

Enhancing Consumer Knowledge of Animal Products and Grains in Cat and Dog Foods

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ABSTRACT

Pet owners are growing increasingly interested in understanding the ingredients in cat and dog food to make informed decisions about their pets' nutrition. To support this interest, the Cornell Animal Science website will provide information beyond what is covered in this article, utilizing well-researched and credible sources. The project aims to educate pet owners, helping them confidently navigate the evolving landscape of pet food ingredient options.

Chapter 1 examines the use of animal products in pet food, beginning with clarifying the origins of animals used in foods and addressing the sustainability and nutritional safety of animal byproducts. Definitions of raw and rendered animal products according to AAFCO guidelines are provided, including a distinction between raw ingredients and raw products. This chapter also includes examples of raw and rendered animal products and byproducts as they appear in real ingredient lists and offers a nutrient comparison to further illustrate their benefits in pet food.

Chapter 2 explores the factors driving the increasing popularity of grain-free diets. It clarifies the primary allergens commonly found in cats and dogs, categorizes the carbohydrate sources in pet foods, and offers examples of grain-free and grain-inclusive labels. This chapter also discusses the functional benefits of cereal and pulse grains, and tuber vegetables.

In a rapidly evolving pet food market, where the misconception of animal byproducts and grain-free diets are increasingly shaping consumer choices, this project serves as a resource for pet owners to make well-informed decisions by bridging the understanding of ingredient sources and their roles in pet food.

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LIST OF ABBREVIATIONS

AAFCO	Association of American Feed Control Officials
AVMA	American Veterinary Medical Association
CDC	Centers for Disease Control and Prevention
FDA	Food and Drug Administration
FD&C Act	Federal Food, Drug, and Cosmetic Act
FMIA	Federal Meat Inspection Act
FSIS	Food Safety and Inspection Service
NARA	National Animal Renderers Association
NRC	National Research Council
NFE	Nitrogen-Free Extract
PPIA	Poultry Products Inspection Act
USDA	United States Department of Agriculture

CHAPTER ONE

Chapter 1: Animal Products in Cat and Dog Foods

1.1 Introduction

Animal byproducts in cat and dog foods play an essential and often underappreciated role in pet nutrition. These ingredients, which include nutrient-rich organs, bones, and trimmings, are not only safe but offer significant health benefits for pets. However, pet owners' opinions about these byproducts reflect a diverse range of perspectives, often influenced by their understanding of these ingredients and their considerations for pet health and ethics. Many pet owners may not fully realize the significant nutritional benefits that byproducts can offer, leading to some confusion about their quality and safety. For example, a survey conducted by Connolly, Heinze, and Freeman (2014) found that 49.1% of pet owners view animal byproducts as a valuable component of pet food, recognizing their role in providing essential nutrients. This indicates a growing awareness but also highlights the opportunity to further enhance understanding of how byproducts contribute to a balanced and nutritious diet for pets.

Byproducts are not mere fillers; in many cases, they are nutrient-dense sources of vitamins, minerals, and proteins. These ingredients contribute to the sustainability of the pet food industry by ensuring that valuable animal resources are fully utilized, thereby minimizing waste and supporting environmental sustainability. This approach not only benefits the planet but also helps pet owners feel confident that they are making responsible and beneficial choices for their pets and the environment.

This chapter will explore the various sources of animal products used in commercial cat and dog food, emphasizing the positive impact of byproducts both nutritionally and environmentally. It will also highlight the rigorous standards and regulations that ensure the safety and quality of these ingredients. Through a deeper understanding of these aspects, pet owners can feel assured that they are providing their pets with high-quality nutrition that supports both their pets' health and the well-being of the planet.

1.2 Sources of Animal Products in Commercial Cat and Dog Food Products

The United States Department of Agriculture (USDA) plays an important role in ensuring the safety and quality of animal products consumed by both humans and pets. Facilities that process swine, cattle (including beef, veal, and culled cows), sheep (lamb and mutton), and goats are subject to mandatory inspection under the Federal Meat Inspection Act (FMIA), overseen by the USDA's Food Safety and Inspection Service (FSIS). Similarly, facilities that process domesticated poultry—such as chickens, turkeys, ducks, geese, guineas, ratites, and squab—are subject to inspection under the Poultry Products Inspection Act (PPIA), also mandated by USDA FSIS. These inspected animal products are commonly found in supermarkets, butcher shops, and delis, which also serve as sources for ingredients in cat and dog food (USDA, 2024; U.S. Department of Agriculture, Food Safety and Inspection Service, 2023; Ockerman et al., 2006).

On the other hand, certain food animals are not required to undergo mandatory federal inspection, with Congress designating their inspection as voluntary. These animals include buffalo, antelope, reindeer, elk, deer, migratory waterfowl, game birds, and rabbit, with voluntary inspections conducted under the Agricultural Marketing Act. However, some states require inspection under their laws before these products can be sold (USDA, 2024).

The Federal Food, Drug, and Cosmetic (FD&C) Act prohibits the use of animals that are diseased or have perished through means other than slaughter in pet food, deeming such products adulterated and unlawful for production, marketing, or distribution. Animals that are deceased or disabled are not permitted to enter USDA-inspected slaughterhouses in the first place, and any animal parts rejected from human consumption must be processed to remove harmful bacteria prior to inclusion in cat and dog food products. Dispelling common misconceptions, no animal products in pet food are sourced from euthanized cats or dogs, or animals from zoos and shelters (Food and Drug Administration 2017, 2021).

These regulations are in place to ensure that the pet food industry upholds rigorous standards throughout sourcing, processing and distribution to protect the health and safety of pets while maintaining the quality of the food supply chain.

1.3 Cultural Significance and Use of Animal Byproducts in Cat and Dog Food Products

There is often a misunderstanding among pet owners regarding what constitutes animal byproducts. In many cases, byproducts are nutritious, but misconceptions can sometimes cause hesitation and concern. In 2023, the U.S. meat industry generated over 106.9 billion pounds of red meat and poultry; notably, more than half of each processed animal is not consumed by humans (Shagam, 2024; Vidyarthi, 2021). This excess includes edible byproducts such as organs, bones, and muscle tissue trimmings, which are essential components of animal-derived food products. When included in cat and dog foods, these organs—often referred to as variety meats—are rich in nutrients such as proteins, vitamins and minerals. Their inclusion offers significant health benefits, contributing to a more balanced and complete diet.

Despite their nutritional value, some pet owners perceive animal byproducts as low-quality or undesirable ingredients, often associating the term with poor nutrition or the inclusion of non-meat parts that may be harmful. However, many animal byproducts already contribute to a variety of familiar human foods. For instance, rennet is an enzyme extracted from the stomach of veal and plays a crucial role in the milk curdling process during cheesemaking (Marti, Johnson, & Mathews, 2011). Gelatin, derived from collagen protein of cattle and pig bones, cartilage and skin, is valued for its gelling and blending properties in the manufacturing of many food items, such as marshmallows and ice cream. Similarly, sausages are encased using either "natural" casings or collagen casings. Natural casings are sourced from the small intestines of animals such as beef, sheep, and swine, while collagen casings, which are also edible, are made from the hides of cattle or swine (FSIS, 2024).

Organs such as kidneys, tongue, liver and brains are minimally processed and enjoyed in various cuisines and culinary traditions around the world who have long embraced the versatility

and nutritional value of these variety meat products. For example, Asian dishes frequently feature pork hocks, pork tails and chicken feet (Marti, Johnson, & Mathews, 2011). In Mexico, menudo, a soup made with tripe, enjoys widespread popularity. Scotland's national dish, haggis, combines the liver, heart, and lungs of sheep, while the traditional French-Canadian dish, cheese head, utilizes meat from pork heads or hocks (Britannica, 2024). Calf's brains, or 'cervelle de veau,' are traditional delicacies in Europe, Quebec and Morocco. Sweetbreads, a traditional component of French cuisine, can be prepared from the thymus gland, pancreas, parotid and sublingual glands, ovaries or testicles. Each year, Potterville in Michigan hosts their gizzard festival (Potterville Gizzard Fest Committee, 2020). Finally, the traditional "feijoada," a Brazilian delicacy, includes pig ears, trotters, and tails (Nollet & Toldra, 2011).

When pet food labels list "poultry byproducts" or "animal byproducts" as ingredients, they refer to the same nutritious components that many cultures enjoy seeing on their plate. In addition to animal and poultry byproducts, various muscle tissues from the animal carcass defined as "meat" or "poultry" in the listing of ingredients on pet food labels constitute an important portion of cat and dog food products. Below, the official definitions of "meat" and "poultry" as they appear in the ingredient lists are provided, along with their respective compositions.

1.4 Raw vs Rendered Animal Products

The ingredients in any commercially manufactured pet food must be listed on the label, following guidelines established by the Association of American Feed Control Officials (AAFCO, 2023). The AAFCO is an independent organization that provides guidelines for state, federal and international feed regulators in order to ensure consistency and safety throughout manufacturing.

Animal products used in pet food manufacturing are either fresh (defined as "raw" by AAFCO) or rendered. Fresh animal products are predominantly used in canned pet foods, which benefit from their high moisture content. In contrast, rendered products have a lower fat content and are dry, making them ideal for use in dry foods (i.e., kibbles). The rendering process entails cooking animal byproducts to remove water and fat, followed by drying and grinding the remaining protein-rich product into a "meal." During this process, the extracted fat is purified, and its quality carefully assessed prior to its incorporation into pet food formulations. Each year, the US rendering industry transforms 56 billion pounds of animal byproducts into 18.2 billion pounds of proteins and fats (Vidyarthi, 2021).

With the global population projected to exceed 9.5 billion by 2050, the demand for food is projected to rise by over 70% (Meeker and Meisinger, 2015). The rendering industry plays a crucial role in addressing this growing demand by recycling meat byproducts into valuable feed ingredients for cats, dogs and other animals. This sustainable practice not only minimizes waste and landfill contributions but also transforms potential waste into essential resources. By reducing environmental impacts and supporting the need for growing global food demands,

rendering offers a practical and necessary solution for a more efficient food production cycle and sustainable future (NARA, 2024).

Unless the packaging of a product is specifically labeled as raw, all commercially produced complete pet foods—whether canned (moist), semi-moist or dry—are cooked during manufacturing to eliminate harmful bacteria such as Salmonella, E. Coli and Listeria (Meeker and Meisinger, 2015). This processing step is essential to meet regulatory standards that ensure the final pet food product is free from contaminants that could pose health risks to pets. Similar to food preparation for human consumption, this cooking process can lead to the degradation or loss of certain vitamins and minerals due to thermal leakage. To compensate for this, synthetic vitamins and minerals, which are the same as those used in human foods, are often added to pet foods to ensure pets receive a balanced diet (Godoy, Amaya-Farfan, & Rodriguez-Amaya, 2021; Czerwonka and Szterk, 2015).

Unlike their cooked counterparts, raw and freeze-dried pet food products available on the market are not subjected to the same cooking or processing methods and do not fall under the same regulatory oversight (AVMA, 2024; U.S. Food and Drug Administration, 2018; Centers for Disease Control and Prevention, 2024). These raw products are marketed as fresh or frozen and sold in their natural, uncooked state. They include raw or freeze-dried meats, bones, vegetables, and other ingredients that are intended to be consumed by pets without prior heat treatment. Because these products are not cooked to eliminate pathogens, they carry a higher risk of contamination with bacteria. Consequently, strict handling and storage practices are extremely important to minimize the risk of foodborne illnesses. Consumers who opt to feed their pets raw or freeze-dried diets must be diligent about maintaining cleanliness and proper refrigeration to ensure the safety of their pets and household members.

1.5 Official Definitions of Raw Animal Product Ingredients

Officially recognized raw animal product ingredients defined by AAFCO fall into one of these four categories: meat, meat byproducts, poultry and poultry byproducts. Though termed “raw,” they are cooked during manufacturing to eliminate harmful pathogens.

Meat: Meat is limited to cattle, pigs, sheep, or goats. If the meat originates from any other mammal, such as buffalo or rabbit, that species must be clearly identified on the ingredient listing. For non-mammalian sources, like poultry or fish, an appropriate identifying term must be specified. For instance, if "poultry" is listed, it can refer to either chicken or turkey. Conversely, if strictly chicken is used, the identifying term “chicken” can be used. To be defined as meat, the tissue must originate from striated muscle tissues and other muscle tissues such as the tongue, diaphragm, heart, or esophagus. Depending on the muscle cut, fat, skin, vessels and other tissues that normally accompany muscle may be included.

Meat byproducts: Meat byproducts refer to the other parts of the mammals beyond muscle tissue, such as a range of organs, tissues and bones. Specific organs include lungs, spleen, liver, tripe, kidneys, brain, blood, and stomachs and intestines emptied of contents and thoroughly

cleaned. As mentioned earlier, many pet owners associate the term byproducts with the inclusion of non-meat parts like beaks, feathers, or hooves, which they believe could be harmful or less nutritious for their pets. Animal hair, horns, teeth, and hoofs are not allowed. Similar to meat, if the byproducts originate from mammals other than cattle, pigs, sheep, or goats, the species must be specified. A specific meat byproduct may be listed on its own. Liver is a common meat byproduct appearing on its own in ingredient listings.

Poultry: Poultry refers to the flesh and skin obtained from either chickens or turkeys. Less valuable portions of the bird, such as backs and necks, may be included, while feathers, heads, feet, and entrails are excluded. Poultry may or may not include bones. If bones are removed, it may be termed “deboned.”

Poultry byproducts: Poultry byproducts may include heads, feet, and organs from either chicken, turkey or both, but exclude feathers. Parts such as heads and feet contain structural proteins such as collagen and keratins that are processed to improve their digestibility

1.6 Official Definitions of Rendered Animal Product Ingredients

Rendered products fall into one of five categories: meat meal, meat and bone meal, animal byproduct meal, poultry byproduct meal, and poultry meal. Rendering is the practice of removing most of the water and fat through heat and pressure, leaving behind protein and minerals. The end product is ground into a consistent size known as “meal.” All rendered products have been cooked prior to being supplied to pet food manufacturers.

Meat Meal: Meat meal is the rendered form of meat derived from mammalian tissues. Unlike fresh meat, meat meal can be sourced from any mammal, and the specific species does not need to be stated on the label. Typically, this implies sources like swine, cattle, sheep, or goat. However, meat meal may also include other mammals such as buffalo, antelope, reindeer, elk, deer, and rabbit; non-food animals are prohibited.

Meat and bone meal: Meat and bone meal adhere to the same regulations as meat meal but include bones, and therefore contain higher levels of minerals, particularly calcium and phosphorus.

Animal byproduct meal: Animal byproduct meal follows the same regulations as meat meal but also includes bones and additional byproducts, such as organs, that are not found in meat meal or meat and bone meal.

Poultry byproduct meal: Poultry byproduct meal comprises the ground, clean carcasses from slaughtered poultry. Components may consist of necks, feet, undeveloped eggs, and intestines. Feathers are excluded, except for trace amounts that may unavoidably occur due to good processing practices.

Poultry Meal: Poultry meal is the dried product from clean flesh and skin. It is the rendered version of the “poultry” ingredient. While the inclusion of bones may be optional, it excludes feathers, heads, feet.

1.7 Raw and Rendered Animal Products in Ingredient Lists

The following are examples of partial ingredient lists from cat and dog food products, with AAFCO defined raw and rendered animal products bolded. Some ingredients have been omitted from the lists to focus on the most relevant information and maintain the anonymity of the brands.

Example 1. Canned Cat Food Ingredients: **Ocean Whitefish, Poultry By-Products, Meat By-Products, Liver**, Water, **Fish, Tuna**, Rice, Artificial And Natural Flavors, Guar Gum, (rest of ingredients omitted).

In this ingredient list, all animal products fall under fresh (raw) products. No rendered products are listed. **Liver** is a fresh meat byproduct, and **meat byproducts** include fresh organs, as described earlier. Poultry byproducts include fresh organs and may include feet and necks. The **ocean whitefish, fish** and **tuna** are from non-mammalian species and therefore must be listed by their specific names (e.g., "fish" or "tuna") rather than being categorized as "meat" or "meat by-products" under AAFCO guidelines.

Example 2: Dry Cat Food Ingredients: **Chicken**, Whole Grain Wheat, Corn Gluten Meal, Powdered Cellulose, Chicken Fat, Wheat Gluten, **Chicken Meal**, Chicken Liver Flavor, Dried Beet Pulp, Fish Oil, Potassium Chloride, Green Peas, Apples, Cranberries, Carrots, Broccoli, (rest of ingredients omitted).

Here, **chicken** is a fresh (raw) ingredient consisting of flesh, skin and bones strictly from chicken, and **chicken meal** consists of rendered flesh, skin and bones strictly from chicken.

Example 3: Canned Wet Dog Food Ingredients: Water Sufficient for Processing, **Chicken, Pork Liver, Chicken By-products, Pork By-products**, Corn Meal, Brewers Rice, Brewers Rice Flour, **Salmon**, Powdered Cellulose, Dried Plain Beet Pulp, (rest of ingredients omitted).

In this ingredient list, **chicken** is classified under poultry. **Pork liver** and **pork byproducts** are categorized as meat byproducts, similar to how **chicken by-products** are categorized as poultry byproducts. The inclusion of **salmon**, a non-mammalian protein source, must be listed by its specific name, in accordance with AAFCO guidelines.

Example 4: Dry Dog Food Ingredients: **Deboned Chicken, Chicken Meal**, Brown Rice, Oatmeal, Barley, Pea Protein, Peas, Chicken Fat (preserved with Mixed Tocopherols), **Fish Meal** (source of Omega 3 Fatty Acids), Dried Egg Product, (rest of ingredients omitted).

In this final example, **deboned chicken** is a fresh (raw) ingredient consisting solely of flesh and skin from chicken, without any bones, and is classified as meat. **Chicken meal**, on the other hand, is made from rendered flesh, skin, and bones exclusively from chicken.

These examples illustrate the use of various fresh (raw) and rendered animal products, including byproducts, in cat and dog foods. Whether fresh or rendered, they are excellent sources of proteins and important sources of fats. The fats may come directly from fresh ingredients or be added as a derived ingredient from rendered animal products. Table 1 outlines the nutritional components of commonly added raw and rendered animal products, including byproducts, to underscore that rendered products and byproducts can offer nutritional value as high or higher than that of raw meat and poultry.

1.8 Table 1. Nutrient Comparison of Protein, Fat, Minerals (Ash), Calcium and Phosphorus per 100g in Raw and Rendered Poultry, Meat, and Byproducts.

	Protein (g)	Fat (g)	Ash (g)	Calcium (mg)	Phosphorus (mg)
Chicken, Deboned (Raw)	38	49	4	1.21	0.81
Chicken Meal (Rendered)	62	14	21	6.84	4.03
Chicken Liver (Raw, Byproduct)	72	21	5	0.03	1.26
Chicken Byproduct Meal (Rendered, Byproduct)	68	15	16	3.79	1.89
Beef, Deboned (Raw)	37	58	5	1.19	0.8
Meat Meal (Rendered)	72	14	11	3.23	1.98
Beef Liver (Raw, Byproduct)	70	12	5	1.71	1.32
Beef Byproduct Meal (Rendered, Byproduct)	57	15	25	8.02	3.94

Note: The water content of the raw products was adjusted to calculate nutrients on a dry-matter (water-free) basis.

As demonstrated in the table, rendered products can offer a higher protein concentration compared to their raw counterparts. For instance, chicken meal contains 62 grams of protein per 100 grams (62%) of product, with a fat content of 14 grams (14%). In comparison, raw deboned chicken provides 38 grams of protein (38%) and 49 grams of fat (49%) per 100 grams. This illustrates how the rendering process effectively concentrates protein by reducing moisture and fat content. Similarly, chicken byproduct meal, which is rendered, offers 68 grams of protein (68%) and 15 grams of fat (15%) per 100 grams, whereas raw chicken liver, a byproduct, contains 72 grams of protein (72%) and 21 grams of fat (21%) per 100 grams (FoodDataCentral, 2019).

A similar pattern is observed in beef products. Raw deboned beef contains 37 grams of protein (37%) and 58 grams of fat (58%) per 100 grams. In contrast, meat meal provides 72 grams of protein (72%) and 14 grams of fat (14%) per 100 grams of product, reflecting the efficiency of the rendering process in concentrating nutrients (Choi, Won, & Kim, 2021). Beef byproduct meal also shows a high nutrient density, with 57 grams of protein (57%) and 15 grams of fat (15%) per 100 grams, compared to 70 grams of protein (70%) and 12 grams of fat (12%) in raw beef liver (Urriola et al., 2017; USDA, 2019).

In addition to the differences in protein and fat content, the mineral composition of these products also varies. Rendered products generally have a higher ash content, which is indicative

of greater mineral concentration. For example, chicken meal has an ash content of 21 grams per 100 grams, which includes 6.84 mg of calcium and 4.03 mg of phosphorus. In comparison, raw deboned chicken has only 4 grams of ash, with significantly lower levels of calcium (1.21 mg) and phosphorus (0.81 mg). Similarly, chicken byproduct meal provides 3.79 mg of calcium and 1.89 mg of phosphorus, compared to the much lower 0.03 mg of calcium and 1.26 mg of phosphorus in raw chicken liver. Beef products follow this trend as well; meat meal contains 11 grams of ash, with 3.23 mg of calcium and 1.98 mg of phosphorus, while raw deboned beef has 5 grams of ash, with 1.19 mg of calcium and 0.8 mg of phosphorus. Beef byproduct meal is particularly rich in minerals, offering 8.02 mg of calcium and 3.94 mg of phosphorus, compared to the 1.71 mg of calcium and 1.32 mg of phosphorus in raw beef liver.

Many pet owners prefer to purchase pet foods labeled as containing “chicken” or “beef” ingredients, believing these to be of higher quality. They might choose to avoid byproducts or rendered products entirely. However, this table clearly illustrates that byproducts and rendered products are excellent sources of protein and minerals. The rendering process not only enhances nutrient density but also ensures that valuable animal products, which exceed the demand for human consumption, are efficiently utilized, providing essential proteins and fats in pet food formulations. This approach reflects the pet food industry’s commitment to producing safe, nutritious, and sustainable foods.

1.9 Conclusion

To summarize, various raw and rendered animal products, including byproducts, play an integral role in the formulation of commercial cat and dog foods. Contrary to common misconceptions, byproducts are vital sources of essential nutrients, contributing to a balanced diet for pets. The USDA’s rigorous inspection processes ensure that only safe and high-quality animal products are used in pet food, whether sourced from inspected facilities or through voluntary state inspections. Furthermore, the rendering process significantly enhances the nutrient density of animal products, making efficient use of resources and supporting sustainability efforts by minimizing waste. Byproducts, in particular, help reduce waste by making use of parts of the animal that might otherwise be discarded, appealing to those concerned with sustainability and reducing environmental impact. Ultimately, the inclusion of these animal products in pet food not only meets the nutritional requirements of pets but also aligns with broader environmental sustainability goals.

CHAPTER TWO

Chapter 2: Roles of Grains in Cat and Dog Foods

2.1 Introduction

In recent years, the growing trend of grain-free diets for cats and dogs reflects a shift in pet owners' perceptions and concerns regarding traditional pet food ingredients. More owners are turning to grain-free diets due to concerns about potential grain sensitivities, allergies, and a desire to feed their pets a diet perceived as more natural or aligned with the ancestral diets of wild canines and felines. The popularity of grain-free diets has sparked a debate about their nutritional adequacy and the role that grains play in pet nutrition.

Traditionally, grains such as wheat, rice, and corn have been staples in pet food formulations, valued for their high starch content, which provides a readily available source of energy and contributes to the structural integrity and appeal of wet and dry foods. In contrast, grain-free diets often substitute these cereal grains with alternative carbohydrate sources, such as pulses (legume grains) and tubers. These alternatives are used to maintain the necessary starch levels but bring their own challenges in terms of digestibility and nutrient absorption.

This chapter explores the roles that grains and their alternatives play in pet food, comparing their nutritional contributions, digestibility, and impact on overall pet health. Real-world examples of grain-free and grain-inclusive diets will be examined to clarify common misconceptions and provide a deeper understanding of how these ingredients influence the formulation of cat and dog foods. The discussion also includes the environmental and sustainability aspects of using grains versus grain-free alternatives, as well as the implications for pet health and diet-related concerns among pet owners.

2.2 The Rise of Grain-Free Diets

In the United States, annual expenditure on cat and dog food reflects the special role pets play in our households, with an estimated 65.1 million households with at least one dog and 46.5 million households with at least one cat in 2023 (Statista, 2022). Alongside the growing number of pet-owning households and rising interest in pet nutrition, the pet industry has broadened its focus on offering specialized diets.

A growing movement toward grain-free diets has emerged, driven by concerns about potential grain sensitivities and allergies (Beynen, 2014). However, environmental factors are the most common culprits behind allergies in cats and dogs, with dust mites, flea bites, outdoor pollen, and molds lurking indoors and outdoors as the top environmental allergy triggers (Dopierała, 2019; Mueller, 2015). In reality, food allergies affect less than 1% of cats and dogs (Verlinden, 2007). Of the food allergens, beef, dairy and chicken are the most common for dogs, while beef, fish and chicken top the list for cats (Mueller et al., 2016).

As a result of these concerns about grain sensitivities and allergies, pet owners are increasingly discerning in their choices of pet food. Those who follow grain-free or special diets themselves or those who believe grains are unhealthy for their pets are more likely to select

grain-free options (Banton et al., 2021). Marketing claims such as “no fillers” and “no byproducts” can also sway consumer decisions, further fueling the grain-free diet movement.

2.3 Cereal Grains and Cereal-Grain Alternatives in Cat and Dog Foods

Grains are fundamental components in the formulation of cat and dog foods, primarily due to the benefits of their high starch content. Starches are a complex carbohydrate and can make up a significant proportion of cereal grains, ranging from 50 to 70% of the weight depending on the specific grain. They serve as essential structure-forming components due to their physicochemical properties and provide a sustained source of energy for pets. While grain-free pet food products sound devoid of all grains, they typically only exclude cereal grains such as wheat, rice, corn, barley, oats, rye, triticale, millet, and sorghum (Beynen, 2014; Hui, 2005).

These formulations replace cereal grains with pulses (legume grains) and tuber vegetables that provide alternative sources of necessary starches. However, legume grains typically contain around 47% starch, compared to the 50-70% found in cereal grains. To compensate, many formulations include not only pulses but also tubers and purified starch sources such as tapioca starch, potato flour, or cornstarch. Tubers are particularly rich in starches, containing between 61% and 77% starch on a dry weight basis (Hui, 2005; USDA FoodData Central).

Common legume grains incorporated into grain-free foods are lentils, dried beans, peas and chickpeas. These pulses are also rich in proteins, fibers, vitamins and minerals (Asif et al., 2013), but the type of fibers in pulses can reduce nutrient digestibility and cause gastrointestinal issues such as gas and bloating (Quilliam et al., 2023). Therefore, it is important to carefully limit their inclusion levels. On the other hand, cereal grains have a notably high digestibility, largely due to their composition and how they interact with the digestive enzymes in cats and dogs. Studies have shown that cereals like rice and corn exhibit superior digestibility for key nutrients such as protein, starch and energy when compared to pulses (De-Oliveira et al., 2008). Both cereal and legume grains are often processed into flour or meal to enhance their accessibility to digestive enzymes, thereby facilitating better nutrient absorption.

Tuber vegetables such as potatoes, sweet potatoes, yams and cassava, are frequently integrated into grain-free pet food formulations. These tubers are valued for their starch content and the additional vitamins and minerals they offer. However, their nutrient content can vary depending on the specific part of the tuber used and the processing methods applied. Tapioca, a starch extracted from cassava, is often included in these diets due to its purity and high starch concentration, though it is low in fiber and micronutrients compared to the whole cassava (Shewry, 2003).

In summary, grains play a crucial role in the formulation of cat and dog foods due to their high starch (carbohydrate) content, which serves as a primary source of energy and essential structure-forming components. Cereal grains are highly digestible and are a readily available source of energy in pet foods. Conversely, grain-free diets often replace cereal grains with pulses

and tuber vegetables, which can present challenges in digestibility and nutrient absorption. Pulses typically contain less starch and may reduce nutrient digestibility due to their fiber content. Tubers contribute more starch than pulses but the nutritional value of these alternatives can be affected by processing methods, which may reduce their vitamin and mineral content. Although processing methods like grinding, splitting, and pre-cooking can improve digestibility, they may not match the nutrient density or digestibility of whole cereal grains. This necessitates careful consideration when formulating diets to meet the nutritional needs of pets.

2.4 Benefits of Starches

Starches are key components of pet food formulations, accounting for one-third of dog food ingredients and a quarter of cat food ingredients (Alvarenga and Aldrich, 2020). As pet owners increasingly seek grain-free options, manufacturers are turning to various alternatives to cereal grains. These alternatives often need to provide similar starch levels to maintain the consistency and performance of traditional grain-inclusive diets (Beynen, 2014). Starches play essential roles in pet foods, contributing to their overall quality and appeal to both the pet and owner (Hui, 2005):

1. **Texture, Structure, and Binding:** Starches act as thickeners, stabilizers, and gelling agents, helping to achieve the desired texture and consistency. They function as the "glue" that binds ingredients together, preventing separation and ensuring uniform texture. In wet foods, even small amounts of starches and other carbohydrates are essential for binding ingredients, such as keeping meaty chunks intact.
2. **Moisture Retention:** Starches help retain moisture in foods, preventing them from becoming too dry or tough during cooking. This is particularly important for maintaining the right texture in dry foods and ensuring that canned meat products remain moist and tender.
3. **Crust Formation:** Starches contribute to the formation of a crispy outer crust or coating, providing a barrier that helps seal in moisture while providing a crunchy texture in dry food products.
4. **Flavor Release and Color:** Starches can serve as carriers for flavors and colors of foods, enhancing the food's taste and appearance. Browning reactions during cooking produce rich flavors and appealing golden-brown hues, creating that enticing aroma when you open a bag of pet food.
5. **Retrogradation Inhibition:** Retrogradation inhibition in cat and dog foods involves using certain starches or additives to prevent the firming up of cooked starches over time, thereby maintaining the food's softness, freshness, and appealing texture for longer periods. This process enhances the shelf life and quality of pet foods, making them more enjoyable for pets to eat.
6. **Freeze-Thaw Stability:** Starches contribute to the stability and quality of frozen pet foods. They help prevent the formation of ice crystals, maintaining a smooth texture upon thawing and protecting the food from texture degradation and quality loss.

2.5 Cats and Dogs Can Process and Utilize Starch

There is a common misconception that cats and dogs are strict carnivores or carnivorous and should, therefore, not be fed diets containing carbohydrates. While cats and dogs are carnivorans, meaning that they are members of the *Carnivora* taxonomic order, their dietary evolution differs. Domestic cats have indeed evolved as carnivores, primarily consuming animal-based diets, while domestic dogs have adapted over nearly 30,000 years to be omnivores. Thus, while dogs are classified as *carnivorans*, they are not strictly carnivorous (Bradshaw, 2006).

Despite their carnivorous evolution, cats are capable of metabolizing starch. Although cats do not require starch in their diet as long as their protein intake is sufficient for glucose production through a process known as gluconeogenesis, they can still metabolize starches at levels commonly found in commercial dry cat food products (Laflamme, 2022). Their habit of eating frequent, small meals allow them to effectively digest starch in small quantities. Moreover, cats possess some pancreatic amylase, which is necessary for digesting small amounts of glycogen naturally found in muscle tissues and liver. This same enzyme is also used to break down dietary starches.

Dogs, on the other hand, have evolved to possess higher levels of pancreatic amylase, making them more efficient at digesting starch and absorbing glucose, regardless of meal size. This evolutionary adaptation allows dogs to better utilize starches as a significant energy source, which is reflected in their ability to thrive on diets that include a variety of plant-based ingredients (Axelsson, 2013).

The life expectancy of both cats and dogs has increased due to advancements in veterinary medicine and nutrition (Saad, França, Aquino, & Saad, 2011). Starch-containing ingredients have been integral to dry pet food formulation since its inception, contributing to nutritional improvements that enhance health and longevity of both cats and dogs.

2.6 Grain-Free and Grain-Inclusive Label Comparisons

Grain-free does not mean carbohydrate-free or low-calorie. In fact, grain-free foods can sometimes contain as many or more carbohydrates and calories compared to grain-inclusive options. Below are real examples of grain-free and grain-inclusive cat and dog food products, along with their ingredient lists, highlighting the sources of carbohydrates and which grain-inclusive or grain-free category they fall under. Some ingredients have been omitted from the lists to focus on the most relevant information and to protect the anonymity of the brands.

Example 1: Grain-free dry cat food. Chicken, Turkey, Menhaden Fish Meal, **Peas**, **Chickpeas**, Ocean Whitefish Meal, Herring Meal, **Lentils**, Coconut Oil, Natural Flavor, Pumpkin, Sunflower Oil (Preserved with Mixed Tocopherols), Dandelion Greens, Chicken Liver, Chicken Neck, **Potatoes**, **Tapioca**, Salt, (rest of ingredients omitted).

Pulses: Peas, Chickpeas, Lentils

Tubers: Potatoes, Tapioca

Calories: 3,700 kcal/kg

Carbohydrate content: 28%

Example 2: Grain-inclusive dry cat food. Wild-Caught Pacific Salmon, Menhaden Fish Meal, **Brown Rice, Peas, Milo**, Coconut Oil, Ocean Whitefish Meal, Natural Flavour, **Lentils**, (rest of ingredients omitted).

Cereal grains: Brown Rice, Milo

Pulses: Peas, Lentils

Calories: 3,500 kcal/kg

Carbohydrate content: 35%

In example 1, the grain-free dry cat food does not contain any cereal grains but contains pulses like peas, chickpeas, and lentils, and tubers such as potatoes and tapioca. In example 2, the grain-inclusive dry cat food includes cereal grains such as brown rice and milo, along with pulses such as peas and lentils. The energy content of the grain-free cat food is 3,700 kcal/kg and that of the grain-inclusive cat food is 3,500 kcal/kg. Both products have high carbohydrate contents of 28% and 35%, respectively.

Example 3: Grain-free wet cat food. Water, Salmon, Chicken, Poultry By-Products, Animal Plasma, **Tapioca Starch**, Glycine, Potassium Chloride, Fish Oil, Choline Chloride, (rest of ingredients omitted).

Tuber: Tapioca Starch

Calories: 941 kcal/kg

Carbohydrate content: 2%

Example 4: Grain-inclusive wet cat food. Turkey Broth, Turkey, **Wheat Gluten**, Meat By-Products, Liver, Chicken, **Corn Starch-modified, Soy Flour**, Glycine, Salt, Natural Flavor, Tricalcium Phosphate, Taurine, (rest of ingredients omitted).

Starch source: Corn Starch-modified

Legume: Soy Flour

Calories: 832 kcal/kg

Carbohydrate content: 2.8%

In both examples 3 and 4, the inclusion of starch containing ingredients is much lower compared to dry food products. A smaller amount of starch is needed for thickening and adding viscosity to

canned products compared to the starch needed for expansion and structure formation of dry kibbles. The carbohydrate content in the wet cat food is much lower compared to the dry food.

Example 5: Grain-free dry dog food. Chicken, **Yellow Peas**, **Potatoes**, **Potato Starch**, Chicken Meal, Chicken Fat, Pea Protein, Chicken Liver Flavor, Dried Beet Pulp, Soybean Oil, Flaxseed, Egg Product, Pork Flavor, Calcium Sulfate, Potassium Chloride, **Green Peas**, (rest of ingredients omitted).

Tubers: Potatoes, Potato Starch
Pulses: Yellow Peas, Green Peas
Calories: 3,763 kcal/kg
Carbohydrate content: 48%

Example 6: Grain-inclusive dry dog food. Chicken, **Cracked Pearled Barley**, **Whole Grain Wheat**, **Whole Grain Corn**, **Whole Grain Sorghum**, Corn Gluten Meal, Soybean Meal, Chicken Fat, **Brewers Rice**, Chicken Liver Flavor, Chicken Meal, Dried Beet Pulp, Soybean Oil, Pork Flavor, Lactic Acid, Calcium Carbonate, Flaxseed, Potassium Chloride, Choline Chloride, Riboflavin Supplement, Biotin, Oat Fiber, Mixed Tocopherols for freshness, Natural Flavors, Beta-Carotene, Apples, Broccoli, Carrots, Cranberries, **Green Peas**, (rest of ingredients omitted).

Cereal grains: Cracked Pearled Barley, Whole Grain Wheat, Whole Grain Corn, Whole Grain Sorghum, Brewers Rice
Pulse: Green Peas
Calories: 3.657 kcal/kg
Carbohydrate content: 54%

Similar to examples 1 and 2 for the dry cat food products, the grain-free and grain-inclusive products contain large concentrations of carbohydrates of 48 and 54%, respectively, with grain-free containing more energy than the grain-inclusive products. Note here that the dog dry food products contain notably larger concentrations of carbohydrates than the cat dry food products shown in examples 1 and 2.

Example 7: Grain-free wet dog food. Salmon, Fish Broth, Redfish, Turkey, Turkey Liver, Vegetable Broth, Mackerel, **Chickpea Flour**, Sunflower Oil, Tuna, Cod, **Dried Sweet Potatoes**, Flaxseed Meal, (rest of ingredients omitted).

Pulse: Chickpea Flour
Tuber: Dried Sweet Potatoes
Calories: 1171 kcal/kg
Carbohydrate content: 4.18%

Example 8: Grain-inclusive wet dog food. Chicken, Chicken Broth, Chicken Liver, **Brown Rice Flour**, **Barley**, Dried Egg Product, Salmon Oil, (rest of ingredients omitted).

Cereal Grains: Brown Rice Flour, Barley

Calories: 1,210 kcal/kg

Carbohydrate content: 4.01%

In examples 7 and 8, the grain-free wet dog food contains a pulse and a tuber that contribute to a carbohydrate content of 4.18%. The grain-inclusive wet dog food incorporates cereal grains, resulting in a slightly lower carbohydrate content of 4.01%. The energy content of the grain-free option is 1,171 kcal/kg, while the grain-inclusive food provides a slightly higher energy content of 1,210 kcal/kg. Both options have relatively low carbohydrate percentages compared to dry foods. This example illustrates that grain-free wet dog foods can sometimes have similar or even higher carbohydrate levels compared to their grain-inclusive counterparts.

2.7 Conclusion

This chapter has explored the roles that grains and their alternatives play in the formulation of cat and dog foods, shedding light on the complexities surrounding grain-free and grain-inclusive diets. Traditional grains like wheat, rice, and corn have long been valued in pet food for their high starch content, which not only provides a source of energy but also contributes to the texture and stability of foods. In contrast, grain-free diets, which often rely on pulses and tubers as alternative starch sources, present unique challenges related to digestibility and nutrient absorption. While these alternatives can provide necessary carbohydrates, they do not always match the digestibility and nutritional efficiency of traditional cereal grains, leading to potential concerns about the overall adequacy of grain-free formulations. It is important to note that both cats and dogs can effectively utilize starches (carbohydrates) in their diets, although their digestive efficiency can vary.

The review of real-world examples of grain-free and grain-inclusive pet foods demonstrates that grain-free options are not necessarily lower in carbohydrates or calories. In fact, the carbohydrate content in grain-free diets can be similar to or exceed that of grain-inclusive diets, depending on the formulation. Moreover, environmental and sustainability factors related to the use of grains versus alternatives highlight the importance of carefully evaluating the ingredients used in pet food to ensure that they meet the nutritional needs of pets while also considering broader environmental impacts.

Ultimately, while grain-free diets may appeal to pet owners concerned about grain sensitivities or looking to mirror their pets' perceived ancestral diets, it is crucial to understand that grains play an essential role in providing balanced nutrition for cats and dogs. The choice between grain-free and grain-inclusive diets requires a thorough understanding of the nutritional benefits and potential drawbacks of each, ensuring that pet foods are formulated to support the health and well-being of pets.

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