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Rendered ingredients significantly influence sustainability, quality, and safety of pet food[1]

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ABSTRACT: The rendering industry collects and safely processes approximately 25 million t of animal byproducts each year in the United States. Rendering plants process a variety of raw materials from food animal production, principally offal from slaughterhouses, but include whole animals that die on farms or in transit and other materials such as bone, feathers, and blood. By recycling these byproducts into various protein, fat, and mineral products, including meat and bone meal, hydrolyzed feather meal, blood meal, and various types of animal fats and greases, the sustainability of food animal production is greatly enhanced. The rendering industry is conscious of its role in the prevention of disease and microbiological control and providing safe feed ingredients for livestock, poultry, aquaculture, and pets. The processing of otherwise low-value OM from the livestock production and meat processing industries through rendering drastically reduces the amount of waste. If not rendered, biological materials would be deposited in landfills, burned, buried, or inappropriately dumped with large amounts of carbon dioxide, ammonia, and other compounds polluting air and water. The majority of rendered protein products are used as animal feed. Rendered products are especially valuable to the livestock and pet food industries because of their high protein content, digestible AA levels (especially lysine), mineral availability (especially calcium and phosphorous), and relatively low cost in relation to their nutrient value. The use of these reclaimed and recycled materials in pet food is a much more sustainable model than using human food for pets.

Key words: ingredient, pet food, rendering, safety, sustainability

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INTRODUCTION

The world population is projected to grow to around 9.6 billion by the year 2050 (United Nations, 2013). The amount of food needed for this population will be 70 to 100% more than current production. Most population growth will be in the developing world where the standard of living is also expected to rise along with the corresponding meat consumption (FAO, 2009). To meet this demand, there will likely be a significant increase in livestock production and the feed resources for those food animals. Annual meat production is expected to rise by over 200 million t to reach 470 million t (FAO, 2009). In most parts of the world, this increase in the quantity and quality of life is also accompanied by a similar growth in both the quantity of and amount of money spent on companion animals, predominantly cats and dogs. Wise use of all resources, including the nearly doubling of animal byproducts, will be essential for all people and animals to be sustainably fed.

MEAT CONSUMPTION AND PRODUCTION IN THE UNITED STATES

Meat is considered by many to be an essential part of the human diet. Trends of meat consumption in the United States have been relatively stable over time (Table 1). Meat consumption customs, tradi-

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Table 1. Total retail weight disappearance per capita of red meat and poultry in the United States since 1970 (USDA, 2014c)

Year	1970	1975	1980	1985	1990	1995	2000	2005	2010	2013
Weight, kg	87.6	83.3	88.5	90.3	90.3	89.4	93.3	95.7	79.1	76.9

tional harvest practices, social customs, and current regulations in North America dictate that many organ meats and other tissues are not harvested for human food, instead remaining in offal for rendering or being harvested for pet foods. These trends and customs bode well for the future sustainability of pet food as these byproducts are well suited for dog and cat diets.

The United States currently produces, slaughters, and processes approximately 112 million pigs, 32 million cattle, and 8.5 billion chickens annually (USDA, 2014a,b). Dressing percentages and retail yields vary, but a significant portion of every food animal grown and slaughtered is not consumed by humans. The amount considered inedible by humans, such as bones, fat, blood, feathers, and some internal organs, is a large volume of byproduct that would quickly overtake landfills if not rendered (Meeker and Hamilton, 2006). Some modern trends, such as prepacked/table-ready meat products and further processing, increase the raw material quantities for rendering compared to older methods where trim was sold with the meat and usually thrown away by the consumer. The current volume of raw material rendered in the United States and Canada is nearly 25 million t annually (Informa Economics, 2011).

Meat consumption worldwide is expected by the Food and Agriculture Organization of the United Nations to increase to about 45.3 kg per capita by 2030, up dramatically from the 1964/1966 amount of 24.2 kg per capita (FAO, 2009). This large increase is mostly due to the increase in meat consumption by people in developing countries (FAO, 2009). Meat is likely to be a major part of the worldwide diet, long term. The sustainability of animal agriculture depends on a reasonable and practical use of the byproducts generated.

PET OWNERSHIP AND EXPENDITURES

Ownership and total expenditures on dogs and cats is high in the United States and Europe and growing fast in many emerging markets such as Brazil and China. In the United States, cats and dogs are the most popular pets with 45.3 million households owning cats and 56.7 million households owning dogs (APPA, 2014). Taking into account households with multiple animals, there are a total of 95.6 million pet cats in the United States and 83.3 million pet dogs (APPA, 2014). The next most popular United States pet categories are fish in 14.3 million households and birds in 6.9 million households (APPA, 2014).

Total expenditures on pets in the United States in 2013 were US$55.7 billion and are projected to be $58.5 billion in 2014 and up from $17 billion in 1997 (Table 2). Growth in the pet market did not appear to be affected by the recent economic recession. On average, each U.S. household spent just over $500 on pets, including food, or about 1% of their total household spending in 2011 (BLS, 2013). This percentage remains unchanged regardless of total household income and remained constant during the recession (BLS, 2013), which suggests a deep commitment to pets.

In 2013, pet food sales reached roughly $11.8 billion at pet retail stores, veterinary clinics, and farm feed stores (Tagore, 2014). Sales of pet food in all retail outlets was $21.6 billion of the $55.7 billion total spent on pets (Table 3). Dog owners typically spend more per year on their dogs, averaging about $304 a year on food and treats, as compared with $239 a year on food and treats for cats (APPA, 2014). Such a large, growing market can only be sustained long term by the wise use of resources.

Dog and cats are carnivores, belonging to the mammalian order Carnivora along with large predators such as bears, lions, and wolves (Van Valkenburgh and Wayne, 2010). Whereas dogs are able to exist on properly balanced meatless diets, in nature, canines eat meat (prey). Cats are obligate carnivores and require meat in their diet due to their taurine requirement and inability to convert carotene to retinol, which means that a vegetarian diet does not supply enough vitamin A (Legrand-Defretin, 1994). However, feeding domestic pet carnivores as they might have behaved in the wild would not be acceptable to most consumers and likely not sustainable.

Dogs and cats both require a number of nutrients that come from animal-based diets, such as B vitamins,

Table 2. Total United States pet industry expenditures from 1994 (US$, billions; APPA, 2014)

Year	1994	1998	2002	2006	2010	2011	2012	2013	2014
US$, billions	17	23	29.5	38.5	48.4	51.0	53.3	55.7	58.5 (projected)

Table 3. Sales breakdown within the United States market in 2013 (US$, billions; APPA, 2014)

Item	US$, billions
Food	21.6
Supplies and over-the-counter medicine	13.1
Veterinary care	14.4
Live animal purchases	2.2
Pet services (grooming and boarding)	4.4
Total	55.7

phosphorus, and calcium. Cats also digest protein less efficiently than dogs and require a higher amount of it in their diet (Baker and Czarnecki-Maulden, 1991).

DEFINING SUSTAINABILITY

Sustainability can be defined in many ways spanning from very self-centered perspectives focused on survival to global perspectives with little industry-specific detail. A very useful definition of nutritional sustainability for a pet food discussion was offered by Carter et al. (2014): "Nutritional sustainability is the ability of a food system to provide sufficient energy and the amounts of essential nutrients required to maintain good health of the population without compromising the ability of future generations to meet their nutritional needs." The Environmental Protection Agency (**EPA**, 2014b) offers this definition: "Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations." We suggest a current working definition for this discussion that includes both direct reference to pet food and the environment is "The ability to produce pet food that provides sufficient energy and the amounts of essential nutrients required to maintain good health now and into the future with the smallest possible environmental footprint." Inherent in this definition is the assumption that the products would necessarily be affordable for the customer and maintain a profit margin by which the supplier can remain in business.

To provide high-quality, safe, and affordable pet food, environmental-friendly ingredient sourcing must surely include rendered products. Recycling products that do not compete for human food resources and would otherwise be wasted and sparing the amount of extra ingredients and the land, water, and nutrients to produce them is the epitome of a sustainable process and essentially describes rendering.

A DESCRIPTION OF RENDERING

Rendering is one of the oldest forms of recycling and is the basis for improved sustainability of animal agriculture. Byproducts from food animal agriculture are rendered into many useful products. For instance, meat and bone meal, meat meal, poultry meal, hydrolyzed feather meal, blood meal, fish meal, and animal fats are some of the primary products resulting from the rendering process. The most important and valuable use for these animal byproducts is as feed ingredients for livestock, poultry, aquaculture, and companion animals. Without the rendering industry, the accumulation of unprocessed animal byproducts would impede the meat industries, add cost for disposal to the human food system, and pose a serious potential hazard to animal and human health (Meeker and Hamilton, 2006).

The North American rendering industry consists of more than 49 firms operating more than 180 plants across the United States and 20 in Canada (Informa Economics, 2011). It includes plants that are "integrated" with meat processing companies to process the "captive" byproducts generated by these firms, and it also includes "independent" renderers that are not directly owned or operated by meat processing companies but instead collect and process byproducts from many different sources, including livestock slaughter and processing facilities, grocery stores, restaurants, and other entities along the meat production chain. Animal byproduct materials have been used for centuries for use in items such as fertilizer, soap, and candles (Meeker and Hamilton, 2006). So-called "offal" is safely consumed in many countries around the world by humans. Historically, much more of an animal was consumed by humans with much less "waste" produced (Meeker and Hamilton, 2006). This animal offal (including viscera, heads, bone, blood, and other byproducts) is the primary raw material for rendering operations, with additional amounts coming from condemned or fallen animals, material generated from restaurants (such as fryer grease), grocery stores (such as bones, fat, and scrap from meat cutting or leftovers from the deli), and butcher shops. Not all of these materials are used in pet foods—some materials are legal and safe for pet food but are excluded because the consumer (purchaser) may see the items as unsavory. The products produced from the "inedible" (meaning not consumed by humans) raw material from animal agriculture make important economic contributions to their allied industries and society.

Raw materials destined for rendering vary in composition, but an overall approximation of content is 60% water, 20% protein and mineral, and 20% fat (Meeker and Hamilton, 2006). About 10 million t of

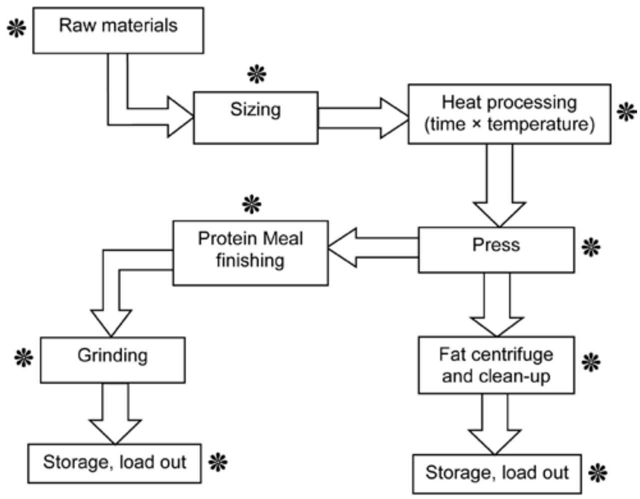

Figure 1. The rendering processes briefly described and its possible hazard control points (Meeker and Hamilton, 2006). Process control points are indicated by *.

rendered products are made annually in the United States and Canada with 31% of rendered proteins and 15% of rendered fats used as pet food ingredients (Informa Economics, 2011). These unprocessed raw materials are high in moisture, highly perishable, and laden with microorganisms as these raw materials are an ideal "growth medium." Some of the microorganisms are pathogenic and would be a hazard to both humans and animals. Rendering offers a safe and integrated system of animal raw material handling and processing that complies with all of the fundamental requirements of environmental protection and disease control. The resulting finished products are stable and more safely handled and stored (Aldrich, 2006).

Integrated renderers are estimated to process 48% of all raw materials, but their input stream consists entirely of animal byproducts produced by their affiliated meat packing plants. Of the 52% of all raw materials handled by independent renderers, 10% consists of restaurant grease, 7% is grocery/butcher scraps, and the remaining 83% is in the form of slaughter byproducts, such as viscera, fat, bone, feathers, or blood (Informa Economics, 2011). Across all species of livestock and poultry, approximately 938 million kg of food animals that die before slaughter are rendered, which amounts to 3.75% of the total raw material rendered (Informa Economics, 2011).

Rendering is a process of both physical and chemical transformation using a variety of equipment and processes (Fig. 1). All rendering processes involve the application of heat, the extraction of moisture, and the separation of fat. Like all technology, the rendering process has changed over the years and continues to improve. Modern rendering facilities are constructed to separate raw material handling from the processing and finished product storage areas to minimize opportunities for cross-contamination of finished products with raw materials. Process controls are applied and monitored to achieve cooking times and temperatures shown to inactivate specific microorganisms deemed to be food safety hazards. Temperatures far in excess of the thermal death time requirements are unnecessary and avoided because heavily denatured proteins are not as nutritious. Therefore, rendering processes in North America generally do not incorporate cooking under pressure except for feathers and other high keratin-containing tissues (Meeker and Hamilton, 2006) where hydrolyzation is necessary to make these types of proteins digestible.

Rendering is essential to public health, protecting the environment from excessive nutrients in inappropriate locations and protecting animal and public health by removing potential pathogens from the perishable byproducts. Rendering plants comply with a large number of federal, state, and local regulations to ensure clean air, clean water, and safe working conditions, in addition to food safety requirements (Franco, 2006). The availability of rendered products for animal feeds in the future depends on regulation and the market. If regulatory agencies put restrictions on animal byproducts for use in animal feed, structural shifts in rendering infrastructure will likely occur resulting in fewer rendering facilities, reduced or eliminated rendering services, and diminished supplies of ingredients and choices for the creation of animal feed. These shifts will be reflected in higher consumer prices for not only pet food but meats, poultry, and eggs as well. Pet food consumers' expectations, regardless of their origins, will also impact the use of certain raw materials, the economics of finding alternatives, and the overall sustainability of animal agriculture.

INDUSTRY PROGRAMS TO ENSURE THE QUALITY AND SAFETY OF RENDERED PRODUCTS

The rendering industry has an aggressive approach to animal food ingredient quality and safety. Nearly all renderers have quality and safety control systems in place via formal programs such as the rendering industry code of practice (National Renderers Association, 2014a). A concerted effort is made to foresee product safety hazards likely to occur and to prevent those occurrences. Testing is used to monitor and verify rendering processes are correctly operated and managed.

Temperatures between 115 to 146°C for an average of 40 min or more are used in the rendering process (Meeker and Hamilton, 2006). Troutt et al. (2001) sampled unprocessed animal byproducts at 17 different rendering facilities in each of 2 seasons. *Clostridium*

Table 4. Efficacy of U.S. rendering in the destruction of pathogenic bacteria (Troutt et al., 2001)[1]

Pathogen	Raw tissue, %[2]	Postprocess, %[2]
Clostridium perfringens	71.4	0
Listeria species	76.2	0
Listeria monocytogenes	8.3	0
Campylobacter species	29.8	0
Campylobacter jejuni	20.0	0
Salmonella species	84.5	0

[1]Samples from 17 different facilities taken during the winter and summer.

[2]Percent of positive samples found for specific pathogens out of the total samples collected.

perfringens, *Listeria* species, and *Salmonella* species were found in more than 70% of the samples taken before processing (Table 4). All samples taken after heat processing were negative for these and other pathogens. These data suggest the standard rendering process is effective for the control of pathogenic bacteria.

The rendering process is designed to control common feed bacterial and viral pathogens. The range of temperatures and times used in current rendering protocols in the United States and Canada were deemed sufficient to destroy the avian influenza virus (Leaphart et al., 2012). The temperature/time to kill porcine epidemic diarrhea virus as determined by the National Pork Board (2013) are well below that used in the rendering process. Heat treatment of 80°C is recognized by the European Union to inactivate many viruses including foot and mouth disease, classical swine fever, swine vesicular disease, African swine fever, avian influenza, Newcastle disease, rinderpest, and sheep and goat plague (EU, 2003). These data indicate that rendering is effective for the control of viruses.

THE RENDERING CODE OF PRACTICE

The Rendering Code of Practice was developed by a task force of renderers from the United States and Canada and was implemented in 2006 (North American Rendering Code of Practice, 2014b). The task force members represented a cross-section of livestock and poultry packer–renderers, independent renderers, and protein blenders. The intent of the program is to enhance the safety, quality, and reputation of rendered products by controlling biological, chemical, and physical hazards. Each rendering plant develops its own food safety plan based on the raw materials processed and the intended use of the products manufactured and is assessed by independent third-party auditors to check compliance with hazard analysis and critical control point principles. Process controls closely monitor, control, and record critical manufacturing processes such as cooking temperatures. Good manufacturing practices (**GMP**) are followed so that finished products are clean and safe (North American Rendering Code of Practice, 2014b). Animal food ingredients from rendered animal fats and recycled restaurant cooking oils are held from shipment pending negative tests for chemical and pesticide hazards that could have a likelihood of occurrence. Rendering plants use GMP to address these items: 1) product flow and traffic control to minimize cross-contamination; 2) raw material inspection; 3) preventive maintenance and calibration schedules and documentation; 4) procedures and schedule for cleaning and sanitation of equipment; 5) employee training on their role in safe feed; 6) procedures to assure the segregation and proper use of chemicals in the plant; 7) receiving, storage, loading, and shipping; 8) traceability and recall plans; and 9) pest control. By mid 2014, more than 117 rendering plants representing approximately 95% of the rendering processing capacity in the United States and Canada were certified in the Rendering Code of Practice (National Renderers Association, 2014a).

BIOGENIC AMINES

Breakdown and decay of animal byproducts begins immediately after slaughter. Biogenic amines are organic bases of low molecular weight that exhibit biological activity and are usually produced by decarboxylation of AA or by amination and transamination of aldehydes and ketones during decomposition (Geornaras et al., 1995). Toxicity due to biogenic amines in animal diets has been suggested as a risk because various degrees of spoilage in raw materials before rendering are inevitable. However, research in broilers showed performance was not reduced and there were no significant gross intestinal lesions or histopathological changes evident when fed diets containing twice the amounts of biogenic amines likely to occur in rendered products (Bermudez and Firman, 1998; Friday and Firman, 1999). Histamine is the biogenic amine of greatest concern in pet food and is more common in fish meal than poultry and mammalian rendered protein meals (Radosovich, 2006). Therefore, biogenic amines are not likely to be a hazard in animal food ingredients derived from modern rendering where their formation is limited by the prompt processing or preservation of raw materials. In fact, biogenic amines have been shown to be stimulating to appetite and gut development in low doses (Edwards, 2013).

ANIMAL FOOD REGULATION

The Food Safety Modernization Act (**FSMA**) was signed into law January 4, 2011, and provides the U.S.

Food and Drug Administration (**FDA**) with sweeping new authorities (Government Printing Office, 2011). It authorizes the FDA to promulgate new rules for preventive controls and develop performance standards and creates new administrative detention rules and and provides authority for mandatory recall of adulterated products and the hiring of more than 4,000 new field staff among other provisions. The FDA is proceeding with rulemaking to meet the new law's regulation deadlines. A consent decree that the FDA agreed to in court sets the deadline for the final rules for animal food preventive controls as August 30, 2015 (Oxman, 2014). The FSMA provides framework for a shift in regulatory philosophy by placing the principal focus on prevention of hazards that can pose a risk to human or animal health. The rendering industry has a long history of using preventive measures to produce safe products and has long understood the responsibility for manufacturing safe animal food products. The rendering industry welcomes this shift in regulatory focus provided it is reasonable and flexible in implementation.

The animal food, rendering, and other ingredient industries are now working with the FDA to assist in writing training materials and guidance documents to ensure the efficient industry adoption of the new regulations, which are expected to be similar to and reach the same goals as previous voluntary animal food safety industry programs. The industry is already meeting and exceeding many of the likely new rules due to FSMA, which shows that the industry is already very proactive through the code of practice and third-party audits.

RENDERED PRODUCTS AND ANIMAL NUTRITION

The main requirements in the diets of animals are protein, energy, and minerals. Rendered animal products are an excellent source of all 3 (Meeker and Hamilton, 2006). Rendered protein meals such as meat meal, meat and bone meal, poultry meal, poultry byproduct meal, and fish meal are widely used in pet foods (Aldrich, 2006). Generally, rendered products provide high-quality protein with a good balance of AA (Table 5).

Nutrient availability and/or dietary utilization can be hampered by excessive heat treatment, dilution of essential AA with connective tissue, high levels of ash, and oxidation (Aldrich, 2006). To address these issues, renderers use processing and marketing options to better target appropriate end uses for these materials.

Rendered fats and oils such as tallow, lard, poultry fat, and fish oil provide a supplementary source of energy, flavor, texture, and nutrients in pet foods (Aldrich, 2006). Whereas energy is commonly derived from the carbohydrates in grain, animal fats provide a concentrated source of calories (Table 6) and remain more stable and palatable than the more unsaturated vegetable oils (Edwards, 2013).

Table 5. Total protein and AA content (%) of rendered meat products compared to soybean meal (U.S. Pork Center of Excellence, 2010)

Component	Soybean meal	Meat and bone meal	Meat meal	Blood meal (spray dried)	Plasma proteins (spray dried)
DM	89	96	96	93	91
Protein	44.0	52.8	56.4	88.8	78.0
Lysine	2.83	2.76	3.29	7.45	6.84
Threonine	1.73	1.62	1.89	3.78	4.72
Methionine	0.61	0.72	0.87	0.99	0.75
Cysteine	0.70	0.51	0.52	1.04	2.63
Tryptophan	0.61	0.36	0.43	1.48	0.36
Isoleucine	1.99	1.54	1.92	1.03	2.71
Valine	2.06	2.28	2.60	7.03	4.94
Arginine	3.23	3.55	3.58	3.69	4.55
Histidine	1.17	0.98	1.29	5.30	2.55
Leucine	3.42	3.17	3.71	10.81	7.61
Phenylalanine	2.18	1.74	2.00	5.81	4.42
Tyrosine	1.69	1.16	1.37	2.71	3.53

Minerals are important in all animal diets for the formation of bone and cartilage as well as the normal function of organs, blood, and muscles. The most important macrominerals, calcium and phosphorous, are essential minerals for dogs and cats and are readily available in rendered products. Phosphorus is also the most important mineral in agriculture in general as it is essential for plant, animal, and bacterial life forms. Phosphorus has no substitute in animal food (Ashley et al., 2011). The high availability of phosphorus in rendered products is another contribution to sustainability because phosphate rock is nonrenewable and is running out worldwide (Edwards, 2013). Ingredients such as meat and bone meal with naturally occurring calcium and phosphorus are superior to meat for some diets, and their use reduces the requirement for additional minerals to obtain the same nutrient profile.

DIGESTIBILITY OF RENDERED PRODUCTS

Modern rendering processes, improved equipment, and computer-monitored systems have resulted in significant improvements in the digestibility of animal proteins. Data collected from 1984 to 2001, during an era when many rendering plants were retrofitted with modern continuous flow cookers, demonstrate the digestibility improvements in the essential AA of lysine, threonine, tryptophan, and methionine due to new

Table 6. Energy value of rendered animal products, soybean meal, wheat, and corn (Hazzledine, 2008)[1]

Component	Corn	Wheat	SBM	MBM	BM	PM	FM	Tallow
ME poultry, MJ/kg	13.75	13.00	10.00	10.70	12.20	13.90	12.00	34.00
DE pig, MJ/kg	14.30	14.00	14.90	11.70	18.00	17.00	14.50	33.50
NE pig, MJ/kg	11.18	10.61	8.25	6.84	6.27	11.37	7.29	29.88

[1]SBM = soybean meal; MBM = meat and bone meal; BM = blood meal; PM = poultry meal; FM = feather meal.

Table 8. Amino acid digestibility (%) in pigs of selected rendered proteins and soybean meal (AMI Pig, 2000 **[AU: please add reference for AMI Pig, 2000, to Literature Cited or remove the citation]**)

Amino acid	Soybean meal	Meat and bone meal	Blood meal	Poultry meal	Feather meal
Lysine, %	92	84	86	77	65
Threonine, %	88	82	85	76	78
Tryptophan, %	92	80	88	69	72
Methionine, %	93	86	85	80	71
Isoleucine, %	91	84	86	81	86

technology (Bisplinghoff, 2006). These data are summarized in Table 7. Lysine digestibility in high-quality meat and bone meal improved from 65 to over 87% during this time period. Dramatic improvements in the digestibility of tryptophan and threonine have also been documented (Table 7). Similar improvements in AA digestibility have taken place in all rendered products so that the digestibility of poultry meal, feather meal, and blood meal are near that of soybean meal (Table 8). The rendering industry, through the Fats and Proteins Research Foundation, Inc. (Alexandria, VA), continues to do research to improve the consistency, quality, and safety of rendered products. The results of recent digestibility experiments suggest that differences exist in the digestive capabilities of different species and different ages within the same species, which indicates species-specific nutrient digestibility values or adjustments may be needed for best estimates of nutrient availability (Adedokun et al., 2007, 2014; Rojas and Stein, 2013).

AMERICAN ASSOCIATION OF FEED CONTROL OFFICIALS DEFINITIONS OF PET FOOD INGREDIENTS

A voluntary membership association of state, federal, and international regulatory officials including the FDA, the Association of American Feed Control Officials (**AAFCO**; Champaign, IL) sets guidelines and definitions for animal feed, including pet foods. The AAFCO works to develop and implement uniform and equitable laws, regulations, standards, definitions, and enforcement policies for state laws regulating the safe production and labeling of animal feed, including pet food. The FDA and the AAFCO work together to establish definitions to describe new feed ingredients and to update long-standing definitions as needed. Each year, the AAFCO publishes an official document that includes a model feed bill for states to promote consistent regulation of feed products and a list of accepted feed ingredients. Most states have adopted all or part of the model feed bill and allow feed ingredients listed in the publication to be used in their jurisdictions (AAFCO, 2014).

Table 7. Digestibility (%) of select AA in meat and bone meal from 1984 to 2001

Amino acid	1984[1]	1989[2]	1990[3]	1992[4]	2001[5]
Lysine, %	65	70	78	84	87
Threonine, %	62	64	72	83	86
Tryptophan, %	–	54	65	83	88
Methionine, %	82	–	86	85	88

[1]Jorgensen et al. (1984)**[AU: please add reference for Jorgensen et al. (1984) to Literature Cited or remove the citation]**.

[2]Knabe et al. (1989).

[3]Batterham et al. (1990).

[4]Firman (1992).

[5]Stein et al. (2001).

The AAFCO defines the composition of all legally used feed ingredients including rendered animal products in some detail, but contracts between renderers and pet food manufacturers often dictate much more specific terms and quality attributes. The AAFCO *2014 Official Publication* (AAFCO, 2014) defines approximately 125 individual animal byproducts (43 distinct definitions with species specificity bringing the number to 125). The primary animal protein byproducts are meat and bone meal, meat meal, blood meal, poultry byproduct meal, poultry meal, feather meal, and fish meal. Using meat and bone meal as an example, the AAFCO defines this material as the rendered product from mammalian tissues including bone but exclusive of any added blood, hair, hoof, horn, hide trimmings, manure, stomach and rumen contents, except in such amounts as may occur unavoidably in good processing practices. Meat and bone meal, as defined by the AAFCO, must contain a minimum of 4% phosphorus with a calcium level not to exceed 2.2 times the actual phosphorus level. Ingredients of lower phosphorus content must be labeled meat meal.

CONSUMER AWARENESS AND PET FOOD

Rumors and urban legends distributed in social media by people with little firsthand knowledge and no supporting data offer inaccurate, and even disgusting, descriptions of rendering and pet food ingredients. It is very possible this has increased customer sensitivity about certain words on pet food labels such as "byproduct" and could lead to concern about some rendered ingredients that could diminish the sustainability of pet food manufacturing.

Investigative journalist, author, and dog advocate Ted Kerasote visited rendering plants in 2009 as part of his research for a book about the impact of dog food on the longevity of dogs. He was trying to observe for himself "…whether the rendered products so many kibbles contain, such as meal made from beef, chicken, lamb, fish, or bones, are in fact safe" (Kerasote, 2013, p. 194). Kerasote acknowledged that society needs rendering because it reduces meat byproducts and animal carcasses to usable materials rather than dumping in landfills or using vast amounts of energy and contributing to air pollution after incinerating these materials. Kerasote said, "There would be no modern meat industry without rendering, because the leftovers of slaughterhouses would soon overwhelm landfills and create an enormous health hazard as billions of tons of organic waste rotted. Instead, rendering recycles these wastes into valuable products" (Kerasote, 2013, p. 194). He also said, "I could certainly see that there was not a hint of a dog or a cat going into any of these products" (Kerasote, 2013, p. 203).

Most pet food companies screen raw materials for pentobarbital and other barbiturates to ensure that euthanized pets were not part of the materials that went into the rendered products used as ingredients, but very low levels of these drugs can occasionally be found in pet food (FDA, 2002). In an analyses of a wide variety of pet foods purchased at retail (Bren, 2002), FDA results showed that no dog, cat, or horse DNA were present in their sampling. Researchers at the FDA further concluded that the low levels of pentobarbital that dogs might receive through such food are unlikely to cause any adverse health effects and that further research on that theoretical risk was unnecessary.

MARKET CHOICES IMPACT SUSTAINABILITY

A multiplicity of market choices is welcomed by most, and the pet food market is particularly suited for a wide range of prices and perceived qualities. Some people can afford human food for their pets or they can afford pet food that contains only those ingredients perceived as higher quality. Those choices likely will not improve the overall sustainability of pet food but as long as lower-priced options are available, byproducts can continue to be used in the most sustainable manner. To maximize sustainability and allow for full use of meat animals, all byproducts proven safe should be allowed in pet food, and the market should allow people to choose products that fit their needs and sensitivities. Marketing and advertising emphasizing transparency and accurate nutritional and quality information rather than demonizing competitors for the use of byproducts could likely encourage more sustainable choices by consumers purchasing pet food. The National Advertising Review Board (NARB, New York, NY) recently determined advertisements challenged in court conveyed the unsupported message that major pet food companies were misleading their customers by actively concealing the truth about the ingredients in their products and representing their products as being of high quality when they are not because they include lesser quality ingredients such as chicken byproduct meals and corn gluten. The NARB recommended that the advertisements be changed to avoid misleading consumers by implying competitors' products are less nutritious because they include chicken/meat byproduct meal or other ingredients (Watt Pet Food Industry, 2014). Byproducts are as safe and nutritious as other ingredient. Pet food safety should not be a market choice and basic standards of safety should be required of all available products.

CRITICAL PROBLEMS WITH ALTERNATIVE DISPOSAL METHODS

If byproducts from food animal production are not used as food for animals, most would likely be disposed by means other than rendering. The value of the byproducts as animal food makes the collection and processing of them sustainable. Alternative methods of disposal would not result in high-value animal food ingredients, thus leading to a decrease in the sustainability of food animal production as well as the sustainability of pet food.

The rendering industry provides services for the safe collection of animal byproducts and mortalities; transports the materials in biosecure, leak-proof trucks; and uses heat in a cooking process to dehydrate and separate the fat and solid materials. The rendering process not only yields safe animal food ingredients but also removes potential biohazards and environmental threats because typical pathogens are destroyed rapidly by processing at lethal temperatures (Hamilton et al., 2006). Most alternative disposal methods do not include these added safeguards as well as providing usable products.

As a general rule, the cost of disposal of animal byproducts and/or animal mortalities rises in inverse proportion to the environmental impact of the disposal options chosen. The cheapest disposal methods, including burial, abandonment, and low-investment composting, are seldom safe because the disposal conditions do little to kill or contain pathogens, have a high potential of contaminating groundwater, and attract wildlife and vermin (Hamilton et al., 2006). The rendering process provides a means to break disease cycles that could continue via the more inappropriate disposal alternatives (Hamilton et al., 2006). It also allows carbon sources to be captured instead of contributing to greenhouse gases (**GHG**). To follow is a brief description of some of the problems with alternative disposal methods.

Composting

Interest in using on-farm composting for the disposal of animal byproducts and mortalities is growing because the practice is perceived to be simple and economical. However, properly designed and managed compost sites are complex and management intense and require significant capital investments (Gale, 2002; Hamilton et al., 2006). Simply covering mortalities in manure is not true composting. As a result, many attempts at on-farm composting fail because such sites tend to be poorly managed and are not constructed to prevent or contain runoff and protect the environment and are very similar to simple abandonment. Large-scale composting of meat byproducts results in a relatively low-value product of fertilizer and does not decrease the considerable GHG emissions of decomposition.

Burial

Although it is one of the most widely used alternative disposal methods, burial creates the greatest risk to human health and the environment because of the potential for ground and surface water contamination if strict guidelines are not followed (Hamilton et al., 2006).

Landfills

Space is the most apparent limitation to disposing of animal materials in landfills. Whereas rendering and incineration dehydrate the materials to reduce volume, amendments such as sawdust must be added to animal materials before landfilling to accommodate their high water content, which increases volume (Hamilton et al., 2006). In addition, some national landfill operators no longer accept unprocessed animal materials that cannot be used in feed because they do not want to deal with the biological risk.

Incineration

Because of the high temperatures used, incineration is a biologically safe method if done properly in an approved mortality incinerator. However, current incineration capacity is inadequate (Hamilton et al., 2006). Construction of new incinerators requires significant capital investments and is difficult to permit because of air quality issues. The amount of fuel required and the air pollution issues makes incineration an unsustainable process for byproduct disposal.

Alkaline Digestion

Alkaline digestion is an effective and relatively new technology that uses heat and alkaline conditions to inactivate conventional pathogens. However, alkaline digesters have limited capacity, produce large quantities of effluent that must be disposed, and are limited in number (Gwyther et al., 2011).

RENDERING POSES FEWER POTENTIAL RISKS TO PUBLIC HEALTH

Following their experiences with bovine spongiform encephalopathy and foot and mouth disease, the United Kingdom Department of Health evaluated various methods of animal mortality disposal for potential risks to public health (Mitchell, 2001). Compared with landfills and burial, disposal methods that involved heat processing, such as rendering and incineration, were more effective at controlling biological hazards, including food pathogens (such as *Escherichia coli*, *Listeria*, *Salmonella*, and *Campylobacter*), organisms that cause diseases (such as anthrax, botulism, leptospirosis, bovine tuberculosis, plague, and tetanus), and surface and ground water pathogens (*Cryptosporidium* and *Giardia*). Rendering alone minimized the potential health risks to chemical hazards such as dioxins and hydrogen sulfide as well as emissions of sulfur oxides and nitrogen oxides. Feeding animals is a better use for byproducts, or a more valuable contributor to sustainability use on the food recovery hierarchy described by the U.S. Environmental Protection Agency (Food Waste Reduction Alliance, 2014).

RENDERING'S CARBON FOOTPRINT

Rendering was shown to be an important GHG avoidance technology (Gooding, 2012). Through the rendering process, inedible wastes that are rich in carbon and nitrogen are recycled into useable materials. The rendering process also averts the release of carbon dioxide and other GHG that would otherwise be released into the air through the normal decomposition process. Rendering is the most efficient and environmentally sound disposal alternative.

Table 9 lists the main classes of rendered products manufactured in the United States and the percent of carbon content and shows a total of more than 17 million t of CO_2 emissions avoided per year since these products are rendered into useful products. If all carbon in these products were expressed as CO_2, using the EPA's 2014 estimate (EPA, 2014a) for average emissions of 4.75 t per car, failure to remove these products from the waste stream would be the same as adding 3.6 million cars to the nation's roads.

If 20% of the carbon in decaying organic material is expressed as methane and 10% of the nitrogen (Table 10) is expressed as nitrous oxide (Gooding, 2012), then removing these products from the waste stream (because these GHG have global warming potentials that are substantially greater than CO_2) would be the same as removing 14.2 million cars from the nation's roads. Even though cooking these high-moisture materials is an energy-intensive process, it is energy well spent; for each metric ton of CO_2 produced (scope 1 emissions) by operating rendering plants, 5.68 t of CO_2 are removed from the environment (Gooding, 2012).

Table 9. Carbon removed in the form of rendered products (Gooding, 2012)

Product	Production, t	Carbon content, %	Carbon, t	CO_2, t
Animal fat	4,515,600	75.89	3,426,889	12,566,516
Meat and bone meal	2,314,600	24.27	561,661	2,059,629
Poultry byproduct meal	1,153,500	28.68	330,801	1,213,057
Feather meal	600,900	37.50	225,350	826,364
Pork meal	720,711	25.59	184,427	676,300
Blood products	102,512	37.50	38,444	140,976
Total all products	9,407,823		4,767,571	17,482,842

RENDERING REDUCES THE NEED FOR VIRGIN SOURCES

If rendered materials are removed from pet food, the sources will have to be replaced with other fat and protein sources. If these sources are virgin-use sources, they will require additional water, land, fertilizer, and other resources. This drastically affects the sustainability of pet food. Using human-grade meat as a replacement simply requires more meat to be produced while still requiring a need to use rendered material. Other popular protein sources, such as soybean meal, typically contain approximately 44 to 48% protein, whereas rendered products range from meat and bone meal at 55% protein to blood meal, which is 90% protein. It would require an extremely large amount of soybeans to be planted to replace just this one factor in a pet food diet, not taking into account other nutritional factors such as minerals. Using rendered ingredients reduces the pet food industry's dependence on virgin-use ingredients.

WHAT MORE COULD BE DONE?

Nearly all byproducts from commercial food animal slaughter, including offal, fat, and carcass trimmings, are rendered, but 4.3% is landfilled and 1.2% is composted. The volume of slaughter byproducts fluctuates with commercial meat production. Because this source is the biggest contributor of rendering raw materials, the supply of rendered animal food ingredients is dependent on meat production (Informa Economics, 2011). As meat production increases to meet global demand, rendering byproducts should be chosen over less sustainable disposal options.

Byproducts generated from butcher shops, grocery stores, and other facilities that perform the final processing steps for meat amounts to 857,000 t, but this is just 70% of the total volume of meat, poultry, and seafood loss generated at the retail level. Most of the balance is presumed to be disposed in landfills or composted (Informa Economics, 2011). If retail firms were to separate all meat products from other wastes and direct them to rendering, these unwanted food items could be put to better use, increasing sustainability.

"Fallen animals" or livestock that die outside of slaughter facilities amount to only 3.75% of all rendering raw material (Informa Economics, 2011). Approximately 60% of the cattle that die each year in the United States are not rendered but buried, deposited in landfills, or otherwise left to decompose (Informa Economics, 2011). In the most recent USDA comprehensive study of beef cattle death loss, 1.7 million cattle and 2.3 million calves were lost to all causes during 2010 (USDA, 2012). In 2007, more than 520,000 dairy cattle died on farms (USDA, 2007). Assuming an average weight of 270 kg for beef cattle, 446 kg for dairy cattle, and 45 kg for calves,

Table 10. Nitrogen removed in the form of rendered products (Gooding, 2012)

Product	Production, t	Protein, %	N, t
Meat and bone meal	2,314,600	55	203,685
Poultry byproduct meal	1,153,500	65	119,964
Feather meal	600,900	85	81,722
Pork meal	720,711	58	66,882
Blood products	102,512	85	13,942
Total protein meals	4,892,223		486,195

approximately 477,000 t of cattle material are not used via rendering annually. Based on GHG measurements taken from composting studies, adding 1 t of cattle carcasses to a compost pile would result in 2 t of CO_2 equivalents (Xu et al., 2007). The resulting release of CO_2 emissions from cattle not already rendered is approximately 954,000 t per year. Using the EPA's 2014 estimate (EPA, 2014a) for average emissions of 4.75 t per car, providing incentives to render these additional cattle would equate to taking an additional 200,842 cars off the road each year. Methane and nitrous oxide gases are also emitted during the decomposition process, which makes the total GHG impact much higher. Additional gains in sustainability could be made by rendering a higher percentage of swine and poultry that die on farms. A robust and efficient fallen animal collection system beyond what renderers can now economically provide could further enhance the sustainability of food animal production by reducing the amount of GHG released with no benefit. A dependable market with high values for byproducts from fallen animals would provide financial incentives to redevelop this collection system.

SUMMARY AND CONCLUSIONS

Meat consumption by humans increases as median income rises. Byproducts from meat production are inevitable and responsible use is imperative. The byproducts from food animal production can be rendered into safe and nutritious pet food ingredients. Feeding animals is a greater value use for byproducts than other alternative uses such as energy or fertilizer; therefore, feeding byproducts to animals improves the sustainability of the industries from which the byproducts are derived.

The AAFCO has come under increased pressure from activists in recent years to ban certain raw materials from pet food for aesthetic and emotional reasons rather than nutritional, environmental, or safety concerns rooted in science. If the AAFCO and/or the FDA chose to ban some or all of the current food animal production byproducts from the approved animal feed ingredient list, an increased amount of food suitable for humans would have to be used in the manufacture of pet food. This in turn would raise the price of many pet food products, raise the price of food for people (likely impacting poor people more than affluent people), and force more byproducts into less sustainable uses or less environmentally friendly disposal endpoints. There would be negative environmental impacts as more hectares of crop land, water, fertilizer, and other inputs would need to be engaged to feed both people and pets, greatly undercutting the sustainability of animal agriculture, the meat industry, and the pet food industry, and valuable byproduct would be wasted.

Underused byproducts have the same impacts on the environment and sustainability as wasted food. If rendered ingredients are not used in pet food, virgin-use ingredients will have to be increased. This is not sustainable from an environmental point of view as it requires a large amount of additional inputs and wastes materials that already exist. For long-term sustainability of pet food manufacturing, decisions to exclude certain byproducts for reasons other than food safety should be revisited.

Most people will agree pets (dogs and cats) are higher on the food chain than livestock and animals produced for food. Many would agree that some materials could be excluded from dog and cat foods even if those excluded products are rendered safe by cooking and screening processes. New definitions for preferred ingredients could be developed to accommodate customer preferences regarding such exclusions, but the sustainability of the entire food chain would be lessened if products of lower preference were to be banned by regulation or legislation. There should be a place in low-priced pet food or livestock feed for ingredients that have nutritional value and are safe for animals. Consumer information and marketing materials should include the positive impact the use of byproducts in pet food has on sustainability.

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