressure processing and pulsed electric fields: potential use in probiotic dairy foods processing. *Trends Food Sci. Technol.* **2010**, *21*, 483-493, https://doi.org/10.1016/j.tifs.2010.07.006.
13. Parekh, S.L.; Aparnathi, K.; Sreeja, V. High pressure processing: A potential technology for processing and preservation of dairy foods. *Int J Curr Microbiol App Sci* **2017**, *6*, 3526-3535, https://doi.org/10.20546/ijcmas.2017.612.410.
14. Huang, H.-W.; Yang, B.B.; Wang, C.-Y. Effects of high pressure processing on immunoreactivity and microbiological safety of crushed peanuts. *Food Control* **2014**, *42*, 290-295, https://doi.org/10.1016/j.foodcont.2014.02.030.
15. Pottier, L.; Villamonte, G.; de Lamballerie, M. Applications of high pressure for healthier foods. *Curr. Opin. Food Sci.* **2017**, *16*, 21-27, https://doi.org/10.1016/j.cofs.2017.06.009.
16. Abe, S.; Takimoto, S.; Yamamuro, Y.; Tau, K.; Takenaga, F.; Suzuki, K.; Oda, M. High-pressure and heat pretreatment effects on rehydration and quality of sweet potato. *Am. J. Food Technol.* **2011**, *6*, 63-71, https://doi.org/10.3923/ajft.2011.63.71.
17. Massoud, R.; Belgheisi, S.; Massoud, A. Effect of high pressure homogenization on improving the quality of milk and sensory properties of yogurt: a review. *Int. J. Chem. Eng. Appl.* **2016**, *7*, 66-70, https://doi.org/10.7763/IJCEA.2016.V7.544.
18. Prego, R.; Fidalgo, L.G.; Saraiva, J.A.; Vázquez, M.; Aubourg, S.P. Impact of prior high-pressure processing on lipid damage and volatile amines formation in mackerel muscle subjected to frozen storage and canning. *LWT* **2020**, *135*, 10-15, https://doi.org/10.1016/j.lwt.2020.109957.
19. Vázquez, M.; Fidalgo, L.G.; Saraiva, J.A.; Aubourg, S.P. Preservative effect of a previous high-pressure treatment on the chemical changes related to quality loss in frozen hake (Merluccius merluccius). *Food Bioproc. Tech.* **2018**, *11*, 293-304, https://doi.org/10.1007/s11947-017-2010-4.
20. De Ancos, B.; Rodrigo, M.J.; Sánchez-Moreno, C.; Cano, M.P.; Zacarías, L. Effect of high-pressure processing applied as pretreatment on carotenoids, flavonoids and vitamin C in juice of the sweet oranges 'Navel' and the red-fleshed 'Cara Cara'. *Food Res. Int.* **2020**, *132*, 105-109, https://doi.org/10.1016/j.foodres.2020.109105.
21. Plaza, L.; Sánchez-Moreno, C.; Elez-Martínez, P.; de Ancos, B.; Martín-Belloso, O.; Cano, M.P. Effect of refrigerated storage on vitamin C and antioxidant activity of orange juice processed by high-pressure or pulsed electric fields with regard to low pasteurization. *Eur. Food Res. Technol.* **2006**, *223*, 487-493, https://doi.org/10.1007/s00217-005-0228-2.

22. Sánchez-Moreno, C.; Plaza, L.; Elez-Martínez, P.; De Ancos, B.; Martín-Belloso, O.; Cano, M.P. Impact of high pressure and pulsed electric fields on bioactive compounds and antioxidant activity of orange juice in comparison with traditional thermal processing. *J. Agric. Food Chem.* **2005**, *53*, 4403-4409, https://doi.org/10.1021/jf048839b.
23. Guerrero-Beltrán, J.A.; Barbosa-Cánovas, G.V.; Swanson, B.G. High hydrostatic pressure processing of fruit and vegetable products. *Food Rev. Int.* **2005**, *21*, 411-425. https://doi.org/10.1080/87559120500224827
24. Massoud, R.; Fadaei, N.V.; Khosravi, D.K. The effect of homogenization pressure and stages on the amounts of Lactic and Acetic acids of probiotic yoghurt. *Appl. Food Biotechnol.* **2014**, *1*, 25-29, https://doi.org/10.22037/afb.v2i1.7209.
25. Fernández-Jalao, I.; Sánchez-Moreno, C.; De Ancos, B. Effect of high-pressure processing on flavonoids, hydroxycinnamic acids, dihydrochalcones and antioxidant activity of apple 'Golden Delicious' from different geographical origin. *Innov. Food Sci. Emerg. Technol.* **2019**, *51*, 20-31, https://doi.org/10.1016/j.ifset.2018.06.002.
26. Xi, J. Effect of high pressure processing on the extraction of lycopene in tomato paste waste. *Chem. Eng. Technol.* **2006**, *29*, 736-739.
27. Passos, F.; García, J.; Ferrer, I. Impact of low temperature pretreatment on the anaerobic digestion of microalgal biomass. *Bioresour. Technol.* **2013**, *138*, 79-86, https://doi.org/10.1016/j.biortech.2013.03.114.
28. Paini, M.; Casazza, A.A.; Aliakbarian, B.; Perego, P.; Binello, A.; Cravotto, G. Influence of ethanol/water ratio in ultrasound and high-pressure/high-temperature phenolic compound extraction from agri-food waste. *Int. J. Food Sci. Technol.* **2016**, *51*, 349-358.
29. Corrales, M.; Han, J.H.; Tauscher, B. Antimicrobial properties of grape seed extracts and their effectiveness after incorporation into pea starch films. *Int. J. Food Sci. Technol.* **2009**, *44*, 425-433.
30. Casquete, R.; Castro, S.; Villalobos, M.; Serradilla, M.; Queirós, R.; Saraiva, J.; Córdoba, M.; Teixeira, P. High pressure extraction of phenolic compounds from citrus peels. *High. Press. Res.* **2014**, *34*, 447-451, https://doi.org/10.1080/08957959.2014.986474.
31. Hao, H.; Zhou, T.; Koutchma, T.; Wu, F.; Warriner, K. High hydrostatic pressure assisted degradation of patulin in fruit and vegetable juice blends. *Food Control* **2016**, *62*, 237-242, https://doi.org/10.1016/j.foodcont.2015.10.042.
32. Avsaroglu, M.; Bozoglu, F.; Alpas, H.; Largeteau, A.; Demazeau, G. Use of pulsed-high hydrostatic pressure treatment to decrease patulin in apple juice. *High. Press. Res.* **2015**, *35*, 214-222, https://doi.org/10.1080/08957959.2015.1027700.
33. Pokhrel, P.R.; Toniazzo, T.; Boulet, C.; Oner, M.E.; Sablani, S.S.; Tang, J.; Barbosa-Cánovas, G.V. Inactivation of Listeria innocua and Escherichia coli in carrot juice by combining high pressure processing, nisin, and mild thermal treatments. *Innov. Food Sci. Emerg. Technol.* **2019**, *54*, 93-102 https://doi.org/10.1016/j.ifset.2019.03.007
34. Kalagatur, N.K.; Kamasani, J.R.; Mudili, V.; Krishna, K.; Chauhan, O.P.; Sreepathi, M.H. Effect of high pressure processing on growth and mycotoxin production of Fusarium graminearum in maize. *Food Biosci.* **2018**, *21*, 53-59, https://doi.org/10.1016/j.fbio.2017.11.005.
35. Balakrishna, A.K.; Farid, M. Enrichment of rice with natural thiamine using high-pressure processing (HPP). *J. Food Eng.* **2020**, *283*, 11-14, https://doi.org/10.1016/j.jfoodeng.2020.110040.
36. Narenderan, S.; Meyyanathan, S.; Babu, B. Review of pesticides residue analysis in fruits and vegetables. Pre-treatment, extraction and detection techniques. *Food Res. Int.* **2020**, *133*, 133-140, https://doi.org/10.1016/j.foodres.2020.109141.
37. Wazed, M.A.; Farid, M. Hypoallergenic and low-protein ready-to-feed (RTF) infant formula by high pressure pasteurization: a novel product. *Foods* **2019**, *8*, 408-411, https://doi.org/10.3390/foods8090408.
38. Yordanov, D.; Angelova, G. High pressure processing for foods preserving. *Biotechnol. Biotechnol. Equip.* **2010**, *24*, 1940-1945, https://doi.org/10.2478/V10133-010-0057-8.
39. Aleman, G.; Farkas, D.F.; Torres, J.A.; Wilhelmsen, E.; Mcintyre, S. Ultra-high pressure pasteurization of fresh cut pineapple. *J. Food Prot.* **1994**, *57*, 931-934, https://doi.org/10.4315/0362-028X-57.10.931.
40. Boynton, B.B.; Sims, C.; Sargent, S.; Balaban, M.; Marshall, M. Quality and stability of precut mangos and carambolas subjected to high-pressure processing. *J. Food Sci.* **2002**, *67*, 409-415.
41. Donsi, G.; Ferrari, G.; Di Matteo, M. High pressure stabilization of orange juice: evaluation of the effects of process conditions. *Ital. J. Food Sci.* **1996**, *8*, 99-106.
42. Carlez, A.; Veciana-Nogues, T.; Cheftel, J.-C. Changes in colour and myoglobin of minced beef meat due to high pressure processing. *LWT* **1995**, *28*, 528-538, https://doi.org/10.1006/fstl.1995.0088.
43. Wackerbarth, H.; Kuhlmann, U.; Tintchev, F.; Heinz, V.; Hildebrandt, P. Structural changes of myoglobin in pressure-treated pork meat probed by resonance Raman spectroscopy. *Food Chem.* **2009**, *115*, 1194-1198, https://doi.org/10.1016/j.foodchem.2009.01.027.
44. Jofré, A.; Aymerich, T.; Grèbol, N.; Garriga, M. Efficiency of high hydrostatic pressure at 600 MPa against food-borne microorganisms by challenge tests on convenience meat products. *LWT* **2009**, *42*, 924-928, https://doi.org/10.1016/j.lwt.2008.12.001.

45. McArdle, R.A.; Marcos, B.; Kerry, J.P.; Mullen, A.M. Influence of HPP conditions on selected beef quality attributes and their stability during chilled storage. *Meat Sci.* **2011**, *87*, 274-281, https://doi.org/10.1016/j.meatsci.2010.10.022.
46. Kruk, Z.A.; Yun, H.; Rutley, D.L.; Lee, E.J.; Kim, Y.J.; Jo, C. The effect of high pressure on microbial population, meat quality and sensory characteristics of chicken breast fillet. *Food Control* **2011**, *22*, 6-12, https://doi.org/10.1016/j.foodcont.2010.06.003.
47. Scheinberg, J.A.; Svoboda, A.L.; Cutter, C.N. High-pressure processing and boiling water treatments for reducing Listeria monocytogenes, Escherichia coli O157: H7, Salmonella spp., and Staphylococcus aureus during beef jerky processing. *Food Control* **2014**, *39*, 105-110, https://doi.org/10.1016/j.foodcont.2013.11.002.
48. Woldemariam, H.W.; Emire, S.A. High Pressure Processing of Foods for Microbial and Mycotoxins Control: current trends and future prospects. *Cogent Food Agric.* **2019**, *5*, 16-22, https://doi.org/10.1080/23311932.2019.1622184.
49. Rendueles, E.; Omer, M.; Alvseike, O.; Alonso-Calleja, C.; Capita, R.; Prieto, M. Microbiological food safety assessment of high hydrostatic pressure processing: A review. *LWT* **2011**, *44*, 1251-1260, https://doi.org/10.1016/j.lwt.2010.11.001.
50. Bernaerts, T.M.; Gheysen, L.; Foubert, I.; Hendrickx, M.E.; Van Loey, A.M. Evaluating microalgal cell disruption upon ultra high pressure homogenization. *Algal Res.* **2019**, *42*, https://doi.org/10.1016/j.algal.2019.101616.
51. Huang, H.-W.; Hsu, C.-P.; Wang, C.-Y. Healthy expectations of high hydrostatic pressure treatment in food processing industry. *J. Food Drug Anal.* **2020**, *28*, 1-13, https://doi.org/10.1016/j.jfda.2019.10.002.
52. De Oliveira, T.L.C.; Ramos, A.L.; Ramos, E.M.; Piccoli, R.H.; Cristianini, M. Natural antimicrobials as additional hurdles to preservation of foods by high pressure processing. *Trends Food Sci. Technol.* **2015**, *45*, 60-85, https://doi.org/10.1016/j.tifs.2015.05.007.
53. Gouvea, F.S.; Padilla-Zakour, O.I.; Worobo, R.W.; Xavier, B.M.; Walter, E.H.; Rosenthal, A. Effect of high-pressure processing on bacterial inactivation in açaí juices with varying pH and soluble solids content. *Innov. Food Sci. Emerg. Technol.* **2020**, *66*, 102-112, https://doi.org/10.1016/j.ifset.2020.102490.
54. Silva, F. Inactivation of Byssochlamys nivea ascospores in strawberry puree by high pressure, power ultrasound and thermal processing. *Int. J. Food Microbiol.* **2015**, *214*, 129-136, https://doi.org/10.1016/j.ijfoodmicro.2015.07.031.
55. Kim, H.; Silva, F. Modeling the inactivation of Neosartorya fischeri ascospores in apple juice by high pressure, power ultrasound and thermal processing. *Food Control* **2016**, *59*, 530-537, https://doi.org/10.1016/j.foodcont.2015.06.033.
56. Massoud, R.; Fadaei, V.; Khosravi-Darani, K.; Nikbakht, H.R. Improving the viability of probiotic bacteria in yoghurt by homogenization. *J. Food Process. Preserv.* **2015**, *39*, 2984-2990.
57. Marszałek, K.; Woźniak, Ł.; Kruszewski, B.; Skąpska, S. The effect of high pressure techniques on the stability of anthocyanins in fruit and vegetables. *Int. J. Mol. Sci.* **2017**, *18*, 277-283, https://doi.org/10.3390/ijms18020277.
58. Sharma, P.; Gaur, S.N.; Arora, N. In silico identification of IgE-binding epitopes of osmotin protein. *PLoS One* **2013**, *8*, https://doi.org/10.1371/journal.pone.0054755.
59. Muntean, M.-V.; Marian, O.; Barbieru, V.; Cătunescu, G.M.; Ranta, O.; Drocas, I.; Terhes, S. High pressure processing in food industry–characteristics and applications. *Agric. Agric. Sci. Procedia* **2016**, *10*, 377-383, https://doi.org/10.1016/j.aaspro.2016.09.077.
60. Ardia, A. *Process considerations on the application of high pressure treatment at elevated temperature levels for food preservation.* Doctoral thesis, Technical University of Berlin, Germany, **2004**, http://dx.doi.org/10.14279/depositonce-840.
61. Rastogi, N.; Raghavarao, K.; Balasubramaniam, V.; Niranjan, K.; Knorr, D. Opportunities and challenges in high pressure processing of foods. *Crit. Rev. Food Sci. Nutr.* **2007**, *47*, 69-112, https://doi.org/10.1080/10408390600626420.
62. Marangoni Júnior, L.; Alves, R.M.V.; Moreira, C.Q.; Cristianini, M.; Padula, M.; Anjos, C.A.R. High-pressure processing effects on the barrier properties of flexible packaging materials. *J. Food Process. Preserv.* **2020** (in press), https://doi.org/10.1111/jfpp.14865.
63. Rode, T.M.; Rotabakk, B.T. Extending shelf life of desalted cod by high pressure processing. *Innov. Food Sci. Emerg. Technol.* **2020** (in press), https://doi.org/10.1016/j.ifset.2020.102476
64. Alexandre, E.M.; Pinto, C.A.; Moreira, S.A.; Pintado, M.; Saraiva, J.A. Nonthermal food processing/preservation technologies. In: *Saving Food.* Galanakis, C.M. Ed. Academic Press: Galanakis Laboratories, Chania, Greece, Volume 1, **2019**; pp. 141-169, https://doi.org/10.1016/B978-0-12-815357-4.00005-5.
65. Huang, H.-W.; Wu, S.-J.; Lu, J.-K.; Shyu, Y.-T.; Wang, C.-Y. Current status and future trends of high-pressure processing in food industry. *Food Control* **2017**, *72*, 1-8, https://doi.org/10.1016/j.foodcont.2016.07.019.