YEM FABRİKALARININ, ÜRETİM AKIŞI (BÖLÜMLERİ), EKİPMANLAR, TEDARİK ZİNCİRİ VE TEKNOLOJİK YENİLİKLER

BÖLÜM 14

DOI: 10.37609/akya.3801.c305

Cemal BUDAĞ [1]

1.GİRİŞ

Yem üretim tesisleri, modern hayvancılığın sürdürülebilirliğinde kritik bir rol oynamakta; yüksek kaliteli, güvenli ve dengeli yemlerin üretimi için kompleks bir mühendislik, biyoteknoloji ve kalite kontrol bütünlüğüyle çalışmaktadır. Bu tesisler, hammadde girişinden nihai ürün çıkışına kadar belirli aşamalara ayrılmış olup, her bölüm belirli mekanik ve teknolojik süreçlerin yürütüldüğü spesifik birimler olarak yapılandırılmıştır.

Yem üretim tesislerinin bölümleri, yalnızca fiziksel süreçler değil; aynı zamanda biyogüvenlik, hayvan sağlığı ve beslenme bilimi açısından bütüncül bir sistemdir. Her birimin doğru planlanması ve çalıştırılması, yem kalitesini doğrudan etkiler ve hayvansal üretimin verimliliğine yansır.

Karma yem üretimi, hayvancılık sektöründe verimlilik, ürün kalitesi ve sürdürülebilirlik hedeflerinin karşılanmasında kritik bir role sahiptir. Modern yem fabrikaları, hammaddelerin temininden nihai ürünün dağıtımına kadar uzanan entegre bir süreç yönetimi anlayışı ile çalışmaktadır. Bu süreç, yalnızca yüksek kaliteli hammadde tedarik zincirinin etkin yönetimini değil, aynı zamanda üretimde kullanılan ekipmanların teknik kapasitesi ve teknolojik yeniliklere uyum düzeyini de kapsamaktadır.

Üretim hattında kullanılan başlıca ekipmanlar arasında hammadde alım ve depolama siloları, kırıcılar, öğütücüler, mikserler, dozajlama sistemleri, pelet

[1] Doç. Dr., Van Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi, Zootekni Bölümü, cbudag@yyu.edu.tr, ORCID iD: 0000-0003-3532-7727

KAYNAKLAR

1. Thomas M, van Zuilichem DJ, van der Poel AFB. Physical quality of pelleted animal feed 2. Contribution of processes and its conditions. *Animal Feed Science and Technology*, 1997;64(2-4): 173-192.
2. Behnke KC. Feed manufacturing technology: current issues and challenges. *Animal Feed Science and Technology*, 1996;62(2–4): 49–57.
3. Guevara MA, Calvo L, Soriano R. Mixing efficiency in feed production: Standard deviation and CV control. *Journal of Animal Nutrition*, 2020;14(1): 33–42.
4. Skoch ER, Binder SF, Deyoe CW, et al. Effects of steam pelleting conditions and extrusion cooking on a swine diet containing wheat middlings. *Journal of Animal Science*, 1983;*57*(4): 929-935.
5. Rosentrater KA, Hill L D. *Storage and Handling of Grains and Oilseeds. In Handbook of Farm, Dairy and Food Machinery Engineering* (2nd ed.). Academic Press; 2021.
6. Budağ, C. Yem Fabrikalarında Hijyen Sorunu ve Zoonoz Hastalıklar. *Journal of the Institute of Science and Technology*, 2011;1(2): 141-154.
7. Bühler AG. *Innovations in feed processing.* Bühler AG Technical Report; 2018.
8. FAO. *Animal Feed Safety and Quality: Feed Manufacturing Guidelines.* Food and Agriculture Organization of the United Nations; 2019.
9. Valencia-Palomo G, Rossiter JA Programmable logic controller implementation of an auto-tuned predictive control based on minimal plant information. *ISA transactions*, 2011;50(1): 92-100.
10. Kılıç Ü. International Multilingual Journal of Science and Technology (IMJST) 2020;5(12): 2528-9810
11. Valencia-Palomo G, Rossiter JA. Auto-tuned predictive control based on minimal plant information. *IFAC Proceedings Volumes*, 2009;42(11): 554-559.
12. Popescu, VF, Scarlat C. Supervisory Control and Data Acquisition (SCADA) Systems for Industrial Automation and Control Systems in Industry 4.0. *Land Forces Academy Review*, 2022;27(4): 309-315.
13. Akbay KC, Ak İ. Karma Yem Teknolojisindeki Gelişmelerin Karma Yem Kalitesine ve Yem Değerine Etkileri. Bursa Uludağ Üniversitesi Ziraat Fakültesi Dergisi, 2018;32(2): 175-188.
14. Chkalova M, Pavlidis V. *Assessment of equipment efficiency in models of technological processes for production of combined feed. Engineering for Rural Development*. In 20-th International Scientific Conference Engineering for Rural Development, 2021:doi: https://doi.org/10.22616/erdev.
15. Micheal AB, Nartey AI, Yaw OG. et al. Performance evaluation of mechanical feed mixers using machine parameters, operational parameters and feed characteristics in Ashanti and Brong-Ahafo regions, Ghana. *Alexandria Engineering Journal*, 2021;60, 4905-4918.
16. Amin SAS, Sobhi N. Process optimization in poultry feed mill. *Scientific Reports*, 2023;13(1): 9897.
17. Castillo Alvarez Y, Jiménez Borges R, Monteagudo Yanes JP. et al. Mathematical Model to Improve Energy Efficiency in Hammer Mills and Its Use in the Feed Industry: Analysis and Validation in a Case Study in Cuba. *Processes*, 2025;13(5): 1523.
18. Li Y, Li J, Li Z. et al. Vacuum coating of heat-sensitive liquid ingredients onto feed pellets. *Transactions of the ASAE*, 2003;46(2): 361–366.
19. Adeparusi EO, Famurewa JAV. Water temperature and surface coating effect on floatability, water absorption and thickness swelling of feed. *Journal of Agricultural Science*, 2011;3(2): 91–98.
20. Wang S. Application of *Fermentation* Technology in Animal Nutrition. *Fermentati-*

on, 2024;10(12): 596.
21. van der Vorst JGAJ, Tromp SO, Zee D J. Simulation modelling for food supply chain redesign: Integrated decision making on product quality, sustainability and logistics. *International Journal of Production Research*, 2007;45(13): 3665–3682.
22. Schenkel P, Röder A, Rohn H. Feed and food supply chains: Opportunities and challenges. *Journal of Chain and Network Science*, 2014;14(1): 23–33.
23. Veldman A, Vahl HA. Quality assurance systems in the animal feed industry in the Netherlands. *Animal Feed Science and Technology*, 2015;120(1-2): 19–28.
24. Whitlow LW, Hagler WM. Mycotoxins in feeds. *Feedstuffs*, 2010;82(42): 56–62.
25. Akyıldız R, Gül M. *Yem sanayinde kalite kontrol ve güvenlik sistemleri.* Gıda ve Yem Bilimleri Dergisi, 2019;5(1): 33–42.
26. Makkar HPS. Animal nutrition in a 360-degree view and a framework for future R&D work: Towards sustainable livestock production. *Animal Production Science*, 2016;56(10): 1561–1568. https://doi.org/10.1071/AN15265
27. Kamilaris A, Fonts A, Prenafeta-Boldú FX. The rise of blockchain technology in agriculture and food supply chains. *Trends in Food Science & Technology*, 2019;91, 640–652. https://doi.org/10.1016/j.tifs.2019.07.034
28. Csikai A. Opportunities of integrating supply chain quality management and product development with formulation systems in compound feed manufacturing. *Quality Assurance and Safety of Crops & Foods*, 2011;3(2): 82-88.
29. Sirohi S, Chandel BS, Mondal B. et al. Strengthening value chain of compound cattle feed. Financing Agriculture Value Chains in India: *Challenges and Opportunities,* 2017;171-185.
30. van der Fels- Klerx H, van Asselt ED, van Leeuwen SPJ. et al. Prioritization of chemical food safety hazards in the European feed supply chain. *Comprehensive Reviews in Food Science and Food Safety*, 2024;23(6): e70025.
31. Akdeniz RC, Ak İ. Boyar S. *Türkiye Karma Yem Endüstrisi ve Sorunları.* 2005;https://www.researchgate.net/profile/Serkan-Boyar/publication/334626762_Turkiye_Karma_Yem_Endustrisi_ve_Sorunlari/links/5d3ffbaba6fdcc370a6bd6c2/Tuerkiye-Karma-Yem-Enduestrisi-ve-Sorunlari.pdf (Erişim 26 Haziran 2025)
32. Gorzelańczyk P, Wawrzyniak K. Optimising the process of storage and transport of grains and feeds. *International Journal of Logistics Systems and Management*, 2023;45(2): 175-193.
33. Bryden WL. Mycotoxin contamination of the feed supply chain: Implications for animal productivity and feed security. *Animal Feed Science and Technology*, 2012;173(1-2): 134-158.
34. Gedik Y. Sürdürülebilir Tedarik Zinciri Yönetimi ve Sürdürülebilirliğin Tedarik Zincirlerine Etkileri. *Uluslararası Yönetim İktisat ve İşletme Dergisi,* 2021;17(3): 830-860.
35. Kazan G, Kocamış TU. Tedarik Zincirlerinde Sürdürülebilir Risk Yönetimi: Çevresel, Sosyal ve Jeopolitik Riskleri Azaltma Stratejileri. *Bilgi Ekonomisi ve Yönetimi Dergisi,* 2024;19(1): 75-92.
36. Lee M, García R. Evaluating the Social Impact of GLOBALG.A.P. Certification in Agricultural Practices. *International Journal of Agricultural Sustainability*, 2021;15(2): 89-104.
37. Smith J, Williams L. Social Sustainability in Agricultural Supply Chains: The Role of Certification Systems. *Journal of Sustainable Agriculture*, 2020;12(3): 45-60.
38. You J, Ellis JL, Tulpan D, et al. recent advances and future technologies in poultry feed manufacturing. World's Poultry Science Journal, 2024;80(3): 643-655.
39. Van der Vorst JGAJ, Tromp SO, et al. A framework for product traceability in the food supply chain. *European Journal of Operational Research*, 2005;163(1): 206–215. https://doi.org/10.1016/j.ejor.2004.01.023
40. Cebeci Z, Erdogan Y, Alemdar T, et al. *An ICT-based traceability system in compound feed industry.* Applied Studies in Agribusiness and Commerce– APSTRACT Agroinform Publishing

House, Budapest; 2009.

41. Barge P, Gay P, Merlino VM. A survey of traceability systems in feed and food sector. *Italian Journal of Animal Science*, 2013;12(4): e67. https://doi.org/10.4081/ijas.2013.e67
42. Aung MM, Chang YS. Traceability in a food supply chain: Safety and quality perspectives. *Food Control*, 2014;39, 172–184. https://doi.org/10.1016/j.foodcont.2013.11.007
43. European Commission. *feedTRace: Digital tools for feed traceability.* Retrieved from; 2023.
44. Kılıç Ü. International Multilingual Journal of Science and Technology (IMJST) 2020;5(12): 2528-9810
45. Thomas M, van Zuilichem DJ, van der Poel AFB. Physical quality of pelleted animal feed 3. Storage stability. *Animal Feed Science and Technology*, 1997;66(4): 329–340. https://doi.org/10.1016/S0377-8401(96)01063-4
46. Wolfert S, Ge L, Verdouw C. et al. Big Data in Smart Farming–A review. *Agricultural Systems*, 2017;153, 69-80.
47. Liakos KG, Busato P, Moshou, D. et al. Machine learning in agriculture: A review. *Sensors*, 2018;18(8): 2674.
48. Gürses M. Yem fabrikalarında otomasyon sistemleri ve SCADA uygulamaları. *Tarım Teknolojileri Dergisi,* 2021;8(1): 45-51.
49. Mohanraj I, Ashokumar K, Naren J. A comprehensive review on automation in agriculture using IoT and robotics. *Materials Today: Proceedings*, 2020;33, 1091-1095.
50. Verdouw CN, Wolfert J, Beulens AJ. M. et al. Virtualization of food supply chains with the internet of things. *Journal of Food Engineering*, 2016;176, 128-136.
51. Zhong RY, Xu X, Klotz E. et al. (). Intelligent manufacturing in the context of Industry 4.0: A review. *Engineering*, 2017;3(5): 616-630.
52. Kusiak A. Smart manufacturing. *International Journal of Production Research*, 2018;56(1–2): 508–517. https://doi.org/10.1080/00207543.2017.1351644
53. Ge L, Brewster C, Spek J. et al. Blockchain for agriculture and food: Findings from the pilot study. *International Journal of Food System Dynamics*, 2020;11(2): 158-178.
54. Liu Z, Zhang M, Bhandari B. et. al. 3D printing: Printing precision and application in food sector. *Trends in Food Science & Technology*, 2017;69, 83-94.
55. Galvez JF, Mejuto JC, Simal-Gandara J. Future challenges on the use of blockchain for food traceability analysis. *Trends in Analytical Chemistry*, 2018;107, 222–232. https://doi.org/10.1016/j.trac.2018.08.011
56. Verdouw CN, Wolfert J, Beulens AJM., et. al. Virtualization of food supply chains with the internet of things. *Journal of Food Engineering*, 2016;176, 128-136.
57. Kebreab E, Liedke A, Caro D. et. al. (). Environmental impact of using precision feeding to reduce the carbon footprint of pig production. *Animal*, 2016;10(10):1575-1583.
58. Gasco L, Finke M, van Huis A. (). Can diets containing insect meal affect animal health? A holistic approach. *Journal of Insects as Food and Feed*, 2020;6(1):1–19. https://doi.org/10.3920/JIFF2019.0037
59. Desai KGH, Park HJ. Recent developments in microencapsulation of food ingredients. *Drying Technology*, ;23(7): 1361–1394. https://doi.org/10.1081/DRT-200063478
60. Henry M, Gasco L, Piccolo G. et. al. Review: Insect meals in fish nutrition. *Animal Feed Science and Technology*, 2015;203, 1–22. https://doi.org/10.1016/j.anifeedsci.2015.03.001
61. van Huis A, van Itterbeeck J, Klunder H. et. al. *Edible insects: Future prospects for food and feed security* (FAO Forestry Paper No. 171). Food and Agriculture Organization of the United Nations; 2013.
62. Becker EW. (). Micro-algae as a source of protein. *Biotechnology Advances*, 2007;25(2): 207–210. https://doi.org/10.1016/j.biotechadv.2006.11.002
63. Spolaore P, Joannis-Cassan C, Duran E. et. al. Commercial applications of microalgae. *Journal*

of Bioscience and Bioengineering, 2006;101(2): 87–96. https://doi.org/10.1263/jbb.101.87

64. Ravindra P. Value-added food: Single cell protein. *Biotechnology Advances*, 2000;18(6): 459–479. https://doi.org/10.1016/S0734-9750(00)00045-8
65. Niyogi D, Mitra A. Future prospects of alternate protein sources in animal nutrition: An overview. *Frontiers in Veterinary Science*, 2021;8, 680320. https://doi.org/10.3389/fvets.2021.680320
66. Henry M, Gasco L, Piccolo G. Review: Insect meals in fish nutrition. *Animal Feed Science and Technology*, 2015;203, 1–22. https://doi.org/10.1016/j.anifeedsci.2015.03.001
67. Salemdeeb R, zu Ermgassen EKHJ, Kim MH. Environmental and health impacts of using food waste as animal feed: A comparative analysis of food waste management options. *Journal of Cleaner Production*, 2017;140, 871–880. https://doi.org/10.1016/j.jclepro.2016.05.049
68. Ominski K, McAllister T, Stanford K, et. al. Utilization of by-products and food waste in livestock production systems: A Canadian perspective. *Animal Frontiers*, 2021;11(2): 55-63.
69. Eryılmaz GA, Kılıç O, Boz İ. Türkiye'de organik tarım ve iyi tarım uygulamalarının ekonomik, sosyal ve çevresel sürdürülebilirlik açısından değerlendirilmesi. *Yuzuncu Yıl University Journal of Agricultural Sciences,* 2019;29(2): 352-361.
70. Scialabba NEH, Müller-Lindenlauf M. Organic agriculture and climate change. *Renewable Agriculture and Food Systems*, 2010;25(2): 158–169. https://doi.org/10.1017/S1742170510000116
71. De Quelen F, Brossard L, Wilfart A. et. al. Eco-friendly feed formulation and on-farm feed production as ways to reduce the environmental impacts of pig production without consequences on animal performance. *Frontiers in Veterinary Science*, 2021;8, 689012.
72. Hovi M, Sundrum A, Thamsborg SM. Animal health and welfare in organic livestock production in Europe: current state and future challenges. *Livestock Production Science*, 2003;80(1–2): 41–53. https://doi.org/10.1016/S0301-6226(02)00320-2
73. Smith LG, Kirk, GJD, Jones PJ. et. al. The greenhouse gas impacts of converting food production in England and Wales to organic methods. *Nature Communications*, 2022;13(1): 1-9. https://doi.org/10.1038/s41467-022-28580-2
74. Aragão C, Cabano M, Colen R. et. al. Alternative formulations for gilthead seabream diets: Towards a more sustainable production. *Aquaculture Nutrition*, 2020;26(2): 444-455.
75. De Quelen F, Brossard L, Wilfart A. et. al. (). Eco-friendly feed formulation and on-farm feed production as ways to reduce the environmental impacts of pig production without consequences on animal performance. *Frontiers in Veterinary Science*, 2021;8, 689012.
76. De Quelen F, Brossard L, Wilfart A. et. al. Eco-friendly feed formulation and on-farm feed production as ways to reduce the environmental impacts of pig production without consequences on animal performance. *Frontiers in Veterinary Science*, 2021;8, 689012.
77. Stark CR. *Feed processing to maximize feed efficiency.* in: Feed Efficiency in Swine. Wageningen, Netherlands, 2012:p 131–151
78. Zhou L, Li J, Li F. et. al. Optimization parameters for energy efficiency in end milling. *Procedia CIRP*, 2018; 69, 312-317.
79. Chong CC, Cheng YW, Ishak S. Anaerobic digestate as a low-cost nutrient source for sustainable microalgae cultivation: A way forward through waste valorization approach. *Science of the Total Environment*, 2022;806, 150–160.
80. Meilander J. Caporaso JG. The microbiome science of composting and human excrement composting: A review. *arXiv preprint arXiv*:, 2024;2409.07376.
81. Gerbens-Leenes PW, Mekonnen MM, Hoekstra AY. The water footprint of poultry, pork and beef: A comparative study in different countries and production systems. *Water Resources and Industry*, 2019;25, 100276. https://doi.org/10.1016/j.wri.2019.100276
82. Pahlow M, Van Oel PR, Mekonnen MM. et. al. Increasing pressure on freshwater resources

due to terrestrial feed ingredients for aquaculture production. *Science of The Total Environment*, 536, 847–857. https://doi.org/10.1016/j.scitotenv.2015;07.124
83. Falkenmark M, Rockström J. *Water resilience for human prosperity*. 202;1Island Press.
84. Smith LG, Kirk GJD, Jones PJ. et. al. The greenhouse gas impacts of converting food production in England and Wales to organic methods. *Nature Communications*, 2020;11(1):1–10. https://doi.org/10.1038/s41467-020-17245-5
85. García-Torres S, Albareda L, Seuring S. Sustainability certification and business legitimacy in supply chains: Linking private governance with public roles. *Journal of Cleaner Production*, 2021:296, 126626. https://doi.org/10.1016/j.jclepro.2021.126626
86. Willer H, Trávníček J, Meier C. et. al. (Eds.). *The World of Organic Agriculture: Statistics and Emerging Trends Research Institute of Organic Agriculture* FiBL & IFOAM – Organics International. https://doi.org/10.5281/zenodo. 2023;7594192.
87. Brandi C, Cabani T, Hosang C. et. al. Sustainability standards for palm oil: Challenges for smallholder certification under the RSPO. *Journal of Environment and Development*, 2015:24(3):292–314. https://doi.org/10.1177/1070496515593775
88. Gerber PJ, Steinfeld H, Henderson B. et. al. *Tackling climate change through livestock: A global assessment of emissions and mitigation opportunities.* FAO; 2013.
89. Dekker R, Bloemhof J, Mallidis I. Operations Research for green logistics – An overview of aspects, issues, contributions and challenges. *European Journal of Operational Research*, 2012;219(3): 671–679. https://doi.org/10.1016/j.ejor.2011.11.010
90. McKinnon A, Browne M, Whiteing A. et. al. *Green Logistics: Improving the Environmental Sustainability of Logistics.* Kogan Page Publishers; 2015.
91. FAO. The *State of Agricultural Commodity Markets 2020: Agricultural Markets and Sustainable Development.* Food and Agriculture Organization of the United Nations; 2020.
92. Elkington J. Cannibals with Forks: The Triple Bottom Line of 21st Century Business. Capstone Publishing; 1999.
93. Pretty J, Toulmin C, Williams S. et. al. Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability*, 2011;9(1): 5–24. https://doi.org/10.3763/ijas.2010.0583
94. Schouten G, Glasbergen P. Private multi-stakeholder governance in the agricultural market: An analysis of legitimacy. *Ecological Economics*, 2012;75, 1–11. https://doi.org/10.1016/j.ecolecon.2011.12.017
95. Aguinis H, Glavas A. What We Know and Don't Know About Corporate Social Responsibility: A Review and Research Agenda. *Journal of Management*, 2012;38(4): 932–968. https://doi.org/10.1177/0149206311436079
96. International Labour Organization (ILO). *Decent Work and the 2030 Agenda for Sustainable Development.* https://www.ilo.org/global/topics/dw4sd/lang--en/index.htm (Erişim 20 Haziran 2025).
97. International Organization for Standardization (ISO). *ISO 45001:2018 Occupational health and safety management systems* — Requirements with guidance for use. 2018;https://www.iso.org/iso-45001-occupational-health-and-safety.html(Erişim 20 Haziran 2025).
98. Pretty JN, Williams S, Toulmin C. *Sustainable intensification: increasing productivity in African food and agricultural systems.* Routledge; 2012.
99. Schouten, G., & Glasbergen, P. Private multi-stakeholder governance in the agricultural market place: An analysis of legitimization processes of the roundtables on sustainable palm oil and responsible soy. *International Food and Agribusiness Management Review*, 2012;15, 63-88.
100. Avelino F, Wittmayer JM. Shifting power relations in sustainability transitions: A multi-actor perspective. *Journal of Environmental Policy & Planning*, 2016;18(5); 628–649. https://doi.org/10.1080/1523908X.2015.1112259