



eSupplement

Technology and processes for cultivated meat

Fundamentals, challenges, and perspectives

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References

1. Leip A, Weiss F, Wassenar T: Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS) – final report. European Commission, Joint Research Centre. 30. November 2010.
2. Tuomisto HL, Teixeira De Mattos MJ: Environmental impacts of cultured meat production. *Environ Sci Technol* 2011; 45(14): 6117–23.
3. Clark M, Hill J, Tilman D: The diet, health, and environment trilemma. *Annu Rev Environ Resour* 2018; 43: 109–34.
4. Bryant C, Barnett J: Consumer acceptance of cultured meat: a systematic review. *Meat Sci* 2018; 143: 8–17.
5. Statista: Vegetarische Ernährung: Wichtigste Gründe 2020. <https://de.statista.com/statistik/daten/studie/1192330/umfrage/befragung-gruende-vegetarische-ernaehrung/> (last accessed on 27 May 2024).
6. Statista: Fleischkonsum in Deutschland pro Kopf bis 2023. <https://de.statista.com/statistik/daten/studie/36573/umfrage/pro-kopf-verbrauch-von-fleisch-in-deutschland-seit-2000/> (last accessed on 27 May 2024).
7. Deutsche Gesellschaft für Ernährung e. V. (DGE): Immer mehr Schwangere sind zu dick. Presseinformation: 28/2020. www.dge.de/presse/meldungen/2020/immer-mehr-schwangere-sind-zu-dick/ (last accessed on 27 May 2024).
8. Max Rubner-Institut (MRI) (ed.): Ergebnisbericht Teil 2 Nationale Verzehrsstudie II. 2008.
9. Dawczynski C: Potentiell kritische Nährstoffe bei vegetarischer und veganer Ernährung. *Empfehlung zur bedarfsgerechten Zufuhr – Teil 1. Ernährungs Umschau* 2024; 71(2): M90–105.
10. Phillips F: Vegetarian nutrition. *Nutr Bull* 2005; 30(2): 132–67.
11. Wu G: Amino acids: metabolism, functions, and nutrition. *Amino Acids* 2009; 37(1): 1–17.
12. Chen W, Zhang S, Hu X, Chen F, Li D: A review of healthy dietary choices for cardiovascular disease: from individual nutrients and foods to dietary patterns. *Nutrients* 2023; 15(23): 4898.
13. Muloi D, Ward MJ, Pedersen AB, Fèvre EM, Woolhouse MEJ, Van Bunnik BAD: Are food animals responsible for transfer of antimicrobial-resistant *Escherichia coli* or their resistance determinants to human populations? A systematic review. *Food-borne Pathog Dis* 2018; 15(8): 467–74.
14. Mulchandani R, Wang Y, Gilbert M, Van Boeckel TP: Global trends in antimicrobial use in food-producing animals: 2020 to 2030. *PLOS Glob Public Health* 2023; 3(2): e0001305.
15. Listrat A, et al.: How muscle structure and composition influence meat and flesh quality. *Sci World J* 2016; 2016: 3182746.
16. Ostrovidov S, et al.: Stem cell differentiation toward the myogenic lineage for muscle tissue regeneration: a focus on muscular dystrophy. *Stem Cell Rev Rep* 2015; 11(6): 866–84.
17. Fasciano S, Wheba A, Ddamulira C, Wang S: Recent advances in scaffolding biomaterials for cultivated meat. *Biomater Adv* 2024; 162: 213897.
18. Reiss J, Robertson S, Suzuki M: Cell sources for cultivated meat: applications and considerations throughout the production workflow. 2021; 22(14): 7513.
19. Soice E, Johnston J: Immortalizing cells for human consumption. *IJMS* 2021; 22(21): 11660.
20. Bieback K, Kluter H: Mesenchymal stromal cells from umbilical cord blood. *CSCR* 2007; 2(4): 310–23.
21. Messmer T, et al.: A serum-free media formulation for cultured meat production supports bovine satellite cell differentiation in the absence of serum starvation. *Nat Food* 2022; 3(1): 74–85.
22. Van Der Valk J, et al.: The humane collection of fetal bovine serum and possibilities for serum-free cell and tissue culture. *Toxicol In Vitro*, 2004; 18(1): 1–12.
23. Hubalek S, Post MJ, Moutsatsou P: Towards resource-efficient and cost-efficient cultured meat. *Curr Opin Food Sci* 2022; 47: 100885.
24. Merten O-W: Advances in cell culture: anchorage dependence. *Phil Trans R Soc B* 2015; 370(1661): 20140040.
25. Bomkamp C, Skaalure SC, Fernando GF, Ben-Arye T, Swartz EW, Specht EA: Scaffolding biomaterials for 3D cultivated meat: prospects and challenges. *Adv Sci* 2022; 9(3): 2102908.
26. Lee HJ, Yong HI, Kim M, Choi Y-S, Jo C: Status of meat alternatives and their potential role in the future meat market – a review. *Asian-Australas J Anim Sci* 2020; 33(10): 1533–43.
27. Place TL, Domann FE, Case AJ: Limitations of oxygen delivery to cells in culture: an underappreciated problem in basic and translational research. *Free Radic Biol Med* 2017; 113: 311–22.
28. Krogh A: The supply of oxygen to the tissues and the regulation of the capillary circulation. *J Physiol* 1919; 52(6): 457–74.
29. Bodiou V, Moutsatsou P, Post MJ: Microcarriers for up-scaling cultured meat production. *Front Nutr* 2020; 7: 10.



30. Okutan N, Terzi P, Altay F: Affecting parameters on electrospinning process and characterization of electrospun gelatin nanofibers. *Food Hydrocolloids* 2014; 39: 19–26.
31. Lee KY, Mooney DJ: Hydrogels for tissue engineering. *Chem Rev* 2001; 101(7): 1869–80.
32. Imashiro C, Shimizu T: Fundamental technologies and recent advances of cell-sheet-based tissue engineering. *IJMS* 2021; 22(1): 425.
33. Santos ACA, et al.: Tissue engineering challenges for cultivated meat to meet the real demand of a global market. *IJMS* 2023; 24(7): 6033.
34. Hanga MP, et al.: Bioprocess development for scalable production of cultivated meat. *Biotechnol Bioeng* 2020; 117(10): 3029–39.
35. Kulus M, et al.: Bioreactors, scaffolds and microcarriers and in vitro meat production – current obstacles and potential solutions. *Front Nutr* 2023; 10: 1225233.
36. Socol CR, Molento CFM, Reis GG, Karp SG (eds.): *Cultivated meat: technologies, commercialization and challenges*. Cham: Springer Nature Switzerland 2024.
37. Chmiel H, Takors R, Weuster-Botz D (eds.): *Bioprozess-technik*. Berlin, Heidelberg: Springer Berlin Heidelberg 2018.
38. Schirmer C, Maschke RW, Pörtner R, Eibl D: An overview of drive systems and sealing types in stirred bioreactors used in biotechnological processes. *Appl Microbiol Biotechnol* 2021; 105(6): 2225–42.
39. Neunstoecklin B, Stettler M, Solacroup T, Broly H, Morbidelli M, Soos M: Determination of the maximum operating range of hydrodynamic stress in mammalian cell culture. *J Biotechnol* 2015; 194: 100–9.
40. Ng S, Kurisawa M: Integrating biomaterials and food biopolymers for cultured meat production. *Acta Biomaterialia* 2021; 124: 108–29.
41. Tuomisto HL, Allan SJ, Ellis MJ: Prospective life cycle assessment of a bioprocess design for cultured meat production in hollow fiber bioreactors. *Sci Total Environ* 2022; 851: 158051.
42. Eibl R, Jossen V, Eibl D: Einweg-Bioreaktoren: Therapeutische Antikörper. *Chemie in unserer Zeit* 2018; 52(4): 230–7.
43. Djisalov M, et al.: Cultivating multidisciplinary: manufacturing and sensing challenges in cultured meat production. *Biology* 2021; 10(3): 204.
44. David S, Tsukerman A, Safina D, Maor-Shoshani A, Lavon N, Levenberg S: Co-culture approaches for cultivated meat production. *Nat Rev Bioeng* 2023: 817–31.
45. Allan SJ, De Bank PA, Ellis MJ: Bioprocess design considerations for cultured meat production with a focus on the expansion bioreactor. *Front Sustain Food Syst* 2019; 3: 44.
46. Thyden R, et al.: Recycling spent animal cell culture media using the thermally resistant microalga *Chlorella sorokiniana*. *Syst Microbiol Biomanuf* 2024; 5: 371–84.
47. Huang T, Ko C, Paes D, Smeets E, Post M, Smith B: A review on the safety of growth factors commonly used in cultivated meat production. *Compr Rev Food Sci Food Saf* 2024; 23(3): e13350.
48. Letti LAJ, et al.: Cultivated meat: recent technological developments, current market and future challenges. *Biotechnol Res Innov* 2021; 5(1): e2021001.