COMPANION ANIMALS SYMPOSIUM: Future aspects and perceptions of companion animal nutrition and sustainability

P. Deng* and K. S. Swanson†‡

Abstract

Companion animals play an important role in our lives and are now considered to be and treated as family members in a majority of households in the United States. Because of the high number of pets that now exist, an increasingly stronger pet–human bond, and the importance placed on health and longevity, the pet food industry has realized steady growth over the last few decades. Despite past successes and opportunities that exist in the future, there are also challenges that must be considered. This review will present a brief overview of the current pet food industry and address some of the key issues moving forward. In regards to companion animal research, recent advances and future needs in the areas of canine and feline metabolism, aging, clinical disease, and the gut microbiome using molecular and high-throughput assays; chemical, in vitro, and in vivo testing of feed ingredients; and innovative pet food processing methods is discussed. Training the future workforce for the pet food industry is also of great importance. Recent trends on student demographics and their species and careers of interest, changing animal science department curricula, and technology’s impact on instruction are provided. Finally, the sustainability of the pet food industry is discussed. Focus was primarily placed on the disconnect that exists between opinions and trends of consumers and the nutrient recommendations for dogs and cats, the desire for increasing use of animal-based and human-grade products, the overfeeding of pets and the pet obesity crisis, and the issues that involve the evaluation of primary vs. secondary products in terms of sustainability. Moving forward, the pet food industry will need to anticipate and address challenges that arise, especially those pertaining to consumer expectations, the regulatory environment, and sustainability. Given the already strong and increasingly dynamic market for pet foods and supplies, an academic environment primed to supply a skilled workforce, and continued industry support for basic and applied research initiatives, the future of the pet food industry looks very bright.

Keywords:
cat nutrition; dog nutrition; pet food industry; pet research; student training

INTRODUCTION

The latest nationwide pet owner survey from the American Pet Products Association (APPA, 2012a) reported that more than 63.2% of all American households share their home with at
least 1 cat or dog. Today, the total number of pet dogs and cats in the United States has reached nearly 150 million. Over 13 million birds, horses, and specialty or exotic animals in the United States also are treated as companions (Table 1). The approximately 70 million pet dogs and 74.1 million pet cats that exist in the United States now represent a significant increase over the past 3 decades, with current population being 1.5 times greater than in 1981 (AVMA, 2012). Pet feeding practices in the United States and Australia were recently studied by Laflamme et al. (2008). Those researchers reported that more than 93.2% of dogs and 98.8% of cats consumed at least half of their food in the form of commercial products in those countries. The widespread use of nutritionally complete and balanced commercial foods have contributed to significantly longer life spans and healthier lives for pets, provided convenience to pet owners, and resulted in a highly successful and profitable pet food industry. Although the overall economy has been unstable over the past few years, the pet industry has been relatively resistant to the recession. As reported by the APPA, total U.S. pet industry expenditures averaged 2.4% annual growth from US$17 billion to $55.7 billion from 1994 to 2013 and is estimated to be $58.5 billion in 2014, of which pet food is estimated to make up $22.6 billion (APPA, 2012b).

### CONSUMER AND PET FOOD SALES TRENDS

Although pet ownership decreased by 2.4% in the United States between 2006 and 2011 (AVMA, 2012), the pet food industry maintained strong and steady growth. Much of the growth may be attributed to the increasing humanization of pets. In 2011, 63.2% of pet owners considered their pets to be family members, and another one-third of respondents felt their pets were their companions (AVMA, 2012). The increasing pet humanization trend, the importance placed on pet health and longevity, and the accepted role of diet on health are reflected in the pet food market. The Packaged Facts (Rockville, MD) pet shopper survey (PFI, 2014) reported the following: 1) 51% of dog owners and 48% of cat owners agreed with the statement that “high-quality pet foods are effective for preventive healthcare,” 2) 49% of dog owners and 44% of cat owners agreed with the statement that “fear of pet food contamination/product safety is a key consideration in the pet foods I buy,” and 3) 42% of dog owners and 34% of cat owners agreed with the statement that “natural and organic pet foods are safer than regular pet foods.”

A shift to “premium” and “super premium” formulations is an important factor driving pet food revenue. Even though these terms have no legal definition, they are commonly used by the industry to denote high-quality products. Based on data reported by Packaged Facts (PFI, 2014), approximately 10% of the pet food sold in the United States is super premium. This category is priced 20% or more above the average food and largely overlaps with the “organic” segments. Another 30% is “mass premium,” with “natural” instead of organic positioning and usually priced 10 to 20% above average (Sprinkle, 2014). These premium foods, together with other segments, such as natural, “grain-free,” “limited ingredient” diets, and “freeze-dried” products, are major drivers of pet food market growth (Table 2). GfK (GfK SE, Nuremberg Germany) is a large international company that analyzes market and consumer data, including that pertaining to the pet food industry. According to GfK’s database in 2013 (Beaton, 2014), $11.8 billion of the $20 billion pet food market was sold from pet specialty stores. Of that $11.8 billion, about $7.3 billion was sold in pet shops. In those stores, $4.5 billion was attributed to natural foods, an increase of 11.7% from the year before (Beaton, 2014). Although the legal definition of organic is quite specific, the legal definition of natural by the Association of American Feed Control Officials (AAFCO, 2011) is quite broad. Note that the use of either of these terms alone does not necessarily provide an indicator of quality. Similar to the low-carbohydratefad diets found in the human food market, some pet food companies now provide such diets to meet consumer needs. Although there is some evidence that low-carbohydrate diets may provide health benefit in pets with certain health conditions (Buff et al., 2014), more research in this area is needed.
Even though they are not carbohydrate free and often are not even low in carbohydrates, grain-free diets have been successfully marketed to this segment of pet owners and have become an essential piece of natural and organic pet foods. The sales of grain-free products in the United States reached $1.88 billion in the pet specialty channel in 2013, a sharp increase of 32.4% from 2012 (as reported by GfK; Beaton, 2014). According to GfK’s database (Beaton, 2014), the total revenue for pet food sold in the “specific diseases or conditions” segment accounted for only $1.86 billion, whereas foods in the “general health” segment attributed $5.5 billion of the $7.37 billion U.S. pet food retail sales. Notably, the market for these specialty pet foods is expanding rapidly. For example, both the allergy and joint/mobility diets had more than 20% growth in the past year (Beaton, 2014).

<table>
<thead>
<tr>
<th>Products</th>
<th>Growth, %</th>
<th>Annual sales, US dollars (billions)</th>
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<tbody>
<tr>
<td>Total pet food</td>
<td>6.5</td>
<td>7.30</td>
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<tr>
<td>Natural</td>
<td>11.7</td>
<td>4.50</td>
</tr>
<tr>
<td>Grain free</td>
<td>32.4</td>
<td>1.88</td>
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<tr>
<td>Limited ingredient</td>
<td>26.6</td>
<td>0.52</td>
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<tr>
<td>Fresh or raw</td>
<td>16.6</td>
<td>0.09</td>
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<tr>
<td>Freeze-dried</td>
<td>50.9</td>
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1Source: GfK’s database (2013).

From a consumer trends perspective, the pet food market often follows the human food market. Just as the human food market continues to put emphasis on functional foods and supplements beneficial to health, pet food products have been highlighted with wellness benefits, including the prevention of conditions associated with aging, joint health, cognition, weight maintenance, skin and coat health, oral health, gastrointestinal health, and more. Despite issues from a regulatory (e.g., lack of legal definitions) and a sustainability standpoint (e.g., competition with the human food industry), the number of pet food companies or products making a “human-grade” claim continues to increase, also reflecting the humanization trend.

With steady growth over the last several decades and the increased demand for high-quality pet foods by consumers, the pet food industry will continue to prosper. Continued growth and specialization will likely promise more basic and applied research needs and opportunities for jobs and career development, although foreseeable industry challenges must also be acknowledged. The future is filled with challenges and questions that include several topic areas. First, there is the question of whether the current pet food system and pet ownership trends can be sustained over the long term. Second, it is questioned whether there is sufficient research support and freedom to study alternative ingredients, innovative pet food processing methods, and canine and feline metabolism at a molecular level to develop new science-based products. Finally, the industry must determine how best to prepare the next generation of companion animal biologists, veterinarians, and nutritionists; address the key issues that exist in the pet food system with regards to nutritional sustainability; and develop and test methods by which sustainability may be evaluated. These key aspects of the pet food industry, with relevance now and in the future, will be the main focus of this review.

**COMPANION ANIMAL NUTRITION RESEARCH**

For decades, companion animal nutrition research has been dedicated to improving the health, longevity, and well-being of dogs and cats. The industry has made great progress in this regard, with pet dogs and cats living longer than ever before (Banfield Pet Hospital, 2013). As pet lifespan continues to increase, so does the incidence of chronic disease (German, 2006; Prahl et al., 2007), justifying continued effort in these areas. Improving health and longevity will continue to be a prominent research focus, but other topics will be of importance too. Dog and cat foods are largely based on secondary products of the human food industry, so the pet food industry is currently quite sustainable. Given the increasing global human population and need for food, however, the industry will be challenged to meet their goals with a similar or reduced environmental footprint in the future. Therefore, the search for alternative ingredients and processing methods also continues.

The market segment for diets targeting specific diseases is rather small when compared with the natural or organic segments but requires a considerable amount of research to support health claims made by the manufacturer. Understanding the biology of aging and various disease states is fundamentally important for the development of dietary strategies to
prevent and/or treat these health issues. Nutritional management of various health conditions and development of therapeutic pet diets have become hot topics in veterinary medicine. A wide range of therapeutic pet diets designed for specific diseases or conditions have been developed and become commercially available, including those targeting cognitive dysfunction, behavioral issues, urinary tract diseases, glucose and weight control, dental calculi, osteoarthritis, cardiac failure, chronic kidney disease, hepatic diseases, gastrointestinal diseases, dietary allergies, and skin and coat problems.

Despite the high number of clinical products that exist, controversial and/or inconsistent results from research trials studying the efficacy of the ingredients or diets tested for such conditions has raised concerns (Hill, 2009). First, much of the research supporting clinical pet diets does not undergo peer review and is never published in full journal form. Whereas obtaining patent rights to protect intellectual property is understandable, the field as a whole will benefit only if data are published. Second, many research trials do not provide a dietary history or food intake data. Third, many studies investigate only the metabolic changes rather than the clinical responses to the interventions tested. Lastly, there are many studies that test commercial diets without providing complete dietary ingredient and chemical composition and/or test diets that have more than one nutrient or ingredient altered, making it difficult to interpret the observed outcomes. Therefore, in most areas, more well-controlled randomized trials studying the efficacy of therapeutic diets on disease conditions with consideration of animal breed, age, diet, and environment are needed.

Recent advances in molecular biology, high-throughput methodologies (such as DNA and RNA sequencing techniques and untargeted gas chromatography/mass spectroscopy [GC/LC/MS] platforms), and bioinformatics enable rapid, intelligent, parallel acquisition of experimental data that enable a holistic view of the organism or system of interest. These tools allow the development of novel approaches to understand complex biosystems. Incorporating these technologies into nutritional sciences research projects allows the investigation of the complex interactions within a biosystem at a molecular level. These methodologies have created several new avenues of research with application to pets. “Nutrigenomics” or nutritional genomics focuses on studying nutrient–gene interactions. It is an applied branch of science within the complex field of genomic biology that includes information on DNA sequence (i.e., genomics), DNA structure (i.e., epigenomics), mRNA transcription (i.e., transcriptomics), protein expression (i.e., proteomics), and metabolite profiles (i.e., metabolomics).

With the availability of these powerful resources, researchers have the capability to gain a holistic and mechanistic understanding of the role of particular genes and/or metabolic pathways on host phenotype. Therefore, the relationships among nutritional components, genes, and physiological responses can be studied. Consequently, specific nutritional management strategies to prevent or treat certain diseases may be developed. For example, transcriptomic studies using DNA microarrays and RNA sequencing have identified age- and diet-related changes in gene expression of cerebral cortex (Swanson et al., 2009b), colonic mucosa (Kil et al., 2010b), liver (Kil et al., 2010a), white adipose (Swanson et al., 2009a), and skeletal muscle (Middelbos et al., 2009) tissues between aged (12 yr old) and young adult (1 yr old) dogs. The role of white adipose tissue in energy homeostasis, obesity, and related morbidities also has been heavily studied using molecular tools over the past decade. The research in this area was reviewed recently by de Godoy and Swanson (2013). As noted in that review, dietary intervention strategies including short-chain fructooligosaccharides (Respondek et al., 2008), green tea extract (Sersis et al., 2008), and high-protein diets (Vester et al., 2009) have been shown to modify the expression of genes related to glucose and lipid metabolism in adipose tissue (e.g., uncoupling protein-2, carnitine palmitoyltransferase-1, peroxisome proliferator-activated receptor-γ, lipoprotein lipase, and glucose transporter-4) and skeletal muscle (e.g., peroxisome proliferator-activated receptor-α and lipoprotein lipase) tissues, which may help explain their beneficial effects on glucose and insulin responses (de Godoy and Swanson, 2013).

Another important health condition that recent canine and feline genomics projects have focused on is joint disease. Gao et al. (2013) used gene array hybridization and 2-dimensional electrophoresis techniques to evaluate changes in gene and protein expression from whole blood or serum of cats with degenerative joint disease. Those researchers identified several biological pathways that were dysregulated in diseased cats. The genes and pathways identified were suggested as key regulators of the disease. However, it still remains unclear whether nutritional intervention could be used to regulate the expression of those genes and used as a means to prevent or treat disease. Similarly, Hannah et al. (2005) reported that an omega-3 PUFA–rich supplement improved the mobility of arthritic dogs, which was thought to be due to a reduction of inflammatory markers (e.g., PGE2) and cartilage destructive–associated pathways, including reduced expression of genes such as matrix metalloproteinase-9, matrix metalloproteinase-13, and tissue inhibitor of metalloproteinase-2. Collectively, these studies demonstrate that genomic biology may be used effectively to increase our understanding of canine and feline metabolism, identify alterations with aging or during disease, and assist in the formulation of
therapeutic pet diets to improve animal health. Similar research initiatives are justified in the future.

Molecular and high-throughput assays, publicly available databases, and bioinformatic tools also have been applied to host-associated microbiota, including that of dogs and cats. The microbiome is defined as the collective genomes of the microbes (composed of bacteria, bacteriophage, fungi, protozoa, and viruses) that live inside and on the body. Although the exact number living in and on any given host has been debated, the microbial ecosystem is thought to comprise approximately 10 times more cells and 100 times more genes than the host itself (Qin et al., 2010). Although the importance of gut microbiota to host health has been appreciated for decades, it has been possible to study these microorganisms at the molecular level for only the past few years, with focus on disease states and response to nutritional interventions. Perturbations in the gut microbiome have been associated with some of the most prominent health issues of humans, including gastrointestinal diseases, obesity, cardiovascular disease, and diabetes (Flint et al., 2012). Recent studies have compared gut microbiota of healthy vs. diseased dogs and cats and those fed various dietary interventions using DNA sequencing methods. In general, dogs with inflammatory bowel diseases have been reported to have a less microbial diversity; lower abundance of Bacteroidetes, and greater abundance of Proteobacteria compared with healthy dogs (Chaban et al., 2012; Suchodolski et al., 2010, 2012; Xenoulis et al., 2008). Given the disease complexity and high variability that exists among experiments, more research is needed to identify biomarkers of disease and therapeutic targets.

Whereas disease studies are useful, those focused on the characterization of gut microbiota in healthy animals and identifying how environmental exposures, including diet, impact the activity and number of bacteria are also justified. Several groups, including our laboratory, have recently used high-throughput DNA sequencing techniques to describe the predominant gut microbial taxa and genes present in dogs and cats and how they are affected by dietary intervention, as reviewed by Deng and Swanson (2014). Swanson et al. (2011) were the first to use shotgun 454 pyrosequencing to characterize the phylogeny and functional capacity of the fecal microbiome of healthy dogs, noting that the codominant phyla in canine feces were Bacteroidetes or Chlorobi (35% of sequences), Firmicutes (35% of sequences), Proteobacteria (13 to 15%), Fusobacteria (7 to 8%), and Actinobacteria (1%). They reported that approximately half of all sequences were classified metabolically, with the most abundant functional categories described by the Kyoto Encyclopedia of Genes and Genomes (www.kegg.jp) being those attributed to carbohydrates, protein metabolism; cell wall and capsule; cofactors, vitamins, prosthetic groups, and pigments; DNA metabolism; RNA metabolism; AA and derivatives; and virulence. Similar technologies have been used to determine the phylogeny and functional capacity of the healthy feline gut microbiome (Barry et al., 2012). Dominant bacterial phyla of the fecal microbiome of healthy cats are similar to that of dogs, including Firmicutes (36 to 50%), Bacteroidetes (24 to 36%), and Proteobacteria (11 to 12%). Bacteria (99%) were the dominant microorganism in feline feces followed by Eukaryota (1%) and Fungi (0.02%). The functional capacity of the feline fecal microbiome also was reported to be similar to that in dogs (Swanson et al., 2011).

Hooda et al. (2013) and Deusch et al. (2014) demonstrated that diet may cause dramatic shifts in fecal microbial taxa and gene content. Hooda et al. (2013) applied 16S rRNA gene based 454 pyrosequencing methods to identify the fecal microbial taxonomic shifts in 8- to 16-week-old kittens fed diets containing variable protein to carbohydrate ratios. They reported large shifts in microbial taxa in kittens fed a moderate-protein, moderate-carbohydrate diet (34% protein and 19% fat, DM basis) compared with those fed a high-protein, low-carbohydrate diet (53% protein and 24% fat, DM basis). Deusch et al. (2014) then used Illumina shotgun sequencing (Illumina Inc., San Diego, CA) on these same samples to explore the functional capacity of the microbiome. Those researchers observed strong diet-related differences in pathways related to AA, vitamin, fatty acid, and peptidoglycan biosynthesis; the glycolytic, citric acid, and pentose phosphate pathways; oxidative phosphorylation; and the metabolism of purines, pyrimidines, and sugars. In addition to dietary macronutrient profiles, dietary fibers, prebiotics, and probiotics also have been studied using high-throughput sequencing techniques recently (Barry et al., 2012; Beloshapka et al., 2013; Garcia-Mazzorro et al., 2011; Middelbos et al., 2010; Rossi et al., 2014; Swanson et al., 2011).

Similar to human studies, the vast majority of canine- and feline-specific gut microbiome studies have focused on fecal DNA, providing information on microbial taxonomy and functional capacity but few measures of microbial activity (e.g., mRNA or metabolites). In the future, it will be essential to understand how diet affects the microbial transcriptome, metabolite profiles, and how microbial activity impacts host physiology and health, potentially providing valuable insights into nutritional management. Integrating RNA and DNA sequencing techniques with high-throughput metabolomic analytical platforms allows microbiome–metabolomics analyses that may identify potential disease biomarkers and provide therapeutic solutions to complex health conditions. Untargeted GC/LC/MS was recently used to identify shifts in plasma metabolite profiles in adult cats fed diets composed of variable macronutrient composition (Deng et al., 2014). Interestingly, significant shifts
were noted between cats fed high-protein and high-carbohydrate diets, with microbial-derived metabolites being largely responsible for the shift noted in cats fed the high-protein diet. The examples previously mentioned demonstrate the feasibility of using these rapidly developing technologies to study the role of nutrition on canine and feline metabolism. Further research is needed to expand our knowledge in regards to the metabolism of healthy animals and to identify disease biomarkers and nutrition- or drug-related targets for those with disease.

Whether animal health, sustainability, waste management, marketing, or some other factor is the primary motivator, improving diet quality and nutrient digestibility is another ongoing research emphasis of the pet food industry. This may be accomplished by improving raw ingredient selection or optimizing manufacturing processes. As novel ingredients and processing methods are applied to pet foods, research to verify ingredient and diet quality is necessary. Ingredients may be evaluated at several levels, including chemical analyses, in vitro digestion and fermentation assays, and various in vivo testing protocols. Whereas chemical analyses are commonly performed by commercial laboratories, limited information in regards to in vivo digestibility, bioavailability, and metabolism, all essential for accurate formulation of nutritionally complete and balanced diets, is available for many ingredients.

In vitro fermentation assays have been used to assess feedstuffs in ruminants for decades (Tilley and Terry, 1963). Similar assays have also been used to assess dietary fiber fermentation in nonruminants, including humans (Ehle et al., 1982). Because hydrolytic and enzymatic digestion is much more important in nonruminant species, in vitro assays that simulate gastric and small intestinal digestion as well as large intestinal fermentation are most accurate and useful when screening potential feed ingredients. The assay developed by Boisen and Eggum (1991) is most commonly used to evaluate pet food ingredient digestion characteristics (Faber et al., 2010; Hooda et al., 2012; de Godoy et al., 2014b). Processing may increase the digestibility of starch and protein; however, excessive temperature, pressure, or processing time may lead to damaged proteins and AA, resulting in overall nutrient loss. Therefore, in addition to evaluating raw materials, the tests mentioned herein may also be used to evaluate and optimize pet food processing strategies.

Despite the information that may be learned from in vitro assays, there is no complete substitute for in vivo testing. Because fecal samples provide an inaccurate measure of nutrient digestion, especially for nitrogen-containing compounds (i.e., protein and AA) that are manipulated by colonic microbiota, ileal-cannulated animals (e.g., dogs, cats, pigs) or cecectomized roosters may be used to evaluate ingredient caloric content and/or digestibility. Ileal-cannulated dogs were used effectively to evaluate in vivo protein and AA digestibility in the past (Bednar et al., 2000; Burkalter et al., 2001; Faber et al., 2010), but their use has been limited in recent years, largely due to animal welfare concerns. Due to animal welfare concerns, length of time, and expense associated with cannulated canine or feline models, the precision-fed cecectomized rooster bioassay has been a popular alternative. Because a high correlation between ileal-cannulated dogs and cecectomized roosters has been demonstrated (Johnson et al., 1998), it is a well-accepted model for measuring the nitrogen-corrected true ME (TMEₙ) and true AA digestibility of pet food ingredients. In vivo tests are more comprehensive assays and include all animal physiological responses to the test ingredient or diet. For example, the ability of dietary fiber or low-digestible carbohydrates to decrease nutrient digestibility may be demonstrated in vitro, but its effects on weight maintenance, laxation, glucose or insulin response, or hairball control may be tested only in vivo. A combination of assays is commonly used to evaluate novel ingredients, including 2- or 3-stage in vitro digestion and fermentation assays, TMEₙ quantification using rooster assays, and gastrointestinal tolerance; glycemic, insulimetic, or gut peptide responses; intestinal immune responses; or shifts in gut microbiota of dogs and cats. Such assays have been used to test novel carbohydrates (e.g., soluble corn fiber, polydextrose, resistant starches), protein sources, or treats (Middelbos et al., 2007; Knapp et al., 2008; Faber et al., 2010; Vester Boier et al., 2012; de Godoy et al., 2014a,b).

The identification and testing of novel ingredients, especially alternative protein sources, may positively influence the quality and/or sustainability of pet foods, both of which will continue to be main concerns of the pet food system. The pet food industry is already quite sustainable because its formulas are founded on secondary products of the human food system. However, with a limited supply of traditional protein sources and to minimize competition with the human food system, the pet food industry has compelling reasons to identify alternative protein sources that are cheaper to buy, more readily available, or more efficient to produce than traditional protein sources yet still provide all essential nutrients for health maintenance. Alternative protein sources may include byproducts of the human food system currently viewed as waste, plant proteins, lower order animals, or single-cell organisms. Such protein sources may have a lower environmental impact compared with typical animal-based protein sources (Swanson et al., 2013). At the 2013 Waltham International Nutritional Sciences Symposium (Portland, OR), Bosch et al. (2013) presented the results from a study that evaluated the protein quality of a variety of insect species (e.g., housefly pupae, house cricket, yellow mealworm, lesser mealworm, Morio worm, black soldier fly larvae, and cockroach), which have been proposed to be high-quality, efficient,
and sustainable protein sources for pet food. Those researchers reported that the 2 species of mealworms contained the greatest fat (39.6%; lesser mealworm) and protein (64.8%; yellow mealworm) content and had the greatest protein quality in terms of in vitro nitrogen digestibility and AA scores compared with the other species tested. However, there are still many concerns about the safety and variability of protein quality in regards to using such proteins to replace traditional mammalian-, avian-, fish-, or plant-based protein sources. Therefore, additional research in this area is needed (Bosch et al., 2013).

TRAINING THE FUTURE WORKFORCE

Given the steadily growing pet food industry, large pet population, and stronger pet–human bonds, there are more companion animal biology-based career opportunities in academia (i.e., teaching, research, and outreach), industry, and government than ever before. Research performed in academic institutions will train MS and PhD candidates and postdoctoral researchers, but what about undergraduate training? Over the past 20 yr, progressive animal science departments have expanded their undergraduate curriculums to include courses and outreach activities pertaining to companion animals. The overall mission of animal science programs is to provide science-based education in animal biology, behavior, and well-being and the use of animal products. Whereas this has always been true for domestic livestock species, career opportunities and changing demographics and interests of undergraduate and graduate students have resulted in the addition of companion animal options. Although demographic and student survey data are not commonly published, recent data from a couple prominent programs demonstrate the continual increase of female students, students from suburban and urban environments, and those with a companion animal–related career interest (McNamara, 2009; Nichols and Hay McCammant, 2014).

Over the past 9 yr, a survey was conducted by the Department of Animal Sciences and Industry at Kansas State University (Manhattan, KS) to examine demographics and student interest in regards to species (Nichols and Hay McCammant, 2014). This survey was given to students enrolled in Principles of Animal Science (ASI 102), which is an introductory course for undergraduates. In 2005 when the survey was first administered (n = 263; 61% female), primary species of interest was beef cattle (37% of the class), with companion animals (31%) and horses (29%) closely behind. By 2013 (n = 438; 68% female), companion animals was the most popular species (39% of students) followed by beef cattle (34%).

Similar data have been collected from the University of Illinois (Urbana, IL) undergraduate student population. Over the past 5 yr, undergraduate students enrolled in Introduction to Animal Sciences (ANSC 100; n = approximately 230 students/yr) and Animal Nutrition (ANSC 223; n = approximately 130 students/yr) have completed demographic- and interest-based surveys. The following are 5-yr averages for students in ANSC 100, a course composed primarily of college freshmen during their first semester on campus: 82% of class is female, 87% have intentions of going to veterinary school, 74% grew up in an urban or suburban environments, and 19% grew up on a farm that raised beef cattle, dairy cattle, or swine. In 2013 and 2014, ANSC 223 students, who are primarily sophomores in their fourth college semester, were composed of 83% females and had the following ethnicities: 77.5% white, 8.5% Asian, 6.5% HispanicLatino, 4% African American, and 3.5% other. Of these students, 85% had an indoor pet growing up but only 18.5% grew up on a farm. A majority of these students grew up in a rural nonfarm (17%), suburban (49%), or urban (16%) environment. The animal industry sector or species of interest and ultimate degree goal data from this class is presented in Fig. 1. In this population, small animal (25%), exotic (38%), and zoo (12%) animals are of greater interest than traditional livestock (18%) and horses (7%). Whereas a majority of these students still favor a career in veterinary medicine (57%), nearly 30% are considering graduate school at this point.
Given the changing demographics and demand for trained individuals with knowledge in companion animal biology, departments have broadened their mission to include companion animal–related courses. This may seem conceptually straightforward, but the process by which this takes place may not be from a practical standpoint. To address this issue, Dr. J. P. McNamara, a Professor of Animal Sciences at Washington State University (Pullman), provided his thoughts and experiences in the Companion Animal Nutrition Symposium entitled “Preparing Future Companion Animal Biologists” at the 2014 Joint Annual Meeting in Kansas City, MO (McNamara, 2014). McNamara shared a retrospective view of his personal experiences of switching from dairy nutrition to companion animal biology within a traditional animal science department. In addition to didactic teaching, he pointed out that there is great potential for hands-on or experiential learning opportunities in the area, including youth 4-H programs and projects.

McNamara pointed out that many departments have successfully responded to the changing demographics by including companion animal models in their core disciplinary classes and/or by opening and expanding research into the biology of companion animals. Most animal science departments also teach at least 1 course in companion animals separately from other species (McNamara, 2009). This was demonstrated by a survey of 78 animal science departments in the United States, which indicated that 74% of the departments were teaching companion animal–related classes and 23% had developed companion animal programs (McNamara, 2009). At the University of Illinois, the Companion Animal Program was initiated in 1974 and has developed an extensive undergraduate curriculum since that time. In addition to its highly active research program that includes undergraduate research fellows, the department has an active internship program and teaches a total of 10 courses focused on the biology, nutrition, care, and management of companion animals; public policy; ecology; human–pet interactions; companion animals in society; and animal shelter management (http://ansci.illinois.edu/groups/companion-animal-biology/courses, University of Illinois, 2014).
The cooperation with other departments such as veterinary medicine, human food and nutrition, biology, and zoology departments are also important. Based on a survey conducted by Lafframme et al. (2008), most dog and cat owners obtain information about pet nutrition through their veterinarians. This information underscores the importance of nutrition education in the pre-veterinary and veterinary curricula, so that the veterinary healthcare professionals have the capability and confidence to provide guidance on such subjects. Given the technological advances made in classrooms over the past decade, cooperation among animal science departments via distance learning may also be performed. Similarly, social media and other technologies have changed teaching and extension activities in companion animal programs. These new tools may make the classroom more attractive to students, provide more information, and inspire interaction between educators and students in and out of the classroom. These technologies may improve collaboration and communication by conducting surveys, sharing information in real time, and sharing the limited human and facility resources in existing programs. Although there usually is not a substitute for in-person communication and interaction and a danger that emerging technologies and social media become more of a distraction than learning tool, they are certain to be mainstays that affect the pet food industry and the way that the future workforce communicates and becomes trained. The most effective educators in the future will likely be those who are able to use a combination of traditional didactic teaching methods, hands-on activities, and available technologies, thereby stimulating student interest, engagement, and active learning.

**SUSTAINABILITY OF THE PET FOOD INDUSTRY**

With an increasing human population and impact on the environment, sustainability is continuously questioned. To be sustainable, the needs of the present must be met without compromising the ability of future generations to meet their needs. This concept that includes 3 main pillars, namely economics, social issues, and the environment, has been used to provide standards for numerous systems, including the food system (Manning et al., 2012). Nutritional sustainability is the ability of a food system to provide safe and adequate nutrition to maintain health in the population without compromising the ability of future generations to meet their nutritional needs (Swanson et al., 2013). This concept is essential not only for human food production but also for the pet food industry. The pet food system is quite unique in many ways, however. Although it competes with livestock production and the human food system for some ingredients, the industry is largely based on secondary products of the human food system. Because so many of those products are used, the methods and/or equations by which “environmental cost” of pet foods is estimated must be modified from those used for human foods. With the anthropomorphism of pets, pet food production and marketing have focused on what society believes to be culturally acceptable yet still provide cost-effective, nutritious, and palatable diets. Weighing the social and economic costs associated with pet foods also will be difficult and may be a moving target as consumer beliefs continue to evolve.

Looking forward, the pet food industry will need to address a few key issues in regards to sustainability. The first is the disconnect that exists between the canine and feline nutrient requirements and guaranteed analysis of pet foods, with primary emphasis on dietary protein concentrations. According to the NRC (2006), the recommended allowance for CP is 10 (DM basis) and 20% (DM basis) for adult dogs and cats, respectively. These recommendations account for differences in nutrient bioavailability among ingredients and genetic variation of dogs or cats and are similar to the Association of American Feed Control Officials (2011) recommendations (i.e., 16 and 26% CP on a DM basis for dogs and cats, respectively). Comparing these recommendations with data from a recent study by Hill et al. (2009), whereby chemical analysis of 1,158 canned and 750 dry commercial pet foods was conducted, shows how much excess protein exists in pet foods. In that study, average CP concentrations were reported to be 40.8% (DM basis) for canned foods and 31.4% (DM basis) for dry foods. Other factors, such as protein quality (AA profile) and digestibility, are of importance because they also affect animal health and performance. Although general statements about the entire pet food industry cannot be made in regards to sustainability, we do believe that environmental-friendly recommendations for certain diets may be proposed without compromising pet health. For high-protein (>40% CP) diets formulated with ingredients of high protein quality (i.e., balanced AA profile), for example, a reduction of CP by a few percentage units may be done to reduce environmental load, assuming that the ingredients used for replacement were also secondary products of the human food system.

Another difficult issue that the pet food industry must face is the high demand for and use of animal-based protein sources. Whereas dogs and cats evolved as carnivores, they require specific nutrients, not specific ingredients. Therefore, as long as complementary ingredients are used, all nutrient needs may be met with a combination of animal- and plant-based ingredients. In general, animal-based proteins have a much larger carbon and water footprint than plant-based proteins (Pimentel and Pimentel, 1996, 2003). Therefore, incorporating a balance of these ingredients will aid in maintaining the sustainability of pet food industry. The use of human-grade ingredients that has been suggested in some pet foods, especially in homemade or raw diets, is also problematic in regards to sustainability.
In contrast to the majority of pet foods based on secondary products of the human food system, including grain byproducts, animal byproducts, vegetable and fruit pulps and pomaces, etc., that are essentially reducing the footprint of human foods, pet foods made with human-grade ingredients are in direct competition with human foods and should be evaluated as such. Whereas environmental assessment of animal feeds has been studied in recent years (LEAP, 2014), a system specifically designed for pets that considers the environmental footprint of ingredients and known nutritional requirements has not been developed and/or published. Such a system should consider the raw material source, nutrient density and bioavailability, and its potential use. Ingredients that may be consumed by humans should have the highest “cost” followed by those with potential for livestock or aquaculture production followed by those with potential use as fertilizers followed by those that would not be used by another industry and would be deposited in landfills.

Finally, pet owners tend to overfeed their pets, resulting in obesity. The prevalence of overweightness or obesity has been reported to range between 34 and 59% for dogs (Courcier et al., 2010a; Lund et al., 2006) and between 27 and 39% for cats (Collard et al., 2009; Courcier et al., 2010b; Lund et al., 2005). Pet obesity not only reduces the quality and length of life while increasing veterinary costs for our pets, but it is a wasteful practice from a sustainability perspective. Pet owner education programs focused on nutrient and energy requirements, understanding pet food labels and feeding guidelines, and selecting the appropriate food for their pet may not only improve the health of pets but also improve the sustainability of the pet food industry.

**SUMMARY AND CONCLUSIONS**

With a growing and more passionate pet owner population, the pet food industry has been strong over the past several years despite an unstable global economy. Despite recent success, it is important to assess the current status of the industry and look toward the future to identify potential opportunities and challenges. Research initiatives in academia, industry, and government must address current needs and those predicted to be of importance in the future, whether they are related to ingredient supply and safety, pet food processing and production, or pet health. Recent advances in molecular biology, high-throughput methodologies, and bioinformatics may be applied to pet health–related issues, such as aging and chronic diseases, that continue to increase and are highly complex. Chemical, in vitro, and in vivo testing protocols and innovative pet food processing methods may be used to answer many of the fundamental questions pertaining to ingredient composition and safety, nutritional quality, nutrient bioavailability, and sustainability. In addition to advances in research, a continued emphasis must be placed on training the workforce of tomorrow. Over the past 2 decades, animal science programs across the country have expanded their curriculums to include companion animal–related courses. Most recently, engaging technologies and social media have been used to connect with students and provide them with more resources and opportunities. Such advancements must continue to occur so that the pet food industry has a constant supply of well-trained and knowledgeable employees. Finally, the industry must continue to adapt to consumer wants and needs yet be sustainable. Because the pet food system is largely based on secondary products of the human food system, it is quite sustainable in its current form. Increased pet humanization and recent product preference trends by owners, however, have increased the financial and environmental costs of some foods. To be sustainable in the future, pet food professionals will need to balance consumer expectations, pet health considerations, and the environment. By continuing to evaluate and improve ingredients and pet food products in regards to pet health, optimize manufacturing processes, evaluate and enforce regulations, and educate the public, the pet food system will continue to be a strong and sustainable industry in the future.

**References**


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Footnotes

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