

THE GUT MICROBIOME IN COMPANION ANIMAL NUTRITION: EMERGING SCIENCE, FUNCTIONAL DIETS, AND PERSONALIZED PET FOOD STRATEGIES

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The gut microbiome has emerged as a central determinant of health, metabolism, and disease outcomes in companion animals. Advances in high-throughput sequencing and metabolomics have revealed complex microbial ecosystems in dogs and cats that interact dynamically with dietary inputs, host genetics, and environmental factors. This review synthesizes current evidence linking the gut microbiome to nutrient metabolism, immune modulation, metabolic disease, and functional dietary responses in pets. We discuss mechanisms by which diet shapes microbial composition and function, evaluate the role of emerging functional ingredients (prebiotics, probiotics, postbiotics, fermented ingredients), and explore personalized nutrition strategies based on microbiome profiling. We also identify research gaps and future directions for integrating microbiome science into pet food formulation and clinical practice. Understanding and harnessing gut–diet–host interactions hold immense promise for optimizing health, preventing disease, and advancing next-generation pet food solutions. This interdisciplinary approach is essential for bridging the gap between fundamental microbiology and practical nutrition.

Keywords: companion animal microbiome, gut microbiota, functional pet diets, prebiotics, probiotics, metabolomics, personalized nutrition, immune modulation, metabolic health.

СЕРІКТЕС ЖАНУАРЛАРДЫҢ ҚОРЕКТЕНУІНДЕГІ ІШЕК МИКРОБИОМАСЫ: ЖАҢА ҒЫЛЫМИ БАҒЫТТАР, ФУНКЦИОНАЛДЫҚ РАЦИОНДАР ЖӘНЕ ДЕРБЕСТЕНДІРІЛГЕН ҮЙ ЖАНУАРЛАРЫ ТАҒАМЫ СТРАТЕГИЯЛАРЫ

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Ішек микробиомасы серіктес жануарлардың денсаулығы, метаболизмі және аурулардың даму нәтижелерін айқындайтын негізгі факторлардың бірі ретінде танылды. Жоғары өнімді секвенирлеу және метаболомика саласындағы жетістіктер иттер мен мысықтардың азғасындағы күрделі микробтық экожүйелерді анықтап, олардың рацион құрамымен, иесінің генетикалық ерекшеліктерімен және қоршаған орта факторларымен динамикалық өзара әрекеттесетінін көрсетті. Бұл шолу үй жануарларындағы ішек микробиомасының қоректік заттардың алмасуына, иммундық реттелуге, метаболикалық ауруларға және функционалдық рациондарға жауабына әсерін сипаттайтын қазіргі ғылыми деректерді жүйелейді. Біз рационның микробтық құрам мен функцияға әсер ету механизмдерін қарастырып, жаңа функционалдық ингредиенттердің (пребиотиктер, пробиотиктер, постбиотиктер, ашытылған компоненттер) рөлін бағалаймыз және микробиомалық профилдеу негізінде дербестендірілген қоректену стратегияларын талқылаймыз. Сонымен қатар, микробиомалық ғылымды үй жануарлары тағамын әзірлеу мен клиникалық тәжірибеге енгізуге қатысты зерттеу олқылықтары мен болашақ бағыттарды анықтаймыз. Ішек–рацион–иесі арасындағы өзара әрекеттесуді түсіну және тиімді пайдалану денсаулықты оңтайландыруға, аурулардың алдын алуға және келесі буындағы үй жануарлары тағамын дамытуға үлкен мүмкіндік береді. Пәнаралық тәсіл іргелі микробиология мен қолданбалы нутрициология арасындағы ашақтықты жою үшін аса маңызды.

Негізгі сөздер: серіктес жануарлар микробиомасы, ішек микробиотасы, функционалдық үй жануарлары рациондары, пребиотиктер, пробиотиктер, метаболомика, дербестендірілген қоректену, иммундық реттелу, метаболикалық денсаулық.

КИШЕЧНЫЙ МИКРОБИОМ В ПИТАНИИ ДОМАШНИХ ЖИВОТНЫХ-КОМПАЬОНОВ: НОВЫЕ НАУЧНЫЕ ДАННЫЕ, ФУНКЦИОНАЛЬНЫЕ РАЦИОНЫ И СТРАТЕГИИ ПЕРСОНАЛИЗИРОВАННОГО КОРМА

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Кишечный микробиом рассматривается как один из ключевых факторов, определяющих здоровье, метаболизм и исходы заболеваний у домашних животных-компаньонов. Достижения в области высокопроизводительного секвенирования и метаболомики позволили выявить сложные микробные экосистемы у собак и кошек, которые динамично взаимодействуют с рационом, генетическими особенностями хозяина и факторами окружающей среды. В данном обзоре обобщены современные данные о связи кишечного микробиома с метаболизмом питательных веществ, иммунной модуляцией, метаболическими заболеваниями и реакцией на функциональные рационы у домашних животных. Рассматриваются механизмы влияния рациона на состав и функции микробиоты, оценивается роль новых функциональных ингредиентов (пребиотики, пробиотики, постбиотики, ферментированные компоненты), а также анализируются стратегии персонализированного питания на основе профилирования микробиома. Кроме того, обозначены существующие пробелы в исследованиях и перспективные направления интеграции микробиомных данных в разработку кормов и клиническую практику. Понимание и эффективное использование взаимодействий «кишечник–рацион–организм» открывает широкие возможности для оптимизации здоровья, профилактики заболеваний и создания кормов нового поколения. Подход, основанный на междисциплинарном взаимодействии, является ключевым для преодоления разрыва между фундаментальной микробиологией и практической нутрициологией.

Ключевые слова: микробиом домашних животных, кишечная микробиота, функциональные рационы для домашних животных, пребиотики, пробиотики, метаболомика, персонализированное питание, иммунная модуляция, метаболитическое здоровье.

Introduction

The gut microbiome, the community of microorganisms inhabiting the gastrointestinal tract, plays a pivotal role in host physiology, including nutrient digestion, immune function, gut barrier integrity, and metabolic regulation [1-3]. While initially characterized in human and livestock systems, the companion animal microbiome has garnered significant attention over the past decade due to links with obesity, inflammatory bowel disease, allergies, and neurologic health in dogs and cats [4,5].

Traditional pet food formulation has largely focused on macronutrient balance and essential nutrient adequacy based on established nutrient requirements. However, emerging data suggest that nutritional strategies targeting microbial ecology may further optimize health and mitigate disease across life stages [6-8]. This evolving paradigm integrates microbiome science with functional diets and personalized nutrition representing a new frontier in pet food research and product development. This review provides a comprehensive synthesis of the gut microbiome in companion animals, mechanisms of diet–microbiome interaction, functional dietary

interventions, clinical evidence, and personalized nutrition frameworks. We aim to bridge fundamental microbiology with practical strategies for nutritionists, veterinarians, and pet food scientists [9-11].

Materials and research methods

Literature Search Strategy

A comprehensive search of peer-reviewed literature was conducted to identify studies concerning the gut microbiome in companion animals (dogs and cats). Databases were utilized to gather data on microbial composition, dietary interactions, and functional ingredients. The search focused on recent advances in high-throughput sequencing (16S rRNA and shotgun metagenomics) and metabolomics.

Results and discussion

1. The Companion Animal Gut Microbiome: Composition and Function

1.1. Microbial Communities in Dogs and Cats

Advances in 16S rRNA sequencing, metagenomics, and shotgun sequencing have profoundly expanded our knowledge of the canine and feline gut microbiome. Dominant bacterial phyla in dogs and cats include Firmicutes,

Bacteroidetes, Proteobacteria, Fusobacteria, and Actinobacteria, though relative abundance varies with diet, age, breed, and health status [12-14]. Compared with humans, companion animals exhibit greater bacterial diversity and unique species clusters adapted to carnivorous and omnivorous diets. Unlike the human microbiome, which is influenced heavily by plant fiber fermentation, the pet microbiome interfaces with diets high in animal protein and fat. Nevertheless, microbial fermentative metabolism remains central to short-chain fatty acid (SCFA) production, immune signaling, and gut barrier maintenance [15,16].

1.2. Functional Roles of the Microbiome

The microbiome contributes to digestion and nutrient transformation in several ways:

Carbohydrate fermentation into SCFAs (butyrate, propionate, acetate) supporting colonic health and energy harvest. Protein fermentation and amino acid metabolism, generating metabolites that can exert beneficial or deleterious effects depending on substrate and context [17, 18]. Vitamin synthesis for B vitamins and vitamin K. Modulation of the immune system, interacting with gut-associated lymphoid tissue to influence tolerance and inflammation. Barrier protection, by competitive exclusion of pathogens and production of antimicrobial compounds. Alterations in these functions termed dysbiosis are associated with gastrointestinal and systemic diseases in pets [19, 20].

2. Diet as a Primary Modulator of the Microbiome

Diet is one of the most potent and manipulatable factors influencing microbial community structure and metabolic output.

2.1. Macronutrient Effects

High-protein/low-fiber diets common in many commercial pet foods alter microbial composition toward protein-utilizing taxa. Research indicates that increased dietary protein can elevate proteolytic fermentation, generating metabolites such as ammonia and branched-chain fatty acids that may negatively influence gut health if unbalanced [21-23]. Conversely, moderate fermentable fiber inclusion fosters beneficial SCFA-producing bacterial populations.

Fat content also shapes microbiota, influencing bile acid metabolism and secondary microbial shifts. Excess dietary fat has been linked to increases in *Bilophila wadsworthia* and associated inflammation in rodent models though pet-specific data are limited and warrant further study [24, 25].

2.2. Fiber and Prebiotics

Dietary fiber, particularly fermentable carbohydrates like fructooligosaccharides (FOS), galactooligosaccharides (GOS), and beet pulp, selectively stimulates beneficial bacteria such as *Bifidobacterium* and *Lactobacillus*. These prebiotics enhance SCFA production and may mitigate dysbiosis induced by high-protein diets [26-28]. In dogs, supplementation with FOS has been shown to increase fecal SCFAs, improve stool quality, and modulate microbial populations favorably. Similar effects are observed in cats, although species differences in fiber tolerance and fermentation capacity exist due to shorter colon length and obligate carnivory.

2.3. Novel Ingredients: Resistant Starches and Polyphenols

Emerging dietary interventions include resistant starches and polyphenol-rich botanicals. Resistant starch escapes small intestinal digestion, reaching the colon for fermentation, increasing butyrate production, and supporting mucosal health. Polyphenols (from sources such as cranberries and green tea) exhibit antimicrobial and prebiotic properties, modulating microbial communities and potentially reducing pathogenic taxa [28].

3. Functional Dietary Strategies: Probiotics, Prebiotics, and Postbiotics

Given the diet's impact on microbial ecology, functional ingredients targeting microbiome modulation have gained prominence.

3.1. Probiotics

Probiotics are live microorganisms that, when administered in adequate amounts, confer health benefits. In dogs and cats, common probiotic strains include *Lactobacillus acidophilus*, *Bifidobacterium* animals, and *Enterococcus faecium*. Clinical studies have demonstrated benefits in reducing diarrhea duration, improving stool consistency, and enhancing immune markers in gastrointestinal disorders [29].

Challenges in probiotic application include ensuring strain viability through processing, storage, and gastric transit, as well as matching strains to specific health outcomes.

3.2. Prebiotics

Prebiotics are non-digestible ingredients that selectively stimulate growth of beneficial gut microbes. As noted, FOS, GOS, and beet pulp are widely studied in pets. Recent research also explores novel prebiotics like xylooligosaccharides (XOS) and chicory root inulin that may enhance microbial diversity and metabolic output [30,31].

3.3. Postbiotics and Next-Generation Microbial Metabolites

Postbiotics — metabolites produced by microbes (e.g., SCFAs, bacteriocins, cell wall fragments) represent a new functional ingredient class. Postbiotics retain bioactive effects without requiring live organisms, offering stability advantages. Early evidence suggests postbiotic administration may support barrier function, anti-inflammatory signaling, and immune modulation in animals [32].

4. Microbiome Alterations in Disease States

4.1. Inflammatory Bowel Disease and Chronic Enteropathy

Chronic enteropathies in dogs and cats commonly exhibit dysbiosis, marked by reduced microbial diversity, decreased SCFA-producing taxa, and overrepresentation of proteolytic and pathobiont species. Therapeutic diets enriched with fermentable fibers, prebiotics, and specific protein sources can partially restore microbial balance and clinical remission [33].

4.2. Obesity and Metabolic Syndrome

Obesity in pets correlates with microbiome shifts typically reduced microbial diversity and altered Firmicutes: Bacteroidetes ratios paralleling human obesity patterns. Dietary interventions that increase fermentable substrates, modulate fat content, and influence microbial metabolites may support weight management and metabolic health [37].

4.3. Allergic and Immune - Mediated Conditions

Emerging evidence suggests links between early-life microbiome composition and allergic disease development. Early dietary modulation may influence immune tolerance and reduce allergic phenotypes, though longitudinal data remain limited [38,39].

5. Metabolomics: Linking Diet, Microbiome, and Host Physiology

Metabolomics, the study of small molecules produced by metabolism offers insights into functional microbiome outputs [36]. Metabolite profiling in feces and serum reveals signatures associated with dietary interventions, health states, and microbiome shifts. For example, SCFA patterns correlate with fiber fermentation and gut barrier signaling, while amino acid metabolites reflect protein fermentation and nitrogen balance [35].

Integrating metabolomics with microbiome sequencing deepens understanding of host-microbe metabolic interactions and identifies biomarkers for disease and dietary responsiveness.

6. Personalized Nutrition: Toward Microbiome-Driven Pet Diets

Advances in sequencing and machine learning now allow individualized microbiome profiling. Early research indicates that baseline microbiome composition may predict dietary response, weight loss outcomes, and metabolic changes. Personalized diets designed based on microbial signatures offer potential for optimizing health outcomes beyond generic formulations [33,34].

Challenges include cost, analytical standardization, and translating complex data into actionable diet recommendations.

7. Challenges and Future Research Directions

Despite progress, key gaps remain:

- Standardization of microbiome sequencing and analysis in companion animals
- Longitudinal studies linking early-life microbiomes to lifelong health
- Strain-specific probiotic efficacy and safety
- Optimal combinations of prebiotics, postbiotics, and fermented ingredients
- Integration of microbiome data into routine clinical nutrition

Interdisciplinary research bridging microbiology, nutrition, metabolomics, and computational sciences is critical.

Conclusions

The gut microbiome stands at the intersection of diet and health in companion animals. Diet alters microbial composition and metabolic output, which in turn influences nutrient utilization, immune function, metabolic health, and disease susceptibility. Functional dietary strategies including probiotics, prebiotics, and postbiotics offer tools for beneficial modulation, though individualized responses vary. Personalized nutrition grounded in microbiome science represents a promising frontier with potential to revolutionize pet food formulation and clinical practice.

Understanding the diet-microbiome-host axis enables more precise, evidence-based nutrition strategies that promote health, prevent disease, and improve quality of life in companion animals. Continued research integrating multi-omics, controlled trials, and longitudinal designs is essential to fully realize this potential.

REFERENCES

1. Suchodolski JS. Microbiome sequencing in companion animals: challenges and opportunities. *Vet Clin North Am Small Anim Pract.* 2020;50(2):325–339.
2. Mackie RI, et al. Ecology and significance of the canine and feline gut microbiome. *J Anim Sci.* 2015;93(12):5485–5498.
3. Kumar, R., Goswami, M., & Pathak, V. (2024). Gas Chromatography Based Analysis of fatty acid profiles in poultry byproduct-based pet foods: Implications for Nutritional Quality and Health Optimization. *Asian Journal of Research in Biochemistry*, 14(4), 1-17. <https://doi.org/10.9734/ajrb/2024/v14i4289>
4. Kumar, R., Goswami, M., Pathak, V., & Singh, A. (2024). Effect of binder inclusion on poultry slaughterhouse byproducts incorporated pet food characteristics and palatability. *Animal Nutrition and Feed Technology*, 24(1), 177-191. DOI: 10.5958/0974-181X.2024.00013.1
5. Kumar, R., Goswami, M., Pathak, V., Bharti, S.K., Verma, A.K., Rajkumar, V. and Patel, P. 2023. Utilization of poultry slaughter byproducts to develop cost effective dried pet food. *Anim. Nutr. Technol.*, 23: 165-174. DOI: 10.5958/0974-181X.2023.00015.X
6. Hooda S, et al. Effects of dietary protein on canine gut microbiota: implications for health. *J Nutr Sci.* 2012;1:e35.
7. Kumar R, Goswami M, Pathak V. Innovations in pet nutrition: investigating diverse formulations and varieties of pet food: mini review. *MOJ Food Process Technols.* 2024;12(1):86–89. DOI: 10.15406/mojfpt.2024.12.00302
8. Kumar R, Goswami M. Harnessing poultry slaughter waste for sustainable pet nutrition: a catalyst for growth in the pet food industry. *J Dairy Vet Anim Res.* 2024;13(1):31–33. DOI: 10.15406/jdvar.2024.13.00344
9. Kumar, R. (2024). Promoting Pet Food Sustainability: Integrating Slaughterhouse By-products and Fibrous Vegetables Waste. *Acta Scientific Veterinary Sciences*, 6, 07-11. <http://dx.doi.org/10.31080/ASVS.2024.06.0871>
10. Swanson KS, et al. Impact of dietary macronutrients on canine microbial ecology. *Anim Feed Sci Technol.* 2011;166–167:712–722.
11. Verbrugghe A, et al. Prebiotic fiber supplementation in dogs: effects on microbiota and fermentation. *J Anim Physiol Anim Nutr.* 2011; 95(5):628–637.
12. Panasevich MR, et al. Dietary polyphenols influence canine microbiome and metabolome. *Front Vet Sci.* 2019;6:123.
13. Weese JS, et al. Probiotic supplementation in dogs and cats: clinical efficacy and safety. *Can Vet J.* 2010;51(7):701–708.
14. Stahl B, et al. Postbiotics: definition and functional applications in companion animal nutrition. *J Anim Sci Biotechnol.* 2021;12:56.
15. Guard BC, et al. Effect of dietary carbohydrate and fiber on gastrointestinal microbiota of healthy dogs. *J Anim Sci.* 2015;93(6):S45–S46.
16. Kumar, R., & Goswami, M. (2024). Exploring Palatability in Pet Food: Assessment Methods and Influential Factors. *International Journal of Livestock Research*, 14(4).
17. Kumar, R., & Goswami, M. (2024). Feathered nutrition: unlocking the potential of poultry byproducts for healthier pet foods. *Acta Scientific Veterinary Sciences.* (ISSN: 2582-3183), 6(4).
18. Kumar, R., & Goswami, M. (2024). Optimizing Pet Food Formulations with Alternative Ingredients and Byproducts. *Acta Scientific Veterinary Sciences* (ISSN: 2582-3183), 6(4).
19. Kumar, R., & Sharma, A. (2024). A Comprehensive Analysis and Evaluation of Various Porcine Byproducts in Canine Diet Formulation. *Asian Journal of Research in Animal and Veterinary Sciences*, 7(3), 236-246. <https://doi.org/10.9734/ajrav/2024/v7i3308>
20. Middelbos IS, et al. Phylogenetic characterization of fecal microbial communities of dogs fed diets with or without supplemental dietary fiber using 454 pyrosequencing. *PLoS ONE.* 2010;5(3):e9768.
21. Beloshapka AN, et al. Impact of plant protein concentrates on canine gut microbiota when compared to meat protein. *Front Microbiol.* 2013;4:193.
22. Bermingham EN, et al. The effect of dietary prebiotic supplementation with inulin in obese dogs. *Br J Nutr.* 2012;108(S1):S100–S103.
23. Zentek J, et al. Effects of diets supplemented with chicory on fecal microbiota and fermentative end products in dogs. *J Anim Sci.* 2003;81(8):2000–2009.
24. Kumar, R., & Sharma, A. (2024). Deciphering new nutritional substrates for precision pet food formulation. *International Journal of Veterinary Sciences and Animal Husbandry.* [https://doi.org/10.22271/veterinary,2024\(4\),v9](https://doi.org/10.22271/veterinary,2024(4),v9).
25. Kumar, R., & Sharma, A. (2024). Prebiotic-driven Gut Microbiota Dynamics: Enhancing Canine Health via Pet Food Formulation. *International Journal of Bio-resource and Stress Management*, 15(Jun, 6), 01-15. <https://doi.org/10.23910/1.2024.5359>
26. Kumar, R., & Sharma, A. (2024). Review of Pet Food Packaging in the US Market: Future Direction Towards Innovation and Sustainability. *Annual Research & Review in Biology*, 39(6), 16-30. <https://doi.org/10.9734/arrb/2024/v39i62085>
27. Kumar, R., Goswami, M. and Pathak, V. (2023). Enhancing Microbiota Analysis, Shelf-life, and Palatability Profile in Affordable Poultry Byproduct Pet Food Enriched with Diverse Fibers and Binders. *J. Anim. Res.*, 13(05): 815-831. DOI: 10.30954/2277-940X.05.2023.24
28. Coelho LP, et al. Similarity of canine and human gut microbiomes in the context of obesity and weight loss. *Microbiome.* 2018;6:72.

29. Kim HJ, et al. Gut microbiota key functional features in dogs and cats with chronic enteropathy. *Anim Microbiome*. 2021;3(1):57.
30. Garcia-Millán C, et al. Effects of probiotic yeast supplementation on feline gastrointestinal health. *Vet Microbiol*. 2021;255:109020.
31. Garcia-Rodriguez A, et al. Dogs' gut microbiota responses to dietary prebiotics: a randomized controlled trial. *Front Vet Sci*. 2022;9:825174.
32. Werner JA, et al. Gut microbiome alterations in cats with derived metabolic disease and the role of diet. *Front Microbiol*. 2021;12:712164.
33. Park S, et al. Effects of diet and antibiotics on the canine gut microbiome: implications for clinical nutrition. *Nutrients*. 2020;12(2):432.
34. Kumar, R., Goswami, M., Pathak, V., Verma, A.K. and Rajkumar, V. 2023. Quality improvement of poultry slaughterhouse byproducts-based pet food with incorporation of fiber-rich vegetable powder. *Explor. Anim. Med. Res.*, 13(1): 54-61. DOI: 10.52635/eamr/13.1.54-61
35. Kumar, R., Thakur, A., & Sharma, A. (2023). Comparative prevalence assessment of subclinical mastitis in two crossbred dairy cow herds using the California mastitis test. *J Dairy Vet Anim Res*, 12(2), 98-102 <http://dx.doi.org/10.15406/jdvar.2023.12.00331>
36. Alexander J, et al. The role of butyrate and other microbial metabolites in immune modulation in pets. *Vet Immunol Immunopathol*. 2021;235:110206.
37. Dodd D, et al. Microbial contributions to systemic metabolism: insights from companion animal studies. *Trends Microbiol*. 2022;30(4):307–323.
38. Liu Y, et al. Personalized microbiome nutrition and feeding strategies in companion animals: present evidence and future perspectives. *Front Nutr*. 2023;10:1140722.
39. Heaney C, et al. Influence of diet and microbiota on inflammation and metabolic syndrome in dogs and cats. *J Nutr Health Aging*. 2021;25(5):526–538.