Bölüm 8

ATIKLARDAN ENERJİ ÜRETİMİ

Chapter 8

WASTE-TO-ENERGY (WTE)

Mehmet Hakkı ALMA - Tufan SALAN

BÖLÜM İÇERİĞİ

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Özet

Atık, toplumun kaçınılmaz bir ürünüdür ve gelecek nesiller için en büyük zorluklardan biri, büyük miktarlardaki atıkların nasıl sürdürülebilir bir şekilde yönetileceğini anlamak olacaktır. Üretilen atık miktarını en aza indirgemek ve daha büyük miktarda atık geri dönüşümü sağlamak başlıca yaklaşımlardır. Bununla birlikte, istenmeyen zararlı nihai ürünler ile ilgili önemli kaygılar bulunmaktadır ve bu nedenle atık yönetiminde uygun çözümler bulunmalıdır. Bu bağlamda, enerji sektörünün, sürekli olarak artan bir enerji talebini karşılayabilme ihtiyacından dolayı, atıkların sadece toplumun istenmeyen bir ürünü değil, aynı zamanda değerli bir enerji kaynağı olabileceğinin farkına varılmıştır. Atıktan elde edilen enerji, geri dönüştürülemeyen ve yeniden kullanılamaz atık miktarlarının azaltılması ve tüketicinin ihtiyaçlarını karşılamak için enerji hatlarına dahil edilebilecek önemli miktarda enerji üretilmesini sağlayabilir. Farklı teknolojiler kullanılarak atıktan enerji dönüşümü elde edilebilir. Bu metotlardan her biri belirli özelliklere sahiptir ve birçok parametreye bağlı olarak az ya da çok uygulanabilir olabilir. Bu bölümde atıklardan enerji üretiminde kullanılan farklı teknolojiler açıklanmaya çalışılmıştır.

Anahtar Kelimeler

Atık, Geri Dönüşüm, Enerji, Yakma, Gazlaştırma, Anaerobik Fermantasyon, Biyo-Gaz

Abstract

Waste is an inevitable product of society and one of the biggest challenges for future generations will be how to manage large quantities of waste in a sustainable way. The main approaches are to reduce the amount of waste produced and to obtain a greate amount waste recycling. However, there are considerable concerns about undesirable end products, and therefore appropriate solutions should be found in waste management. In this context, it was realized that waste is not only an undesirable product of society, but also a valuable energy source due to constantly rising energy demand in the sector. The energy obtained from the waste can enable the production of significant quantities of energy that can be included in energy lines to reduce the amount of non-recyclable and non-reusable waste and to meet the needs of the consumer. Energy conversion from waste can be achieved using different technologies. Each of these methods has specific properties and may be more or less applicable depending on many parameters. In this section, different technologies used in energy production from the waste were tried to be explained.

Keywords

Waste, Recycling, Energy, Incineration, Gasification, Anaerobic Fermentation, Bio-Gas

8.7. KAYNAKLAR / REFERENCES

[1] M. Mazzanti, R. Zoboli, Waste generation, waste disposal and policy effectiveness: Evidence on decoupling from the European Union, Resources, Conservation and Recycling. 52 (2008) 1221-1234.

[2] D. Mutz, D. Hengevoss, C. Hugi, T. Gross, Waste-to-Energy options in municipal solid waste management a guide for decision makers in developing and emerging countries, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Germany, 2017.

[3] A. Bosmans, I. Vanderreydt, D. Geysen, L. Helsen, The crucial role of Waste-to-Energy technologies in enhanced landfill mining: a technology review, J Clean Prod. 55 (2013) 10-23.

[4] L. Helsen, A. Bosmans. Waste-to-Energy through thermochemical processes: matching waste with process. 1 st International Symposium on Enhanced Landfill Mining, Houthalen-Helchteren, Belgium, 2010, p. 4-6.

[5] H. Kleis, S. Dalager, 100 years of waste incineration in Denmark, Babcock & Wilcox Vølund and Rambøll, Denmark, 2004.

[6] E.N. Kalogirou, Waste-to-Energy technologies and global applications, CRC Press, Florida, 2017.

[7] P. Stehlik, Up-to-date Waste-To-Energy approach: from idea to industrial application, Springer, Switzerland, 2016.

[8] K. Moustakas, M. Loizidou, Solid waste management through the application of thermal methods, In: E.S. Kumar (Ed.), Waste Management, IntechOpen, Croatia, 2010, pp. 89-124.

[9] A. Demirbas, Waste management, waste resource facilities and waste conversion processes, Energ Convers Manage. 52 (2011) 1280-1287.

[10] World Energy Council, World Energy Resources Waste To Energy Report, London, 2016.

[11] B. Leckner, Process aspects in combustion and gasification Waste-to-Energy (WtE) units, Waste Manage. 37 (2015) 13-25.

[12] H.D. Beyene, A.A. Werkneh, T.G. Ambaye, Current updates on waste to energy (WtE) technologies: a review, Renewable Energy Focus. 24 (2018) 1-11.

[13] A.T. Sipra, N. Gao, H. Sarwar, Municipal solid waste (MSW) pyrolysis for bio-fuel production: A review of effects of MSW components and catalysts, Fuel Process Technol. 175 (2018) 131-147.

[14] A. Kan, General characteristics of waste management: A review, Energy Education Science and Technology Part a-Energy Science and Research. 23 (2009) 55-69.

[15] P.H. Brunner, H. Rechberger, Waste to energy–key element for sustainable waste management, Waste Manage. 37 (2015) 3-12.

[16] K. Whiting, S. Wood, M. Fanning, Waste technologies: Waste to energy facilities. A Report for the Strategic Waste Infrastructure Planning (SWIP) Working Group, WSP Environmental Ltd for the Government of Western Australia, Department of Environment and Conservation, London, 2013.

[17] A. Tabasová, J. Kropáč, V. Kermes, A. Nemet, P. Stehlík, Waste-to-energy technologies: Impact on environment, Energy. 44 (2012) 146-155.

[18] R.L. Skaggs, A.M. Coleman, T.E. Seiple, A.R. Milbrandt, Waste-to-Energy biofuel production potential for selected feedstocks in the conterminous United States, Renewable and Sustainable Energy Reviews. 82 (2018) 2640-2651.

[19] T. Kolb, H. Seifert, Thermal waste treatment: State of the art–a summary, Waste Manage. (2002)

[20] J. Mata-Alvarez, S. Mace, P. Llabres, Anaerobic digestion of organic solid wastes. An overview of research achievements and perspectives, Bioresource Technol. 74 (2000) 3-16.

[21] A. Tozlu, E. Özahi, A. Abuşoğlu, Waste to energy technologies for municipal solid waste management in Gaziantep, Renewable and Sustainable Energy Reviews. 54 (2016) 809-815.

[22] D. Reimann, CEWEP energy report II (Status 2004–2007), CEWEP - The Confederation of European Waste-to-Energy Plants, Brussels, 2009.

[23] UK Department for Environment, Food & Rural Affairs, Energy from waste – A guide to debate, UK, 2014

[24] E. Gomez, D.A. Rani, C.R. Cheeseman, D. Deegan, M. Wise, A.R. Boccaccini, Thermal plasma technology for the treatment of wastes: A critical review, J Hazard Mater. 161 (2009) 614-626.

[25] P.H. Brunner, Thermal treatment of waste: Key element for sustainable waste management. In: M. Kaltschmitt, N.J. Themelis, L.Y. Bronicki, L. Söder, L.A. Vega (Eds), Renewable Energy Systems, Springer, New York, 2013.

[26] U. Arena, Process and technological aspects of municipal solid waste gasification. A review, Waste Manage. 32 (2012) 625-639.

[27] T. Astrup, J. Møller, T. Fruergaard, Incineration and co-combustion of waste: accounting of greenhouse gases and global warming contributions, Waste Manage Res. 27 (2009) 789-799.

[28] S. Consonni, F. Viganò, Waste gasification vs. conventional Waste-To-Energy: A comparative evaluation of two commercial technologies, Waste Manage. 32 (2012) 653-666.

[29] T. Lecomte, J.F.F. de la Fuente, F. Neuwahl, M. Canova, A. Pinasseau, I. Jankov, T. Brinkmann, S. Roudier, L.D. Sancho, Best Available Techniques (BAT) Reference Document for Large Combustion Plants, Publications Office of the European Union, Luxembourg, 2017.
[30] L.M. Schabbach, G. Bolelli, F. Andreola, I. Lancellotti, L. Barbieri, Valorization of MSWI bottom ash through ceramic glazing process: a new technology, J Clean Prod. 23 (2012) 147-157.
[31] P. Stehlík, Contribution to advances in waste-to-energy technologies, J Clean Prod. 17 (2009) 919-931.
[32] C.R. Cheeseman, S. Monteiro da Rocha, C. Sollars, S. Bethanis, A.R. Boccaccini, Ceramic processing of incinerator bottom ash, Waste Manage. 23 (2003) 907-916.
[33] M. Cyranka, M. Jurczyk, Energy Recovery from Municipal Waste based on Moving Grate Technology, 20 (2016) 23-33.
[34] L. Lombardi, E. Carnevale, A. Corti, A review of technologies and performances of thermal treatment systems for energy recovery from waste, Waste Manage. 37 (2015) 26-44.
[35] D. Moya, C. Aldás, G. López, P. Kaparaju, Municipal solid waste as a valuable renewable energy resource: a worldwide opportunity of energy recovery by using Waste-To-Energy Technologies, Energy Procedia. 134 (2017) 286-295.
[36] Deltaway Energy, Waste-to-Energy: How It Works, https://deltawayenergy.com/2018/08/waste-to-energy-how-it-works/, 2019 (erişim tarihi: 26.04.2019).
[37] V. Kirubakaran, V. Sivaramakrishnan, R. Nalini, T. Sekar, M. Premalatha, P. Subramanian, A review on gasification of biomass, Renewable and Sustainable Energy Reviews, 13 (2009) 179-186.
[38] H. Knoef, Practical aspects of biomass gasification, in: H. Knoef (Ed.), Handbook Biomass Gasification, Biomass Technology Group (BTG), Netherlands, 2005, pp. 13-37.
[39] A. Kumar, D. Jones, M. Hanna, Thermochemical biomass gasification: a review of the current status of the technology, Energies. 2 (2009) 556-581.
[40] S.K. Sansaniwal, K. Pal, M.A. Rosen, S.K. Tyagi, Recent advances in the development of biomass gasification technology: A comprehensive review, Renewable and Sustainable Energy Reviews. 72 (2017) 363-384.
[41] M.D. Baker, Gasification: Chemistry, Processes, and Applications, Nova Science Publishers, UK, 2011.
[42] P. Mondal, G.S. Dang, M.O. Garg, Syngas production through gasification and cleanup for downstream applications — Recent developments, Fuel Process Technol. 92 (2011) 1395-1410.
[43] R. Warnecke, Gasification of biomass: comparison of fixed bed and fluidized bed gasifier, Biomass and Bioenergy. 18 (2000) 489-497.
[44] M.L. Mastellone, D. Santoro, L. Zaccariello, U. Arena. The effect of oxygen-enriched air on the fluidized bed co-gasification of coal, plastics and wood. Third International Symposium on Energy from Biomass and Waste, Venice, 2010.
[45] L. Bébar, P. Stehlík, L. Havlen, J. Oral, Analysis of using gasification and incineration for thermal processing of wastes, Appl Therm Eng. 25 (2005) 1045-1055.
[46] G. Genon, V. Tedesco, P. Urso. Assessment of the feasibility of an innovative technology plant aimed at the energetic valorization of municipal waste in the province of Turin. Third International Symposium on Energy from Biomass and Waste, Venice, 2010.
[47] L. Wang, C.L. Weller, D.D. Jones, M.A. Hanna, Contemporary issues in thermal gasification of biomass and its application to electricity and fuel production, Biomass and Bioenergy. 32 (2008) 573-581.
[48] D.J. Wilhelm, D.R. Simbeck, A.D. Karp, R.L. Dickenson, Syngas production for gas-to-liquids applications: technologies, issues and outlook, Fuel Process Technol. 71 (2001) 139-148.
[49] D.W. Griffin, M.A. Schultz, Fuel and chemical products from biomass syngas: a comparison of gas fermentation to thermochemical conversion routes, Environ Prog Sustain. 31 (2012) 219-224.
[50] P. Chen, Q. Xie, M. Addy, W. Zhou, Y. Liu, Y. Wang, Y. Cheng, K. Li, R. Ruan, Utilization of municipal solid and liquid wastes for bioenergy and bioproducts production, Bioresource Technol. 215 (2016) 163-172.
[51] F. Fischer, H. Tropsch, The preparation of synthetic oil mixtures (synthol) from carbon monoxide and hydrogen, Brennstoff-Chem. 4 (1923) 276-285.
[52] M.E. Dry, Present and future applications of the Fischer–Tropsch process, Applied Catalysis A: General. 276 (2004) 1-3.
[53] J. Hu, F. Yu, Y. Lu, Application of Fischer–Tropsch synthesis in biomass to liquid conversion, Catalysts. 2 (2012) 303-326.
[54] S.T. Sie, R. Krishna, Fundamentals and selection of advanced Fischer–Tropsch reactors, Applied Catalysis A: General. 186 (1999) 55-70.
[55] R. Guettel, U. Kunz, T. Turek, Reactors for Fischer-Tropsch Synthesis, Chem Eng Technol. 31 (2008) 746-754.
[56] B.H. Davis, Fischer–Tropsch synthesis: Overview of reactor development and future potentialities, Top Catal. 32 (2005) 143-168.
[57] M.E. Dry, Practical and theoretical aspects of the catalytic Fischer-Tropsch process, Applied Catalysis A: General. 138 (1996) 319-344.

[58] A.V. Bridgwater, Renewable fuels and chemicals by thermal processing of biomass, Chem Eng J. 91 (2003) 87-102.
[59] W. Buah, A. Cunliffe, P. Williams, Characterization of products from the pyrolysis of municipal solid waste, Process Saf Environ. 85 (2007) 450-457.
[60] S.M. Al-Salem, P. Lettieri, J. Baeyens, Recycling and recovery routes of plastic solid waste (PSW): A review, Waste Manage. 29 (2009) 2625-2643.
[61] P.T. Williams, Pyrolysis of waste tyres: A review, Waste Manage. 33 (2013) 1714-1728.
[62] X. Yang, L. Sun, J. Xiang, S. Hu, S. Su, Pyrolysis and dehalogenation of plastics from waste electrical and electronic equipment (WEEE): A review, Waste Manage. 33 (2013) 462-473.
[63] G.C. Young, Municipal solid waste to energy conversion processes: Economic, technical, and renewable comparisons, John Wiley & Sons, New Jersey, 2010.
[64] A. Saffarzadeh, T. Shimaoka, Y. Motomura, K. Watanabe, Chemical and mineralogical evaluation of slag products derived from the pyrolysis/melting treatment of MSW, Waste Manage. 26 (2006) 1443-1452.
[65] D. Chen, L. Yin, H. Wang, P. He, Reprint of: Pyrolysis technologies for municipal solid waste: A review, Waste Manage. 37 (2015) 116-136.
[66] N.B. Klinghoffer, M.J. Castaldi, Gasification and pyrolysis of municipal solid waste (MSW), in: N.B. Klinghoffer, M.J. Castaldi (Eds.), Waste to Energy Conversion Technology. Woodhead Publishing, Cambridge, 2013, pp. 146-176.
[67] Y. Younan, M.W.M. van Goethem, G.D. Stefanidis, A particle scale model for municipal solid waste and refuse-derived fuels pyrolysis, Computers & Chemical Engineering. 86 (2016) 148-159.
[68] P.T. Williams, E. Slaney, Analysis of products from the pyrolysis and liquefaction of single plastics and waste plastic mixtures, Resources, Conservation and Recycling. 51 (2007) 754-769.
[69] J. Cheng, Biomass to renewable energy processes, CRC Press, Florida, 2017.
[70] I. Velghe, R. Carleer, J. Yperman, S. Schreurs, Study of the pyrolysis of municipal solid waste for the production of valuable products, J Anal Appl Pyrol. 92 (2011) 366-375.
[71] N. Miskolczi, F. Ateş, N. Borsodi, Comparison of real waste (MSW and MPW) pyrolysis in batch reactor over different catalysts. Part II: Contaminants, char and pyrolysis oil properties, Bioresource Technol. 144 (2013) 370-379.
[72] S. Luo, B. Xiao, Z. Hu, S. Liu, Effect of particle size on pyrolysis of single-component municipal solid waste in fixed bed reactor, Int J Hydrogen Energ. 35 (2010) 93-97.
[73] J. Zheng, Y.-q. Jin, Y. Chi, J.-m. Wen, X.-g. Jiang, M.-j. Ni, Pyrolysis characteristics of organic components of municipal solid waste at high heating rates, Waste Manage. 29 (2009) 1089-1094.
[74] F. Ateş, N. Miskolczi, N. Borsodi, Comparision of real waste (MSW and MPW) pyrolysis in batch reactor over different catalysts. Part I: Product yields, gas and pyrolysis oil properties, Bioresource Technol. 133 (2013) 443-454.
[75] U. Arena, M.L. Mastellone, Fluidized bed pyrolysis of plastic wastes, Feedstock recycling and pyrolysis of waste plastics: converting waste plastics into diesel and other fuels. (2006) 435-474.
[76] R. Font, A. Marcilla, A.N. García, J.A. Caballero, J.A. Conesa, Kinetic models for the thermal degradation of heterogeneous materials, J Anal Appl Pyrol. 32 (1995) 29-39.
[77] C. Di Blasi, Kinetic and Heat Transfer Control in the Slow and Flash Pyrolysis of Solids, Ind Eng Chem Res. 35 (1996) 37-46.
[78] S. Luo, B. Xiao, Z. Hu, S. Liu, Y. Guan, L. Cai, Influence of particle size on pyrolysis and gasification performance of municipal solid waste in a fixed bed reactor, Bioresource Technol. 101 (2010) 6517-6520.
[79] O. Auciello, D. Flamm, Plasma Diagnostics, Plasma-materials Interactions, Academic Press, Boston, 1989.
[80] A. Gleizes, J.J. Gonzalez, P. Freton, Thermal plasma modelling, Journal of Physics D: Applied Physics. 38 (2005) R153-R183.
[81] C. Tendero, C. Tixier, P. Tristant, J. Desmaison, P. Leprince, Atmospheric pressure plasmas: A review, Spectrochimica Acta Part B: Atomic Spectroscopy. 61 (2006) 2-30.
[82] H. Huang, L. Tang, Treatment of organic waste using thermal plasma pyrolysis technology, Energ Convers Manage. 48 (2007) 1331-1337.
[83] M. Tendler, P. Rutberg, G.v. Oost, Plasma based waste treatment and energy production, Plasma Physics and Controlled Fusion. 47 (2005) A219-A230.
[84] J. Heberlein, A.B. Murphy, Thermal plasma waste treatment, Journal of Physics D: Applied Physics. 41 (2008) 053001.
[85] B. Ruj, S. Ghosh, Technological aspects for thermal plasma treatment of municipal solid waste—A review, Fuel Process Technol. 126 (2014) 298-308.
[86] D. Czajczyńska, L. Anguilano, H. Ghazal, R. Krzyżyńska, A.J. Reynolds, N. Spencer, H. Jouhara, Potential of pyrolysis processes in the waste management sector, Thermal Science and Engineering Progress. 3 (2017) 171-197.

[87] L. Tang, H. Huang, H. Hao, K. Zhao, Development of plasma pyrolysis/gasification systems for energy efficient and environmentally sound waste disposal, Journal of Electrostatics. 71 (2013) 839-847.
[88] A. Sanlisoy, M.O. Carpinlioglu, A review on plasma gasification for solid waste disposal, Int J Hydrogen Energ. 42 (2017) 1361-1365.
[89] B. Lemmens, H. Elslander, I. Vanderreydt, K. Peys, L. Diels, M. Oosterlinck, M. Joos, Assessment of plasma gasification of high caloric waste streams, Waste Manage. 27 (2007) 1562-1569.
[90] E. Iacovidou, D.-G. Ohandja, J. Gronow, N. Voulvoulis, The Household Use of Food Waste Disposal Units as a Waste Management Option: A Review, Critical Reviews in Environmental Science and Technology. 42 (2012) 1485-1508.
[91] T.P.T. Pham, R. Kaushik, G.K. Parshetti, R. Mahmood, R. Balasubramanian, Food waste-to-energy conversion technologies: Current status and future directions, Waste Manage. 38 (2015) 399-408.
[92] E. Uçkun Kiran, A.P. Trzcinski, W.J. Ng, Y. Liu, Bioconversion of food waste to energy: A review, Fuel. 134 (2014) 389-399.
[93] F. Xu, Y. Li, X. Ge, L. Yang, Y. Li, Anaerobic digestion of food waste – Challenges and opportunities, Bioresource Technol. 247 (2018) 1047-1058.
[94] C.S.K. Lin, L.A. Pfaltzgraff, L. Herrero-Davila, E.B. Mubofu, S. Abderrahim, J.H. Clark, A.A. Koutinas, N. Kopsahelis, K. Stamatelatou, F. Dickson, S. Thankappan, Z. Mohamed, R. Brocklesby, R. Luque, Food waste as a valuable resource for the production of chemicals, materials and fuels. Current situation and global perspective, Energ Environ Sci. 6 (2013) 426-464.
[95] J.H. Ebner, R.A. Labatut, J.S. Lodge, A.A. Williamson, T.A. Trabold, Anaerobic co-digestion of commercial food waste and dairy manure: Characterizing biochemical parameters and synergistic effects, Waste Manage. 52 (2016) 286-294.
[96] T. Katami, A. Yasuhara, T. Shibamoto, Formation of Dioxins from Incineration of Foods Found in Domestic Garbage, Environ Sci Technol. 38 (2004) 1062-1065.
[97] H. Ma, Q. Wang, D. Qian, L. Gong, W. Zhang, The utilization of acid-tolerant bacteria on ethanol production from kitchen garbage, Renew Energ. 34 (2009) 1466-1470.
[98] S. Guran, Sustainable Waste-to-Energy Technologies: Gasification and Pyrolysis, in: T.A. Trabold, C.W. Babbitt (Eds.), Sustainable Food Waste-To-energy Systems, Academic Press, London, 2018, pp. 141-158.
[99] J. Sanders, E. Scott, R. Weusthuis, H. Mooibroek, Bio-Refinery as the Bio-Inspired Process to Bulk Chemicals, Macromolecular Bioscience. 7 (2007) 105-117.
[100] C.O. Tuck, E. Pérez, I.T. Horváth, R.A. Sheldon, M. Poliakoff, Valorization of Biomass: Deriving More Value from Waste, Science. 337 (2012) 695.
[101] T.A. Trabold, C.W. Babbitt, Introduction, in: T.A.Trabold, C.W. Babbitt (Eds.), Sustainable Food Waste-To-energy Systems, Academic Press, London, 2018, pp. 1-10.
[102] R.A. Labatut, J.L. Pronto, Sustainable waste-to-energy technologies: Anaerobic digestion, in: T.A.Trabold, C.W. Babbitt (Eds.), Sustainable Food Waste-To-energy Systems, Academic Press, London, 2018, pp. 47-67.
[103] S. Hegde, T.A. Trabold, Sustainable waste-to-energy technologies: Fermentation, in: T.A.Trabold, C.W. Babbitt (Eds.), Sustainable Food Waste-To-energy Systems, Academic Press, London, 2018, pp. 69-88.
[104] S.S. Win, T.A. Trabold, Sustainable waste-to-energy technologies: Transesterification, in: T.A.Trabold, C.W. Babbitt (Eds.), Sustainable Food Waste-To-energy Systems, Academic Press, London, 2018, pp. 89-109.
[105] D. De Clercq, Z. Wen, O. Gottfried, F. Schmidt, F. Fei, A review of global strategies promoting the conversion of food waste to bioenergy via anaerobic digestion, Renewable and Sustainable Energy Reviews. 79 (2017) 204-221.
[106] L.D. Nghiem, K. Koch, D. Bolzonella, J.E. Drewes, Full scale co-digestion of wastewater sludge and food waste: Bottlenecks and possibilities, Renewable and Sustainable Energy Reviews. 72 (2017) 354-362.
[107] X. Jia, B. Xi, M. Li, T. Xia, Y. Hao, D. Liu, J. Hou, Evaluation of biogasification and energy consumption from food waste using short-term hydrothermal pretreatment coupled with different anaerobic digestion processes, J Clean Prod. 152 (2017) 364-368.
[108] L. Li, X. Peng, X. Wang, D. Wu, Anaerobic digestion of food waste: A review focusing on process stability, Bioresource Technol. 248 (2018) 20-28.
[109] R.A. Labatut, L.T. Angenent, N.R. Scott, Biochemical methane potential and biodegradability of complex organic substrates, Bioresource Technol. 102 (2011) 2255-2264.
[110] A. Wellinger, J.D. Murphy, D. Baxter, The biogas handbook: science, production and applications, Woodhead Publishing, Cambridge, 2013.
[111] R. Posmanik, R.A. Labatut, A.H. Kim, J.G. Usack, J.W. Tester, L.T. Angenent, Coupling hydrothermal liquefaction and anaerobic digestion for energy valorization from model biomass feedstocks, Bioresource Technol. 233 (2017) 134-143.

[112] L. Appels, J. Lauwers, J. Degrève, L. Helsen, B. Lievens, K. Willems, J. Van Impe, R. Dewil, Anaerobic digestion in global bio-energy production: Potential and research challenges, Renewable and Sustainable Energy Reviews. 15 (2011) 4295-4301.
[113] D.P. Chynoweth, J.M. Owens, R. Legrand, Renewable methane from anaerobic digestion of biomass, Renew Energ. 22 (2001) 1-8.
[114] A. Hilkiah Igoni, M.J. Ayotamuno, C.L. Eze, S.O.T. Ogaji, S.D. Probert, Designs of anaerobic digesters for producing biogas from municipal solid-waste, Appl Energ. 85 (2008) 430-438.
[115] J.D. Murphy, E. McKeogh, G. Kiely, Technical/economic/environmental analysis of biogas utilisation, Appl Energ. 77 (2004) 407-427.
[116] B.E. Asikong, O.U. Udensi, J. Epoke, E.M. Eja, E.E. Antai, Microbial analysis and biogas yield of water hyacinth, cow dung and poultry dropping fed anaerobic digesters, British Journal of Applied Science & Technology. 4 (2014) 650-661.
[117] R. Braun, Anaerobic digestion: a multi-faceted process for energy, environmental management and rural development, in: P. Ranalli (Ed.), Improvement of Crop Plants for Industrial End Uses, Springer, Dordrecht, 2007, pp. 335-416.
[118] D. Deublein, A. Steinhauser, Biogas from waste and renewable resources: an introduction, John Wiley & Sons, Weinheim, 2011.
[119] S.K. Khanal, Anaerobic biotechnology for bioenergy production: principles and applications, John Wiley & Sons, Iowa, 2011.
[120] K. Paritosh, S.K. Kushwaha, M. Yadav, N. Pareek, A. Chawade, V. Vivekanand, Food Waste to Energy: An Overview of Sustainable Approaches for Food Waste Management and Nutrient Recycling, BioMed Research International. 2017 (2017) 1-19.
[121] K. Mital, Biogas systems: policies, progress and prospects, New Age International Pvt Ltd Publishers, New Delhi, 1997.
[122] M.P. Bryant, Microbial Methane Production—Theoretical Aspects, Journal of Animal Science. 48 (1979) 193-201.
[123] B. Schink, Energetics of syntrophic cooperation in methanogenic degradation, Microbiology and Molecular Biology Reviews. 61 (1997) 262-280.
[124] X. Jiang, S.G. Sommer, K.V. Christensen, A review of the biogas industry in China, Energy Policy. 39 (2011) 6073-6081.
[125] E. Ryckebosch, M. Drouillon, H. Vervaeren, Techniques for transformation of biogas to biomethane, Biomass and Bioenergy. 35 (2011) 1633-1645.
[126] Yadvika, Santosh, T.R. Sreekrishnan, S. Kohli, V. Rana, Enhancement of biogas production from solid substrates using different techniques—a review, Bioresource Technol. 95 (2004) 1-10.
[127] K. Rajendran, S. Aslanzadeh, M.J. Taherzadeh, Household Biogas Digesters—A Review, Energies. 5 (2012) 2911-2942.
[128] P. Weiland, Biogas production: current state and perspectives, Appl Microbiol Biot. 85 (2010) 849-860.
[129] T. Amon, B. Amon, V. Kryvoruchko, W. Zollitsch, K. Mayer, L. Gruber, Biogas production from maize and dairy cattle manure—Influence of biomass composition on the methane yield, Agriculture, Ecosystems & Environment. 118 (2007) 173-182.
[130] YEGM (Enerji İşleri Genel Müdürlüğü), Biyogaz Üretiminde Kullanılan Organik Atık/Artık Hammaddeler, http://www.yegm.gov.tr/yenilenebilir/biyogaz.aspx, 2019 (erişim tarihi: 26.04.2019)
[131] Y. Chen, J.J. Cheng, K.S. Creamer, Inhibition of anaerobic digestion process: A review, Bioresource Technol. 99 (2008) 4044-4064.
[132] N.J. Themelis, P.A. Ulloa, Methane generation in landfills, Renew Energ. 32 (2007) 1243-1257.
[133] M. Di Addario, B. Ruggeri, Landfill bioreactor technology for waste management, in: O.P. Karthikeyan, S.S. Muthu, K. Heimann (Eds.), Recycling of Solid Waste for Biofuels and Bio-chemicals, Springer, Singapore, 2016, pp. 211-235.
[134] M. Warith, X. Li, H. Jin, Bioreactor landfills: state-of-the-art review, Emirates Journal for Engineering Research. 10 (2005) 1-14.
[135] Metro Waste Authority, A Landfill Cell is a Complex System, https://www.mwatoday.com/news/garbage/landfill-construction.aspx, 2019 (erişim tarihi: 26.04.2019)
[136] A. Mutungwazi, P. Mukumba, G. Makaka, Biogas digester types installed in South Africa: A review, Renewable and Sustainable Energy Reviews. 81 (2018) 172-180.
[137] A. Kumar, B. Mandal, A. Sharma, Advancement in biogas digester, in: A. Sharma, S.K. Kar (Eds.), Energy Sustainability Through Green Energy, Springer, New Delhi, 2015, pp. 351-382.
[138] H. Bouallagui, Y. Touhami, R. Ben Cheikh, M. Hamdi, Bioreactor performance in anaerobic digestion of fruit and vegetable wastes, Process Biochem. 40 (2005) 989-995.
[139] M. Öztürk, Hayvan gübresinden biyogaz üretimi, Çevre ve Orman Bakanlığı, Ankara, 2005

[140] YEGM (Enerji İşleri Genel Müdürlüğü), Biyogaz Üretim Prosesi, http://www.yegm.gov.tr/yenilenebilir/biyogaz.aspx, 2019 (erişim tarihi: 26.04.2019)
[141] S.J. Grimberg, D. Hilderbrandt, M. Kinnunen, S. Rogers, Anaerobic digestion of food waste through the operation of a mesophilic two-phase pilot scale digester – Assessment of variable loadings on system performance, Bioresource Technol. 178 (2015) 226-229.
[142] L. Matsakas, D. Kekos, M. Loizidou, P. Christakopoulos, Utilization of household food waste for the production of ethanol at high dry material content, Biotechnol Biofuels. 7 (2014) 1-9.
[143] J.W. Jensen, C. Felby, H. Jørgensen, Cellulase Hydrolysis of Unsorted MSW, Appl Biochem Biotech. 165 (2011) 1799-1811.
[144] K. Sakai, Y. Ezaki, Open L-lactic acid fermentation of food refuse using thermophilic Bacillus coagulans and fluorescence in situ hybridization analysis of microflora, Journal of Bioscience and Bioengineering. 101 (2006) 457-463.
[145] D.-H. Kim, S.-H. Kim, H.-S. Shin, Hydrogen fermentation of food waste without inoculum addition, Enzyme and Microbial Technology. 45 (2009) 181-187.
[146] K. Ma, Z. Ruan, Z. Shui, Y. Wang, G. Hu, M. He, Open fermentative production of fuel ethanol from food waste by an acid-tolerant mutant strain of Zymomonas mobilis, Bioresource Technol. 203 (2016) 295-302.
[147] R.S. Tubb, Amylolytic yeasts for commercial applications, Trends in Biotechnology. 4 (1986) 98-104.
[148] P. Tomasik, D. Horton, Enzymatic conversions of starch, in: D. Horton (Ed.), Advances in Carbohydrate Chemistry and Biochemistry (Vol. 68), Academic Press, Oxford, 2012, pp. 59-436.
[149] P. Ducroo, Improvements relating to the production of glucose syrups and purified starches from wheat and other cereal starches containing pentosans, European Patent Application EP., 1987.
[150] L. Yao, S.-L. Lee, T. Wang, J.M.L.N.d. Moura, L.A. Johnson, Effects of fermentation substrate conditions on corn–soy co-fermentation for fuel ethanol production, Bioresource Technol. 120 (2012) 140-148.
[151] Hadiyanto, D. Ariyanti, A.P. Aini, D.S. Pinundi, Optimization of Ethanol Production from Whey Through Fed-batch Fermentation Using Kluyveromyces Marxianus, Energy Procedia. 47 (2014) 108-112.
[152] A.H. Förster, J. Gescher, Metabolic Engineering of Escherichia coli for Production of Mixed-Acid Fermentation End Products, Frontiers in Bioengineering and Biotechnology. 2 (2014) 1-12.
[153] I.K. Kapdan, F. Kargi, Bio-hydrogen production from waste materials, Enzyme and Microbial Technology. 38 (2006) 569-582.
[154] W.-J. Deng, Turning food waste into biofuel, in: O.P. Karthikeyan, S.S. Muthu, K. Heimann (Eds.), Recycling of Solid Waste for Biofuels and Bio-chemicals, Springer, Singapore, 2016, pp. 357-379.
[155] Y.-W. Lee, J. Chung, Bioproduction of hydrogen from food waste by pilot-scale combined hydrogen/methane fermentation, Int J Hydrogen Energ. 35 (2010) 11746-11755.
[156] E.M. Green, Fermentative production of butanol—the industrial perspective, Current Opinion in Biotechnology. 22 (2011) 337-343.
[157] V. Ujor, A.K. Bharathidasan, K. Cornish, T.C. Ezeji, Feasibility of producing butanol from industrial starchy food wastes, Appl Energ. 136 (2014) 590-598.
[158] S.-K. Chen, W.-C. Chin, K. Tsuge, C.-C. Huang, S.-Y. Li, Fermentation approach for enhancing 1-butanol production using engineered butanologenic Escherichia coli, Bioresource Technol. 145 (2013) 204-209.
[159] Y.-X. Huo, K.M. Cho, J.G.L. Rivera, E. Monte, C.R. Shen, Y. Yan, J.C. Liao, Conversion of proteins into biofuels by engineering nitrogen flux, Nature Biotechnology. 29 (2011) 346-352.
[160] M. Hajjari, M. Tabatabaei, M. Aghbashlo, H. Ghanavati, A review on the prospects of sustainable biodiesel production: A global scenario with an emphasis on waste-oil biodiesel utilization, Renewable and Sustainable Energy Reviews. 72 (2017) 445-464.
[161] A.N. Phan, T.M. Phan, Biodiesel production from waste cooking oils, Fuel. 87 (2008) 3490-3496.
[162] Z. Yaakob, M. Mohammad, M. Alherbawi, Z. Alam, K. Sopian, Overview of the production of biodiesel from Waste cooking oil, Renewable and Sustainable Energy Reviews. 18 (2013) 184-193.
[163] M.K. Lam, K.T. Lee, A.R. Mohamed, Homogeneous, heterogeneous and enzymatic catalysis for transesterification of high free fatty acid oil (waste cooking oil) to biodiesel: A review, Biotechnology Advances. 28 (2010) 500-518.
[164] M.R. Anuar, A.Z. Abdullah, Challenges in biodiesel industry with regards to feedstock, environmental, social and sustainability issues: A critical review, Renewable and Sustainable Energy Reviews. 58 (2016) 208-223.
[165] A. Talebian-Kiakalaieh, N.A.S. Amin, H. Mazaheri, A review on novel processes of biodiesel production from waste cooking oil, Appl Energ. 104 (2013) 683-710.
[166] A. Gnanaprakasam, V.M. Sivakumar, A. Surendhar, M. Thirumarimurugan, T. Kannadasan, Recent Strategy of Biodiesel Production from Waste Cooking Oil and Process Influencing Parameters: A Review, Journal of Energy. 2013 (2013) 1-10.

Önerilen Kaynaklar

[1] M.J. Rogoff, F. Screve, Waste-to-energy: Technologies and Project Implementation (3rd Edition), William Andrew, UK, 2019.
[2] Hoornweg, D., & Bhada-Tata, P. (2012). What a waste: a global review of solid waste management (Vol. 15, p. 116). World Bank, Washington, DC.
[3] Pan, S. Y., Du, M. A., Huang, I. T., Liu, I. H., Chang, E. E., & Chiang, P. C. (2015). Strategies on implementation of waste-to-energy (WTE) supply chain for circular economy system: a review. Journal of Cleaner Production, 108, 409-421.
[4] Kumar, A., & Samadder, S. R. (2017). A review on technological options of waste to energy for effective management of municipal solid waste. Waste Management, 69, 407-422.
[5] Fernández-González, J. M., Grindlay, A. L., Serrano-Bernardo, F., Rodríguez-Rojas, M. I., & Zamorano, M. (2017). Economic and environmental review of Waste-to-Energy systems for municipal solid waste management in medium and small municipalities. Waste Management, 67, 360-374.
[6] Beyene, H. D., Werkneh, A. A., & Ambaye, T. G. (2018). Current updates on waste to energy (WtE) technologies: a review. *Renewable Energy Focus*, *24*, 1-11.
[7] D. Kaya, H.H. Öztürk, Biyogaz Teknolojisi: Üretim-Kullanım-Projeleme, Umuttepe Yayınları, İzmit, 2012.
[8] O. Tabasaran, Katı Atık Yönetimi ve Teknolojileri, İSTAÇ, İstanbul, 2016
[9] Öztürk, İ., Arıkan, O., Altınbaş, M., Alp, K., & Güven, H. (2015). Katı Atık Geri Dönüşüm ve Arıtma Teknolojileri (El Kitabı). Türkiye Belediyeler Birliği. Ankara 286p.
[10] Tolay, M. (2012). Katı Atıklardan ve Biyokütleden Enerji Üretimi Teknolojileri ve Entegre Katı Atık Yönetiminde Yatırım Fizibilite Çalışmaları. TOLAY Energy, İstanbul.

Önerilen Websayfaları

[1] http://www.yegm.gov.tr
[2] http://www.biyogazder.org
[3] http://www.enver.org.tr
[4] https://ortadoguenerji.com.tr
[5] https://www.izaydas.com.tr
[6] https://www.istac.istanbul
[7] https://www.wtert.net
[8] https://www.studentenergy.org
[9] http://www.eswet.eu
[10] http://www.cewep.eu