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EMERGING INNOVATIONS IN PET FOOD (2023–2025): ALTERNATIVE PROTEINS, MICROBIOME-TARGETED NUTRITION, AND SAFETY-BY-DESIGN PROCESSING

*[1]RISHAV KUMAR *, [2]ANKIT SHARMA*

([1]Department of Livestock Products Technology, College of Veterinary Sciences and AH, DUVASU, Mathura, U.P., India
[2]Department of Livestock Production Management, College of Veterinary and Animal Sciences, GBPUAT, Pantnagar, Uttarakhand, India)
*Corresponding author's e-mail: rishavvet42@gmail.com

The pet-food sector has experienced rapid innovation between 2023 and mid-2025 driven by sustainability goals, advances in microbiome science, and new processing and packaging scrutiny. This review synthesizes recent developments across four major domains: (1) alternative and novel proteins (insects, single-cell proteins, and cultivated meat), (2) microbiome-targeted nutrition with emphasis on postbiotics and early precision approaches, (3) safety-by-design processing—particularly high-pressure processing (HPP) for raw and minimally processed diets—and (4) contaminant and packaging concerns (mycotoxins, antimicrobial resistance, PFAS). We discuss regulatory milestones, summarize key data (nutrient compositions, validated processing parameters, surveillance outcomes), identify critical knowledge gaps (feline requirements, long-term feeding trials, formulation-specific process validation), and propose an R&D agenda for industry and academic stakeholders. In the near term, research should focus on well-designed feeding trials specific to pets, validation of processes at the formulation level, and clear supply-chain traceability to ensure that sustainability claims are supported by nutrient-adjusted impact data. Progress will also depend on close collaboration among industry, academia, and regulators to advance innovations from pilot projects into safe, affordable, and beneficial pet foods for the wider market.

Keywords: black soldier fly, cultivated meat, postbiotics, high-pressure processing, mycotoxins, PFAS, AAFCO, pet food safety.

ҮЙ ЖАНУАРЛАРЫНА АРНАЛҒАН АЗЫҚТАРДЫҢ ЖАҢА ИННОВАЦИЯЛАРЫ (2023–2025): БАЛАМА АҚУЫЗДАР, МИКРОБИОМҒА БАҒЫТТАЛҒАН ТАМАҚТАНУ ЖӘНЕ ҚАУІПСІЗДІКТІ ЕСКЕРЕ ОТЫРЫП АЗЫҚТЫ ӨҢДЕУ

*[1]РИШАВ КУМАР *, [2]АНКИТ ШАРМА*

([1]Жануарларды өндіру технологиясы департаменті, Ветеринария және ауыл шаруашылығы колледжі, DUVASU, Матхура, Уттар-Прадеш, Үндістан
[2]Мал шаруашылығын басқару департаменті, Ветеринария ғылымдары және мал шаруашылығы колледжі, GBPUAT, Пантнагар, Уттаракханд, Үндістан)
Автор-корреспонденттің электрондық поштасы: rishavvet42@gmail.com*

Үй жануарларына арналған азық-түлік секторы 2023 және 2025 жылдың ортасы аралығында тұрақтылық мақсаттарына, микробиома ғылымындағы жетістіктерге және өңдеу мен ораудағы жаңа зерттеулерге негізделген жылдам инновацияларды бастан кешірді. Бұл шолу төрт негізгі домен бойынша соңғы әзірлемелерді синтездейді: (1) баламалы және жаңа протеиндер (жәндіктер, бір жасушалы ақуыздар және өсірілетін ет), (2) постбиотиктер мен ерте дәлдік тәсілдеріне баса назар аудара отырып, микробиомаға бағытталған тамақтану, (3) дизайн бойынша қауіпсіздікті өңдеу - әсіресе жоғары қысымды өңдеу және PP-ге арналған өңдеу). (4) ластаушы заттар мен қаптамаға қатысты мәселелер (микотоксиндер, микробқа қарсы төзімділік, PFAS). Осы мақалада реттеуші кезеңдер талқыланады, негізгі деректер (қоректік заттардың құрамы, расталған өңдеу параметрлері, қадағалау нәтижелері) қорытындалады, білімдегі маңызды кемшіліктерді анықталады (мысықтардың қорегіне қойылатын талаптар, ұзақ мерзімді азықтандыру сынақтары, рецептураға тән процесті тексеру) және сала мен академиялық мүдделі тараптар үшін ҒЗТКЖ

күн тәртібі ұсынылады. Жақын болашақтағы зерттеу күн тәртібі үй жануарларына арналған мақсатты түрде жүргізілетін азықтандыру сынақтарын, құрам деңгейіндегі технологиялық үдерістердің валидациясын және жеткізу тізбегінің ашықтығын басым бағыттар ретінде айқындауы тиіс. Бұл тұрақтылыққа қатысты тұжырымдардың қоректік көрсеткіштерге түзетілген әсер деректерімен негізделуін қамтамасыз етеді. Сонымен қатар, инновацияларды пилоттық кезеңнен қауіпсіз, қолжетімді әрі ғылыми тұрғыда дәлелденген үй жануарларының негізгі азықтарына енгізу үшін өнеркәсіп, академиялық орта және реттеуші органдар арасындағы үйлесімді ынтымақтастық шешуші рөл атқарады.

НОВЫЕ ИННОВАЦИИ В ОБЛАСТИ КОРМОВ ДЛЯ ДОМАШНИХ ЖИВОТНЫХ (2023–2025): АЛЬТЕРНАТИВНЫЕ БЕЛКИ, ПИТАНИЕ, ОРИЕНТИРОВАННОЕ НА МИКРОБИОМ И ОБРАБОТКА С УЧЕТОМ БЕЗОПАСНОСТИ

*[1]РИШАВ КУМАР *, [2]АНКИТ ШАРМА*

([1]Кафедра технологии продуктов животноводства, Колледж ветеринарных наук и сельского хозяйства, DUVASU, Матхура, Уттар-Прадеш, Индия
[2]Кафедра управления животноводством, Колледж ветеринарных наук и животноводства, GBPUAT, Пантнагар, Уттаракханд, Индия)
Электронная почта автора-корреспондента: rishavvet42@gmail.com*

В период с 2023 до середины 2025 года в секторе кормов для домашних животных произошли быстрые инновации, вызванные целями в области устойчивого развития, достижениями в науке о микробиоме и новыми требованиями к переработке и упаковке. В этом обзоре обобщены последние разработки в четырех основных областях: (1) альтернативные и новые белки (насекомые, одноклеточные белки и культивируемое мясо), (2) питание, ориентированное на микробиом, с акцентом на постбиотики и ранние подходы к точному питанию, (3) переработка с учетом безопасности, в частности переработка под высоким давлением (HPP) для сырых и минимально обработанных рационов и (4) проблемы, связанные с загрязнителями и упаковкой (микотоксины, устойчивость к антимикробным препаратам, PFAS). Мы обсуждаем важные этапы в области регулирования, обобщаем ключевые данные (состав питательных веществ, проверенные параметры обработки, результаты мониторинга), выявляем критические пробелы в знаниях (потребности кошек, долгосрочные испытания кормов, валидация процессов для конкретных рецептур) и предлагаем программу НИОКР для заинтересованных сторон из промышленности и академических кругов. В ближайшей перспективе исследования должны сосредоточиться на тщательно проведённых испытаниях кормления домашних животных, валидации процессов на уровне рецептуры и прозрачности цепочки поставок, чтобы заявления о устойчивости опирались на данные о воздействии, скорректированные по питательной ценности. Дальнейший прогресс также будет зависеть от тесного сотрудничества между индустрией, наукой и регулирующими органами, чтобы перевести инновации из пилотных проектов в безопасные, доступные и полезные корма для широкого рынка домашних животных.

Ключевые слова: черная солдатская муха, культивированное мясо, постбиотики, обработка высоким давлением, микотоксины, PFAS, AAFCO, безопасность кормов для домашних животных.

Introduction

Companion-animal feeding mirrors many of the same drivers shaping human food systems: consumer demand for lower-impact protein, interest in functional ingredients that target the gut microbiome, and heightened regulatory and public scrutiny of contaminants and packaging materials. From 2023 onward an acceleration of product launches, regulatory actions, and targeted trials has occurred—most notably regulatory actions (AAFCO label modernization), industrial approvals for novel proteins (cultivated meat permitted in the UK for pet food), and a growing body of experimental studies validating process interventions such as high-pressure processing (HPP) for pathogen control in raw diets (AAFCO, 2023; Kumar et al.,2023,2024,FoodNavigator, 2024; Lee, 2023; FDA, 2025). This review collates and evaluates that evidence base with emphasis on data and practical implications.

Materials and research methods

A targeted literature search was conducted to identify peer-reviewed papers, regulatory documents, industry press releases, and consensus statements published approximately between 2021 and mid-2025. Primary electronic sources included PubMed/PMC, Google Scholar, major regulatory websites (FDA, AAFCO), and trade/industry outlets (FoodNavigator, Petfood Industry). Search terms included combinations of “black soldier fly larvae”, “Hermetia illucens”, “single-cell protein”, “cultivated meat pet food”, “high-pressure processing pet food”, “postbiotic dogs”, “PFAS packaging animal food”, and “AAFCO label modernization”. Priority was given to (a) systematic reviews/meta-analyses, (b) experimental studies with well-described methods (inoculation, treatment, storage), and (c) authoritative regulatory reports and consensus statements (e.g., ISAPP on postbiotics).

Results and discussion

1. Alternative and novel protein sources

1.1 Black Soldier Fly Larvae (BSFL) and insect proteins

Black soldier fly larvae (BSFL, *Hermetia illucens*) remain the most advanced insect protein candidate for pet foods. Recent systematic reviews and meta-analyses report wide but consistent proximate ranges for BSFL meals: crude protein commonly between ~40% and 60% (dry matter basis) and full-fat materials with ~20%–35% fat, with defatted meals enriching protein content (Su, 2025; Banks, 2025). Benefits include favorable amino-acid profiles relative to many plant proteins, efficient substrate conversion, and lower greenhouse-gas intensity compared with conventional meats. However, species-specific concerns persist taurine content and bioavailability data are limited (important for obligate carnivores such as cats), chitin content can affect digestibility metrics, and heavy-metal or contaminant accumulation is substrate-dependent—requiring validated rearing and feed-stock controls (Kotob, 2022; Su, 2025). Practical implications: BSFL can be used in treats and formulated diets, but full-diet trials including digestibility, long-term health outcomes, and feline taurine adequacy are needed prior to broad substitution of traditional animal proteins in cat diets.

1.2 Single-cell proteins (SCP)

Microbial biomass from yeasts, filamentous fungi (mycoprotein), and bacterial cells offers high protein density (often 40%–70% protein depending on organism and processing), with functional molecules such as β-glucans and nucleotides that may provide health benefits (reviewed across 2023–2025 literature). Pet-specific data are still emerging palatability and digestibility trials in dogs are more common than in cats, and regulatory acceptance pathways vary by jurisdiction. SCPs may be particularly useful in blended formulations that complement amino-acid completeness and micronutrient needs.

1.3 Cultivated (cell-cultured) meat for pet food

A notable milestone occurred in 2024–2025 when the UK authorized cultivated chicken for pet food and companies (e.g., Meatly) launched limited commercial pet products (Meatly, 2024; FoodNavigator, 2024). Cultivated meat promises animal-origin nutrition with lower upstream impacts, but major challenges remain cost of goods, scale-up of bioreactors, ensuring full nutrient equivalency (essential amino acids, micronutrients, heme/iron bioavailability), and palatability testing. Regulatory frameworks for cultivated ingredients in pet foods are nascent and likely to diverge by jurisdiction in short term; the UK experience provides an initial case study for other jurisdictions (Meatly, 2024).

2. Microbiome-targeted nutrition: postbiotics & precision approaches

2.1 Postbiotics — definition and pet applications

The International Scientific Association for Probiotics and Prebiotics (ISAPP) defined “postbiotics” as “preparations of inanimate microorganisms and/or their components that confer a health benefit on the host” (Salminen et al., 2021). Postbiotics combine the functional potential of microbial products (metabolites, cell components) with logistical advantages—heat stability, shelf-stability, and avoidance of viability issues inherent to probiotics. Recent canine trials (e.g., ADM’s PRIOME® MH) reported reductions in postprandial blood glucose and metabolic markers in controlled cohorts, and separate trials showed oral-health benefits from postbiotic formulations (ADM, 2025; Petfood Industry, 2025). However, peer-reviewed, large-scale, and multi-site randomized controlled trials (RCTs) are still limited; heterogeneity of strain, dose, endpoints, and reporting precludes broad, evidence-based clinical claims at present.

2.2 Precision/personalized nutrition

The pet sector has begun to adapt human precision-nutrition tools—wearables, at-home microbiome testing, and AI-driven dietary recommendations—to pets. Most systems remain exploratory and industry-driven; rigorous validation, standardized outcome measures (e.g., stool quality indices, validated behavior scales, or biomarker endpoints), and ethical considerations (data privacy, owner compliance) are outstanding issues.

3. Safety-by-design processing: High-Pressure Processing (HPP) and other interventions

3.1 HPP for raw and minimally processed pet foods

Raw pet foods present known hazards (*Salmonella, Listeria, STEC*), and HPP has emerged as an effective non-thermal lethality option. Experimental work has shown that HPP treatments around ~450–750 MPa for appropriate durations can achieve ≥5-log reductions of *Salmonella* and STEC in many raw formulations; Lee (2023) and follow-up studies demonstrated that parameters such as 586 MPa for 1–4 min commonly achieved target reductions for *Salmonella* and STEC, while Listeria monocytogenes often exhibited greater resistance necessitating optimization or combined interventions (Lee, 2023; Lee, 2024). HPP's benefits include nutrient retention relative to thermal treatments, but lethality is formulation-dependent (fat content, particle size, and matrix buffering capacity influence outcomes). Multi-hurdle approaches (HPP + organic acids or post-packaging chilled/frozen storage) improve robustness.

3.2 Practical considerations and limits

HPP requires capital investment and careful validation for each formulation. Some pathogens (or stressed survivors) may be repaired during storage if sub-lethal injury occurs, thus validation must include storage studies. HPP also does not alter chemical contaminants (e.g., mycotoxins, PFAS) and does not substitute for upstream ingredient quality controls.

4. Contaminants and packaging: mycotoxins, AMR, and PFAS

4.1 Mycotoxins

Surveillance in feeds and pet foods shows frequent detection of multiple mycotoxins, though non-compliance rates vary by region and commodity. Recent European surveillance (multi-year data) reported ~26% of samples positive above LOQ, with a smaller fraction exceeding guidance limits (MDPI/Italian surveillance; 2018–2022). Climate volatility may increase mycotoxin risk in cereal/legume ingredients and thus in blended dry pet foods—calling for ingredient testing and risk-based sourcing (MDPI Foods, 2024).

4.2 Antimicrobial resistance (AMR) and raw diets

Raw pet foods have been found to carry Salmonella, Listeria, and AMR organisms more frequently than heat-processed products. This has public-health implications (human exposures via handling) and necessitates validated lethality steps or consumer education on safe handling. Surveillance and standardized methods to report AMR prevalence in pet foods remain a priority.

4.3 PFAS in food packaging

PFAS used in grease-proofing and coatings have been a regulatory focus. The FDA's FY2024 survey of animal food packaging documented targeted sampling and analytical work and accompanies broader actions to phase out certain PFAS uses, with compliance guidance (FDA, 2025). Pet-food manufacturers should audit packaging specifications and consider tested alternative coating systems.

5. Regulatory landscape and milestones (2023–2025)

Key regulatory developments include:

AAFCO Label Modernization (2023): AAFCO adopted model labeling updates to standardize nutrition information, ingredient statements, and storage/handling guidance—intended to improve consumer clarity (AAFCO, 2023).

UK cultivated-meat approvals (2024–2025): The UK authorized cultivated chicken for pet food (Meatly) and early commercial launches followed, establishing a case precedent for cultivated proteins in pet-food supply chains (Meatly, 2024; FoodNavigator, 2024).

FDA PFAS activities (2024–2025): The FDA reported targeted sampling of packaging and set timelines for phasing out certain PFAS grease-proofing uses (FDA, 2025).

Regulatory harmonization remains limited: jurisdictions vary in acceptance of novel ingredients and in definitions/claims for functional additives (e.g., postbiotics). Industry developers must therefore plan multi-jurisdictional strategies and robust safety dossiers.

6. Knowledge gaps and research priorities

Feline-specific nutrition: taurine sufficiency when replacing conventional animal protein with insects or SCPs; long-term health outcomes. Formulation-specific HPP validation: Listeria resistance variability, interactions with fat/organs/particle size, and storage-linked repair dynamics. Large, independent RCTs of postbiotics: standardized endpoints, dose-response, and replication across breeds and ages. Comprehensive LCAs: nutrient-adjusted life-cycle analyses comparing beef/poultry to insect SCP and cultivated meat on a bioavailable-nutrition basis.

Packaging migration studies: larger-scale PFAS and alternative migrant surveys across packaging materials and global supply chains.

Conclusions

Between 2023 and mid-2025 the pet-food industry advanced from concept toward implementation: insect and single-cell proteins moved into commercial products and trials; cultivated meat achieved regulatory clearance and pilot sales in the UK; postbiotics gained mechanistic plausibility and initial clinical trial data; and HPP established itself as an effective processing control for many pathogen risks in raw diets. However, adoption at scale will depend on solving technical (cost, scale-up), nutritional (feline requirements, amino-acid completeness), safety (process validation, contaminant control), and regulatory (claims, approvals) challenges. The near-term research agenda should prioritize rigorous, pet-specific feeding trials, formulation-level process validation, and transparent supply-chain traceability so that sustainability claims are grounded in nutrient-adjusted impact metrics. Collaboration between industry, academia, and regulators will be essential to move innovations from pilot stages to safe, affordable, and beneficial mainstream pet foods.

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