

BAB IV

KESIMPULAN

1. *Pulsed electric field* (PEF) merupakan metode pengawetan nontermal yang baik untuk diaplikasikan pada bahan makanan berfasa cair atau semi cair.
2. PEF dapat dimanfaatkan untuk beberapa aplikasi lain selain pengawetan antara lain meningkatkan kualitas ekstraksi, meningkatkan kualitas pengeringan, dan meningkatkan kadar nutrisi makanan.
3. PEF mempunyai peluang untuk dimanfaatkan sebagai metode untuk mengawetkan pasta jahe sekaligus sebagai metode pengganti *blanching* untuk melunakkan jaringan pada jahe tanpa menurunkan kualitas jahe.
4. Variabel proses yang mempengaruhi keberhasilan perlakuan menggunakan metode PEF antara lain jenis bahan makanan, kekuatan tegangan, waktu *treatment*, temperatur dan tekanan proses, panjang gelombang, dan jenis gelombang.
5. Proses PEF dapat meningkatkan waktu penyimpanan makanan sebanyak 8 sampai 28 minggu tanpa menurunkan kualitas dari bahan makanan.

DAFTAR PUSTAKA

- Ade-Omowaye, B.I.O., Angersbach, A., Taiwo, K.A., & Knorr, D. (2001). *Use of pulsed electric field pre-treatment to improve dehydration characteristics of plant based foods. Trends in Food Science & Technology, 12(8), 285-295.* doi:10.1016/s0924-2244(01)00095-4
- Aguiló-Aguayo, I., Soliva-Fortuny, R., & Martín-Belloso, O. (2010). High-intensity pulsed electric fields processing parameters affecting polyphenoloxidase activity of strawberry juice. *Journal of food science, 75(7), C641-C646.*
- Ahmed, J. (2004). *Rheological behaviour and colour changes of ginger paste during storage.* International Journal of Food Science and Technology, 39(3), 325–330.
- Álvarez, I., & Heinz, V. (2007). *Hurdle technology and the preservation of food by pulsed electric fields. Food Preservation by Pulsed Electric Fields, 165–177.* doi:10.1533/9781845693831.2.165
- Ancy, J., Thayumanavan, B., & Pournami, P. R. (2012). Characterization of polyphenol oxidase in ginger (*Zingiber officinale* R.). *Journal of Spices and Aromatic Crops, 21(1), 33-41.*
- Angersbach, A. (2000). *Effects of pulsed electric fields on cell membranes in real food systems. Innovative Food Science & Emerging Technologies, 1(2), 135–149.* doi:10.1016/s1466-8564(00)00010-2
- Apriliana, E., Witono, J.R., Handojo, L.A. (2018). Pembuatan Pasta Jahe Menjadi Bahan Siap Pakai. Bandung: Program Studi Teknik Kimia Fakultas Teknologi Industri – UNPAR
- Ayhan, Z., Yeom, H. W., Zhang, Q. H., & Min, D. B. (2001). *Flavor, Color, and Vitamin C Retention of Pulsed Electric Field Processed Orange Juice in Different Packaging Materials. Journal of Agricultural and Food Chemistry, 49(2), 669–674.* doi:10.1021/jf000984b
- Badan Pusat Statistik (2017). Statistik Tanaman Biofarmaka Indonesia.
- Badan Pusat Statistik dan Direktorat Jenderal Hortikultura (2017). Dikutip dari [http://www.pertanian.go.id/Data5tahun/HortiATAP2017\(.pdf\)/Produksi%20Jahe.pdf](http://www.pertanian.go.id/Data5tahun/HortiATAP2017(.pdf)/Produksi%20Jahe.pdf) . (Diakses 14 Mei 2019).
- Bai-Lin Qin, Qinghua Zhang, Barbosa-Canovas, G. V., Swanson, B. G., & Pedrow, P. D. (1994). *Inactivation of microorganisms by pulsed electric fields of different voltage*

- waveforms. *IEEE Transactions on Dielectrics and Electrical Insulation*, 1(6), 1047–1057. doi:10.1109/94.368658
- Baranowski, J. D. (1985). *Storage Stability of a Processed Ginger Paste*. *Journal of Food Science*, 50(4), 932–933. doi:10.1111/j.1365-2621.1985.tb12982.x
- Bendicho, S., Barbosa-Canovas, G. V., & Martin, O. (2003). *Reduction of Protease Activity in Simulated Milk Ultrafiltrate by Continuous Flow High Intensity Pulsed Electric Field Treatments*. *Journal of Food Science*, 68(3), 952–957. doi:10.1111/j.1365-2621.2003.tb08270.x
- Bhattarai, S., Tran, V. H., & Duke, C. C. (2001). *The Stability of Gingerol and Shogaol in Aqueous Solutions*. *Journal of Pharmaceutical Sciences*, 90(10), 1658–1664. doi:10.1002/jps.1116
- Bode, A. M., & Dong, Z. (2011). The amazing and mighty ginger. *Herbal medicine: Biomolecular and clinical aspects*, 2.
- Castro, I., Teixeira, J. A., Salengke, S., Sastry, S. K., & Vicente, A. A. (2003). *The Influence of Field Strength, Sugar and Solid Content on Electrical Conductivity of Strawberry Products*. *Journal of Food Process Engineering*, 26(1), 17–29. doi:10.1111/j.1745-4530.2003.tb00587.x
- Choi, E. J., Lee, K. A., Kim, B. S., & Ku, K. H. (2012). Effect of Pre-treatment and Storage Conditions on the Quality Characteristics of Ginger Paste. *Preventive nutrition and food science*, 17(1), 46–52. <https://doi.org/10.3746/pnf.2012.17.1.046>
- Cousin, M. A., & Blackburn, C. D. W. (2006). Detection, enumeration and identification methods for spoilage molds. *Food spoilage microorganisms*. Woodhead, Cambridge, 55-85.
- De Haan, S. W. H. (2007). *Circuitry and pulse shapes in pulsed electric field treatment of food*. *Food Preservation by Pulsed Electric Fields*, 43–69. doi:10.1533/9781845693831.1.43
- Del Valle, J. M., Aránguiz, V., & León, H. (1998). *Effects of blanching and calcium infiltration on PPO activity, texture, microstructure and kinetics of osmotic dehydration of apple tissue*. *Food Research International*, 31(8), 557–569. doi:10.1016/s0963-9969(99)00029-0
- Devi, T. B., Dash, S. K., Bal, L. M., & Sahoo, N. R. (2016). Physicochemical and microbiological characteristics of ginger paste (cv. Suprabha) during storage in different packaging and temperature conditions. *Cogent Food & Agriculture*, 2(1).

- Elez-Martínez, P., Martín-Belloso, O. M., Rodrigo, D., & Sampedro, F. (2007). Impact of pulsed electric fields on food enzymes and shelf-life. *Food Preservation by Pulsed Electric Fields: From Research to Application*, 212-246.
- Evrendilek, G. A., Dantzer, W. R., Streaker, C. B., Ratanatriwong, P., & Zhang, Q. H. (2001). Shelf-life evaluations of liquid foods treated by pilot plant pulsed electric field system. *Journal of Food Processing and Preservation*, 25(4), 283-297.
- Evrendilek, G. A., Tok, F. M., Soylu, E. M., & Soylu, S. (2008). *Inactivation of Penicillium expansum in sour cherry juice, peach and apricot nectars by pulsed electric fields. Food Microbiology*, 25(5), 662–667. doi:10.1016/j.fm.2008.03.009
- Food Nutrition Table. Dikutip dari <http://www.foodnutritiontable.com/nutritions/nutrient/?id=664> (Diakses 10 September 2018).
- Fung, F., & Clark, R. F. (2004). *Health Effects of Mycotoxins: A Toxicological Overview. Journal of Toxicology: Clinical Toxicology*, 42(2), 217–234. doi:10.1081/clt-120030947
- Garner, A. L., Chen, N., Yang, J., Kolb, J., Swanson, R. J., Loftin, K. C., Schoenbach, K. H. (2004). *Time Domain Dielectric Spectroscopy Measurements of HL-60 Cell Suspensions After Microsecond and Nanosecond Electrical Pulses. IEEE Transactions on Plasma Science*, 32(5), 2073–2084. doi:10.1109/tps.2004.835973
- Giner, J., Gimeno, V., Barbosa-Cánovas, G. V., & Martín, O. (2001). *Effects of Pulsed Electric Field Processing on Apple and Pear Polyphenoloxidases. Food Science and Technology International*, 7(4), 339–345. doi:10.1106/mj46-8j9u-1h11-t0ml
- Giner, J., Ortega, M., Meseguer, M., Gimeno, V., Barbosa-Canovas, G. V., & Martin, O. (2002). *Inactivation of Peach Polyphenoloxidase by Exposure to Pulsed Electric Fields. Journal of Food Science*, 67(4), 1467–1472. doi:10.1111/j.1365-2621.2002.tb10307.x
- Govindarajan, V. S., & Connell, D. W. (1983). *Ginger — chemistry, technology, and quality evaluation: Part I. C R C Critical Reviews in Food Science and Nutrition*, 17(1), 1–96. doi:10.1080/10408398209527343
- Han, Z., Zeng, X. A., Yu, S. J., Zhang, B. S., & Chen, X. D. (2009). *Effects of pulsed electric fields (PEF) treatment on physicochemical properties of potato starch. Innovative Food Science & Emerging Technologies*, 10(4), 481–485. doi:10.1016/j.ifset.2009.07.003

- He, X., Bernart, M. W., Lian, L., & Lin, L. (1998). *High-performance liquid chromatography–electrospray mass spectrometric analysis of pungent constituents of ginger*. *Journal of Chromatography A*, 796(2), 327–334. doi:10.1016/s0021-9673(97)01013-3
- Heinz, V., & Knorr, D. (2000). *Effect of pH, ethanol addition and high hydrostatic pressure on the inactivation of Bacillus subtilis by pulsed electric fields*. *Innovative Food Science & Emerging Technologies*, 1(2), 151–159. doi:10.1016/s1466-8564(00)00013-8
- Ho, S. Y., Mittal, G. S., & Cross, J. D. (1997). *Effects of high field electric pulses on the activity of selected enzymes*. *Journal of Food Engineering*, 31(1), 69–84. doi:10.1016/s0260-8774(96)00052-0
- Icier, F., & Ilicali, C. (2004). *The effects of concentration on electrical conductivity of orange juice concentrates during ohmic heating*. *European Food Research and Technology*, 220(3-4), 406–414. doi:10.1007/s00217-004-1043-x
- Jaeger, H., Meneses, N., & Knorr, D. (2009). *Impact of PEF treatment inhomogeneity such as electric field distribution, flow characteristics and temperature effects on the inactivation of E. coli and milk alkaline phosphatase*. *Innovative Food Science & Emerging Technologies*, 10(4), 470–480. doi:10.1016/j.ifset.2009.03.001
- Kumar, Satyendra & Agarwal, Nidhi & Raghav, Pramod. (2016). Pulsed Electric Field Processing of Foods- A Review. 1. 2455-4200.
- Kumar, Y., Patel, K. K., & Kumar, V. (2015). Pulsed electric field processing in food technology. *International Journal of Engineering Studies and Technical Approach*, 1(2), 6-17.
- Lebovka, N.I., Shynkaryk, N.V., & Vorobiev, E. (2007). *Pulsed electric field enhanced drying of potato tissue*. *Journal of Food Engineering*, 78(2), 606-613. doi:10.1016/j.jfoodeng.2005.10.032
- Lee, C. Y., & Smith, N. L. (1979). *Blanching Effect on Polyphenol Oxidase Activity in Table Beets*. *Journal of Food Science*, 44(1), 82–83. doi:10.1111/j.1365-2621.1979.tb10010.x
- Liang, Z., Cheng, Z., & Mittal, G. S. (2006). *Inactivation of spoilage microorganisms in apple cider using a continuous flow pulsed electric field system*. *LWT - Food Science and Technology*, 39(4), 351–357. doi:10.1016/j.lwt.2005.02.019

- Lima, M. (2004). Food preservation aspects of ohmic heating. *Food Science and Technology-New York-Marcel Dekker-*, 167, 741.
- Matser, A. M., Schuten, H. J., Mastwijk, H. C., & Lommen, A. (2007). Toxicological aspects of preservation of food by pulsed electric fields. *Food preservation by pulsed electric fields*, 201-210.
- Membré, J.-M., Kubaczka, M., & Chèné, C. (2001). *Growth rate and growth–no-growth interface of Penicillium brevicompactum as functions of pH and preservative acids. Food Microbiology*, 18(5), 531–538. doi:10.1006/fmic.2001.0442
- Min, S., Jin, Z. T., & Zhang, Q. H. (2003). *Commercial Scale Pulsed Electric Field Processing of Tomato Juice. Journal of Agricultural and Food Chemistry*, 51(11), 3338–3344. doi:10.1021/jf0260444
- Mishra, B. B., Gautam, S., & Sharma, A. (2006). Shelf-Life Extension of Fresh Ginger (*Zingiberofficinale*) by Gamma Irradiation. *Journal of Food Science*, 69(9), M274–M279. doi:10.1111/j.1365-2621.2004.tb09942.x
- Morshuis, P. H. F. (2007). *Technical and occupational safety requirements when treating foods by pulsed electric fields. Food Preservation by Pulsed Electric Fields*, 118–123. doi:10.1533/9781845693831.1.118
- Nierop Groot, M., Abee, T., & van Bokhorst-van de Veen, H. (2018). *Inactivation of conidia from three Penicillium spp. isolated from fruit juices by conventional and alternative mild preservation technologies and disinfection treatments. Food Microbiology*. doi:10.1016/j.fm.2018.06.004
- Ohshima, T., Tamura, T., & Sato, M. (2007). Influence of pulsed electric field on various enzyme activities. *Journal of Electrostatics*, 65(3), 156-161.
- Olivenbaum, J. E., & Kester, R. A. (1990). *U.S. Patent No. 4,904,947*. Washington, DC: U.S. Patent and Trademark Office.
- Overy, D. P., & Frisvad, J. C. (2005). *Mycotoxin Production and Postharvest Storage Rot of Ginger (Zingiber officinale) by Penicillium brevicompactum. Journal of Food Protection*, 68(3), 607–609. doi:10.4315/0362-028x-68.3.607
- Pawar, N., Pai, S., Nimbalkar, M., & Dixit, G. (2011). *RP-HPLC analysis of phenolic antioxidant compound 6-gingerol from different ginger cultivars. Food Chemistry*, 126(3), 1330–1336. doi:10.1016/j.foodchem.2010.11.090
- Penicillium brevicompactum. A-C. Colonies grown at 25°C for 7 days. A. CYA. B. MEA. C. CREA. D-I. Conidiophores and conidia. Scale bar = 10 µm. J. Houbraken & R.A.

- Samson. CBS-KNAW Fungal Biodiversity Centre, Utrecht, The Netherlands.
Dikutip dari <https://mycocosm.jgi.doe.gov/Penbr2/Penbr2.home.html> (Diakses 19 Oktober 2018)
- Picart, L., Dumay, E., & Cheftel, J. C. (2002). *Inactivation of Listeria innocua in dairy fluids by pulsed electric fields: influence of electric parameters and food composition. Innovative Food Science & Emerging Technologies, 3(4), 357–369.* doi:10.1016/s1466-8564(02)00055-3
- Pitt, J. I., & Hocking, A. D. (1997). *Penicillium and Related Genera. Fungi and Food Spoilage, 203–338.* doi:10.1007/978-1-4615-6391-4_7
- Pothakamury, U. R., Vega, H., Zhang, Q., Barbosa-Canovas, G. V., & Swanson, B. G. (1996). *Effect of Growth Stage and Processing*
- Pourzaki, Mirzaee, A., & Hossein (2008). Pulsed Electric Field Generators in food processing.
- Prasad, S., & Tyagi, A. K. (2015). *Ginger and Its Constituents: Role in Prevention and Treatment of Gastrointestinal Cancer. Gastroenterology Research and Practice, 2015, 1–11.* doi:10.1155/2015/142979
- Puértolas, E., López, N., Saldaña, G., Álvarez, I., & Raso, J. (2010). *Evaluation of phenolic extraction during fermentation of red grapes treated by a continuous pulsed electric fields process at pilot-plant scale. Journal of Food Engineering, 98(1), 120–125.* doi:10.1016/j.jfoodeng.2009.12.017
- Puértolas, E., Luengo, E., Álvarez, I., & Raso, J. (2012). *Improving Mass Transfer to Soften Tissues by Pulsed Electric Fields: Fundamentals and Applications. Annual Review of Food Science and Technology, 3(1), 263–282.* doi:10.1146/annurev-food-022811-101208
- Ramesh, M. N. (2007). Canning and sterilization of foods. In *Handbook of Food Preservation* (pp. 603-642). CRC Press.
- Ramesh, M. N. (2007). Pasteurization and food preservation. In *Handbook of food preservation* (pp. 589-602). CRC Press.
- Roodenburg, B. (2007). *Electrochemistry in pulsed electric field treatment chambers. Food Preservation by Pulsed Electric Fields, 94–107.* doi:10.1533/9781845693831.1.94
- Ross, I. A. (2005). Zingiber officinale. *Medicinal Plants of the World, Volume 3: Chemical Constituents, Traditional and Modern Medicinal Uses, 507-560.*

- Rousk, J., Brookes, P. C., & Baath, E. (2009). *Contrasting Soil pH Effects on Fungal and Bacterial Growth Suggest Functional Redundancy in Carbon Mineralization*. *Applied and Environmental Microbiology*, 75(6), 1589–1596. doi:10.1128/aem.02775-08
- R. Zhang, N. Zheng, H. Liu and L. Wang, "Influencing Factors of Dielectric Breakdown in the PEF Treatment Chamber," in *IEEE Transactions on Plasma Science*, vol. 43, no. 2, pp. 610-616, Feb. 2015, doi: 10.1109/TPS.2014.2363934.
- Sahu, Jatindra. (2014). *High-Voltage Pulsed Electric Field Processing of Foods*. 10.1201/b16696-8.
- Schweiggert, U., Hofmann, S., Reichel, M., Schieber, A., & Carle, R. (2008). *Enzyme-assisted liquefaction of ginger rhizomes (Zingiber officinale Rosc.) for the production of spray-dried and paste-like ginger condiments*. *Journal of Food Engineering*, 84(1), 28–38. doi:10.1016/j.jfoodeng.2007.04.013
- Sirot, V., Fremy, J.-M., & Leblanc, J.-C. (2013). *Dietary exposure to mycotoxins and health risk assessment in the second French total diet study*. *Food and Chemical Toxicology*, 52, 1–11. doi:10.1016/j.fct.2012.10.036
- Smit, C., & de Haan, W. (2007). *Hygienic design for pulsed electric field installations*. *Food Preservation by Pulsed Electric Fields*, 108–117. doi:10.1533/9781845693831.1.108
- Stanley, D. W., & Parkin, K. L. (1991). *Biological membrane deterioration and associated quality losses in food tissues*. *Critical Reviews in Food Science and Nutrition*, 30(5), 487–553. doi:10.1080/10408399109527554
- Tamborrino, A., Urbani, S., Servili, M., Romaniello, R., Perone, C., & Leone, A. (2019). *Pulsed Electric Fields for the Treatment of Olive Pastes in the Oil Extraction Process*. *Applied Sciences*, 10(1), 114. doi:10.3390/app10010114
- Thomas, D. G. (1962). *Transport characteristics of suspensions: Part IV. Friction loss of concentrated-flocculated suspensions in turbulent flow*. *AIChE Journal*, 8(2), 266–271. doi:10.1002/aic.690080227
- Thompson, E. H., Wolf, I. D., & Allen, C. E. (1973). *Ginger Rhizome: A New Source of Proteolytic Enzyme*. *Journal of Food Science*, 38(4), 652–655. doi:10.1111/j.1365-2621.1973.tb02836.x
- Thuwapanichayanan, R., Phowong, C., Jaisut, D., & Štencl, J. (2014). Effects of pretreatments and drying temperatures on drying characteristics, antioxidant

- properties and color of ginger slice. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 62(5), 1125-1134.
- Ulmer, H. M., Herberhold, H., Fahsel, S., Ganzle, M. G., Winter, R., & Vogel, R. F. (2002). *Effects of Pressure-Induced Membrane Phase Transitions on Inactivation of HorA, an ATP-Dependent Multidrug Resistance Transporter, in Lactobacillus plantarum*. *Applied and Environmental Microbiology*, 68(3), 1088–1095. doi:10.1128/aem.68.3.1088-1095.2002
- Van den Bosch, H. F. M. (2007). *Chamber design and process conditions for pulsed electric field treatment of food*. *Food Preservation by Pulsed Electric Fields*, 70–93. doi:10.1533/9781845693831.1.70
- Vega-Mercado, H., Gongora-Nieto, M. M., Barbosa-Canovas, G. V., & Swanson, B. G. (2004). Pulsed electric fields in food preservation. *Food Science and Technology-New York-Marcel* -, 167, 783.
- Wan, J., Coventry, J., Swiergon, P., Sanguansri, P., & Versteeg, C. (2009). Advances in innovative processing technologies for microbial inactivation and enhancement of food safety—pulsed electric field and low-temperature plasma. *Trends in Food Science & Technology*, 20(9), 414-424.
- Wiktor, A., Sledz, M., Nowacka, M., Rybak, K., Chudoba, T., Lojkowski, W., & Witrowa-Rajchert, D. (2015). *The impact of pulsed electric field treatment on selected bioactive compound content and color of plant tissue*. *Innovative Food Science & Emerging Technologies*, 30, 69–78. doi:10.1016/j.ifset.2015.04.004
- Wouters, P. C., Alvarez, I., & Raso, J. (2001). Critical factors determining inactivation kinetics by pulsed electric field food processing. *Trends in Food Science & Technology*, 12(3-4), 112-121.
- Wouters, P. C., & Smelt, J. P. P. M. (1997). *Inactivation of microorganisms with pulsed electric fields: Potential for food preservation*. *Food Biotechnology*, 11(3), 193–229.