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Review

Gut Health Optimization in Canines and Felines: Exploring the Role of Probiotics and Nutraceuticals

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Abstract: Companion animals such as dogs and cats play a crucial role in modern families. Their overall health is significantly influenced by their gut health, with many health disorders arising from disturbances in the gut microbiome. Our review highlights the ability of probiotics and nutraceuticals to modify the gut microbiota and enhance gastrointestinal health in canine and feline species. We investigated the effects of probiotics and natural antioxidant molecules on digestion, immunological response, and barrier integrity in gastrointestinal health studies concerning dogs and cats. The analysis indicated that probiotics influence gut microbiota composition in a positive manner, enhance digestion, augment the immune response, and help to maintain barrier integrity. Additionally, natural products with antioxidant molecules showed the potential to improve gut health and protect pets from various illnesses. We concluded by advocating the need for more studies in this direction to fully understand their effects and optimize their use in veterinary medicine.

Keywords: antioxidants; cats; dogs; gut microbiome; nutraceuticals; probiotics

Citation: Atuahene, D.; Mukarram, S.A.; Balouei, F.; Antwi, A. Gut Health Optimization in Canines and Felines: Exploring the Role of Probiotics and Nutraceuticals. *Pets* **2024**, *1*, 135–151. https://doi.org/10.3390/pets1020011

Academic Editors: Baichuan Deng, Lian Li and Yun Ji

Received: 14 June 2024
Revised: 18 July 2024
Accepted: 19 July 2024
Published: 25 July 2024

1. Introduction

Domestic cats and dogs are essential companions in modern households. A 2021 survey by the American Pet Products Association (APPA) revealed that 70% of families in the USA own pets [1]. These animals, usually dogs (canines) and cats (felines), are often considered cherished members of the family and contribute significantly to both the physical and mental well-being of their owners [2]. This trend of pet keeping has led to a growing focus on pet healthcare, with a particular interest in gut health, which is a common source of problems for pets.

The animal gastrointestinal tract (GIT) contains a wide variety of microbes, including viruses, fungi, bacteria, protists, and archaea. These microbes are major contributors to intestinal homeostasis, facilitating nutrient provision, followed by digestion and absorption. In addition, they significantly contribute to improving the gut barrier and modulating the immune system [3,4]. According to recent statistics, there are thousands of different microbial species in the mammalian gut [5]. Surprisingly, 10^{10} to 10^{14} microorganisms are thought to exist in the intestines of cats and dogs, which is ten times more than the number of the host's own somatic cells. The gut microbiome is a term for the symbiotic relationship between the resident bacteria and host cells [6].

Microorganisms are necessary because they use nutrients in their hosts to carry out specialized tasks and create metabolites that the hosts can utilize (Table 1). All canine and feline species have different microbiological profiles [7,8]. There is usually little overlap in bacterial species between individual animals, and the most notable differences are found at the bacterial species and strain levels. Notably, bacterial species produce metabolites such as secondary bile acids and short-chain fatty acids (SCFAs), which influence host gut health [9]. The former are modified forms of primary bile acids that are either deconjugated or dehydroxylated by intestinal microbes and play a key role in immunomodulation [10]. The fermentation of ingested fibers yields SCFAs, such as butyrate, acetate, and propionate, which are vital for maintaining a healthy gut epithelium, possess an anti-inflammatory potential, and regulate energy metabolism [11–13]. Disruptions in the gut microbiome, characterized by a decline in microbial diversity or altered metabolite profiles, can contribute to various health problems in pets' chronic enteropathies (CEs) such as inflammatory bowel disease (IBD) and acute uncomplicated diarrhea [14].

Evidently, the gut microbiota plays an essential role in human and animal health. To maintain a balance in the gut microbiome, live microorganisms called "probiotics", which include bacteria and yeasts, are administered in adequate doses and offer a promising strategy for gut microbiome manipulation [15]. Research suggests that probiotics can prevent or treat different diseases in humans, such as IBD, antibiotic-induced diarrhea, colon cancer, allergies, diabetes (type II), and atopic dermatitis [16]. In animal production, probiotics are being explored as potential alternatives to antibiotics because of their positive effects on growth, gut health, and immune function [17]. Studies have shown that probiotics in farm animals can improve nutrient digestion and absorption, enhance intestinal health, optimize gut microbiota composition, and reduce inflammation [18]. *Saccharomyces*, *Lactobacillus*, *Enterococcus*, and *Bifidobacterium* are some of the most common probiotic species found in dietary supplements and functional foods [19]. Notably, the intestinal epithelial layer functions as the initial physical barrier against the surroundings in the animal body, maintaining intestinal homeostasis through the mucus layer and tight junctions between cells [20]. Probiotics contribute to improved epithelial barrier function by promoting the production of mucins and tight junction proteins, either indirectly or directly, in addition to other benefits [21]. Studies have shown that *Bifidobacterium*, *Lactobacillus*, *Akkermansia muciniphila*, and the SCFAs produced by gut bacteria can trigger the expression, production, and secretion of mucins [22]. Probiotics also modulate immune function by triggering T-cell differentiation, regulating the balance of pro- and anti-inflammatory cytokines, and inducing secretory IgA production [23]. Moreover, some probiotic microbes, such as *Lactobacillus species* and *Streptococcus thermophilus* can produce β-galactosidase and bile salt hydrolase enzymes. These enzymes are in turn, a vital part of lactose digestion and bile acid metabolism, respectively [24]. Notably, probiotics work in a strain-specific manner [25]. Attaining deeper insights into probiotic–host interactions is necessary for facilitating the identification of effective probiotics [26].

In addition to probiotics, natural food substances such as plants or their derived vegetables in untreated forms have antioxidant potential and can minimize the harmful effects of redox reactions that occur in metabolic pathways by scavenging free radicals [27]. These dietary antioxidants are diverse molecules that work by neutralizing free radicals and promoting overall gut health [28]. Moreover, a broader category of products called nutraceuticals (which includes phytochemicals, as well as antioxidants) is derived from food sources and employed to provide benefits beyond basic nutrition [29]. They are administered in an adequate dose to improve various conditions, including the maintenance of a healthy gut [30].

Notably, traditional medical practices for the treatment of digestive problems can result in undesirable side effects. This has led researchers to explore alternative approaches, including combining functional foods rich in beneficial compounds and using nutraceuticals and supplements containing gut-friendly elements [31]. Probiotics, antioxidants, and nutraceuticals have recently gained immense popularity in the pet care industry as new treatment alternatives [32]. As opposed to humans, research on dogs and cats is still a new field, but the latest findings point to putative benefits for improving health and preventing diseases. Considering the above information, this review examines the most recent developments in the use of probiotics, nutraceuticals, and antioxidants in pets, providing insightful information for future research and use in the field of veterinary medicine.

Table 1. Activities performed by gut microbiota of cats and dogs.

Microbial Activity	Products	Representative Microbes	Ref.
Decarboxylation and deamination of amino acids	Ammonia	*Clostridium* species, *Peptostreptococcus* species, *Peptococcus* species	[33]
Deconjugation and dehydroxylation of bile acids	Secondary bile acids (cholate, deoxycholate)	*Clostridium hiranonis*, *Lactobacillus* species	[34]
Synthesis of vitamins	Vitamin K2, B12, biotin, folate	*Enterococcus* species, *Pseudomonas* species, *Sphingomonas* species, *Lactobacillus* species	[35]
Fermentation of carbohydrates	Lactate, propionate, acetate, butyrate	*Clostridium* cluster XIVa, *Prevotella* species, *Faecalibacterium* species, *Bifidobacterium* species	[36]
Fermentation of amino acids	Hydrogen, methane, amines, phenols, ammonia, organic acids, hydrogen sulfide	Sulfate-reducing bacteria (SRB), *Desulfovibrio* species, *Clostridium* species, *Peptostreptococcus* species	[37]
Oxalate degradation	Formate and CO_2	*Oxalobacter formigenes*	[38]
Degradation of inulin and starch	Lactate	*Bifidobacterium* species	[39]
Metabolism of hydrogen, alcohols, and acetic acid	Methane and CO_2	Methanogenic bacteria	[40]

Canine and Feline Microbiota

Dogs and cats have different microbiomes, even though they have a similar gut microbial community, dominated by *Firmicutes*, *Bacteroidetes*, *Proteobacteria*, and *Fusobacteria*, as depicted by 16S rRNA sequencing [41,42]. These differences can be ascribed to various factors, such as species (e.g., dogs versus cats), breed (within species), and geographic location (different niches inside the digestive tract harbor different bacteria). Interestingly, breed seems to influence gut microbiome more than diet. For instance, a study depicted that high levels of Fusobacterium were present in Maltese dogs as opposed to Miniature Schnauzers and Poodles [43]. More particularly, the dog and cat microbiomes are dominant in different phyla. While canine guts are dominated by *Fusobacteria*, feline guts possess more members from Firmicutes. Also, the latter has more members from Bacteroides and Prevotella phyla [44]. These differences are mostly attributed to diet, as cats are obligate carnivores, but dogs are omnivores [45]. It is interesting to note that as these microorganisms exist at different positions in the digestive system, their concentrations and varieties diversify [46]. This demonstrates the distinct and species-specific ecology of the digestive systems of dogs and cats [47]. Notably, the colon and small intestine (duodenum, jejunum, and ileum) have a disproportionately high concentration of *Clostridium*, a member of the *Firmicutes* phylum [41]. In contrast, the ileum and colon contain the highest concentrations of *Fusobacteria* and *Bacteroides* [48]. Additionally, fungi have been found; phyla including *Ascomycota*, *Basidiomycota*, *Glomeromycota*, and *Zygomycota* have been reported [49].

Moreover, a mixed community of *lactobacilli*, with numbers ranging from 10^4 to 10^8 CFU/mL, is present in the canine digestive system [50]. The most prevalent species among them is *Lactobacillus acidophilus* [51]. A healthy canine gut microbiome is also known to contain *Lactobacillus salivarius*, *Lactobacillus rhamnosus*, and *Lactobacillus fermentum* [52]. In addition to these common dwellers, the canine digestive tract has been shown to harbor

Lactobacillus paraplantarum Lactobacillus reuteri, *Lactobacillus animalis*, *Lactobacillus murinus*, and *Lactobacillus sanfranciscensis* [53]. It is interesting to note that the intestinal lactobacilli in cats are similar to those in dogs [54]. The generally recognized species include *Lactobacillus johnsonii*, *Lactobacillus acidophilus*, *Lactobacillus salivarius*, *Lactobacillus reuteri*, and *Lactobacillus sakei*. These species can be found in the digestive tracts of other animals, including humans, and are not limited to cats and dogs [45].

2. Effects of Gut Diseases and Disorders

The gut microbiota in the digestive system has a significant impact on animal health. This microbial community performs numerous tasks, such as producing vital nutrients through fermentation and metabolic processes, helping develop and mature the intestinal epithelium and immune system, and competitively maintaining enteric pathogens (colonization resistance) [55–58]. After initial colonization during pregnancy or soon after delivery, the gut microbiota undergoes a dynamic succession that takes several months to acquire a stable adult composition [59].

Although it was previously believed that intestinal microbiota only affects gut health, this is no longer the case. Research conducted on human subjects has demonstrated its impact on a wide range of illnesses outside the digestive system, such as autoimmune diabetes, multiple sclerosis, atopic disorders, and disorders of the central nervous system [60]. Models using dogs and cats provide an excellent opportunity to investigate this multisystemic role in more detail.

Notably, acute diarrhea and other short-term alterations in the gut environment can have a substantial impact on microbial diversity. According to Guard et al. (2015), dogs suffering from acute diarrhea exhibit reduced variety, as seen by decreasing populations of *Faecalibacterium* and *Bacteroidetes* and an increase in *Clostridium*. Additionally, this study discovered that afflicted dogs had lower levels of some functional genes and advantageous short-chain fatty acids [61].

Most pets visit veterinarians because of digestive problems that can lead to an imbalance in the gut microbiota. Upon diagnosis, several bacterial infections have been found in dogs, including *Campylobacter* and *Salmonella*, which can spread to humans [62]. This presents a challenge for medical experts and pet owners. Dogs can also carry and excrete roundworm (ascaris) eggs and *Giardia lamblia* cysts, without showing any signs [30]. Humans can contract both ascariasis and Giardia, which are common zoonotic illnesses [31]. Enteric zoonotic agents can also be found in domestic cats [63]. In cat feces, Tun et al. found a range of possible zoonotic infections (0.02–1.25%) and genes linked to antibiotic resistance (0.02–0.7%) [64].

In dogs and cats, chronic enteropathy (CE) manifests as ongoing vomiting or diarrhea and is classified according to how the patient reacts to dietary modifications, antibiotics, or steroids [65,66]. A subtype of CE, idiopathic IBD disease is characterized by inflammation in the gastrointestinal tract, poor response to treatment, and an unknown origin [67]. Improved diagnosis and treatment for chronic enteropathies in cats and dogs may result from further investigation into the function of the intestinal microbiota in these disorders.

Although the exact origin of IBD remains unknown, several factors are likely to play important roles. One important contributing factor is microbial dysbiosis, which is characterized by changes in the composition of the gut microbiota [68]. Research on several species has repeatedly demonstrated a correlation between IBD and an increase in gram-negative bacteria, such as Enterobacteriaceae, and a decline in Firmicutes. [69]. For example, compared to healthy controls, researchers discovered that dogs with IBD had lower numbers of *Prevotellaceae*, *Clostridiales*, *Bacteroidaceae*, and *Fusobacteria* [70]. Another study suggested a strong link between SCFAs in the gut and GI disorders such as colorectal cancer and IBD [71]. It was observed that reduced levels of SCFAs in dogs were associated with the progression of GI disorders, similar to what has been observed in human subjects [71]. Moreover, other studies associated acute diarrhea in dogs and intestinal issues with altered concentrations of SCFAs [61,72]. Similarly, Xenoulis and his group reported that cats diagnosed with IBD showed a diverse microbial community with a significant decrease in *Bacteroides* and *Spirochaetes* and an increase in mucosal *Enterobacteriaceae* and *Firmicutes* [50].

Interestingly, these microbial variations are mostly associated with inflammatory responses. Janeczko et al. (2008) observed an increase in mucosal *Enterobacteriaceae* in cats with IBD, which correlated with alterations in the intestinal epithelial structure and disease severity. Additionally, research indicated that pro-inflammatory cytokines (IL-1, IL-8, and IL-12) were elevated in these cats [73]. Notably, Maeda et al. (2016) discovered that dogs diagnosed with IBD exhibited reduced levels of anti-inflammatory cytokines and regulatory T-cells [74]. These findings indicate that the gut microbiota, inflammatory immune response, or both may impact the onset of IBD in companion animals. It is very likely that toll-like receptors (TLRs), known for their ability to recognize microbial patterns and trigger inflammation, play a significant role in this process. In a healthy gut, these sensor TLRs help to maintain a balance by triggering an appropriate immune response when required [75]. However, in the case of IBD, the balance is disrupted. Under normal conditions, the TLR signaling is beneficial, but when the regulatory cells are impaired, in a diseased state (IBD), the otherwise suppressed abnormally excessive immune response is triggered. Therefore, T helper cells become overactive and significantly damage the gut homeostasis and microbiome, leading to inflammation [76].

The world's knowledge of how the gut microbiota impacts health and wellness is rapidly evolving. Research has demonstrated that administering antibiotics to dogs can significantly alter the diversity of their gut microbiota in a major way [77]. Both the immediate and long-term effects may have resulted from this disruption. A decline in beneficial bacterial populations after antibiotic use is a major concern. This may increase the risk of gastrointestinal problems by causing the overgrowth of potentially hazardous pathogens [78]. Antibiotic medication may also be a factor in the development of antimicrobial resistance in the gut flora [79]. This resistance may even be dangerous in hospital environments and contagious between owners and their dogs [80]. For instance, tylosin is a macrolide antibiotic whose effects on the gut flora of dogs were examined in a recent study. The microbial diversity in the canine small intestine was analyzed using 16S rRNA gene sequencing [81]. The findings showed that bacterial taxa such as Moraxella, Bacteroidales, and Fusobacteria, became less common. In contrast, the percentages of bacteria that resembled *Enterococcus*, *Pasteurella*, *Dietzia*, and *Escherichia* increased. Interestingly, some bacterial species, including *Prevotellaceae*, Streptomycetaceae, and *Spirochaetes*, were completely eliminated following antibiotic therapy [81].

3. Role of Probiotics on Companion Animal Gut Health

A notable alternative to antibiotics, probiotics, are live bacteria that have been shown to provide health benefits [82]. They are used more often to support the intestinal health of companion animals. These bacteria can be classified as defined or undefined. Probiotics support healthy gut microbiota by generating substances that combat bad bacteria, displacing pathogens for available space and possibly affecting the immune system [83,84]. This in turn can help with infection prevention and stress management, and even affect the growth of the pet or have an impact on allergies and obesity [85].

Most commercially available probiotics for pets are not generated from the gut bacteria of dogs or cats. Furthermore, little research has been conducted on how well these probiotics survive in the digestive tract of pets. Although they make up a small portion of the canine gut microbiome, lactobacilli are common, and certain strains have been shown to have antibacterial properties in laboratory settings [86]. During feeding, they have the ability to persist and even take over the lactic acid bacteria (LAB) in the small intestine, which may have an impact on gut ecology [87]. Furthermore, many strains of canine lactobacilli have demonstrated good adherence to canine intestinal mucosa, inhibiting the adhesion of common pathogens [88].

Two recent studies have investigated potential canine probiotics made from dog excrement. Isolated from dog excrement, *Lactobacillus* fermentum AD1 showed encouraging traits. It thrives in acidic conditions (which resemble the stomach) and bile (which mimics the intestines) in laboratory testing. It also effectively stuck to the mucous in the intestines of dogs. Over the course of one week, when administered to fifteen healthy dogs, the number of lactobacilli and enterococci (beneficial bacteria) in their stools increased [89]. *Enterococcus faecium* EE3, a probiotic strain obtained from dogs, was the subject of another study. Eleven healthy dogs were administered the supplement for a week, and even when the supplement was stopped, it was still present in their stools three months later. This strain seemed to increase the abundance of other beneficial LAB and decrease *Staphylococci* and *Pseudomonas*. Interestingly, the *E. coli* levels were unaffected [90].

Research on the use of probiotics in dogs is promising; however, selection must be performed carefully. After delivery, *Lactobacillus rhamnosus* GG (LGG) remained in the canine gut; however, *E. faecium* NCIB 10415, surprisingly, increased the number of dangerous bacteria. This emphasizes the importance of comprehensive testing. It is interesting to note that scientists discovered bifidobacteria strains from healthy dogs that survived digestion and showed possible probiotic traits [91]. This finding opens the possibility of developing probiotics specifically for dogs in the future.

Moreover, researchers have investigated the effects of the probiotic strain *L. acidophilus* DSM13241 in healthy cats [92]. They discovered that taking the medication every day for 4.5 weeks changed the gut microbiota by increasing good lactobacilli and decreasing potentially dangerous *Enterococcus faecalis* and *Clostridium difficile*. Furthermore, the probiotic reduced the pH of the feces, reduced the level of dangerous endotoxins in the blood, and may have strengthened the cats' immune systems [93]. These results suggest that *L. acidophilus* DSM13241 may be a useful probiotic for enhancing the digestive health of cats.

Evidently, beneficial living microorganisms are becoming increasingly popular as treatments for acute gastroenteritis in dogs and cats. A study using a combination of *Lactobacillus* and *Bacillus* strains showed that dogs with ailments recovered faster [94]. Nevertheless, given that certain strains of Bacillus species have been associated with health hazards and that these bacteria may spread from animals to humans, questions have been raised about the safety of these probiotics for dogs. Another common problem in animal shelters is diarrhea, which can be caused by pathogenic agents, food modifications, and stress. Remarkably, a study assessing a particular probiotic strain (*E. faecium* SF68) demonstrated efficacy in lowering episodes of diarrhea in shelter cats, but not in dogs, indicating a benefit specific to select species from probiotics [95].

The use of multi-strain probiotics to treat dietary allergies and *Helicobacter* infections in dogs has been further investigated. In one study, dogs with food-responsive diarrhea demonstrated improvements in gut health and clinical symptoms when a three-strain combination of *Lactobacillus acidophilus*, *Lactobacillus reuteri*, and *Lactobacillus johnsonii* was administered, together with a particular diet [96]. Furthermore, another study showed that in dogs with non-specific dietary sensitivities, a probiotic containing *Lactobacillus acidophilus* (strain DSM13241) improved the gut flora and stool consistency [97].

Interestingly, probiotic strains such as *Lactobacillus casei* DN-114 001 have demonstrated potential in conjunction with conventional therapy to eradicate *Helicobacter* infections in pediatric patients [98]. This implies that probiotics may also be an effective treatment for these diseases in cats and dogs.

Interestingly, the relationship between probiotics and viruses or parasites in the guts of companion animals has been the subject of numerous studies, with varying degrees of success. Dogs with diarrhea were administered a particular probiotic mix (*Lactobacillus fermentum* VET9A, *Lactobacillus plantarum* VET14A, and *Lactobacillus rhamnosus* VET16A) as part of a double-blind, placebo-controlled trial. After a week, this medication had little effect on the pre-existing viruses [99]. In a different study, the probiotic *Enterococcus faecium* SF68 was investigated for Giardia in dogs; however, neither the parasite nor the immune response was affected [100]. On the other hand, probiotics may have an impact on how feline viruses spread in cats, according to research; however, the data were not very strong [101].

4. Role of Nutraceuticals and Antioxidants in Companion Animal Gut Health

The digestive tract of pets is essential for digestion, nutrient and water absorption, and waste removal. However, suspicions about the possible connection between commercially produced pet food and health issues are rising. Customers are becoming more concerned about the quality and safety of the food that their pets are fed [102].

The majority of pet owners place great emphasis on the health and welfare of their animals, but some are still concerned about the contents of commercial pet food. For example, some pet owners consider it harmful to include corn and wheat, even though both of these ingredients have been shown to provide health benefits, such as antioxidant and anti-cancer characteristics [103]. Although the Association of American Feed Control Officials (AAFCO) has established guidelines for these additives, some pet owners feel that they are inferior or lack sufficient nutrition for their dogs and cats [104].

Notably, natural substances and medicinal plants have been used to cure, prevent, and manage a variety of health issues. The potential of novel plant chemicals to prevent or treat various illnesses has attracted increasing attention. These new chemicals may possess characteristics that support the regulation of cell growth, alter the immune system, or combat microorganisms [105–107]. The bioactive substances found in plants include polyphenols, phytosterols, phytoestrogens, and polyunsaturated fatty acids (PUFAs) [108]. These substances have potential as functional foods or nutraceuticals and provide enticing solutions for treating a range of health issues [109]. As a result, research on nutraceuticals and their ability to prevent and/or protect against disease, with little to no side effects, is becoming increasingly important.

Food is essential for sustaining both a healthy digestive tract and regular bodily processes. Proper nutrient absorption, prevention of deficiencies and malnutrition, repair of damaged intestinal lining, restoration of gut bacterial balance, promotion of healthy gut motility, and support of a robust immune system are all made possible by a balanced diet [110]. Pet owners are now investigating complementary and alternative methods of providing healthcare for their animals, owing to these factors, as well as the growing expense and shortcomings of traditional medicine. Functional foods can enhance general well-being and provide health advantages beyond basic nutrition when included in a balanced diet [111].

It should be noted that dogs and cats, despite their shared status as companion animals, may have differing dietary needs when managing gut diseases [112]. Scientific research suggests various approaches, including hydrolyzed diets, where proteins are broken down for easier digestion, and limited-ingredient diets that restrict potential allergens. Fat reduction and gluten-free options have also been explored, albeit with varying levels of conclusive evidence. Parenteral nutrition, while offering precise nutrient control and bowel rest, is a last resort because of its high cost and complexity [113].

For example, curcumin, the active component of turmeric, is promising for the treatment of colitis. Because of its components, which are soluble in both fat and water, this yellow spice has potent antioxidant properties. Curcumin has the interesting ability to control autophagy, a cellular cleansing mechanism that may help in colitis. It also exhibits anti-inflammatory properties in both acute and chronic inflammation [114]. According to previous research, it can help dogs with digestive disorders by reducing inflammation and boosting their antioxidant system. Although curcumin and a particular formulation (*Meriva curcumin* phytosome) showed promise in treating canine IBD, no antioxidant effects were observed in this study [115]. To date, there is very little information regarding the use of curcumin in cats, though a study depicts its antiviral effects in feline infectious peritonitis [116]. Likewise, the plant *Boswellia serrata* (*B. serrata*), which is a member of the Burseraceae family, is a source of frankincense, a resin with therapeutic qualities [117].

The active components of frankincense, such as boswellic acid and its derivatives, are thought to have anti-inflammatory and antioxidant properties [118]. *Boswellia serrata* has further applications in veterinary medicine. Studies have shown that it works well as an antioxidant and anti-inflammatory agent in dogs [119]. To determine how well it works for treating canine IBD and CE and how it affects cats, further research is necessary.

Interestingly, succulent and drought-resistant Aloe vera, another natural food additive, has been utilized for a variety of health benefits. Numerous bioactive substances, such as vitamins, terpenoids, and flavonoids, are abundant in the leaves and combine to generate antibacterial, anti-inflammatory, and antioxidant activities [120]. Little research has been conducted on the potential use of aloe vera in veterinary medicine for treating digestive disorders. Although it is mentioned in one article as a stomach soother for dogs, no particular research has been conducted on how well it works to treat canine IBD and CE [121]. Likewise, because of its antioxidant properties, zinc is essential for several physiological processes in dogs and cats. Although the maximum amount of zinc that should be present in dog food is known, research suggests a possible connection between low zinc levels and canine lymphocytic–plasmacytic enteritis (LPE), a type of IBD [122,123]. Future research should use serum zinc content as a predictor of LPE prognosis.

The digestive systems of pets, among other parts of their health, depend on vitamins. The antioxidant capacity of specific vitamins and their potential advantages in gut health are the main topics of this section. For example, vitamins A and E shield the cells from the damaging effects of free radicals [124]. These anti-inflammatory effects may also be attributed to vitamin E. According to previous studies, pet food that contains an adequate amount of vitamin E may help prevent oxidative damage [125]. As a precursor to vitamin A, beta-carotene is crucial for the immune system and gut lining health. Inflammation in patients with ulcerative colitis (UC) has been associated with decreased beta-carotene levels [126]. Moreover, vitamin D supplementation has shown anti-inflammatory potential in murine models with IBD, but studies regarding dogs are still in the primary stages [127]. Further research is required to ascertain whether vitamin supplementation can effectively cure IBD in pets, although some evidence indicates that beta-carotene may provide protective advantages against UC in mice [128]. On the other hand, vitamin B12 deficiency has been reportedly related to the prognosis of CE. Oral intake of vitamin B12 supplements can potently reduce gut inflammation in dogs [129]. Tables 2 and 3 briefly summarize a few recent studies carried out on canine and feline subjects to analyze the effects of nutraceuticals and probiotics.

Table 2. Studies involving the effects of nutraceuticals and probiotics on canine health.

Supplement Source	Amount	Animal (*n*)	Purpose of Testing	Results	Ref.
Saccharomyces boulardii	1×10^9 CFU di/kg of feed/day for 35 days	Healthy American Staffordshire Terrier dogs; age: 2–8 years (25)	Analysis of gut microbiota and mycobiota composition	decreased fecal calprotectin immunoglobulin A; improved gut health	[130]
Ultramicronised Palmi-toylethanolamide (PEA), bovine colostrum and *Bacillus subtilis*	PEA, 100 mg; Bacillus subtilis, 1.5×10^9 CFU bovine colostrum, 200 mg/stick dose: 1 stick/10 kg body weight (BW)/animal for 30 days	Healthy Golden Retriever weaning puppies; age: 4 weeks (29)	Analysis of gut health and microbiome	gut inflammations were significantly decreased	[131]

Table 2. *Cont.*

Supplement Source	Amount	Animal (*n*)	Purpose of Testing	Results	Ref.
Saccharomyces cerevisiae	96.36% dry matter, 14.65% crude protein along with dietary fiber	Healthy female Beagles age: ~5 years (12)	measurement calprotectin, immunoglobulin A (IgA), *Escherichia coli*, and *Clostridium perfringens*	better IgA levels, reduced calprotectin levels compared to controls, and improved gut health	[132]
Lactobacillus acidophilus	*Lactobacillus acidophilus* 5.0 × 10^9 cfu/kg of dry food for 28 days	Healthy adult Boxer dogs; age: >1 year (40)	Effect on fecal quality and gut welfare of dogs	improved nutritional status and fecal parameters	[133]
Medicinal plants fermented *by Enterococcus faecium*	Turmeric, glasswort and Ganghwa mugwort (5%, 2.5% and 2.5% *w*/*v*) fermented and added in diet plan for 16 days	Healthy Beagles; age: 5–10 years (9)	Effect on fecal microbiota and antioxidant potential	increased number of beneficial bacteria in fecal matter, indicating antioxidant potential of the additives	[134]
Lentinula edodes, *Quercetin*, *And Bromelain*	Lentinula edodes, 10.0 mg/g; Quercetin, 13.5 mg/g; bromelain, 13.5 mg/g; maltodextrin, 583.4 mg/g; appetite stimulants, 379.6 mg/g dose: 1 g/10 kg of BW for 28 days	Healthy American Staffordshire Terrier adult female dogs; age: 5 ± years (30)	Analysis of anti-inflammatory and immunomodulatory function and gut health	increase in short-chain fatty acids and decrease in fecal calprotectin, cortisol, indole/skatole, and N-methylhistamine increases in *Bifidobacterium* and *Lactobacillus*	[135,136]
Platycladus orientalis leaf extracts (PLE)	Food additive (0, 0.25, 0.50, and 1.00 g/kg PLE/food) for 125 days	Healthy male black Raccoon Dogs; age: ~85 days (60)	Analysis of growth, impact on fur quality and serum parameters, along with effect on intestinal microbiota	decrease in number of harmful bacteria such as *Prevotella copri*	[137]
Clove, rosemary, and oregano	Blend of clove, rosemary, and oregano along with vitamin E for 28 days	Healthy adult Beagle dogs; age: N/a (10)	Analysis of effects of plant-based antioxidants on animals' gut health	lower oxidative stress and increased systemic antioxidant enzymes	[138]
Commercial Nutraceutical	ZT455C 1: 500 mg, Mannooligosaccharides (prebiotics): 300 mg, Carob flour (dietary fiber): 140 mg, Nucleotides: 50 mg, *Enterococcus faecium* (probiotic): 40 mg at 35 × 10^9 CFU/g, Vitamin B12: 5 mg for 1400mg tablets (daily 1 tablet per 5 kg of BW for 6 days)	Dogs with acute non-hemorrhagic diarrhea; age: N/a (30)	Analysis of effects of treatments on the intestinal microbiota	similar therapeutic effects as antibiotics	[107]

Table 2. *Cont.*

Supplement Source	Amount	Animal (*n*)	Purpose of Testing	Results	Ref.
Relaxigen Pet dog® tablet	Relaxigen pet dog® daily for 60 days	Stressed and healthy dogs; age: 1 to 10 years (30 + 10)	Analysis of nutraceutical on the fecal microbiome and stress-related behaviors	increased concentration of *lactobacilli* in fecal matter	[139]
Multistrain probiotic (Visbiome™)	112–225 × 109 CFU/10 kg capsules daily for 8 weeks	A mix of breeds with IBD; age: N/a (34)	Effect of probiotics on mucosal bacteria	enhanced tight junction protein expression to maintain gut microbiome homeostasis	[140]

Table 3. Studies involving the effects of probiotics and nutraceuticals on cats.

	Amount	Animal (*n*)	Purpose of Testing	Results	Ref.
Enterococcus hirae	2.85–4.28 × 10^8 CFU/day	Kittens (16)	Analysis of methods for preventing atypical Enteropathogenic *E. coli* (aEPEC) in the gut	helped lessen the negative effects of an *E. coli* infection on overall gut health and prevented dehydration	[141]
Lactobacillus acidophilus	food with the addition of 10 g/100 kg of *L. acidophilus*, corresponding to (at least) 5 × 10^9 CFUs /kg food	Adult Maine Coon cats (10)	Analysis of improvement in gut health	improved fecal quality parameters, reduced coliform counts	[142]
Saccharomyces boulardii and *Pediococcus acidilactici*	*Saccharomyces boulardii*, 2.0 × 10^{10} CFU/g and *Pediococcus acidilactici* 2.5 × 10^{10} CFU/g in addition to basic diet (0.5 g/kg BW) for 28 days	Short-haired domestic cats (10)	Analysis of gut health and colonization of beneficial bacterial species	positively influenced gut health by promoting beneficial bacteria, raising SCFAs and antioxidants, and lowering inflammatory markers in stool	[143]
Lactobacillus plantarum	*Lactobacillus plantarum* 10^9 CFU/kg feed/day for 28 days	Healthy adult cats (12)	Analysis of fecal microbiota, SCFAs, odorous substances	odorous substances are reduced to improve the digestibility of nutrients	[144]
Test food containing natural vegetables	Beet pulp, carnitine, chicken, corn gluten meal, fiber blend (broccoli and tomato pomace), fish oil, oat groats, pea, soybean oil, and brown rice for 40 days	Healthy domestic shorthair cats	Analysis of fecal microbiota and antiaging potential	increase in beneficial microbiota in the fecal matter	[145]

The Challenges Associated with Probiotics and Nutraceuticals Use

While probiotic supplements show promise in promoting gut health by influencing the gut microbiome in pets, several limitations might hinder their widespread use. For, instance, delivering live bacteria to the target location (the intestines) is very challenging. The harsh acidic environment of the stomach can kill unprotected probiotics. To curb this issue, encapsulation techniques have been developed, but these increase the overall cost and raise safety concerns [146]. Moreover, the natural antibiotic supplements (bacteriocins) produced by gut bacteria have certain limitations. Particularly, their production is time-consuming and expensive [147]. Likewise, nutraceutical manufacturing may suffer from inconsistency in quality control, which might raise safety concerns. In addition, the need for nutraceutical dose optimization for every organism and the lack of rules for quality assessment further complicate their administration [148].

5. Concluding Remarks

The health of companion animals is greatly influenced by their intestinal microbiome. In pets, disruption of the gut microbiota has been linked to several health issues, such as acute diarrhea, CE, and IBD. The potential of probiotics, nutraceuticals, and antioxidants to support gut health in dogs and cats is examined in this review. Although this field of study is still in its early years, there is mounting evidence that certain therapies have major advantages. It has been demonstrated that probiotics increase the diversity of gut microbes, strengthen the function of the epithelial barrier, and alter the immune system. Pets with digestive issues may benefit from the anti-inflammatory and antioxidant properties of nutraceuticals such as curcumin and *Boswellia serrata*. Similarly, certain minerals and vitamins, such as zinc and beta-carotene, vit. A, and vit. E, may support gut health in general. The effectiveness of particular probiotic strains, nutraceutical combinations, and ideal food plans for sustaining intestinal health in companion animals requires further investigation. Ultimately, more targeted and efficient methods for supporting digestive health in pets will be possible with a greater comprehension of the intricate relationships that exist between the gut microbiome, nutrition, and immune system function.

Author Contributions: Conceptualization, D.A.; methodology, D.A. and S.A.M.; investigation, D.A., F.B. and A.A.; writing—original draft preparation, D.A.; writing—review and editing, D.A., S.A.M., F.B. and A.A.; supervision, D.A. and S.A.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were generated or analyzed in support of this research. All information and data discussed in this review are derived from previously published research articles, which are cited accordingly in the reference section. For details on specific datasets, readers are encouraged to consult the original sources listed in the references.

Acknowledgments: We would like to express our gratitude to Giorgia Meineri, Bruno Stefanon, and Elisa Martello, our academic tutors for their invaluable support and expertise.

Conflicts of Interest: The authors declare no conflicts of interest.

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