Sustainability and Pet Food

Is There a Role for Veterinarians?

Heather L. Acuff, MS[1], Amanda N. Dainton, MS[1], Janak Dhakal, DVM, PhD[2], Samuel Kiprotich, MS[1], Greg Aldrich, PhD*

KEYWORDS

• Sustainability • Pet food • Life-cycle assessment • Carbon footprint • Waste

KEY POINTS

- Sustainability is defined here as the conscientious management of resources and waste necessary to meet the physiologic requirements of companion animals without compromising the ability of future generations to meet their environmental, social, or economic needs.
- Life-cycle analysis of pet foods has identified that the most significant impact category to the environment is climate change (quantified as kg CO_2 eq), with wet foods tending to have a greater impact than dry foods, and dogs having a greater impact than cats.
- Opportunities for improvement in sustainability exist at all phases of the pet food life cycle, including formulation, ingredient selection, manufacturing processes, packaging materials, transportation methods, reduction of food and packaging wastes, and proper disposal of pet waste.
- Veterinarians have a central role as a resource for clients on diet selection, feeding management, and proper pet waste disposal practices, as well as the sustainable farming of livestock animals.
- The advancement of sustainable practices in companion animal care will require a collaborative effort between pet food industry stakeholders, veterinarians, and pet owners.

INTRODUCTION

The overuse of resources has become a concern as world populations increase. The environmental footprint of pet ownership and provision of necessary supplies and food for pets on the use of natural resources, emissions, and waste are also growing. The questions regarding the size of that impact and where opportunities for

Department of Grain Science and Industry, Kansas State University, Manhattan, KS 66502, USA
[1] Present address: 1301 Mid Campus Drive, 201 Shellenberger Hall, Manhattan, KS 66506.
[2] Present address: Integrated Life Science Building, 1981 Kraft Drive, Blacksburg, VA 24060.
* Corresponding author. 1301 Mid Campus Drive, 201 Shellenberger Hall, Manhattan, KS 66506.
E-mail address: aldrich4@ksu.edu

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improvement exist begin with the pet owner and the general public's perception of the topic regarding sustainability and move upstream to the raw material suppliers, food manufacturing companies, packaging producers, and transportation sectors. Overcoming barriers to sustainability will require the implementation of successful intervention strategies, and the pet owner will need to assign value to this effort, as sustainable products are likely to cost more at retail. The following objectives are critical to the discussion of sustainability of pet food: (1) to define sustainability and its importance to veterinary practitioners; (2) to describe the life-cycle analysis (LCA) of the pet food industry and identify areas for improvement; (3) to determine how food process, product type, nutrient composition, and ingredient selection might influence the sustainability of pet foods; and (4) to provide veterinarians information about the pet food LCA in order to educate pet owners in areas where they can influence sustainability.

CURRENT KNOWLEDGE

Environmental Impact of Dog and Cat Ownership

According to recent US pet ownership statistics, two-thirds of US households are estimated to own at least 1 pet across nearly 85 million homes.[1] Companion animals enrich the lives of their owners in numerous ways, such as increasing physical activity, lowering blood pressure, and reducing risks of certain heart diseases.[2] Pet ownership has also been associated with psychological benefits, including increased self-esteem in children, reduced risk of depression, and increased social engagement and cohesion.[2–4]

Despite the many rewards of pet ownership, our pet-centric way of life may take a toll on the environment. The growing populations of urbanized pets have been linked to loss of wildlife biodiversity because of predation and disturbance, as well as a greater consumption of goods and services.[5,6] Driven largely by humanization and concern for their pet's well-being, owners serve generous portions of food and treats and supply products that support a comfortable and stimulating environment. Many pets receive regular veterinary care and participate in a variety of vocational and social activities. It is estimated that the cumulative US pet industry expenditures reached $95.7 billion in 2019, with pet food and treats making up the largest sales segment (38%), followed by veterinary care and product sales (31%), and then supplies and other services.[1] All of these place a demand, either directly or indirectly, on the consumption of natural resources and energy and generation of waste into the environment.

Pet excrement (urine and feces) is perhaps the most widely scrutinized contributor to impact the environment. Dog and cat feces present a public health risk because of the potential for pathogenic, parasitic, or antibiotic-resistant microorganism transmission through direct contact or contamination of municipal waterways, especially in urban areas where human and animal populations are dense.[7] Abandoned pet waste carried into nearby streams or lakes by stormwater also contains nutrients that can encourage excessive algae growth and release ammonia, which can be toxic to fish and other aquatic wildlife.[8] Alternative methods of disposal of pet feces include passage through sanitary sewage lines (eg, flushing) or in municipal solid waste channels (eg, landfill). The latter is the preferred method recommended by the Environmental Protection Agency (EPA); however, decaying fecal material results in greenhouse gas (GHG) emissions in the form of CO_2, NH_3, CH_4, and N_2O.[8] Researchers estimate 5.62×10^6 US tons of total (cat and dog) fecal matter are produced annually in the United States.[9] This amount is comparable to the amount of landfill waste generated annually by the state of Indiana (population 6.73 million in 2019).[10]

Several researchers have also evaluated the environmental impact of dogs and cats based on annual pet food consumption, with results ranging from 27 to 1444 kg CO_2 eq per year for dogs (Table 1), and 43 to 228 kg CO_2 eq per year for cats (Table 2). Because pet excrement is a direct product of food intake, it could be argued that pet food production and consumer purchasing behaviors should shoulder the responsibility of environmental stewardship. Thus, considering sustainability as it relates to all aspects of pet food allows for a broader understanding of the environmental impact of our pets.

Defining Sustainability in the Pet Food Industry

Sustainability has previously been defined as practices that ensure the current population meets their requirements without compromising the ability of future generations to meet their needs.[2] The EPA defines sustainability as a harmonious and productive system in which humans and nature could exist, permitting the fulfilment of social, economic, and other requirements of the present generation without jeopardizing the needs and requirements of future generations.[11] From the perspective of pet food production, sustainability has been defined as the ability to produce pet food in adequate amounts while providing the sufficient essential nutrients required to maintain optimum health and viability now and in the future with the smallest environmental footprint.[12] Here, the authors propose a broader definition for sustainability that incorporates the stewardship of companion animals: the conscientious management of resources and waste necessary to meet the physiologic requirements of companion animals without compromising the ability of future generations to meet their environmental, social, or economic needs.

Quantifying Carbon Footprints with Pet Food Life-Cycle Analysis

The environmental impact of a food system can be quantified by analyzing all material inputs (energy and natural resources) and outputs (waste and emissions) and their associated costs, a process known as LCA. Following ISO 14044:2006 standards, LCA serves as a globally recognized model framework to study the environmental impact categories associated with a product or process such as climate change (biogenic and land use and transformation), ozone depletion, human toxicity risk (cancerous and noncancerous), particulate matter, ionizing radiation, photochemical ozone formation, acidification, eutrophication (terrestrial, freshwater, and marine), freshwater ecotoxicity, and natural resource use.[13]

The LCA of dog and cat foods is highly complex considering the variety of raw materials, manufacturing technologies, and packaging options that exist today. The environmental impact of food and agricultural systems can differ considerably.[14–16] Geographic location also influences the environmental burden of agricultural products, in terms of both production and transportation. In addition to raw material extraction, manufacturing technology (eg, extrusion, canning, baking, freeze-drying), nutritional composition of product (eg, moisture and protein level), packaging specifications, distribution channel, and storage and usage requirements are additional factors interlinked with a product's carbon footprint.

Despite these many complexities, in 2018 the European Commission adopted the Product Environmental Footprint Category Rules (PEFCRs) as a standardized model for calculating environmental impacts for the full life cycle of prepared pet foods for dogs and cats. The model development consists of 4 LCA studies of complete pet foods sold in Europe representing cat and dog foods, kibble, and canned foods. Dog food (wet and dry) collectively had a greater environmental impact than cat food because of higher consumption volume of dog food. The estimated impact of wet food also exceeded dry food because of the high use of natural resources for

Table 1
Summary of climate change impact (CO_2 eq) estimations of dog ownership

Sector	Functional Unit	Assumptions	Footprint Estimation	Geographic Area	Source
Wet dog food	Annual impact for 1 pet	Only includes products sold and consumed in the European Union Average dog weighs 15 kg Excludes impact of use stage	464 kg CO_2 eq	European Union	FEDIAF,[17] 2018
Dry dog food	Annual impact for 1 pet	Only includes products sold and consumed in the European Union Average dog weighs 15 kg Excludes impact of use stage	139 kg CO_2 eq	European Union	FEDIAF,[17] 2018
Companion dogs consuming dry food	Annual impact for 1 pet	Average dog weight of 10–20 kg; per capita dry food consumption of 61–247 kg per year	317–1292 kg CO_2 eq	Netherlands	Martens et al,[75] 2019
Companion medium-sized dogs consuming dry food	Annual impact for 1 pet	Average dog weight of 10–20 kg; per capita dry food consumption of 19–123 kg per year	115–754 kg CO_2 eq	Japan	Martens et al,[75] 2019; Su and Martens,[76] 2018
Companion dogs consuming dry food	Annual impact for 1 pet	Average dog weight of 10–20 kg; per capita dry food consumption of 48–243 kg per year	284–1444 kg CO_2 eq	China	Martens et al,[75] 2019
Companion small-sized dogs consuming dry food	Annual impact for 1 pet	Average dog weight of 1.5–10 kg; per capita dry food consumption of 5–61 kg per year	27–372 kg CO_2 eq	Japan	Martens et al,[75] 2019

Companion large-sized dogs consuming dry food	Annual impact for 1 pet	Average dog weight of 25–59 kg; per capita dry food consumption of 96–498 kg per year	109–191 kg CO_2 eq	Japan	Martens et al,[75] 2019
Average-sized dogs consuming wet food	Annual impact for 1 pet[a]	Average dog weight of 15 kg and average life expectancy of 13 y; per capita wet food consumption of 348 kg per year	631 kg CO_2 eq	European Union	Yavor et al,[77] 2020
Large-sized dogs consuming wet food	Annual impact for 1 pet[a]	Average dog weight of 30 kg and high life expectancy of 18 y; per capita wet food consumption of 365 kg per year	1056 kg CO_2 eq	European Union	Yavor et al,[77] 2020
Small-sized dogs consuming wet food	Annual impact for 1 pet[a]	Average dog weight of 7.5 kg and short life expectancy of 8 y; per capita wet food consumption of 199 kg per year	375 kg CO_2 eq	European Union	Yavor et al,[77] 2020

[a] Annual impact for 1 pet for was calculated as lifetime impact CO_2 eq/life span for each dog size scenario.

Table 2
Summary of climate change impact (CO_2 eq) estimations of cat ownership

Sector	Functional Unit	Assumptions	Footprint Estimation	Geographic Area	Source
Wet cat food	Annual impact for 1 pet	Only includes products sold and consumed in the European Union Average cat weighs 4 kg Excludes impact of use stage	141 kg CO_2 eq	European Union	FEDIAF,[17] 2018
Dry cat food	Annual impact for 1 pet	Only includes products sold and consumed in the European Union Average cat weighs 4 kg Excludes impact of use stage	43 kg CO_2 eq	European Union	FEDIAF,[17] 2018
Companion cats consuming dry food	Annual impact for 1 pet	Average cat weight of 2–6 kg; per capita dry food consumption of 20–33 kg per year	136–228 kg CO_2 eq	Netherlands	Martens et al,[75] 2019
Companion cats consuming dry food	Annual impact for 1 pet	Average cat weight of 2–6 kg; per capita dry food consumption of 18–31 kg per year	110–191 kg CO_2 eq	Japan	Martens et al,[75] 2019; Su & Martens,[76] 2018
Companion cats consuming dry food	Annual impact for 1 pet	Average cat weight of 2–6 kg; per capita dry food consumption of 20–34 kg per year	128–215 kg CO_2 eq	China	Martens et al,[75] 2019

packaging production (tin plating). Overall, the most relevant impact categories for pet food were determined to be climate change, eutrophication (freshwater, marine, terrestrial), land use, and natural resource depletion (water, mineral, and fossil).[17] Although the PEFCRs were developed using data sets for EU energy reporting, pet food production in the United States follows a similar life cycle (Fig. 1), and thus, the principles of the PEFCRs could be applied to the US pet food systems.

Pet Food Life-Cycle Analysis by Segment

Diet selection and nutritional composition

There are 2 defining attributes that influence the path of a pet food product's life cycle. Diet selection, which dictates the intended species, life stage, food format, and inclusion or exclusion of specific ingredients, and nutritional composition, which determines the level of raw materials needed to achieve the desired nutrient levels, both of which have a direct impact on the resources required to construct a product.

Protein is the most expensive and ecologically demanding macronutrient, yet is a key factor for the selection of pet food products by pet owners.[18–20] Pets require a moderate level of protein in their diets, with Association of American Feed Control Officials minimums set at 18% for adult dogs and 26% for adult cats on a dry matter (DM) basis.[21,22] However, high-protein formulas (>30% crude protein on a DM basis) are commonly marketed for both species, as more protein may be needed to maintain lean body mass and support the needs of older dogs and cats, and working dogs, as examples. The idea that protein levels in excess of an animal's requirement are beneficial is debatable and adds strain to the increasing global demand for protein for humans, agricultural animals, and companion animals.[9,20]

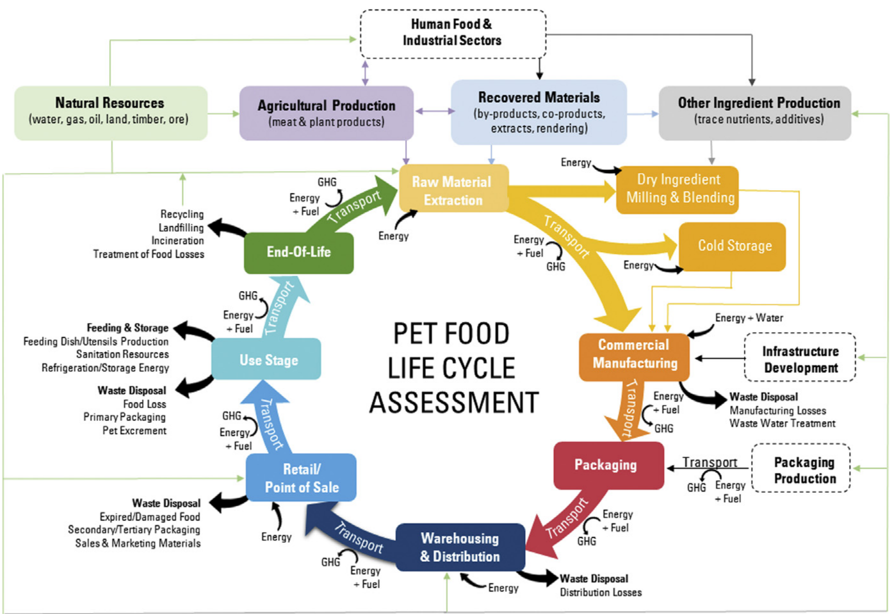

Fig. 1. A generic LCA for commercially prepared pet food beginning with raw material extraction and tracing through manufacturing, packaging, distribution, retail, usage, and end-of-life disposal.

There is a belief, shared by 29.4% of dog owners and 21.7% of cat owners, that raw diets are healthier for their pets; however, only 3.9% of veterinary professionals agree with this.[23] One in 5 pet owners also report following raw feeding practices originating from online resources rather than published references or seeking veterinary advice, which may exacerbate nutritional or safety risks associated with raw feeding.[24] With regard to sustainability, raw pet foods are thought to compete with the human food chain because of the high inclusion of edible ingredients.[25] In addition, the handling and storage of the leftover raw pet food can become a safety concern to pet owners because of the high risk of exposure to pathogens.[26] The American Veterinary Medical Association (AVMA) also discourages feeding pets raw animal-based foods, especially those that have not gone through pathogen elimination steps during processing.[27]

Raw Material Selection

Animal-based protein sources

Much of the protein in pet foods originates from animal sources, and there is a trend for increasing both quality and quantity of meat in pet foods.[9] Dog and cat owners generally prefer meat as a source of protein for their pets compared with alternative sources, such as insect proteins, vegetable proteins, or laboratory-grown meats.[23] Animal-based ingredients are considered to be a high-quality source of dietary protein, containing a complete profile of essential amino acids dogs and cats require. However, these tend to have a greater ecological footprint as compared with plant-based proteins (**Table 3**).[28]

Antibiotic-free protein sources, especially poultry, have become increasingly popular in both human food and pet food. This popularity is attributed to a widely accepted belief that antibiotic-free products are healthier and safer; however, there are no scientific data to support the nutritional superiority of the antibiotic-free animal tissues.[29,30] Antibiotic-free animal production, in turn, has potentially adverse effects on the sustainability aspects of the food chain because of compromised animal health, reduced production efficiency, and increased costs of production.[31] The AVMA recommends the judicious use of medically important antimicrobials in animal production in order TO sustain their utility for both man and animal.[32]

Animal-based coproducts

A by-product, by regulatory definitions, is merely the secondary product produced from manufacturing the primary product. Critics would suggest this presumes the secondary product has little value. The authors' way of thinking should probably shift to that of a "coproduct," in which the entire value proposition is considered. Presuming that there will be meat consumption by the North American human population for the foreseeable future, the proper use of all the available resources, including animal by-products, is necessary.[11] Average carcass yield, or dressing percentage, ranges between 50% and 74% of live animal weight for red meat, pork, and poultry products in the United States, leaving behind a significant portion of animal-derived material that does not enter the human food system.[33] When managed responsibly, producers can lessen the environmental effects of organic waste disposal and help recover valuable nutrients.[34] Clean animal offals, for example, provide good-quality protein and higher levels of trace minerals, such as iron, zinc, calcium, and copper, in comparison to muscle tissues and can be incorporated into pet foods in raw, dried, or rendered forms.[35,36] According to the National Renderers Association, 56 billion pounds of renderable raw material is diverted from landfills and recycled into useable fat, oil, and protein products annually in North America.[37] Rendering also avoids at least 90% of potential GHG emissions when compared with industrial composting, which is equivalent to removing more than 12 million cars from the road.[38]

Table 3
Average global warming potential estimates of select insect-, animal-, and plant-origin ingredients with applications in US pet foods

Ingredient	LCA Study Location[1]	Carbon Footprint (kg CO_2 Eq/kg Functional Unit)	Reference
Insect, origin			
Black soldier fly larvae[a]	DEU	1.36–15.1	Smetana et al,[78] 2016
Animal, origin			
Plains, ranched beef[b]	USA	20.4–23.2	Rotz et al,[79] 2019
Pasture, finished beef[c]	USA	19.2	Pelletier et al,[80] 2010
Feedlot beef[c]	USA	14.8	Pelletier et al,[80] 2010
Grassland, grazed lamb[b]	NZL	19	Ledgard et al,[81] 2011
Hillside, raised lambs[c]	ENG	17.9	Jones et al,[82] 2014
Lowland, raised lambs[c]	ENG	10.9	Jones et al,[82] 2014
Organic farmed salmon[c]	CAN	2.7	Pelletier and Tyedmers,[83] 2007
Farmed salmon[c]	CAN	2.1	Pelletier and Tyedmers,[83] 2007
Pork[c]	USA	2.01–3.02	Thoma et al,[84] 2015
Chicken[c]	USA	1.99	Putman et al,[85] 2017
Poultry by-product meal	PRT	0.73	Campos et al,[86] 2020
Poultry fat	PRT	0.67	Campos et al,[86] 2020
Hydrolyzed feather meal	PRT	0.60	Campos et al,[86] 2020
Rendered animal protein	GBR	0.15	Ramirez et al,[87] 2012
Rendered animal fat	GBR	−0.77 to 0.15	Ramirez et al,[87] 2012
Plant, origin			
Rice	USA	1.41–1.88	Johnson et al,[88] 2016
Potato	FRA	0.10–0.11	Godard et al,[89] 2012
Sorghum	USA	0.60–1.24	Johnson et al,[88] 2016
Wheat	USA	0.45–1.32	Johnson et al,[88] 2016
Soybean	USA	0.34–0.70	Johnson et al,[88] 2016
Oats	FRA	0.31	Wilfart et al,[90] 2016
Corn	USA	0.30–1.68	Johnson et al,[88] 2016
Spring peas	FRA	0.29	Wilfart et al,[90] 2016
Rainfed legumes	ESP	0.23	Aguilera et al,[91] 2015

[a] Functional unit = 1 kg insect protein meal.
[b] Functional unit = 1 kg carcass weight.
[c] Functional unit = 1 kg live weight.
[1] CAN = Canada; DEU = Germany; ENG = England; ESP = Spain; FRA = France; GBR = United Kingdom; NZL = New Zealand; PRT = Portugal; USA = United States of America

Plant-based ingredients

Exchanging protein sources of animal origin with those of plant origin has been proposed to improve the sustainability of pet foods by using fewer natural resources and maintaining a smaller carbon footprint.[39] Animal-based proteins are widely perceived as superior in quality for dogs and cats compared with plant-based proteins; however, the relative digestibility has been reported to be similar between both sources.[40] Plant-based proteins generally contain a limited amount of 1 or 2 essential amino acids, which reduces their overall protein quality. However, by combining complementary ingredients, those that provide an abundance of the limiting amino acids of the other, the overall quality of plant-based protein can be at least as good as that from animal-source proteins.[41] Dogs, being omnivores, are well adapted for a plant-based diet; however, cats are obligate carnivores, so are not able to meet their nutritional requirements from unsupplemented plant-based diets alone.[42]

In addition to providing bioavailable protein, fat, and energy to pets (**Table 4**), plant-based ingredients and their coproducts possess food-functional properties as well. An ingredient that is currently underutilized but has substantial availability includes distillers dried grains with solubles (DDGS) derived from ethanol production. For instance, 50 kg of corn yields approximately 20.8 L of ethanol, which reduces the dependence on fossil fuels and generates 13.9 kg of DDGS. DDGS contain moderate levels of protein and fermentable fiber and improve palatability in pet food applications.[43] Plant-based coproduct inclusion in foods for pets supports environmental sustainability by using every aspect of the respective crop and supports economic sustainability by increasing the number of competitively priced ingredients available to pet food formulators.

Meat analogues are emerging sources of dietary protein that imitate the texture, appearance, or flavor of animal muscle tissues.[44] Dried texturized vegetable protein is an example of a modern meat analogue that can be made from extruded defatted soy meal, soy protein concentrates, or wheat gluten.[45,46] Plant-based proteins with elastic or spongy textures, such as wheat gluten and soy protein, also offer versatility in structural formation, and texturized soy proteins can produce meatlike textural attributes with high nutritional quality.[47–50] These components have been used with success in canned, frozen, or dried pet foods.

Alternative ingredients

Alternative ingredients, such as single-cell organisms (SCO: yeast, fungi, and algae) and insects, are being evaluated as potential meat or plant substitutes.[51] The idea behind use of SCO and insects is that they can be grown on carbon sources that might otherwise be considered unrecoverable in the food production system. For example, a recent LCA of microbial protein produced using a potato wastewater system reported an 87% lower impact on the ecosystem compared with traditional soybean meal production.[52] Microbial proteins are currently being used as a source of high-quality protein and essential fatty acids in aquaculture and are reported to contain higher levels of crude protein compared with conventional animal or plant sources.[53] Insects, such as black soldier fly (*Hermetia illucens*) larvae, housefly (*Musca domestica*), and mealworm (*Tenebrio molitor*), are a major protein source in many countries in Asia, Africa, and Latin America, but are less common in the United States because of negative public perceptions.[54] Application of insect protein as a key ingredient in pet food formulation has gained interest; however, there are few data regarding nutritional quality, and regulatory approvals are pending.[55–57]

Commercial Manufacturing

The greatest potential for sustainability improvement within the commercial manufacturing sectors are cropland, energy, and water usage.[58] Total annual production of dog and cat food in the United States is estimated to be 9.8 million metric tons.[59] Through LCA, the environmental impact translates to roughly 851 gha of cropland, 14 TJ of energy, and 686,821 KL of water used to produce 1 metric ton of pet food.[58] There is room for improvement, but the impacts made by producing food for dogs and cats are estimated to be lower than many human food product industries.[58]

Impacts on cropland are not directly affected by processing, but energy usage and water could be decreased with operational planning, such as installing more energy

Table 4
Proximate composition (as-is basis) of select pet food ingredients and coproducts

Ingredient	DM, %	CP, %	Fat, %	TDF, %	Ash, %	Reference
Beef, MSM	40.6	15.0	23.5	0.0	2.1	NRC,[92] 2006
Beef liver	31.0	20.0	3.9	0.0	1.3	NRC,[92] 2006
Beef heart	24.4	17.1	3.8	0.0	1.0	NRC,[92] 2006
Beef kidney	23.0	16.6	3.1	0.0	1.1	NRC,[92] 2006
Beef tripe	18.6	14.6	4.0	0.0	0.4	NRC,[92] 2006
Animal fat	99.0	0.0	98.0	NR	NR	Batal et al,[93] 2016
Meat & bone meal	92.0	45.0	8.5	NR	37.0	Batal et al,[93] 2016
Chicken, whole carcass	33.9	18.5	12.0	NR	NR	Kadim et al,[94] 2005
Chicken, meat & skin	38.2	17.6	20.3	0.0	1.0	NRC,[92] 2006
Chicken gizzard	23.8	18.2	4.2	0.0	0.9	NRC,[92] 2006
Chicken liver	26.4	18.0	3.9	0.0	1.2	NRC,[92] 2006
Poultry fat	99.0	0.0	98.0	NR	NR	Batal et al,[93] 2016
Chicken meal	95.9	64.2	12.2	NR	14.7	Donadelli et al,[96] 2019
Poultry by-product meal	93.5	59.0	13.5	NR	16.0	NRC,[92] 2006
Feather meal	93.0	85.0	4.0	NR	3.9	Batal et al,[93] 2016
Dried whole egg	96.6	47.2	41.1	0.0	3.6	NRC,[92] 2006
Eggshell meal	99.6	6.6	0.0	NR	53.6	Ode et al,[95] 2016
SD egg white	91.1	76.0	0.1	NR	4.9	Donadelli et al,[96] 2019
SD inedible whole egg	93.5	45.8	34.9	NR	3.9	Donadelli et al,[96] 2019
Corn meal, whole kernel	89.7	8.1	3.6	7.3	1.1	NRC,[92] 2006
Corn starch	91.7	0.3	0.1	0.9	0.1	NRC,[92] 2006
Corn germ meal	90.1	28.4	6.0	45.0	3.9	de Godoy et al,[97] 2009
Corn gluten meal	89.1	55.2	1.1	NR	1.2	Donadelli et al,[96] 2019
Corn protein concentrate	91.4	72.1	2.3	NR	0.8	Donadelli et al,[96] 2019
Corn fiber	98.9	11.0	6.0	71.4	0.9	de Godoy et al,[97] 2009
DDGS	90.2	26.8	9.0	NR	4.7	NRC,[92] 2006
Soybean flour, full fat	96.2	38.1	21.9	NR	5.9	NRC,[92] 2006
Soybean meal, expeller	89.0	42.0	3.5	NR	6.0	Batal et al,[93] 2016
Soy protein isolate	95.0	84.6	0.6	NR	3.8	Donadelli et al,[96] 2019
Soybean hulls	90.9	12.6	2.4	NR	4.4	NRC,[92] 2006
Wheat flour, whole grain	89.7	13.7	1.9	12.2	1.6	NRC,[92] 2006
Wheat flour, white	88.1	10.3	1.0	2.7	0.5	NRC,[92] 2006
Wheat germ meal	89.0	25.0	7.0	NR	5.3	Batal et al,[93] 2016
Wheat gluten	93.3	75.6	0.8	NR	0.8	Tomás-Vidal et al,[98] 2017
Wheat middlings	89.5	16.6	4.0	NR	4.5	NRC,[92] 2006
Wheat bran	89.0	14.8	4.0	NR	6.4	Batal et al,[93] 2016

Abbreviations: MSM, mechanically separated meat; NR, not reported; SD, spray-dried; TDF, total dietary fiber.

efficient equipment or reducing the amount of water used during extrusion or retort processing. A tuna canning plant for pet food in Thailand reduced their water consumption by 32% by switching to hot water and reducing water usage when cleaning cans, cooling cans with pressurized spray nozzles, and teaching employees about the importance of using less water and how they could make a difference.[60] Many such decisions could be considered when new pet food manufacturing facilities are built.

Food Packaging

Food packaging serves many important functions, including protecting food from spoilage and nutritional degradation, improving efficiencies in distribution and storage, and serving as a source of information to feed regulators and pet owners. Pet food bags and containers are commonly constructed from layers of plastic (polyethylene and its derivatives), paper and paperboard, or metals (aluminum, tin, or steel). Most pet food packages are also designed for single use and nonrecyclable, leaving pet owners few options besides disposal.[61] Food containers and packaging waste are estimated to make up just under one-third of all municipal solid waste in the United States.[62] Packaging developers face many challenges with regards to sustainability. In order for sustainable packaging to be effective, it must reduce food waste, preserve food quality, and prevent food contamination. It must also address the issue of plastic waste accumulation in the environment. In addition, the materials must also be nontoxic for humans and animals, and cost-effective for feasibility of use.[63]

The next generation of sustainable food packaging research is focusing on the use of renewable starting materials to develop biodegradable polymeric films. For example, dairy-based films are currently being explored as an alternative to petroleum-based packaging by the Agricultural Research Service.[64] Biopolymers from cornstarch, chitosan, carrot processing waste, cellulose, and other agricultural products also show promise for biodegradable film construction in the effort to reduce plastic wastes accumulation in the environment.[65–67] However, the cost and performance of ecofriendly and lower-barrier packaging compared with synthetic alternatives may still impede their widespread adoption.

Transportation and Distribution

The transportation of material between each phase of the pet food life cycle is an integral part of today's modern food system; however, it contributes directly to fossil fuel consumption and GHG emissions. The EPA estimates a total 6677 million metric tons of GHG emissions were produced in the United States in 2018, of which transportation was the largest contributor at 29%, followed by electricity (27%), industry (22%), commercial and residential (13%), and agriculture (10%).[68] The concept of "food miles" is an important consideration because many raw materials, packaging, and finished products embark on global transport through its life cycle. Reduction of pet food's carbon footprint through sourcing local or regional raw materials is a marketing strategy that has gained popularity.

In addition to geographic distance traveled, the method of transport has an impact on GHG emissions from fossil fuel combustion. The US Department of Transportation estimates that the largest share of total GHG emissions by vehicle type are passenger vehicles and light-duty trucks (59%), medium and heavy-duty trucks (23%), aircraft (9%), ships and boats (3%), rail (2%), and buses, motorcycles, and pipelines (4%).[69] Many of the early pet food life-cycle phases use bulk transportation of dry ingredients, which minimizes the number of vehicles required, and thus the environmental burden. However, when transportation of high-moisture commodities, such as fresh or frozen animal or plant products, is required, the use of refrigerated trucks can exacerbate energy consumption. Consumer shopping behaviors, such as transportation method, trip length, and trip frequency, also play an important role in the "last mile" of the pet food life cycle.[70] Direct-to-consumer models are estimated to have a net carbon footprint similar to traditional brick-and-mortar retailers because of expedited shipping methods, an increase in lightweight parcel delivery vehicles routing to pet owner residences, and inefficient transit packaging to protect the product from damage in shipping.[71]

APPLICABILITY TO VETERINARY PRACTITIONERS

An overwhelming majority of US dogs and cats are taken to their veterinarian at least once a year.[18] Veterinarians are regarded as reliable sources of information on pet food and pet nutrition and have influence over the foods owners purchase.[72,73] During annual visits, veterinarians have the opportunity to educate owners on the importance of pet foods and ingredients, as well as guidance on diet selection, feeding quantities, and waste management strategies, thus influencing the environmental impact of their clients and patients.

Veterinarians also play a central role in the sustainable farming of livestock animals.[74] Because veterinarians are a trusted source of information for livestock producers, communicating about animal welfare, judicious use of antibiotics, and the search for alternative and sustainable sources of food for livestock are a few key factors in which veterinarians can take a lead. Furthermore, veterinary professionals serve as educators of food safety, food quality, food security, and biodiversity maintenance. Because of the nature of veterinary professionals' daily duties and their regular interaction with both livestock producers and pet owners, the hands-on sharing of information has become critical for a client to begin considering sustainability in the food selections they make for their animals.

SUMMARY

Sustainability in the pet food industry can be summarized as those practices and beliefs that can continue indefinitely for future generations. Key opportunities for the improvement to sustainability of pet foods involve sustainable ingredient selection, avoiding nutritional and feeding excesses, and optimizing resource and waste management. Progress will depend on the collective efforts of suppliers, manufacturers, personnel, availability of ingredients, and consumer purchasing choices. There are many aspects of the pet food industry that are sustainable, such as using coproducts from the human food industry and decreasing energy and natural resources used during production. In fact, pet food production is more sustainable than many human food processing industries in terms of cropland, energy, and water usage. However, the pet food industry's ability to adopt some of these practices is limited by negative perceptions of coproducts and novel ingredients, as well as expectations for increasingly rapid product delivery. It also appears that pet owners may not fully understand the direct impacts purchasing decisions have on sustainability. Veterinarians are uniquely positioned to educate pet owners when they bring their animals in for examinations. This education could be in the form of providing more information about the benefits of coproducts discussed here and how to decrease the impact of their pets on the sustainability of pet food. Pet food companies respond to the values of pet owners, and an increase in pet owner awareness and interest in sustainability will encourage the pet food industry to continue improving in this area.

CLINICS CARE POINTS

- Veterinarians have an opportunity to cultivate sustainable practices by educating clients on proper waste disposal, conscientious food selection, and optimal feeding management.

- Veterinarians can help socially conscious pet owners manage their pet's diet in a sustainable manner by encouraging a modest level of protein and the use of conventional ingredients.
- Evidence provided by life-cycle analysis indicates that plant-origin ingredients tend to have a lower carbon footprint compared with animal-origin ingredients, and that poultry, fish, and rendered animal proteins have a lower carbon footprint compared with large ruminant proteins.
- The carbon footprint of pet ownership in the United States is trivial compared with that of the human waste, transportation, and industrial sectors.

DISCLOSURE

The authors have nothing to disclose.

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