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Research Article

The role of nutrigenomics and biotechnology in personalized nutrition: Trends, challenges, and future directions

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Abstract

Personalized nutrition is redefining dietary science through the integration of genetic, metabolic, and microbiome data to enable targeted interventions. Nutrigenomics and nutrigenetics underpin this approach by elucidating gene–diet interactions and inter-individual variability in metabolic responses. Recent advances in high-throughput sequencing, polygenic risk modeling, and microbiome profiling, coupled with multi-omics integration and artificial intelligence, have improved the prediction of diet–health relationships and enabled data-driven nutritional strategies. However, clinical translation remains limited by inconsistent evidence, lack of standardized biomarkers, and insufficient external validation of predictive models, alongside challenges in cost and scalability. Ethical concerns, including data privacy, regulatory oversight, and equitable access, further constrain implementation. Future research should prioritize large, diverse cohorts, rigorous validation frameworks, and integration of AI-driven decision support with clinically actionable outcomes to advance personalized nutrition toward scalable and evidence-based practice.

Keywords: Personalized nutrition; Nutrigenomics; Multi-omics integration; Artificial intelligence; Precision health

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1 Introduction

Personalized nutrition marks a shift from one-size-fits-all guidelines toward individualized dietary strategies based on genetic, metabolic, microbiome, and lifestyle characteristics (1). Evidence from nutrigenetics and nutrigenomics shows that common genetic variants, multi-omic profiles, and gut microbiota composition contribute to large inter-individual differences in dietary response, disease susceptibility, and metabolic outcomes (2). These insights underpin efforts to move from population-level recommendations to precision nutrition frameworks that integrate genomic and phenotypic data to optimize health and prevent chronic disease (3).

Rapid advances in biotechnology and data science have accelerated this transition. High-throughput genotyping and GWAS have identified hundreds of loci involved in nutrient metabolism, obesity, cardiometabolic traits, and host–microbe interactions (4). Parallel progress in epigenomics, transcriptomics, proteomics, metabolomics, and microbiome profiling has enabled multi-omics integration, providing a systems-level view of diet–gene–microbiome interactions (3). Coupled with artificial intelligence, machine learning, and digital health tools (wearables, continuous glucose monitoring, mobile apps), these platforms support real-time monitoring and prediction of individual dietary responses, with large trials such as FOOD4ME and PREDICT demonstrating improved weight, glycemic control, and adherence compared with standard advice (1,3)

However, translation into routine clinical practice and public health remains constrained. Key barriers include limited long-term randomized trials, heterogeneous study designs, lack of validated and standardized biomarkers, high costs of omics technologies, and challenges in high-dimensional data integration and infrastructure (5). Ethical and regulatory concerns data privacy, direct-to-consumer genetic testing, algorithm transparency, and inequitable access further complicate implementation and risk widening health disparities (6).

Against this backdrop, the present review synthesizes current evidence on nutrigenomics and biotechnology in personalized nutrition, delineates major technological and methodological trends, critically evaluates translational, ethical, and regulatory challenges, and proposes future research directions to enhance clinical applicability and population-level impact.

2. Material and Methods

This review employed a narrative and integrative design to synthesize current evidence on nutrigenomics, biotechnology, and personalized nutrition, consistent with recent narrative and scoping reviews in precision nutrition and multi-omics

2.1 Literature Search Strategy

Peer-reviewed literature published between January 2015 and March 2025 was searched in PubMed, Scopus, Web of Science, and Google Scholar, aligning with search practices in related reviews. Search strings combined controlled vocabulary and free-text terms such as:

i. “personalized nutrition” OR “precision nutrition”
ii. “nutrigenomics” OR “nutrigenetics” OR “multi-omics”
iii. “microbiome” OR “gut microbiota”
iv. “biotechnology” OR “artificial intelligence” OR “machine learning”

Boolean operators (AND/OR) were used to refine queries, following strategies applied in recent systematic and semi-systematic reviews. Reference lists of included articles were hand-searched to identify additional records.

2.2 Eligibility Criteria and Study Selection

Studies were eligible if they:

Addressed gene–diet interactions, multi-omics, microbiome, or biotechnology in the context of personalized/precision nutrition. Reported mechanistic insights, technological innovations, or clinical/population applications were original experimental/observational studies, clinical trials, or reviews in humans or human-relevant contexts. Non–peer-reviewed grey literature and preprints were excluded, in line with high-quality review practices 78. Titles and abstracts were screened, followed by full-text assessment where needed, similar to procedures described in recent systematic reviews.

2.3 Additional Sources and Synthesis

To capture translational, ethical, regulatory, and commercial dimensions, policy reports, regulatory documents, and industry/market analyses cited within scientific reviews were examined. Data were extracted on study type, population, omics/biotech tools, and application domain. A qualitative narrative synthesis was used to identify recurring themes, emerging technologies, and knowledge gaps across domains, reflecting methods used in prior integrative reviews in nutrigenomics, microbiome science, and multi-omics healthcare.

3. Results and Discussion

3.1 Biological Basis: Gene–Diet–Microbiome Interactions

Nutrients modulate gene expression via transcriptional and epigenetic mechanisms, while genetic variants shape responses to macronutrients, micronutrients, and dietary patterns, supporting the basis of nutrigenomics and nutrigenetics (7,8). SNPs in genes involved in obesity, insulin resistance, and inflammation alter responses to specific diets and nutrients, and polygenic risk scores can improve prediction of dietary effects on metabolic traits (7,9,10).

The gut microbiota regulates nutrient bioavailability and produces short-chain fatty acids (SCFAs), which influence glucose homeostasis, appetite, inflammation, and cardiometabolic risk (3). Inter-individual variability in microbiome composition and SCFA production contributes to heterogeneous glycemic and metabolic responses, with causal links suggested between butyrate/propionate pathways and insulin response or type 2 diabetes risk (11). However, microbiome dynamics, host genetics, medications, and lifestyle complicate reproducibility and generalization of microbiome-based interventions (3,12).

Host–microbiome interactions are bidirectional: diet and host genetics shape microbiota, while microbiota-derived metabolites feedback on host gene expression and metabolism, reinforcing the need for integrative genomic–microbiomic approaches and longitudinal, systems-level studies (7,11,13).

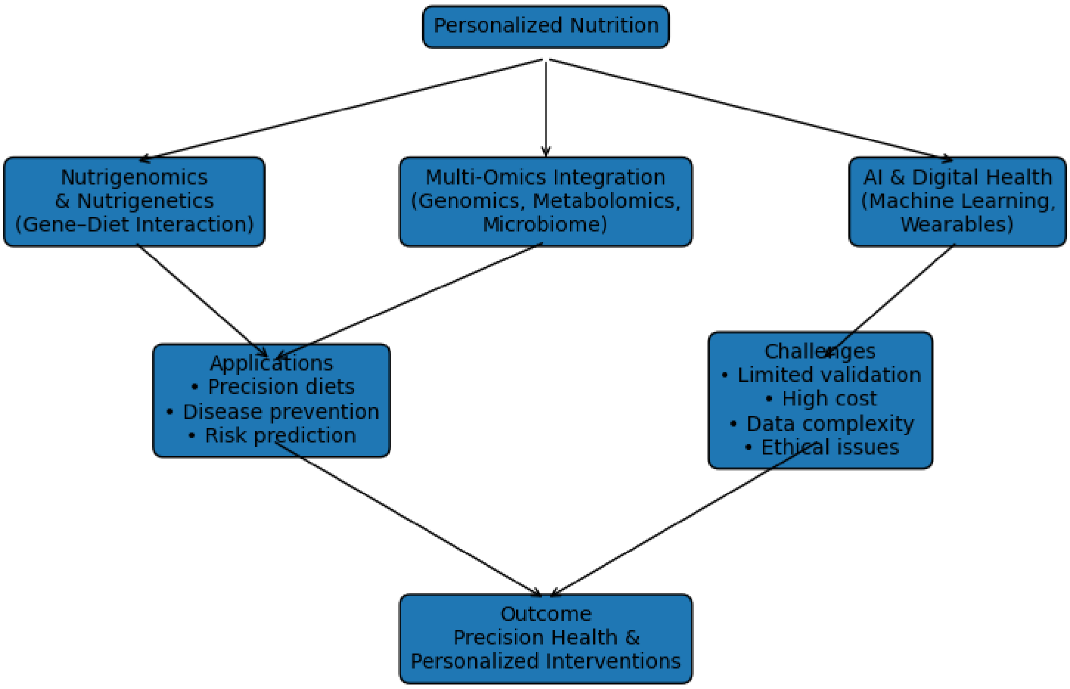

Figure 1. Conceptual framework of personalized nutrition integrating nutrigenomics, multi-omics, and artificial intelligence.

3.2 Biotechnological Innovations Enabling Precision Nutrition

High-throughput sequencing supports comprehensive genotyping and metagenomic profiling, enabling discovery of obesity, insulin resistance, and microbiome-related loci and pathways (14) GWAS and related approaches have identified hundreds of loci for adiposity, insulin resistance, and cardiometabolic traits; PRS are emerging to capture cumulative genetic risk and to stratify dietary response (14,15).

Metabolomics, proteomics, and epigenomics provide functional readouts of dietary exposures and gene–environment interaction, revealing metabolic signatures of prediabetes, obesity, and fiber- or SCFA-linked pathways (7,16). Multi-omics integration offers a holistic view of metabolic phenotypes and supports risk prediction and tailoring of dietary interventions, but is hindered by methodological heterogeneity, high cost, high-dimensional data, and lack of standardized integration pipelines and clinical workflows (10,14).

3.3 AI and Digital Health Technologies

AI and ML are increasingly applied to multi-omics and digital nutrition data to model complex diet–gene microbiome–phenotype relationships (17,18). ML models, including deep architectures, can predict individual metabolic responses and optimize personalized interventions, with some multi-omics-driven precision nutrition trials reporting superior improvements in glycemic control, lipid profiles, and adherence compared with standard care (16,18).

Wearables, mobile apps, and continuous glucose monitoring enable real-time acquisition of dietary, physiological, and behavioral data, supporting AI-assisted dietary assessment and dynamic feedback (16,18). Image-based and sensor-based tools reduce recall bias and enhance precision of intake estimation, facilitating personalized diet management in obesity and diabetes (18). Yet, many AI systems lack external validation, use small or homogeneous samples, and provide limited transparency about algorithms, raising concerns about generalizability, bias, and interpretability that constrain clinical adoption (16,17).

3.4 Clinical Applications and Translational Potential

Precision nutrition strategies integrating genetics, metabolomics, and microbiome features have shown benefits for obesity, insulin resistance, type 2 diabetes, and related metabolic disturbances, including improved glycemic control, lipids, weight, and inflammatory markers in controlled and real-world studies 2141615+2 MORE. Microbiome-informed diets and SCFA-enhancing fiber interventions can modulate

glycemic responses and metabolic health, although human evidence is still limited in duration and scale (14).

Functional foods and nutraceuticals rich in bioactive compounds (e.g., fibers, polyphenols, specific fatty acids) interact with genetic and microbiome profiles to improve insulin sensitivity and lipid metabolism, supporting personalized formulations for obesity and type 2 diabetes management (19,20).

However, clinical evidence remains heterogeneous, often constrained by small sample sizes, short follow-up, diverse omics and analytical platforms, and lack of harmonized outcomes, limiting firm conclusions about long-term superiority over conventional guidelines (10).

3.5 Implementation Challenges and Limitations

The multifactorial nature of diet-related diseases, involving polygenic risk, epigenetics, microbiome, and lifestyle, complicates causal inference and robust predictive modeling 1(13,21). Absence of standardized biomarkers and validated clinical endpoints for precision nutrition, together with variability in sample processing and omics pipelines, undermines reproducibility and comparability (22).

High costs of multi-omics profiling, AI infrastructure, and specialized expertise pose economic and scalability barriers, particularly outside research settings (1). Integrating complex multi-omics and digital data into routine clinical workflows requires interoperable systems, trained multidisciplinary teams, and clear practice guidelines (3,6).

3.6 Ethical, Regulatory, and Societal Considerations

Extensive use of genomic, microbiome, and digital health data in personalized nutrition raises significant concerns about privacy, data security, ownership, and informed consent (23,24). Direct-to-consumer genetic and microbiome-based nutrition services often operate ahead of regulatory frameworks, with variable scientific validity and risks of misinterpretation (25–27).

Unequal access to omics testing, AI technologies, and specialized care may widen health disparities, as most current implementations are concentrated in high-resource settings and specific populations (11,22). Addressing these issues calls for robust, harmonized regulation, transparency standards, and inclusive policy and public-engagement strategies (3,22).

Table 1. Key Scientific and Technological Trends in Personalized Nutrition

No.	Trend Area	Description	Citations
1.	Multi-omics integration	Integration of genomics, transcriptomics, proteomics, metabolomics, and microbiome data to enable comprehensive phenotyping and improved risk stratification	(11,30)
2.	Consumer genomics	Rapid expansion of direct-to-consumer (DTC) nutrigenetic testing, enabling personalized health insights and self-directed dietary management	(31,32)
3.	Microbiome-aware nutrition	Characterization of diet–microbiota–host interactions and development of machine learning models to predict glycemic and metabolic responses	(30,31)
4	Functional and bioactive foods	Development of targeted functional ingredients and nutraceuticals tailored to genetic, metabolic, and phenotypic profiles	(33–35)
5	AI and digital nutrition	Application of artificial intelligence, wearable technologies, and digital platforms for real-time monitoring and adaptive dietary decision suppor	(33,35)

Table 2. Summary of Key Findings, Applications, Challenges, and Research Gaps in Personalized Nutrition

Domain.	Key Findings	Applications	Challenges/Limitations	References
Nutrigenomics & Nutrigenetics	Gene–diet interactions influence metabolism and disease risk; strong inter-individual variability	Genotype-based dietary recommendations; disease risk prediction	Limited reproducibility across populations; incomplete mechanistic understanding	(32,36)
Microbiome-based Nutrition	Gut microbiota modulates nutrient metabolism and host responses	Personalized microbiome-targeted diets	High variability; confounding lifestyle factors	(37,38)
Multi-omics Integration	Integration of genomics, proteomics, metabolomics enhances biological insight	Systems-level risk prediction and stratification	Complex data integration; lack of standardization	(37,39,40)
Artificial Intelligence & Data Science	AI enables prediction of diet–health interactions using large datasets	Real-time dietary recommendations; decision support	Limited external validation; model bias	(41,42)
Functional Foods & Nutraceuticals	Bioactive compounds regulate gene expression and metabolic pathways	Personalized nutraceuticals and functional foods	Regulatory uncertainty; inconsistent evidence	(43)
Clinical Implementation	Personalized nutrition shows potential in improving metabolic outcomes	Prevention and management of chronic diseases	High cost; limited scalability; weak long-term evidence	(13,40)
Ethical, Regulatory & Societal Aspects	Increased use of genomic data raises ethical concerns	Direct-to-consumer nutrition services	Privacy risks; inequitable access	(3,13,33,42)

3.7 Future Directions and Research Priorities

Priorities include large, multi-ethnic, longitudinal cohorts integrating genomics, epigenomics, metabolomics, proteomics, microbiome, and detailed lifestyle data to improve generalizability and clarify mechanisms (28). Development of standardized, scalable multi-omics integration frameworks and validated predictive models, coupled with cost-effectiveness and implementation studies, is essential for translation into routine care (29).

Advances in explainable AI and transparent reporting of algorithms will be critical to improve trust, interpretability, and regulatory acceptance (1). Innovation in gene- and microbiome-informed functional foods and nutraceuticals offers promising avenues for tailored dietary interventions, but requires genotype- and phenotype-stratified clinical trials (3,22)

Sustained interdisciplinary collaboration among nutrition scientists, geneticists, microbiologists, data scientists, clinicians, ethicists, and policymakers will be central to evolving personalized nutrition into an equitable, evidence-based component of healthcare.

4. Conclusion

Personalized nutrition, driven by advances in nutrigenomics and biotechnology, represents a transformative shift from generalized dietary guidelines toward data-driven, individualized interventions. The integration of multi-omics approaches—including genomics, metabolomics, and microbiome profiling—together with artificial intelligence and digital health technologies, has significantly enhanced the capacity to predict and modulate diet–health interactions. These developments offer substantial potential for improving prevention and management of chronic diseases.

However, despite rapid technological progress, clinical translation remains limited by insufficient long-term validation, lack of standardized biomarkers, and challenges in data integration and model generalizability. In addition, ethical and regulatory concerns, particularly regarding data privacy, transparency, and equitable access, continue to constrain large-scale implementation.

Future efforts should prioritize robust, multi-ethnic cohort studies, development of validated and explainable predictive models, and integration of personalized nutrition into clinical and public health frameworks. Addressing these challenges will be essential to realize the full potential of precision nutrition as a scalable and evidence-based approach to improving global health outcomes.

Author Contributions

Aulia Yustisia Damayanti: Conceptualization, Analysis, Writing-Original, Visualization.

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Data Availability

No new data were generated or analyzed in this study. All information is based on previously published studies and publicly available sources.

References

1. Singar S, Nagpal R, Arjmandi BH, Akhavan NS. Personalized Nutrition: Tailoring Dietary Recommendations through Genetic Insights. Nutrients. Multidisciplinary Digital Publishing Institute (MDPI); 2024. doi:10.3390/nu16162673 PubMed PMID: 39203810.

2. Lagoumintzis G, Patrinos GP. Triangulating nutrigenomics, metabolomics and microbiomics toward personalized nutrition and healthy living. Human Genomics. BioMed Central Ltd; 2023.

doi:10.1186/s40246-023-00561-w PubMed PMID: 38062537.

3. Nourazarain A, Vaziri Y. Nutrigenomics meets multi-omics: integrating genetic, metabolic, and microbiome data for personalized nutrition strategies. Genes and Nutrition. BioMed Central Ltd; 2025. doi:10.1186/s12263-025-00790-9

4. San-Cristobal R, de Toro-Martín J, Vohl MC. Appraisal of Gene-Environment Interactions in GWAS for Evidence-Based Precision Nutrition Implementation. Current Nutrition Reports. Springer; 2022. p. 563–73. doi:10.1007/s13668-022-00430-3 PubMed PMID: 35948824.

5. Mansour S, Alkhaaldi SMI, Sammanasunathan AF, Ibrahim S, Farhat J, Al-Omari B. Precision Nutrition Unveiled: Gene–Nutrient Interactions, Microbiota Dynamics, and Lifestyle Factors in Obesity Management. Nutrients. Multidisciplinary Digital Publishing Institute (MDPI); 2024. doi:10.3390/nu16050581 PubMed PMID: 38474710.

6. Kohlmeier M, De Caterina R, Ferguson LR, Görman U, Allayee H, Prasad C, et al. Guide and Position of the International Society of Nutrigenetics/Nutrigenomics on Personalized Nutrition: Part 2 - Ethics, Challenges and Endeavors of Precision Nutrition. In: Journal of Nutrigenetics and Nutrigenomics. S. Karger AG; 2016. p. 28–46. doi:10.1159/000446347 PubMed PMID: 27286972.

7. Farzand A, Rohin MAK, Awan SJ, Ahmad AMR, Akram H, Saleem T, et al. Nutrigenomics of Obesity: Integrating Genomics, Epigenetics, and Diet–Microbiome Interactions for Precision Nutrition. Life. Multidisciplinary Digital Publishing Institute (MDPI); 2025. doi:10.3390/life15111658

8. Lagoumintzis G, Patrinos GP. Triangulating nutrigenomics, metabolomics and microbiomics toward personalized nutrition and healthy living. Human Genomics. BioMed Central Ltd; 2023. doi:10.1186/s40246-023-00561-w PubMed PMID: 38062537.

9. Wang X, Sun Z, Xue H, An R. Artificial Intelligence Applications to Personalized Dietary Recommendations: A Systematic Review. Healthcare (Switzerland). Multidisciplinary Digital Publishing Institute (MDPI); 2025. doi:10.3390/healthcare13121417

10. Abeltino A, Riente A, Bianchetti G, Serantoni C, De Spirito M, Capezzone S, et al. Digital applications for diet monitoring, planning, and precision nutrition for citizens and professionals: a state of the art. Nutrition Reviews. Oxford University Press; 2025. p. e574–601. doi:10.1093/nutrit/nuae035 PubMed PMID: 38722240.

11. Ramos-Lopez O, Martinez JA, Milagro FI. Holistic Integration of Omics Tools for Precision Nutrition in Health and Disease. Nutrients. MDPI; 2022. doi:10.3390/nu14194074 PubMed PMID: 36235725.

12. Ramos Meyers G, Samouda H, Bohn T. Short Chain Fatty Acid Metabolism in Relation to Gut Microbiota and Genetic Variability. Nutrients. MDPI; 2022. doi:10.3390/nu14245361 PubMed PMID: 36558520.

13. Lam HN, Lin SP, Nguyen DHN, Chen CM, Su CT, Fang TC, et al. Integrative Roles of Functional Foods, Microbiotics, Nutrigenetics, and Nutrigenomics in Managing Type 2 Diabetes and Obesity. Nutrients . Multidisciplinary Digital Publishing Institute (MDPI); 2025. doi:10.3390/nu17040608 PubMed PMID: 40004938.

14. Kassem H, Beevi AA, Basheer S, Lutfi G, Cheikh Ismail L, Papandreou D. Investigation and Assessment of AI’s Role in Nutrition—An Updated Narrative Review of the Evidence. Nutrients . Multidisciplinary Digital

Publishing Institute (MDPI); 2025. doi:10.3390/nu17010190 PubMed PMID: 39796624.

15. Duarte GBS, Pascoal G de FL, Rogero MM. Polymorphisms Involved in Insulin Resistance and Metabolic Inflammation: Influence of Nutrients and Dietary Interventions. Metabolites. Multidisciplinary Digital Publishing Institute (MDPI); 2025. doi:10.3390/metabo15040245

16. Romero-Tapiador S, Lacruz-Pleguezuelos B, Tolosana R, Freixer G, Daza R, Fernández-Díaz CM, et al. AI4FoodDB: a database for personalized e-Health nutrition and lifestyle through wearable devices and artificial intelligence. Database. 2023;2023. doi:10.1093/database/baad049 PubMed PMID: 37465917.

17. Mohr AE, Ortega-Santos CP, Whisner CM, Klein-Seetharaman J, Jasbi P. Navigating Challenges and Opportunities in Multi-Omics Integration for Personalized Healthcare. Biomedicines. Multidisciplinary Digital Publishing Institute (MDPI); 2024. doi:10.3390/biomedicines12071496 PubMed PMID: 39062068.

18. Phalle A, Gokhale D. Navigating next-gen nutrition care using artificial intelligence-assisted dietary assessment tools—a scoping review of potential applications. Frontiers in Nutrition. Frontiers Media SA; 2025. doi:10.3389/fnut.2025.1518466

19. Investigation of Polymers with Differential Scanning Calorimetry. In: Physik von Makromolekülen. HUMBOLDT-UNIVERSITÄT ZU BERLIN. p. 1–17.

20. Sanna S, van Zuydam NR, Mahajan A, Kurilshikov A, Vich Vila A, Võsa U, et al. Causal relationships among the gut microbiome, short-chain fatty acids and metabolic diseases. Nature Genetics. Nature Publishing Group; 2019. p. 600–5. doi:10.1038/s41588-019-0350-x PubMed PMID: 30778224.

21. Petre ML, Tsichla H, Pertesi ANK, Mpoulioglou OE, Kouvela M, Vamvakaris IN, et al. Precision nutrition: Is tailor-made dietary intervention a reality yet? (Review). Biomedical Reports. Spandidos Publications; 2025. doi:10.3892/br.2025.1964

22. Mundt C, Yusufoğlu B, Kudenko D, Mertoğlu K, Esatbeyoglu T. AI-Driven Personalized Nutrition: Integrating Omics, Ethics, and Digital Health. Molecular Nutrition and Food Research. John Wiley and Sons Inc; 2025. doi:10.1002/mnfr.70293 PubMed PMID: 41163310.

23. Verma M, Hontecillas R, Tubau-Juni N, Abedi V, Bassaganya-Riera J. Challenges in Personalized Nutrition and Health. Frontiers in Nutrition. Frontiers Media S.A.; 2018. doi:10.3389/fnut.2018.00117

24. Abdol Ghaffar Ebadi, Zeliha Selamoglu. Personalized Nutrition in the Genomics and Digital Age: Current Issues, Future Directions, and Evidence. Wah Academia Journal of Health and Nutrition. 2025 Mar 31;1(1):34–9. doi:10.63954/sns00e14

25. The Lancet Diabetes & Endocrinology. Diabetes behind bars: challenging inadequate care in prisons. The Lancet Diabetes and Endocrinology. Lancet Publishing Group; 2018. p. 347. doi:10.1016/S2213-8587(18)30103-7 PubMed PMID: 29680451.

26. Ludvik B, Frías JP, Tinahones FJ, Wainstein J, Jiang H, Robertson KE, et al. Dulaglutide as add-on therapy to SGLT2 inhibitors in patients with inadequately controlled type 2 diabetes (AWARD-10): a 24-week, randomised, double-blind, placebo-controlled trial. Lancet Diabetes Endocrinol. 2018 May 1;6(5):370–81. doi:10.1016/S2213-8587(18)30023-8 PubMed PMID: 29483060.

27. Sivaprasad S, Vasconcelos JC, Prevost AT, Holmes H, Hykin P, George S, et al. Clinical efficacy and safety of a light mask for prevention of dark adaptation in

treating and preventing progression of early diabetic macular oedema at 24 months (CLEOPATRA): a multicentre, phase 3, randomised controlled trial. Lancet Diabetes Endocrinol. 2018 May 1;6(5):382–91. doi:10.1016/S2213-8587(18)30036-6 PubMed PMID: 29519744.

28. Guasch-Ferré M, Wittenbecher C, Palmnäs M, Ben-Yacov O, Blaak EE, Dahm CC, et al. Precision nutrition for cardiometabolic diseases. Nature Medicine. Nature Research; 2025. p. 1444–53. doi:10.1038/s41591-025-03669-9 PubMed PMID: 40307513.

29. Priyadharshini D, Muthuvel I, Saraswathy S, Kavitha PS, Jegadeeswari V. Precision to plate: AI-driven innovations in fermentation and hyper-personalized diets. Frontiers in Nutrition. Frontiers Media SA; 2025. doi:10.3389/fnut.2025.1659511

30. Babu M, Snyder M. Multi-omics profiling for health. Molecular and Cellular Proteomics. 2023;22(6). doi:10.1016/j.mcpro.2023.100561 PubMed PMID: 37119971.

31. Mullins VA, Bresette W, Johnstone L, Hallmark B, Chilton FH. Genomics in personalized nutrition: Can you "eat for your genes"? Nutrients. MDPI AG; 2020. p. 1–23. doi:10.3390/nu12103118 PubMed PMID: 33065985.

32. Lagoumintzis G, Patrinos GP. Triangulating nutrigenomics, metabolomics and microbiomics toward personalized nutrition and healthy living. Human Genomics. BioMed Central Ltd; 2023. doi:10.1186/s40246-023-00561-w PubMed PMID: 38062537.

33. Lam HN, Lin SP, Nguyen DHN, Chen CM, Su CT, Fang TC, et al. Integrative Roles of Functional Foods, Microbiotics, Nutrigenetics, and Nutrigenomics in Managing Type 2 Diabetes and Obesity. Nutrients . Multidisciplinary Digital Publishing Institute (MDPI); 2025. doi:10.3390/nu17040608 PubMed PMID: 40004938.

34. Ben-Yacov O, Godneva A, Rein M, Shilo S, Lotan-Pompan M, Weinberger A, et al. Gut microbiome modulates the effects of a personalised postprandial-targeting (PPT) diet on cardiometabolic markers: a diet intervention in pre-diabetes. Gut. 2023 Aug 1;72(8):1486–96. doi:10.1136/gutjnl-2022-329201 PubMed PMID: 37137684.

35. Fekete M, Lehoczki A, Kryczyk-Poprawa A, Zábó V, Varga JT, Bálint M, et al. Functional Foods in Modern Nutrition Science: Mechanisms, Evidence, and Public Health Implications. Nutrients . Multidisciplinary Digital Publishing Institute (MDPI); 2025. doi:10.3390/nu17132153 PubMed PMID: 40647258.

36. Phillips CM. Nutrigenetics and metabolic disease: Current status and implications for personalised nutrition. Nutrients. MDPI AG; 2013. p. 32–57. doi:10.3390/nu5010032

37. Abeltino A, Hatem D, Serantoni C, Riente A, De Giulio MM, De Spirito M, et al. Unraveling the Gut Microbiota: Implications for Precision Nutrition and Personalized Medicine. Nutrients . Multidisciplinary Digital Publishing Institute (MDPI); 2024. doi:10.3390/nu16223806 PubMed PMID: 39599593.

38. Jardon KM, Canfora EE, Goossens GH, Blaak EE. Dietary macronutrients and the gut microbiome: a precision nutrition approach to improve cardiometabolic health. Gut. 2022;71(6):1214–26. doi:10.1136/gutjnl-2020-323715 PubMed PMID: 35135841.

39. Jardon KM, Canfora EE, Goossens GH, Blaak EE. Dietary macronutrients and the gut microbiome: a precision nutrition approach to improve cardiometabolic health. Gut. 2022;71(6):1214–26.

doi:10.1136/gutjnl-2020-323715 PubMed PMID: 35135841.

40. Olutunde, Timothy, Ani, Chukwuemeka L, Adesue GA. Leveraging Machine Learning for Personalized Dietary Recommendations, Nutritional Patterns, and Health Outcome Predictions. JOSRAR. 1(2):43–56. doi:10.70882/josrar.2024.v1i2

41. Aydın SK, Ali RH, Faiz S, Khan TA. An Integrated AI Framework for Personalized Nutrition Using Machine Learning and Natural Language Processing for Dietary Recommendations. Applied Sciences (Switzerland). 2025 Sep 1;15(17). doi:10.3390/app15179283

42. Kassem H, Beevi AA, Basheer S, Lutfi G, Cheikh Ismail L, Papandreou D. Investigation and Assessment of AI's Role in Nutrition—An Updated Narrative Review of the Evidence. Nutrients . Multidisciplinary Digital Publishing Institute (MDPI); 2025. doi:10.3390/nu17010190 PubMed PMID: 39796624.

43. Arshad Z, Shahid S, Hasnain A, Yaseen E, Rahimi M. Functional Foods Enriched With Bioactive Compounds: Therapeutic Potential and Technological Innovations. Food Science and Nutrition. John Wiley and Sons Inc; 2025. doi:10.1002/fsn3.71024