

BÖLÜM 14

ET ÜRÜNLERİNDE ANTİMİKROBİYAL DİRENÇ: GIDA GÜVENLİĞİ VE HALK SAĞLIĞI BOYUTU

Hatice YAZGAN¹
Tülin Güven GÖKMEN²

GİRİŞ

Gıdalarda mikroorganizmaların kontrol altına alınmasında kimyasal yöntemlerin kullanımı, halk sağlığı açısından önemli riskleri de beraberinde getirmektedir. Bu riskler arasında ilaç direncinin gelişimi, kimyasal kalıntıların gıda zincirine taşınması ve çevresel kirlilik yer almaktadır(1). Gelecekte hasta hayvanların tedavisinde antibiyotik tüketiminin küresel ölçekte haritalandırılması ve halk sağlığı üzerindeki etkilerinin değerlendirilmesine yönelik ilk kapsamlı çalışmalar, van Boeckel ve arkadaşları tarafından gerçekleştirilmiştir (1). Günümüzde hem insan sağlığı hem de gıda üreten hayvanların sağlığı açısından en kritik küresel sorunlardan biri, disiplinler arası bir yaklaşımla ele alınması gereken antimikrobiyal dirençtir (AMR). Lobanovska ve Pila (2), AMR'nin Fleming'in 1928'de penisilini keşfetmesinden kısa bir süre sonra, 1940'lı yıllarda ortaya çıktığını; Escherichia coli suşlarının penisilinaz enzimi üreterek penisilinin terapötik etkilerini ortadan kaldırdığını bildirmiştir. Benzer şekilde, Lakhundi ve Zhang (3), penisilin direncinin Staphylococcus aureus ve Streptococcus pneumoniae suşlarında da doğrulandığını aktarmıştır. Özellikle metisiline dirençli S. aureus (MRSA), sahip olduğu çok sayıda virülans faktörü nedeniyle "süper mikrop" olarak nitelendirilmekte; genetik içerik ve gen ekspresyonunu optimize ederek artmış virülans ve kolonizasyon kapasitesine sahip yeni suşlar geliştirebilmektedir (4,5). Antibiyotiklerin gereksiz ve yaygın kullanımı, küresel ölçekte giderek artmakta ve bu durum, mevcut antimikrobiyal ilaçların etkinliğini azaltarak halk sağlığını doğ-

¹ Doç. Dr., Çukurova Üniversitesi, Veteriner Fakültesi, Gıda Hijyeni ve Teknolojisi Bölümü, Gıda Hijyeni ve Teknolojisi AD., hyazgan@cu.edu.tr, ORCID iD: 0000-0002-7520-3342

² Doç.Dr., Çukurova Üniversitesi, Veteriner Fakültesi, Veterinerlik Mikrobiyoloji AD., tguven@cu.edu.tr, ORCID iD: 0000-0001-9673-097X

sel verilerle desteklenmesi gerekmektedir. AMR ile ilişkili bu küresel zorlukla mücadele, “Tek Sağlık” yaklaşımı çerçevesinde insan, hayvan ve çevre sağlığını bütüncül biçimde ele alan politikaların geliştirilmesini zorunlu kılmaktadır. Sonuç olarak, AMR’nin kontrolü ve yönetimi, halk sağlığının korunması, gıda güvenliğinin sürdürülebilirliği ve ekonomik istikrarın sağlanması açısından stratejik bir öncelik olarak ele alınmalıdır. Bu kapsamda, AMR izleme ve gözetim programlarının güçlendirilmesi, politika yapıcılarının aktif katılımıyla ulusal ve uluslararası düzeyde gecikmeden koordine edilmesi gerekmektedir. Ancak bu şekilde, et üretim zincirinde ortaya çıkan direnç eğilimlerinin halk sağlığı üzerindeki olumsuz etkileri azaltılabilir ve güvenli gıda üretimi sürdürülebilir hale getirilebilir.

KAYNAKLAR

1. Kurćubić VS, Munjić MD, Dmitrić MP, et al. Bacterial Antimicrobial Resistance in Meat Products—Current Concepts. *Foods*. 2025;14.16: 2792.
2. Lobanovska M, PILLA G, Penicillin's discovery and antibiotic resistance: lessons for the future?. *The Yale journal of biology and medicine*, 2017, 90.1: 135.
3. Lakhundi S, Zhang K, Methicillin-resistant *Staphylococcus aureus*: molecular characterization, evolution, and epidemiology. *Clinical microbiology reviews*, 2018, 31.4: 10.1128/cmr. 00020-18.
4. Singh B, Bhat A, Ravi K, Antibiotics misuse and antimicrobial resistance development in agriculture: a global challenge. *Environment & Health*. 2024;2.9: 618-622.
5. Shoaib M, Aqib AI, Muzammil I, et al. MRSA compendium of epidemiology, transmission, pathophysiology, treatment, and prevention within one health framework. *Frontiers in Microbiology*. 2023;13: 1067284.
6. Verraes C, Van Boxtael S, Van Meervenne E, et al. Antimicrobial resistance in the food chain: a review. *International journal of environmental research and public health*. 2013; 10.7: 2643-2669.
7. Händel N, Schuurmans JM, Brul S, et al. Compensation of the metabolic costs of antibiotic resistance by physiological adaptation in *Escherichia coli*. *Antimicrobial agents and chemotherapy*. 2013;57.8: 3752-3762.
8. Capita R, Alonso-Calleja C, Antibiotic-resistant bacteria: a challenge for the food industry. *Critical reviews in food science and nutrition*. 2013; 53.1: 11-48.
9. Coates A, Hu Y, Bax R, et al. The future challenges facing the development of new antimicrobial drugs. *Nature reviews Drug discovery*. 2002;1.11: 895-910.
10. Elbehiry A, Marzouk E, Abalkhail A, et al. Microbial Food Safety and Antimicrobial Resistance in Foods: A Dual Threat to Public Health. *Microorganisms*. 2025;13.7: 1592.
11. Shoaib M, He Z, Geng X, et al. The emergence of multi-drug resistant and virulence gene carrying *Escherichia coli* strains in the dairy environment: a rising threat to the environment, animal, and public health. *Frontiers in microbiology*. 2023;14: 1197579
12. Magiorakos AP, Srinivasan A, Carey RB, et al. Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: an international expert proposal for interim standard definitions for acquired resistance. *Clinical microbiology and infection*, 2012, 18.3: 268-281.
13. Pineda-Cortel MR, del Rosario EH, Villaflores OB, Use of veterinary medicinal products in the Philippines: regulations, impact, challenges, and recommendations. *Journal of Veterinary Science*. 2024;25.2: e33.
14. Pirez-Rodriguez F, Mercanoglu TB, A state-of-art review on multi-drug resistant pathogens in foods of animal origin: risk factors and mitigation strategies. *Frontiers in Microbiology*. 2019;10: 2091.
15. Yamaji R, Friedman CR, Rubin J, et al. A population-based surveillance study of shared geno-

- types of *Escherichia coli* isolates from retail meat and suspected cases of urinary tract infections. *Mosphere*. 2018;3.4: 10.1128/msphere. 00179-18.
16. Borzi MM, Cardozo MV, Oliveira ES, et al. Characterization of avian pathogenic *Escherichia coli* isolated from free-range helmeted guineafowl. *Brazilian journal of microbiology*. 2018;49. suppl 1: 107-112.
 17. Interagency Coordination Group on Antimicrobial Resistance. No Time to Wait: Infections from Drug-Resistant Securing the Future from Drug-Resistant Infections; Technical Report; World Health Organization: Geneva, Switzerland, 2019.
 18. Lechner I, Freivogel C, Stärk KD, et al. Exposure pathways to antimicrobial resistance at the human-animal interface—A qualitative comparison of Swiss expert and consumer opinions. *Frontiers in Public Health*. 2020;8: 345.
 19. CDC (Centers for Disease Control and Prevention). About Antimicrobial Resistance. 2015. Available online: <https://www.cdc.gov/v/antimicrobial-resistance/about/index.html> (accessed on 24 May 2025).
 20. Graham JP, Boland JJ, Silbergeld E, Growth promoting antibiotics in food animal production: an economic analysis. *Public health reports*. 2007;122.1: 79-87.
 21. Giubilini A, Birkel P, Douglas T, et al. Taxing meat: Taking responsibility for one's contribution to antibiotic resistance. *Journal of Agricultural and Environmental Ethics*. 2017;30.2: 179-198.
 22. Tang KL, Caffrey NP, N.brega DB, et al. Restricting the use of antibiotics in food-producing animals and its associations with antibiotic resistance in food-producing animals and human beings: a systematic review and meta-analysis. *The Lancet Planetary Health*. 2017;1.8: e316-e327.
 23. Szoke Z, Fauszt P, Mikolas M, et al. Comprehensive analysis of antimicrobial resistance dynamics among broiler and duck intensive production systems. *Scientific Reports*. 2025;15.1: 4673.
 24. Ferri G, Buonavoglia A, Farooq M, et al. Antibiotic resistance in Italian poultry meat production chain: A one-health perspective comparing antibiotic free and conventional systems from the farming to the slaughterhouse. *Frontiers in Food Science and Technology*. 2023; 3: 1168896.
 25. Musuka G, Machakwa J, Mano O, et al. Antimicrobial Resistance and Its Impact on Food Safety Determinants Along the Beef Value Chain in Sub-Saharan Africa—A Scoping Review. *Tropical Medicine and Infectious Disease*. 2025;10.3: 82.
 26. Cameron A, McAllister TA, Antimicrobial usage and resistance in beef production. *Journal of animal science and biotechnology*. 2016;7.1: 68.
 27. Morel, C. Transmission of antimicrobial resistance from livestock agriculture to humans and from humans to animals. In OECD Food, Agriculture and Fisheries Papers, No. 133; OECD Publishing: Paris, France, 2019.
 28. McMahon MAS, Xu J, Moore JE, et al. Environmental stress and antibiotic resistance in food-related pathogens. *Applied and environmental microbiology*. 2007;73.1: 211-217.
 29. Buncic S, Nychas GJ, Lee MRF, et al. Microbial pathogen control in the beef chain: recent research advances. *Meat science*. 2014;97.3: 288-297.
 30. Van Boeckel TP, Glennon EE, Chen D, Reducing antimicrobial use in food animals. *Science*. 2017; 357, 1350–1352.
 31. EMA Regulation (EC) No. 470/2009 of the European Parliament and of the Council of 6 May 2009 Laying Down Community Procedures for the Establishment of Residue Limits of Pharmacologically Active Substances in Foodstuffs of Animal Origin, Repealing Council Regulation (EEC) No. 2377/90 and Amending Directive 2001/82/EC of the European Parliament and of the Council and Regulation (EC) No. 726/2004 of the European Parliament and of the Council-Text with EEA Relevance. Available online: <http://data.europa.eu/eli/reg/2009/470/oj> (accessed on 21 June 2024).
 32. Wissniewski P, Trymers M, Chaj, ecka-Wierzchowska W, et al. Antimicrobial resistance in the context of animal production and meat products in Poland—a critical review and future perspective. *Pathogens*. 2024;13.12: 1123.
 33. Dixit O, Behruznia M, Preuss AL, et al. Diversity of antimicrobial-resistant bacteria isolated from Australian chicken and pork meat. *Frontiers in Microbiology*. 2024;15: 1347597.

34. Gousia P, Economou V, Sakkas H, et al. Antimicrobial resistance of major foodborne pathogens from major meat products. *Foodborne pathogens and disease*. 2011;8.1: 27-38.
35. Tagar S, Qambrani NA, Bacteriological quality assessment of poultry chicken meat and meat contact surfaces for the presence of targeted bacteria and determination of antibiotic resistance of Salmonella spp. in Pakistan. *Food Control*.2023;151, 109786.
36. Zelalem A, Sisay A, Vipham JL, et al. The prevalence and antimicrobial resistance profiles of bacterial isolates from meat and meat products in Ethiopia: a systematic review and meta-analysis. *International Journal of Food Contamination*, 2019, 6.1: 1.
37. Ojha AK, Shah NP, Mishra V, Emanuel, N.; Taneja, N.K. et al. Prevalence of antibiotic resistance in lactic acid bacteria isolated from traditional fermented Indian food products. *Food science and biotechnology*. 2023;32.14: 2131-2143.
38. Wolfe BE, Are fermented foods an overlooked reservoir of antimicrobial resistance?. *Current Opinion in Food Science*, 2023, 51: 101018.
39. Fraqueza MJ, Antibiotic resistance of lactic acid bacteria isolated from dry-fermented sausages. *International journal of food microbiology*. 2015;212: 76-88.
40. Leroy S, Christieans S, Talon R, Tetracycline gene transfer in Staphylococcus xylosus in situ during sausage fermentation. *Frontiers in Microbiology*. 2019;10: 392.
41. Qu T, Wang P, Zhao X, et al. Metagenomic profiles of the antimicrobial resistance in traditional Chinese fermented meat products: Core resistome and co-occurrence patterns. *International Journal of Food Microbiology*.2024; 418: 110740.
42. Shahraz F, Dadkhah H, Khaksar R, et al. Analysis of antibiotic resistance patterns and detection of mecA gene in Staphylococcus aureus isolated from packaged hamburger. *Meat science*. 2012;90.3: 759-763.
43. Karabasil N, MirkoviÄLc M, ViÄLciÄLc I, et al. Antimicrobial resistance in diverse ecological niches One Health perspective and food safety. *Antibiotics*. 2025;14.5: 443.
44. Ajose DJ, Abolarinwa TO, Oluwarinde BO, Application of plant-derived nanoparticles (PDNP) in food-producing animals as a bio-control agent against antimicrobial-resistant pathogens. *Biomedicines*. 2022; 10 (10): 2426.
45. Abukhattab S, Hosch S, Abu-Rmeileh NME, et al. Whole-genome sequencing for One Health surveillance of antimicrobial resistance in conflict zones: a case study of Salmonella spp. and Campylobacter spp. in the West Bank, Palestine. *Applied and environmental microbiology*, 2023, 89.9: e00658-23.
46. Collignon P, Powers JH, Chiller TM, et al. World Health Organization ranking of antimicrobials according to their importance in human medicine: a critical step for developing risk management strategies to control antimicrobial resistance from food animal production. *Clinical infectious diseases*. 2016;63.8: 1087-1093.
47. Trajkovic L, Cvetkovic M, Mitrovic M, Antibiotic resistance patterns of multidrug resistant bacteria in acute myeloid leukemia patients during induction treatment. *Journal of Infection in Developing Countries*. 2025;19, 362-369.
48. Fumagalli D. Antibiotic resistance, meat consumption and the harm principle. *Ethics, Policy & Environment*. 2023;26.1: 53-68.
49. Ma F, Xu S, Tang Z, et al. Use of antimicrobials in food animals and impact of transmission of antimicrobial resistance on humans. *Biosafety and Health*.2021;3.1: 32-38.
50. World Health Organization (WHO). Global action plan on antimicrobial resistance. In: *Global action plan on antimicrobial resistance*. 2015.
51. Pan Y, Deng Z, Shahidi F, Natural bioactive substances for the control of food-borne viruses and contaminants in food. *Food Production, Processing and Nutrition*.2020;2.1: 27.
52. Zhang X, Na F, Zhang M, Microbial Control in the Processing of Low-Temperature Meat Products: Non-Thermal Sterilization and Natural Antimicrobials. *Foods*. 2025;14.2: 225.
53. Liu YY, Wang Y, Walsh TR, et al. Emergence of plasmid-mediated colistin resistance mechanism MCR-1 in animals and human beings in China: a microbiological and molecular biological study. *The Lancet infectious diseases*.2016;16.2: 161-168.

54. World Health Organization, et al. WHO guidelines on use of medically important antimicrobials in food-producing animals. In: *WHO guidelines on use of medically important antimicrobials in food-producing animals*. 2017.
55. O'Neill J, et al. Antimicrobials in agriculture and the environment: reducing unnecessary use and waste. The review on antimicrobial resistance. London: The Review on Antimicrobial Resistance, 2015.
56. O'Neill J, et al. Antimicrobials in agriculture and the environment: reducing unnecessary use and waste. The review on antimicrobial resistance. London: The Review on Antimicrobial Resistance, 2015.
57. Grace, D. Review of Evidence on Antimicrobial Resistance and Animal Agriculture in Developing Countries; International Livestock Research Institute (ILRI): Nairobi, Kenya, 2015.
58. ECDC/EFSA; EMEA; European Centre for Disease Prevention and Control (ECDC); European Food Safety Authority (EFSA); European Medicines Agency (EMA). ECDC/EFSA/EMA first joint report on the integrated analysis of the consumption of antimicrobial agents and occurrence of antimicrobial resistance in bacteria from humans and food-producing animals. *EFSA Journal*.2015;13, 114.
59. Anachinaba IA, Adzitey F, Teye GA, et al. Knowledge and perception of consumers on microbiological meat safety, antibiotic resistance and residues in Tema Metropolis, Ghana. *Journal of Agriculture and Food Sciences*. 2022;20.1: 135-153.
60. Hinchliffe S, Bard A, Chan KW, et al, Regulating antimicrobial resistance: market intermediaries, poultry and the audit lock-in. *Agriculture and Human Values*.2024; 41(2), 801-814.
61. Jung D, Morrison BJ, Rubin JE, A review of antimicrobial resistance in imported foods. *Canadian journal of microbiology*, 2022;68.1: 1-15.
62. Nguyen, H. Antibiotic Resistance in Livestock: A Literature Review of Its Consequences and International Effort on Human Antimicrobial Agents Resistant Crisis. 2024.
63. Yang D, Heederik DJ, Scherpenisse P, et al. Antimicrobial resistance genes aph (3')-III, erm (B), sul2 and tet (W) abundance in animal faeces, meat, production environments and human faeces in Europe. *Journal of Antimicrobial Chemotherapy*, 2022, 77.7: 1883-1893.
64. Naghavi M, Vollset SE, Ikuta KS, et al, GBD 2021 Antimicrobial Resistance Collaborators. Global burden of bacterial antimicrobial resistance 1990-2021: a systematic analysis with forecasts to 2050. *Lancet*. 2024;404.10459: 1199-226.
65. Mc Nulty K, Soon JM, Wallace CA, et al. Antimicrobial resistance monitoring and surveillance in the meat chain: A report from five countries in the European Union and European Economic Area. *Trends in food science & technology*, 2016, 58: 1-13.
66. Timme RE, Wolfgang WJ, Balkey M, et al. Optimizing open data to support one health: best practices to ensure interoperability of genomic data from bacterial pathogens. *One Health Outlook*. 2020;2.1: 20.
67. Pei R, Zhang L, Duan C, et al. Investigation of stress response genes in antimicrobial resistant pathogens sampled from five countries. *Processes*.2021;9.6: 927.
68. 140. Li K, Zheng J, Deng T, et al. An analysis of antimicrobial resistance of clinical pathogens from historical samples for six countries. *Processes*.2019;7.12: 964.
69. Yang K, Wang A, Fu M, et al, Investigation of incidents and trends of antimicrobial resistance in foodborne pathogens in eight countries from historical sample data. *International journal of environmental research and public health*. 2020;17.2: 472.
70. Hua MG, Huang WL, Chen A, et al. Comparison of antimicrobial resistance detected in environmental and clinical isolates from historical data for the US. *BioMed research international*. 2020; 1: 4254530.