Inactivation of Microorganisms in Nuts and Nut Pastes: Table and References

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Inactivation of microorganisms in nuts and nut pastes – published treatments

Process type	Treatment	Nut product tested	References
Chemical	Acid solutions or sprays	Almonds, Pecans, Pine nuts, Sesame seeds (tahini, hummus)	Beuchat et al., 2013; Ha and Kang, 2015; Olaimat et al., 2017a and 2017b; Olaimat et al., 2022a; Pao et al., 2006; Salazar et al., 2018
	Carbon nanofiber (Fe_3C/NC) suspension	Chestnuts	Xu et al., 2020
	Chlorine (bleach, sodium hypochlorite)	Coconut, Hazelnuts, Pecans, Walnuts	Beuchat and Mann, 2011a; Beuchat et al., 2012, 2013; Blessington et al., 2013; Walter et al., 2009; Weller et al., 2013
	Chlorine dioxide gas	Almonds, Sesame seeds	Chai et al., 2022; Golden et al., 2019; Lim et al., 2021; Rane et al., 2020, 2021; Wang et al., 2019; Wihodo et al., 2005
	Mild heat + ClO_2 gas	Almonds	Wang et al., 2019
	(Mild heat +/or moisture) + ClO_2 gas	Almonds	Rane et al., 2021
	Essential oil (cinnamon)	Almonds	Tsai et al., 2017
	Essential oil vapor (cinnamon, oregano)	Sesame seeds	Xu et al., 2022
	Ethanol spray(s)	Almonds	Salazar et al., 2018
	Hydrogen peroxide spray	Almonds	Salazar et al., 2018
	Methyl bromide	Almonds, Walnuts	Schade and King, 1977
	Nitrogen dioxide	Almonds	Oh and Liu, 2020
	Ozone	Almonds (inshell, kernels), Pistachios (inshell, kernels, ground)	Akbas and Ozdemir, 2006; Perry et al., 2019; Rane et al., 2020
	5% NaCl brine (70°C, 10 min) + ozone	Pistachios (inshell)	Perry et al., 2019
	UV-C + hydrogen peroxide + ozone	Pistachios (inshell, kernels)	Hasani et al., 2020
	Peracetic acid	Almonds, Coconut, Hazelnuts, Pecans, Walnuts	Beuchat et al., 2012, 2013; Frelka and Harris, 2015; Pearson et al., 2018; Salazar et al., 2018; Walter et al., 2009; Weller et al., 2013
	Ethanol + peracetic acid	Pistachios (inshell, kernels)	Hasani et al., 2020
	Propylene oxide	Almonds (inshell and kernels), Cashews, Macadamias, Pecans	ABC, 2008a, 2008b; Beuchat, 1973; Blanchard and Hanlin, 1973; Danyluk et al., 2005; Saunders et al., 2018
	Supercritical carbon dioxide ($scCO_2$)	Almonds	Chen et al., 2022
	Thyme oil + $scCO_2$	Almonds	Chen et al., 2022
Thermal	Controlled atmosphere + heat	Almonds (ground)	Cheng et al., 2017; Cheng and Wang, 2018

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Process type	Treatment	Nut product tested	References
Thermal cont'd	Hot air (includes dry roasting)	Almonds, Coconut (desiccated-shredded), Macadamia nuts, Peanuts, Pecans, Pistachios (inshell), Sesame seeds (and tahini)	ABC, 2007c; Beuchat and Mann, 2011b; Brar and Danyluk, 2019; Casulli et al., 2021; den Bakker et al., 2021; Dhowlagher et al., 2021; Moussavi et al., 2020; Poirier et al., 2014; Prestes et al., 2019a, 2019b; Sanders and Calhoun, 2014; Torlak et al., 2013; Yang et al., 2010; Zhang et al., 2017
	Hot air + packing method (e.g., vacuum)	Almonds	Song and Kang, 2021; Xu and Chen, 2022
	Water activity + hot air + packaging	Almonds	Xu and Chen, 2022
	Hot air + 70% ethanol spray(s)	Almonds, Pecans, Pistachios, Walnuts	Salazar et al., 2017
	Hot water	Almonds, Pecans, Pistachios	ABC, 2007b; Beuchat and Mann, 2011a; Cuervo et al., 2016; Harris et al., 2012; Kharel et al., 2018; McKay et al., 2022; Moussavi et al., 2020
	Chlorine + hot water	Pecans	Beuchat and Mann, 2011a
	Indirect heating (water or silicon oil bath)	Peanut butter, Sesame (tahini), Tree nut butters (commercial: almond, almond + cashew, hazelnut)	He et al., 2011; Keller et al., 2012; Li et al., 2014; Ma et al., 2009; Pelaez et al., 2020; Quinn et al., 2021; Shachar and Yaron, 2006; Szpinak et al., 2022; Wright et al., 2018
	Infrared heating (gas catalytic IR)	Almonds	Bingol et al., 2011; Brandl et al., 2008; Yang et al., 2010
	Distilled water + gas catalytic IR	Almonds	Bari et al., 2009
	Dry roasting + gas catalytic IR	Almonds	Bari et al., 2009; Yang et al., 2010
	Electrolyzed water + gas catalytic IR	Almonds	Bari et al., 2009
	Hot water + gas catalytic IR	Almonds	Bari et al., 2009
	Ozonated water + gas catalytic IR	Almonds	Bari et al., 2009
	Superheated steam + gas catalytic IR	Almonds	Bari et al., 2010
	Infrared heating (near IR)	Almonds, Pine nuts	Ha and Kang, 2015
	Distilled water + near IR	Almonds, Pine nuts	Ha and Kang, 2015
	Lactic acid + near IR	Almonds, Pine nuts	Ha and Kang, 2015
	Infrared heating (quartz emitters)	Pistachios	Venkitasamy et al., 2017
	Dry heating + IR	Almonds, Pistachios	Venkitasamy et al., 2017, 2018
	Microwave heating	Peanut butter, Sesame (tahini)	Osaili et al., 2021; Song and Kang, 2016
	915 MHz	Peanut butter	Song and Kang, 2016
	2450 MHz	Sesame (tahini)	Osaili et al., 2021
	Moist air convection heating	Almonds, Pistachios	Casulli et al., 2018, 2021; S. Jeong et al., 2009, 2011, 2017
	Presoak + moist air convection heating	Pistachios	Casulli et al., 2018, 2021

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Process type	Treatment	Nut product tested	References
Thermal cont'd	Oil (includes roasting or hot oil)	Almonds, Peanuts, Pecans, Pistachios, Walnuts	ABC, 2007d; Abd et al., 2012; Beuchat and Mann, 2011b; Brar and Danyluk, 2019; Cuervo et al., 2016; Du et al., 2010; Meyer and Vaughn, 1969; Moussavi et al., 2020; Prestes et al., 2019b; Sanders and Calhoun, 2014
	Radio frequency (RF) heating	Almonds, Hazelnuts (inshell) Pistachios, Sesame seeds, Walnuts (inshell)	Chen et al., 2021; Gao et al., 2011; S.-G. Jeong et al., 2017, 2019; Li et al., 2017; Salazar et al., 2018; Xu et al., 2022; Zhang et al., 2019
	70% ethanol spray(s) + RF heating	Almonds, Pecans, Pistachios, Walnuts	Salazar et al., 2018
	Modified atmosphere pre-storage + RF	Almonds	Cheng and Wang, 2019
	Controlled atmosphere	Almonds	Cheng et al., 2020
	Essential oil vapor + RF heating	Sesame seeds	Xu et al., 2022
	Steam, saturated (≤100°C)	Almonds, Hazelnuts (inshell), Pecans (shelled, inshell), Pistachios	ABC, 2007a; Ban and Kang, 2016; Ban et al., 2018; Chang et al., 2010; Lee at al., 2006; Letchworth, 2020; McKay et al., 2022
	Steam, superheated (125–200°C)	Almonds, Pecans, Pistachios	Ban and Kang, 2016; Ban et al., 2018
	Steam, vacuum-assisted (62–82°C)	Macadamia nuts	Acuff et al., 2020
Non-thermal	Bacteriophage cocktails	Sesame (hummus)	Tayyarcan et al., 2022
	High-intensity 405-nm light	Almonds	Lacombe et al., 2016
	High pressure processing	Almonds, Peanut butter, Sesame seeds	D'Souza et al., 2012; D'Souza et al., 2014; Goodridge et al., 2006; Grasso et al., 2010; Willford et al., 2008; Wuytack et al., 2003
	Irradiation (electron beam)	Almonds, Peanut butter, Pecans	Cuervo et al., 2016; Hvizdzak et al., 2010; Karagöz et al., 2014; Mohammad et al., 2019; Prakash et al., 2010
	Irradiation (gamma rays)	Peanut butter, Pistachios, Walnuts, Sesame seeds (and hummus)	Ban and Kang, 2014; D'Oca et alo., 2021; Olaimat et al., 2022b; Osaili and Al-Nabulsi, 2016; Song et al., 2019; Wilson-Kakashita et al., 1995
	Irradiation (X-rays)	Almonds (kernels, meal, butter), Walnuts	Jeong et al., 2012; Steinbrunner et al., 2019
	Non-thermal plasma	Almonds, Almonds (sliced), Hazelnuts, Pine nuts, Pistachios, Sesame seeds, Walnuts	Deng et al., 2007; Han et al., 2020; Hartanto, 2022; Hertwig et al., 2017; Lee et al., 2021; Niemira, 2012; Pignata et al., 2014; Shirani et al., 2020
	Pulsed light, intense (200-1000 nm)	Sesame seeds	Hwang et al., 2017
	Pulsed light, UV (100-280 nm)	Almond, Walnuts, halves and pieces	Harguindeguy et al., 2021; Izmirlioglu et al., 2020
	Pulsed light + water pre-treatment	Almonds	Liu et al., 2021
	Ultraviolet light (C region; 254 nm)	Almonds, Peanuts, Walnuts (inshell)	Ruiz-Hernández et al., 2021; Yun et al., 2022

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References cited

[ABC] Almond Board of California. 2007a. Considerations for proprietary processes for almond pasteurization and treatment, v1.0, April 13, 2007. https://www.almonds.com/almond-industry/processors-and-suppliers/processing-safe-product/pasteurization-program.

[ABC] Almond Board of California. 2007b. Guidelines for validation of blanching processes, v1.0, April 13, 2007. Available at: https://www.almonds.com/almond-industry/processors-and-suppliers/processing-safe-product/pasteurization-program.

[ABC] Almond Board of California. 2007c. Guidelines for validation of dry roasting processes, v1.2, October 23, 2007. Available at: https://www.almonds.com/almond-industry/processors-and-suppliers/processing-safe-product/pasteurization-program.

[ABC] Almond Board of California. 2007d. Guidelines for validation of oil roasting processes, v1.0, April 13, 2007. Available at: https://www.almonds.com/almond-industry/processors-and-suppliers/processing-safe-product/pasteurization-program.

[ABC] Almond Board of California. 2008a. Guidelines for validation of propylene oxide pasteurization, v3.0, October 1, 2008. Available at: https://www.almonds.com/almond-industry/processors-and-suppliers/processing-safe-product/pasteurization-program.

[ABC] Almond Board of California. 2008b. Guidelines for validation of propylene oxide treatment for in-shell almonds, v2.0, October 1, 2008. Available at: https://www.almonds.com/almond-industry/processors-and-suppliers/processing-safe-product/pasteurization-program.

Abd, S. J., K. L. McCarthy, and L. J. Harris. 2012. Impact of storage time and temperature on thermal inactivation of *Salmonella* Enteritidis PT 30 on oil-roasted almonds. *J. Food Sci.* 71:M42–M47.

Acuff, J. C., J. Wu, C. Marik, K. Waterman, D. Gallagher, H. Huang, R. C. Williams, and M. A. Ponder. 2020. Thermal inactivation of *Salmonella*, Shiga toxin-producing *Escherichia coli*, *Listeria monocytogenes*, and a surrogate (*Pediococcus acidilactici*) on raisins, apricot halves, and macadamia nuts using vacuum-steam pasteurization. *Int. J. Food Microbiol.* 333:108814.

Akbas, M. Y., and M. Ozdemir. 2006. Effectiveness of ozone for inactivation of *Escherichia coli* and *Bacillus cereus* in pistachios. *Int. J. Food Sci. Technol.* 41:513–519.

Ban, C., D. H. Lee, Y. Jo, H. Bae, H. Seong, S. O. Kim, S. Lim, and Y. J. Choi. 2018. Use of superheated steam to inactivate *Salmonella enterica* serovars Typhimurium and Enteritidis contamination on black peppercorns, pecans, and almonds. *J. Food Eng.* 222:284–291.

Ban, G.-H., and D.-H. Kang. 2014. Effects of gamma irradiation for inactivating *Salmonella* Typhimurium in peanut butter product during storage. *Int. J. Food Microbiol.* 171:48–53.

Ban, G.-H., and D.-H. Kang. 2016. Effectiveness of superheated steam for inactivation of *Escherichia coli* O157:H7, *Salmonella* Typhimurium, *Salmonella* Enteritidis phage type 30, and *Listeria monocytogenes* on almonds and pistachios. *Int. J. Food Microbiol.* 220:19–25.

Bari, M. L., D. Nei, I. Sotome, I. Nishina, S. Isobe, and S. Kawamoto. 2009. Effectiveness of sanitizers, dry heat, hot water, and gas catalytic infrared heat treatments to inactivate *Salmonella* on almonds. *Foodborne Path. Dis.* 6:953–958.

Bari, M. L., D. Nei, I. Sotome, I. Y. Nishina, F. Hayakawa, S. Isobe, and S. Kawamoto. 2010. Effectiveness of superheated steam and gas catalytic infrared heat treatments to inactivate *Salmonella* on raw almonds. *Foodborne Path. Dis.* 7:845–850.

Beuchat, L. R. 1973. *Escherichia coli* on pecans: Survival under various storage conditions and disinfection with propylene oxide. *J. Food Sci.* 38:1063–1066.

Beuchat, L. R., and D. A. Mann. 2011a. Inactivation of *Salmonella* on in-shell pecans during conditioning treatments preceding cracking and shelling. *J. Food Prot.* 74:588–602.

Beuchat, L. R., and D. A. Mann. 2011b. Inactivation of *Salmonella* on pecan nutmeats by hot air treatment and oil roasting. *J. Food Prot.* 74:1441–1450.

L. J. Harris, S. Yada, L. R. Beuchat, and M. D. Danyluk. Initial funding (2009–2013) provided by USDA NIFSI, 2009-01951. Currently (2021-present) supported by the Agriculture and Food Research Initiative, Sustainable Agricultural Systems Program grant no. 2020-68012-31822 from the USDA National Institute of Food and Agriculture. Updated 8/12/2022.

Beuchat, L. R., D. A. Mann, and W. Q. Alali. 2012. Evaluation of sanitizers for inactivating *Salmonella* on in-shell pecans and pecan nutmeats. *J. Food Prot.* 75:1930–1938.

Beuchat, L. R., D. A. Mann, and W. Q. Alali. 2013. Efficacy of sanitizers in reducing *Salmonella* on pecan nutmeats during cracking and shelling. *J. Food Prot.* 76:770–778.

Bingol, G., J. Yang, M. T. Brandl, Z. Pan, H. Wang, and T. H. McHugh. 2011. Infrared pasteurization of raw almonds. *J. Food Eng.* 104:387–393.

Blanchard, R. O., and R. T. Hanlin. 1973. Effect of propylene oxide treatment on the microflora of pecans. *Appl. Microbiol.* 26:768–722.

Blessington, T., C. G. Theofel, E. J. Mitcham, and L. J. Harris. 2013. Survival of foodborne pathogens on inshell walnuts. *Int. J. Food Microbiol.* 166:341–348.

Brandl, M. T., Z. Pan, S. Huynh, Y. Zhu, and T. H. McHugh. 2008. Reduction of *Salmonella* Enteritidis population sizes on almond kernels with infrared heat. *J. Food Prot.* 71:897–902.

Brar, P. K., and M. D. Danyluk. 2019. Validation of *Enterococcus faecium* as a surrogate for *Salmonella* under different processing conditions for peanuts and pecans. *Food Microbiol.* 80:9–17.

Casulli, K. E., K. D. Dolan, and B. Marks. 2021. Modeling the effects of product temperature, product moisture, and process humidity on thermal inactivation of *Salmonella* in pistachios during hot-air heating. *J. Food Prot.* 84:47–57.

Casulli, K. E., F. J. Garces-Vega, K. D. Dolan, E. T. Ryser, L. J. Harris, and B. P. Marks. 2018. Impact of process temperature, humidity, and initial product moisture on thermal inactivation of *Salmonella* Enteritidis PT 30 on pistachios during hot-air heating. *J. Food Prot.* 81:1351–1356.

Chai, H.-E., C.-A. Hwang, L. Huang, V. C. H. Wu, and L.-Y. Sheen. 2022. Efficacy of gaseous chlorine dioxide for decontamination of *Salmonella*, Shiga toxin-producing *Escherichia coli*, and *Listeria monocytogenes* on almonds and peppercorns. *Food Control* 132:108556.

Chang, S.-S., A. R. Han, J. I. Reyes-De-Corcuera, J. R. Powers, and D.-H. Kang. 2010. Evaluation of steam pasteurization in controlling *Salmonella* serotype Enteritidis on raw almond surfaces. *Lett. Appl. Microbiol.* 50:393–398.

Chen, H., Y. Guan, A. Wang, and Q. Zhong. 2022. Inactivation of *Escherichia coli* K12 on raw almonds using supercritical carbon dioxide and thyme oil. *Food Microbiol.* 103:103955.

Chen, L., J. Jung, B. D. Chaves, D. Jones, M. Negahban, Y. Zhao, and J. Subbiah. 2021. Challenges of dry hazelnut shell surface for radio frequency pasteurization of inshell hazelnuts. *Food Control* 125:107948. Available at: https://doi.org/10.1016/j.foodcont.2021.107948.

Cheng, T., R. Li, X. Kou, and S. Wang. 2017. Influence of controlled atmosphere on thermal inactivation of *Escherichia coli* ATCC 25922 in almond powder. *Food Microbiology* 64:186–194.

Cheng, T., H. Ramaswamy, R. Xu, Q. Liu, R. Lan, and S. Wang. 2020. Fifty Ohm radio frequency heating treatment under controlled atmosphere for inactivating *Escherichia coli* ATCC 25922 inoculated on almond kernels. *LWT* 123:109124.

Cheng, T., and S. Wang. 2018. Influence of storage temperature/time and atmosphere on survival and thermal inactivation of *Escherichia coli* ATCC 25922 inoculated to almond powder. *Food Control* 86:350–358.

Cheng, T., and S. Wang. 2019. Modified atmosphere packaging pre-storage treatment for thermal control of *E. coli* ATCC 25922 in almond kernels assisted by radio frequency energy. *J. Food Eng.* 246:253–260.

Cuervo, M. P., L. M. Lucia, and A. Castillo. 2016. Efficacy of traditional almond decontamination treatments and electron beam irradiation against heat-resistant *Salmonella* strains. *J. Food Prot.* 79:369–375.

Danyluk, M. D., A. R. Uesugi, and L. J. Harris. 2005. Survival of *Salmonella* Enteritidis PT 30 on inoculated almonds after commercial fumigation with propylene oxide. *J. Food Prot.* 68:1613–1622.

den Bakker, M., H. C. den Bakker, and F. Diez-Gonzalez. 2021. Heat inactivation of *Listeria monocytogenes* on pecans, macadamia nuts, and sunflower seeds. *Microbiol. Spectrum* 9:e01134-21. Available at: https://doi.org/10.1128/Spectrum.01134-21.

L. J. Harris, S. Yada, L. R. Beuchat, and M. D. Danyluk. Initial funding (2009–2013) provided by USDA NIFSI, 2009-01951. Currently (2021-present) supported by the Agriculture and Food Research Initiative, Sustainable Agricultural Systems Program grant no. 2020-68012-31822 from the USDA National Institute of Food and Agriculture. Updated 8/12/2022.

Deng, S., R. Ruan, C. K. Mok, G. Huang, X. Lin, and P. Chen. 2007. Inactivation of *Escherichia coli* on almonds using nonthermal plasma. *J. Food Sci.* 72(2):M62–M66.

Dhowlaghar, N., J. Tang, and M. Zhu. 2021. Thermal inactivation of *Salmonella*, *Listeria monocytogenes* and *Enterococcus faecium* NRRL B-2354 in desiccated shredded coconut. *LWT* 149:111851.

D'Oca, M. C., A. M. Di Noto, A. Bartolotta, A. Parlato, L. Nicastro, S. Sciortino, and C. Cardamone. 2021. Assessment of contamination of *Salmonella* spp. in imported black pepper and sesame seed and salmonella inactivation by gamma irradiation. *Italian J. Food Safety* 10:8914. Available at: https://doi.org/10.4081/ijfs.2021.8914.

D'Souza, T., M. Karwe, and D. W. Schaffner. 2012. Effect of high hydrostatic pressure and pressure cycling on a pathogenic *Salmonella enterica* serovar cocktail inoculated into creamy peanut butter. *J. Food Prot.* 75:169–173.

D'Souza, T., M. Karwe, and D. W. Schaffner. 2014. Effect of high hydrostatic pressure on *Salmonella* inoculated into creamy peanut butter with modified composition. *J. Food Prot*. 10:1664–1668.

Du, W.-X., S. J. Abd, K. L. McCarthy, and L. J. Harris. 2010. Reduction of *Salmonella* on inoculated almonds exposed to hot oil. *J. Food Prot.* 73:1238–1246.

Frelka, J. C., and L. J. Harris. 2015. Evaluation of microbial loads and the effects of antimicrobial sprays in postharvest handling of California walnuts*. Food Microbiol.* 48:133–142.

Gao, M., J. Tang, R. Villa-Rojas, Y. Wang, and S. Wang. 2011. Pasteurization process development for controlling *Salmonella* in in-shell almonds using radio frequency energy. *J. Food Eng*. 104:299–306.

Golden, C. E., M. E. Berrang, W. L. Kerr, and M. A. Harrison. 2019. Slow-release chlorine dioxide gas treatment as a means to reduce *Salmonella* contamination on spices. *Innov. Food Sci. Emerg. Technol*. 52:256–261. [sesame]

Goodridge, L. D., J. Willford, and N. Kalchayanand. 2006. Destruction of *Salmonella* Enteritidis inoculated onto raw almonds by high hydrostatic pressure. *Food Res. Int.* 39:408–412.

Grasso, E. M., J. A. Somerville, V. M. Balasubramaniam, and K. Lee. 2010. Minimal effects of high-pressure treatment on *Salmonella enterica* serovar Typhimurium inoculated into peanut butter and peanut products. *J. Food Sci.* 75(8):E522–E526.

Ha, J.-W., and D.-H. Kang. 2015. Combining lactic acid spray with NIR radiant heating to inactivate *Salmonella enterica* serovar Enteritidis on almond and pine nut kernels. *Appl. Environ. Microbiol.* 81:4517–4524.

Han, J.-Y., W.-J. Song, S. Eom, S. B. Kim, and D.-H. Kang. 2020. Antimicrobial efficacy of cold plasma treatment against food-borne pathogens on various foods. *J. Physics D*: *Applied Physics* 53(20):204003. [almond, hazelnut, pine nut, pistachio, walnut]

Harguindeguy, M., and C. E. Gómez-Camacho. 2021. Pulsed light (PL) treatments on almond kernels: *Salmonella enteritidis* inactivation kinetics and infrared thermography insights. *Food Bioprocess. Technol.* 14:2323–2335. Available at: https://link.springer.com/article/10.1007/s11947-021-02725-9.

Harris, L. J., A. R. Uesugi, S. J. Abd, and K. L. McCarthy. 2012. Survival of *Salmonella* Enteritidis PT 30 on inoculated almond kernels in hot water treatments. *Food Res. Int.* 45:1093–1098.

Hartanto, V. 2022. Application of atmospheric cold plasma for inactivation of foodborne enteric pathogens on raw and dry roasted pistachio kernels and in pineapple juice. M.Sc. dissertation. Iowa State University, Ames. Available at: https://www.proquest.com/openview/122c70541e609ff702a29229eae481c5/1?pq-origsite=gscholar&cbl=18750&diss=y.

Hasani, M., F. Wu, K. Hu, J. Farber, and K. Warriner. 2020. Inactivation of *Salmonella* and *Listeria monocytogenes* on dried fruit, pistachio nuts, cornflakes and chocolate crumb using a peracetic acid-ethanol based sanitizer or Advanced Oxidation Process. *Int. J. Food Microbiol.* 333:108789. Available at: https://doi.org/10.1016/j.ijfoodmicro.2020.108789.

He, Y., D. Guo, J. Yang, M. L. Tortorello, and W. Zhang. 2011. Survival and heat resistance of *Salmonella enterica* and *Escherichia coli* O157:H7 in peanut butter. *Appl. Environ. Microbiol.* 77:8434–8438.

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Hertwig, C., A. Leslie, N. Meneses, K. Reineke, C. Rauh, and O. Schlüter. 2017. Inactivation of *Salmonella* Enteritidis PT30 on the surface of unpeeled almonds by cold plasma. *Innov. Food Sci. Emerg. Technol.* 44:242–248.

Hwang, H.-J., C.-I. Cheigh, and M.-S. Chung. 2017. Construction of a pilot-scale continuous-flow intense pulsed light system and its efficacy in sterilizing sesame seeds. *Innov. Food Sci. Emerg. Technol.* 39:1–6.

Hvizdzak, A. L., S. Beamer, J. Jaczynski, and K. E. Matak. 2010. Use of electron beam radiation for the reduction of *Salmonella enterica* serovars Typhimurium and Tennessee in peanut butter. *J. Food Prot.* 73:353–357.

Izmirlioglu, G., B. Ouyang, and A. Demirci. 2020. Utilization of pulsed UV light for inactivation of *Salmonella* Enteritidis on shelled walnuts. *LWT* 134:110023.

Jeong, S., B. P. Marks, and A. Orta-Ramirez. 2009. Thermal inactivation kinetics for *Salmonella* Enteritidis PT30 on almonds subjected to moist-air convection heating. *J. Food Prot.* 72:1602–1609.

Jeong, S., B. P. Marks, and E. T. Ryser. 2011. Quantifying the performance of *Pediococcus* sp. (NRRL B-2354: *Enterococcus faecium*) as a nonpathogenic surrogate for *Salmonella* Enteritidis PT30 during moist-air convection heating of almonds. *J. Food Prot.* 74:603–609.

Jeong, S., B. P. Marks, E. T. Ryser, and J. B. Harte. 2012. The effect of X-ray irradiation on *Salmonella* inactivation and sensory quality of almonds and walnuts as a function of water activity. *Int. J. Food Microbiol.* 153:365–37.

Jeong, S., B. P. Marks, and M. K. James. 2017. Comparing thermal process validation methods for *Salmonella* inactivation on almond kernels. *J. Food Prot*. 80:169–176.

Jeong, S.-G., O.-D. Baik, and D.-H. Kang. 2017. Evaluation of radio-frequency heating in controlling *Salmonella enterica* in raw shelled almonds. *Int. J. Food Microbiol.* 254:54–61.

Jeong, S.-G., S. Ryu, and D.-H. Kang. 2019. Salt content dependent dielectric properties of pistachios relevant to radio-frequency pasteurization. *Scientific Rep.* 9:2400. Available at: https://doi.org/10.1038/s41598-019-38987-9.

Karagöz, I., R. G. Moreira, and M. E. Castell-Perez. 2014. Radiation D_{10} values for *Salmonella* Typhimurium LT2 and an *Escherichia coli* cocktail in pecan nuts (Kanza cultivar) exposed to different atmospheres. *Food Control* 39:146–153.

Keller, S. E., E. M. Grasso, L. A. Halik, G. J. Fleischman, S. J. Chirtel, and S. F. Grove. 2012. Effect of growth on the thermal resistance and survival of *Salmonella* Tennessee and Oranienburg in peanut butter, measured by a new thin-layer thermal death time device. *J. Food Prot.* 75:1125–1130.

Kharel, K., V. K. Yemmireddy, C. J. Graham, W. Prinyawiwatkul, and A. Adhikari. 2018. Hot water treatment as a kill-step to inactivate *Escherichia coli* O157:H7, *Salmonella enterica*, *Listeria monocytogenes* and *Enterococcus faecium* on in-shell pecans. *LWT – Food Sci. Technol.* 97:555–560.

Lacombe, A., B. A. Niemira, J. Sites, G. Boyd, J. B. Gurtler, B. Tyrell, and M. Fleck. 2016. Reduction of bacterial pathogens and potential surrogates on the surface of almonds using high-intensity 405-nanometer light. *J. Food Prot.* 79:1840–1845.

Lee, S. Y., J. In, M.-S. Chung, and S. C. Min. 2021. Microbial decontamination of particulate food using a pilot-scale atmospheric plasma jet treatment system. *J. Food Eng.* 294:110436. Available at: https://doi.org/10.1016/j.jfoodeng.2020.110436. [sesame]

Lee, S.-Y., S.-W. Oh, H.-J. Chung, J. I. Reyes-De-Corcuera, J. R. Powers, and D. H. Kang. 2006. Reduction of *Salmonella* enterica serovar Enteritidis on the surface of raw shelled almonds by exposure to steam. *J. Food Prot.* 69:591–595.

Letchworth, C. A. 2020. Reduction of *Salmonella* spp. on in-shell hazelnuts using continuous steam blanching and prevalence of *Salmonella* spp. on in-shell Oregon hazelnuts. M.S. thesis. Oregon State University, Corvallis. Available at: https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/0c483r91s.

L. J. Harris, S. Yada, L. R. Beuchat, and M. D. Danyluk. Initial funding (2009–2013) provided by USDA NIFSI, 2009-01951. Currently (2021-present) supported by the Agriculture and Food Research Initiative, Sustainable Agricultural Systems Program grant no. 2020-68012-31822 from the USDA National Institute of Food and Agriculture. Updated 8/12/2022.

Li, C., L. Huang, and J. Chen. 2014. Comparative study of thermal inactivation kinetics of *Salmonella* spp. in peanut butter and peanut butter spread. *Food Control* 45:143–149.

Li, R., X. Kou, T. Cheng, A. Zheng, and S. Wang. 2017. Verification of radio frequency pasteurization process for in-shell almonds. *J. Food Eng.* 192:103–110.

Lim, J., E. Kim, Y. Shin, J. Ryu, and H. Kim. 2021. Antimicrobial activity of ClO_2 gas against *Salmonella* Enteritidis on almonds. *Food Microbiol*. 99:103819.

Liu, X., X. Fan, W. Wang, S. Yao, and H. Chen. 2021. Wetting raw almonds to enhance pulse light inactivation of *Salmonella* and preserve quality. *Food Control* 125:107946.

Ma, L., G. Zhang, P. Gerner-Smidt, V. Mantripragada, I. Ezeoke, and M. P. Doyle. 2009. Thermal inactivation of *Salmonella* in peanut butter. *J. Food Prot.* 72:1596–1601.

McKay, A. M., W. L. Kerr, J. M. Dorick, and L. L. Dunn. 2022. Conditions for optimal shelling, microbial reduction, and kernel quality in pecans. *Postharv. Biol. Technol.* 191:111966.

Meyer, M. T., and R. H. Vaughn. 1969. Incidence of *Escherichia coli* in black walnut meats. *Appl. Microbiol.* 18:925–931.

Mohammad, Z. H., E. A. Murano, R. G. Moreira, and A. Castillo. 2019. Effect of air- and vacuum-packaged atmospheres on the reduction of *Salmonella* on almonds by electron beam irradiation. *LWT – Food Sci. Technol.* 116:108389.

Moussavi, M., J. C. Frelka, I. M. Hildebrant, B. P. Marks, and L. J. Harris. 2020. Thermal resistance of foodborne pathogens and *Enterococcus faecium* NRRL B-2354 on inoculated pistachios. *J. Food Prot.* 83:1125–1136.

Niemira, B. A. 2012. Cold plasma reduction of *Salmonella* and *Escherichia coli* O157:H7 on almonds using ambient pressure gases. *J. Food Sci.* 77(3):M171–M175.

Oh, S., and Y.-B. Liu. 2020. Effectiveness of nitrogen dioxide fumigation for microbial control on stored almonds. *J. Food Prot.* 83:599–604.

Olaimat, A. N., M. A. Al-Holy, M. H. Abu Ghoush, A. A. Al-Nabulsi, T. M. Osaili, M. Ayyash, Y. S. Al-Degs, and R. A. Holley. 2022a. Use of citric acid and garlic extract to inhibit *Salmonella enterica* and *Listeria monocytogenes* in hummus. *Int. J. Food Microbiol.* 362:109474.

Olaimat, A. N., M. A. Al-Holy, M. H. Abu-Ghoush, T. M. Osaili, A. A. Al-Nabulsi, and B. A. Rasco. 2017a. Inhibition of *Shigella sonnei* and *Shigella flexneri* in hummus using citric acid and garlic extract. *J. Food Sci.* 82:1908–1915.

Olaimat, A. N., A. A. Al-Nabulsi, T. M. Osaili, M. Al-Holy, M. Abu Ghoush, H. Alkhalidy, Z. W. Jaradat, M. Ayyash, and R. A. Holley. 2022b. Inactivation of stressed *Salmonella enterica*, *Escherichia coli* O157: H7, and *Listeria monocytogenes* in hummus using low dose gamma irradiation. *J. Food Sci.* 87:845–855.

Olaimat, A. N., A. A. Al-Nabulsi, T. M. Osaili, M. Al-Holy, M. M. Ayyash, G. F. Mehyar, Z. W. Jaradat, and M. A. Ghoush. 2017b. Survival and inhibition of *Staphylococcus aureus* in commercial and hydrated tahini using acetic and citric acids. *Food Control* 77:179–186.

Osaili, T. M., and A. Al-Nabulsi. 2016. Inactivation of stressed *Escherichia coli* O157: H7 in tahini (sesame seeds paste) by gamma irradiation. *Food Control* 69:221–226.

Osaili, T. M., A. A. Al-Nabulsi, Y. M. Al Sheikh, A. R. Alaboudi, A. N. Olaimat, M. Al-Holy, W. M. Al-Rousan, and R. Holley. 2021. Inactivation of *Salmonella* spp., *Escherichia coli* O157:H7 and *Listeria monocytogenes* in tahini by microwave heating. *Foods* 10(12):2972. Available at: https://www.mdpi.com/2304-8158/10/12/2972.

Pao, S., A. Kalantari, and G. Huang. 2006. Utilizing acidic sprays for eliminating *Salmonella enterica* on raw almonds. *J. Food Sci.* 71:M14–M19.

Pearson, E. H., J. Jones, and J. G. Waite-Cusic. 2018. Evaluation of peroxyacetic acid for reducing low levels of *Salmonella* on laboratory-inoculated and naturally contaminated in-shell hazelnuts. *J. Food Prot.* 81:254–260.

L. J. Harris, S. Yada, L. R. Beuchat, and M. D. Danyluk. Initial funding (2009–2013) provided by USDA NIFSI, 2009-01951. Currently (2021-present) supported by the Agriculture and Food Research Initiative, Sustainable Agricultural Systems Program grant no. 2020-68012-31822 from the USDA National Institute of Food and Agriculture. Updated 8/12/2022.

Pelaez, M. A. B., G. R. Anapi, D. V. Bautista, M. D. P. Dallo, J. C. M. Libunao, and A. A. Gabriel. 2020. Thermal inactivation of *Salmonella enterica* in Philippine flowing-type peanut butter. *LWT* 129:109507. Available at: https://doi.org/10.1016/j.lwt.2020.109507.

Perry, J. J., M. Peña-Melendez, and A. E. Yousef. 2019. Ozone-based treatments for inactivation of *Salmonella enterica* in tree nuts: Inoculation protocol and surrogate suitability considerations. *Int. J. Food Microbiol.* 297:21–26.

Pignata, C., D. D'Angelo, D. Basso, M. C. Cavallero, S. Beneventi, D. Tartaro, V. Meineri, and G. Gilli. 2014. Low-temperature, low-pressure gas plasma application on *Aspergillus brasiliensis*, *Escherichia coli* and pistachios. *J. Appl. Microbiol*. 116:1137–1148.

Poirier, D., T. H. Sanders, and J. P. Davis. 2014. *Salmonella* surrogate reduction using industrial peanut dry roasting parameters. *Peanut Sci.* 41(2):72–84.

Prakash, A., F. T. Lim, C. Duong, F. Caporaso, and D. Foley. 2010. The effects of ionizing irradiation on *Salmonella* inoculated on almonds and changes in sensory properties. *Radiat. Phys. Chem.* 79:502–506.

Prestes, F. S., A. A. M. Pereira, A. C. M. da Silva, P. O. Pena, and M. S. Nascimento. 2019a. Effects of peanut drying and blanching on *Salmonella* spp. *Food Res. Int.* 119:411–416.

Prestes, F. S., A. C. M. da Silva, A. A. M. Pereira, and M. S. Nascimento. 2019b. Impact of peanut roasting on *Salmonella* spp. survival. *LWT – Food Sci. Technol.* 108:168–173.

Quinn, A. R., R. F. Liao, F. M. Steele, L. K. Jefferies, and B. J. Taylor. 2021. Isothermal inactivation of *Salmonella*, *Listeria monocytogenes*, *and Enterococcus faecium* NRRL B-2354 in peanut butter, powder infant formula, and wheat flour. *Food Control* 121:107582. Available at: https://doi.org/10.1016/j.foodcont.2020.107582.

Rane, B., D. F. Bridges, and V. C. H. Wu. 2020. Gaseous antimicrobial treatments to control foodborne pathogens on almond kernels and whole black peppercorns. *Food Microbiol.* 92:103576.

Rane, B., A. Lacombe, S. Sablani, D. F. Bridges, J. Tang, J. Guan, and V. C. H. Wu. 2021. Effects of moisture content and mild heat on the ability of gaseous chlorine dioxide against *Salmonella* and *Enterococcus faecium* NRRL B-2354 on almonds. *Food Control* 123:107732. Available at: https://doi.org/10.1016/j.foodcont.2020.107732.

Ruiz-Hernández, K., N. Z. Ramírez-Rojas, E. F. Meza-Plaza, C. García-Mosqueda, D. Jauregui-Vázquez, R. Rojas-Laguna, and M. E. Sosa-Morales. 2021. UV-C treatments against *Salmonella* Typhimurium ATCC 14028 in inoculated peanuts and almonds. *Food Eng. Rev.* 13:706–712.

Salazar, F., S. Garcia, M. Lagunas-Solar, Z. Pan, and J. Cullor. 2017. Efficacy of a heat-spray and heat-double spray process on inoculated nuts with *Salmonella enteritidis* ATCC 1045. *Food Control* 81:74–79.

Salazar, F., S. Garcia, M. Lagunas-Solar, Z. Pan, and J. Cullor. 2018. Effect of a heat-spray and heat-double spray process using radiofrequency technology and ethanol on inoculated nuts. *J. Food Eng.* 227:51–57.

Sanders, T. H., and R. S. Calhoun. 2014. Effect of oil and dry roasting of peanuts at various temperatures and times on survival of *Salmonella* and *Enterococcus faecium*. *Peanut Sci.* 41(2):65–71.

Saunders, T., J. Wu, R. C. Williams, H. Huang, and M. A. Ponder. 2018. Inactivation of *Salmonella* and surrogate bacteria on cashews and macadamia nuts exposed to commercial propylene oxide processing conditions. *J. Food Prot.* 81:417–423.

Schade, J. E., and A. D. King, Jr. 1977. Methyl bromide as a microbicidal fumigant for tree nuts. *Appl. Environ. Microbiol.* 33:1184–1191.

Shachar, D., and S. Yaron. 2006. Heat tolerance of *Salmonella enterica* serovars Agona, Enteritidis, and Typhimurium in peanut butter. *J. Food Prot.* 69:2687–2691.

Shirani, K., F. Shahidi, and S. A. Mortazavi. 2020. Investigation of decontamination effect of argon cold plasma on physicochemical and sensory properties of almond slices. *Int. J. Food Microbiol.* 335:108892.

Song, W.-J., and D.-H. Kang. 2016. Inactivation of *Salmonella* Senftenberg, *Salmonella* Typhimurium and *Salmonella* Tennessee in peanut butter by 915 MHz microwave heating. *Food Microbiol.* 53, Part B:48–52.

L. J. Harris, S. Yada, L. R. Beuchat, and M. D. Danyluk. Initial funding (2009–2013) provided by USDA NIFSI, 2009-01951. Currently (2021-present) supported by the Agriculture and Food Research Initiative, Sustainable Agricultural Systems Program grant no. 2020-68012-31822 from the USDA National Institute of Food and Agriculture. Updated 8/12/2022.

Song, W.-J., and D.-H. Kang. 2021. Influence of packaging methods on the dry heat inactivation of *Salmonella* Typhimurium, *Salmonella* Senftenberg, and *Salmonella* Enteritidis PT 30 on almonds. *LWT* 143:111121. Available at: https://doi.org/10.1016/j.lwt.2021.111121.

Song, W.-J., Y.-H. Kim, and D.-H. Kang. 2019. Effect of gamma irradiation on inactivation of *Escherichia coli* O157:H7, *Salmonella* Typhimurium and *Listeria monocytogenes* on pistachios. *Lett. Appl. Microbiol.* 68:96–102.

Steinbrunner, P. J., P. Limcharoenchat, Q. J. Suehr, E. T. Ryser, B. P. Marks, and S. Jeong. 2019. Effect of food structure, water activity, and long-term storage on X-ray irradiation for inactivating *Salmonella* Enteritidis PT30 in low-moisture foods. *J. Food Prot.* 82:1405–1411. [almond kernels, meal, butter]

Szpinak, V., M. Ganz, and S. Yaron. 2022. Factors affecting the thermal resistance of *Salmonella* Typhimurium in tahini. *Food Res. Int.* 155:111088.

Tayyarcan, E. K., S. Evran, P. Ari Akin, E. Acar Soykut, and I. H. Boyaci. 2022. The use of bacteriophage cocktails to reduce *Salmonella* Enteritidis in hummus. *LWT* 154:112848. Available at: https://doi.org/10.1016/j.lwt.2021.112848.

Torlak, E., D. Sert, and P. Serin. 2013. Fate of *Salmonella* during sesame seeds roasting and storage of tahini. *Int. J. Food Microbiol*. 163:214–217.

Tsai, H.-C., L. Sheng, and M.-J. Zhu. 2017. Antimicrobial efficacy of cinnamon oil against *Salmonella* in almond based matrices. *Food Control* 80:170–175.

Venkitasamy, C., M. T. Brandl, B. Wang, T. H. McHugh, R. Zhang, and Z. Pan. 2017. Drying and decontamination of raw pistachios with sequential infrared drying, tempering and hot air drying. *Int. J. Food Microbiol.* 246:85–91.

Venkitasamy, C., C. Zhu, M. T. Brandl, F. J. A. Niederholzer, R. Zhang, T. H. McHugh, and Z. Pan. 2018. Feasibility of using sequential infrared and hot air for almond drying and inactivation of *Enterococcus faecium* NRRL B-2354. *LWT – Food Sci. Technol.* 95:123–128.

Walter, E. H. M., M. S. Nascimento, and A. Y. Kuaye. 2009. Efficacy of sodium hypochlorite and peracetic acid in sanitizing green coconuts. *Lett. Appl. Microbiol.* 49:366–371.

Wang, L., J. B. Gurtler, W. Wang, and X. Fan. 2019. Interaction of gaseous chlorine dioxide and mild heat on the inactivation of *Salmonella* on almonds. *J. Food Prot.* 82:1729–1735.

Weller, L. D., M. A. Daeschel, C. A. Durham, and M. T. Morrissey. 2013. Effects of water, sodium hypochlorite, peroxyacetic acid, and acidified sodium chlorite on in-shell hazelnuts inoculated with *Salmonella Enterica* serovar Panama*. J. Food Sci.* 78(12):M1885–M1891.

Wihodo, M., Y. Han, T. L. Selby, P. Lorcheim, M. Czarneski, G. Huang, and R. H. Linton. 2005. Decontamination of raw almonds using chlorine dioxide gas, (Abstract 99E-12). Institute of Food Technologists Annual Meeting 2005, New Orleans, LA, July 15–20.

Willford, J., A. Mendonca, and L. D. Goodridge. 2008. Water pressure effectively reduces *Salmonella enterica* serovar Enteritidis on the surface of raw almonds. *J. Food Prot.* 71:825–829.

Wilson-Kakashita, G., D. L. Geredes, and W. R. Hall. 1995. The effect of gamma irradiation on the quality of English walnuts (*Juglans regia*). *Lebensm. Wiss. Technol.* 28:17–20.

Wright, D. G., J. Minarsich, M. A. Daeschel, and J. Waite-Cusic. 2018. Thermal inactivation of *Salmonella* spp. in commercial tree nut and peanut butters in finished packaging. *J. Food Safety* 38:e12371.

Wuytack, E. Y., A. M. J. Diels, K. Meersseman, and C. W. Michiels. 2003. Decontamination of seeds for seed sprout production by high hydrostatic pressure. *J. Food Prot*. 66:918–923.

Xu, H., W. Ma, T. Zhang, Y. Hu, G. Du, H. Yang, Y. Li, Y. Xu, and R. Li. 2020. Efficient inhibition of *Salmonella* on chestnuts via Fe3C/NC bacteriostatic suspension prepared by electrochemical method. *Inorganic Chem. Comm.* 118:108034.

Xu, S., and H. Chen. 2022. Vacuum packaging improved inactivation efficacy of moderate dry heat for decontamination of *Salmonella* on almond kernels. *Int. J. Food Microbiol.* 379:109849.

L. J. Harris, S. Yada, L. R. Beuchat, and M. D. Danyluk. Initial funding (2009–2013) provided by USDA NIFSI, 2009-01951. Currently (2021-present) supported by the Agriculture and Food Research Initiative, Sustainable Agricultural Systems Program grant no. 2020-68012-31822 from the USDA National Institute of Food and Agriculture. Updated 8/12/2022.

Xu, Y., R. Li, K. Li, J. Yu, J. Bai, and S. Wang. 2022. Inactivation of inoculated *Salmonella* and natural microflora on two kinds of edible seeds by radio frequency heating combined with cinnamon oil vapor. *LWT* 154:112603. Available at: https://doi.org/10.1016/j.lwt.2021.112603.

Yang, J., G. Bingol, Z. Pan, M. T. Brandl, T. H. McHugh, and H. Wang. 2010. Infrared heating for dry-roasting and pasteurization of almonds. *J. Food Eng.* 101:273–280.

Yun, Y.-S., S.-J. Bae, and S.-H. Park. 2022. Inactivation of foodborne pathogens on inshell walnuts by UV-C radiation. *J. Food Prot.* (online 5 May 2022).

Zhang, Y., S. E. Keller, and E. M. Grasso-Kelley. 2017. Fate of *Salmonella* throughout production and refrigerated storage of tahini. *J. Food Prot.* 80:940–946.

Zhang, L., J. G. Lyng, R. Xu, S. Zhang, X. Zhou, and S. Wang. 2019. Influence of radio frequency treatment on in-shell walnut quality and *Staphylococcus aureus* ATCC 25923 survival. *Food Control* 102:197–205.

L. J. Harris, S. Yada, L. R. Beuchat, and M. D. Danyluk. Initial funding (2009–2013) provided by USDA NIFSI, 2009-01951. Currently (2021-present) supported by the Agriculture and Food Research Initiative, Sustainable Agricultural Systems Program grant no. 2020-68012-31822 from the USDA National Institute of Food and Agriculture. Updated 8/12/2022.