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Palatability and digestibility studies for pet foods

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Complete and balanced (complete) pet food is designed to provide all the nutritional needs of the pet in one product. When it comes to formulating complete and balanced pet food and assuring nutritional adequacy, pet food manufacturers in the US can follow the nutritional profiles set by The Association of American Feed Control Officials (AAFCO).[1] In Europe, complete nutritional guidelines have been published by the European Pet Food Association (FEDIAF).[2] Both AAFCO and FEDIAF nutrient profiles have global recognition. While formulating to meet the nutrient requirements of the pet is the first step to manufacturing a high-quality pet food, it is also important to ensure that the pet is willing to eat the food and that they digest and utilize the nutrients contained in the food. Palatability and apparent digestibility tests are not required by AAFCO and FEDIAF but should be considered when developing a new pet food recipe, particularly when incorporating new ingredients (**Box 1**).

Palatability tests can be used to assess the acceptability of a particular pet food and can also be used to compare preference between two pet foods. There are no standardized palatability test methodologies defined by AAFCO or FEDIAF; however, relevant protocols are available and published. Acceptability of a product is typically tested using a monadic palatability test consisting of offering one pet food at a time and comparing the amount eaten to the pet's daily needs or consumption of a reference product over the same time duration. Preference is typically tested by feeding two products at the same time and noting which product is consumed significantly more by weight. Ensuring palatability is an important part of producing a high-quality pet food.

Apparent digestibility studies determine total digestibility (dry matter digestibility) and digestibility of key nutrients including protein, fat, carbohydrates, and fiber. These tests can be used to assess a pet's ability to break down and absorb nutrients from the pet food. If a pet food has a low apparent digestibility (e.g., protein digestibility below 80%), it should have increased nutrient levels above the minimum guidelines in order to ensure adequate availability of each nutrient.

Of Note

- The acceptance or palatability of a pet food can be assessed to ensure pets will consume enough food to meet their nutritional and energy needs.
- Since some nutrients can affect the availability of other nutrients, a feeding test, such as a digestibility study, can be used as part of ensuring a pet food is high quality.

In general, highly digestible foods can be fed at lower amounts than less digestible foods and still help ensure nutrient availability to the pet. However, it is important to note that undigestible fiber is important for gut health, so even the highest quality pet food will not be 100% digestible.

AAFCO has the option to declare if an apparent digestibility test (referred to as a Metabolizable Energy Protocol) has been completed on a product by using "as fed" in the Calorie content statement or by making claims that the product is highly digestible. In addition, manufacturers can voluntarily declare results of their digestibility trials.

AAFCO animal feeding tests are not the same as an "apparent digestibility" study. In AAFCO, the nutritional adequacy statement can be used to determine if the pet food is complete and balanced. The statement "animal feeding tests using AAFCO procedures substantiate that X product provides complete and balanced nutrition for cat/dog growth/maintenance" will be included if there has been completion of a maintenance or growth trial (6-month duration for maintenance and 10 weeks for growth). Manufacturers may complete an AAFCO animal feeding test, an apparent digestibility test, or both on a given diet.

Box 1. Key terminology

- Palatability is defined as being agreeable or acceptable to the palate. It aligns with the preferences of the individual.
- Palatability test is a method utilized to assess the acceptance or preference of an individual for a product.
- Digestibility test is a method utilized to assess the apparent absorption (digestibility) of a specific nutrient or nutrient category (e.g., protein) absorbed by an individual. It may also be predicted.
- Digestibility refers to the amount of a specific nutrient or nutrient category (e.g., protein) absorbed by an individual.
- Apparent digestibility is the percentage of the difference between the amount of a specific nutrient or nutrient category (e.g., protein) ingested from a product and the amount of the same specific nutrient or nutrient category in the feces after digestion.

Fecal scoring is another parameter that can be easily assessed in a digestibility study. Fecal scores can be used to ensure good tolerance of the product when fed as well as provide basic insights into the gut health of the pet. The Nestlé Purina fecal score chart can be found at: https://www.purinainstitute.com/sites/default/files/2024-02/fecal-chart.pdf. The aim is to have firm feces without too much hardness.

Neither palatability tests nor apparent digestibility tests will tell you about the ability of the pet food to support growth or long-term health maintenance of a pet. Since apparent digestibility tests are used to assess nutrient groups, they do not provide insights into each individual essential nutrient, such as amino acids or essential fatty acids. However, when a diet meets the AAFCO or FEDIAF nutrient profiles (i.e., the pet food is complete and balanced), combined with the fact that the manufacturer performs palatability and digestibility tests, it can provide reassurance that the food will provide pets with the nutrients they require, pets will consume the food readily, and pets can digest and absorb the nutrients in the pet food.

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The benefits of canned and dry pet food

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Extrusion and retort processing have been widely used in pet food manufacturing since the early to mid-20th century. The extrusion process, adapted from the human food industry, was first introduced for pet food in the 1950s by the Ralston Purina Company. Researchers Jim Corbin and Joe Vandepopuliere developed the first expanded dog food using this method. Retort processing, on the other hand, was applied even earlier—in the 1920s, shortly after World War I—when P. M. Chappel, a horse trader from Rockford, Illinois, began canning horse meat and selling it through pet shops in the U.S.[1,2] Pet food innovation has come a long way since then, but these thermal processing methods have become foundational to the development of the current pet food industry. Pet food manufacturing is a complex process and subject to at least 40 different federal regulations to assure food safety.[3] Understanding how these technologies work—and how they contribute to pet food safety and nutritional quality—is crucial for anyone involved in pet food manufacturing, pet health providers, and pet owners.

Extrusion is primarily used in the production of complete and balanced dry kibble pet foods and treats. The process begins with the mixing of raw materials—typically a blend of meat meals, cereal grains or other carbohydrate sources (e.g., potatoes, pulses, tubers), vitamins, and minerals—into a homogenous dough. At the preconditioner, water and steam are added to achieve the desired consistency and facilitate cooking. At this stage, fresh meats and animal fat or vegetable oils can also be added. The preconditioned dough is then fed into an extruder (single or twin screw), where it is subjected to high temperature (typically 100–150°C) for a short period of time (<1 minute), pressure, and mechanical shear. Inside the extruder, the food undergoes gelatinization of starches, partial protein denaturation, and anti-nutritional and microbial inactivation. Upon exiting the die, the sudden drop in pressure causes the product to expand and form its characteristic shape. A drying and cooling stage follows to remove moisture and stabilize the product (target moisture lower than 10%), and finally, fats and palatability enhancers are often sprayed on the surface of the product prior to final packaging.[4]

Of Note

- Extrusion and retort are well-established manufacturing methods that are essential to the pet food industry due to their cost-effectiveness, scalability, versatility, and ability to ensure food safety.
- Extrusion is used in the production of complete and balanced dry pet food and some treats. Extrusion can improve digestibility and make nutrients more accessible, and it includes a step to eliminate pathogens.
- Retort processing is used for wet pet foods, and produces a sterile and palatable product. Wet food supports hydration for dogs and cats.

Extrusion improves digestibility by breaking down complex carbohydrates and denaturing proteins, making nutrients more accessible to enzymatic digestion and more bioavailable to animals. The process also enables the production of a wide range of products with varied shapes, textures, and bulk densities, offering customization options based on processing parameters and hardware design. For example, different die formats can be used to create shapes that influence food preference, aid in prehension for brachycephalic animals, or slow down food intake for pets that tend to eat too quickly. The crunchy texture of extruded products can also support dental health through mechanical action, providing a toothbrush-like effect. As a thermal process, extrusion includes a critical kill step that effectively eliminates pathogenic microorganisms such as *Salmonella* spp., *Listeria monocytogenes*, and *E. coli*, resulting in a shelf-stable product with minimal contamination risk. Additionally, extrusion is a high-throughput, versatile process that allows for the precise inclusion of heat-sensitive nutrients (e.g., vitamins and minerals)

post-extrusion. Co-extrusion technology can also be leveraged for the creation of multi-textured, multi-colored and multi-flavored products within a single piece—offering even greater flexibility in pet food product development.

Retort processing is typically used for wet pet foods. In this method, ingredients are pre-cooked, filled into containers (e.g., metal cans, trays, or pouches), sealed, and then heat-treated in a retort chamber using steam or hot water under pressure. This process is akin to pressure cooking and operates at temperatures above 121°C and pressure between 15 and 20 psi. The goal is to achieve commercial sterility, eliminating biological hazards (e.g., *C. botulinum*) and ensuring that the product is safe for long-term storage without refrigeration. Time and temperature are carefully controlled to eliminate microbial contaminants while minimizing nutrient degradation.[5] In the U.S., wet pet food is regulated as low-acid canned foods and must follow Title 21, Code of Federal Regulations (CFR), Part 108 and 113 that apply for human food in hermetically sealed containers.[6,7]

Retort processing offers several advantages in pet food manufacturing. One of its key benefits is the retention of high moisture content, which enhances palatability and supports hydration—especially important for pets with low water intake. While some heat-sensitive nutrients, such as B vitamins, may degrade during thermal processing, formulations are typically adjusted to compensate for these losses. The sealed environment also minimizes oxidation, helping preserve fats and vitamins more effectively. In terms of physical properties, retort-processed foods maintain a moist, meat-like texture that is highly palatable and ideal for pets with dental issues, reduced appetites, or special hydration needs. Similarly to extrusion, the high-temperature sterilization step ensures food safety, allowing for a long shelf life without the need for chemical preservatives—making retort an essential technology for producing safe, nutritious, and convenient wet pet foods.

Overall, extrusion and retort are well-established manufacturing methods that are essential to the pet food industry due to their cost-effectiveness, scalability, versatility, and ability to ensure food safety. Compared to newer technologies like high-pressure processing (HPP) and freeze-drying, extrusion is ideal for producing shelf-stable, nutritious dry kibble and treats with appealing texture and convenience, whereas retort processing is better suited for high-moisture, palatable products that closely mimic the texture of fresh meat. Emerging technologies face several challenges, including high operational costs, lower energy efficiency, lack of a thermal kill step to control microbial growth, and the need for validation of processing conditions tailored to specific ingredients and nutrient profiles. In contrast, traditional thermal processes allow manufacturers to reliably produce pet foods that are not only nutritionally complete and physically appealing but also safe and shelf-stable—meeting the dietary needs of pets and the safety expectations of pet owners worldwide.

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The importance of chemical food safety in pet food quality

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High-quality pet food is characterized by its safety, nutritional balance, and benefits for pets. A key aspect of this quality is food safety, which encompasses the absence of potential hazards that can be categorized into chemical, microbial, and physical types. This article focuses specifically on chemical food safety, often referred to as food toxicology, which addresses the various chemical hazards that could be present in pet food and measures taken to prevent and/or minimize their presence in pet food.

Chemical hazards can be classified into two main categories: intrinsic and extrinsic. Intrinsic hazards are those that naturally occur within the ingredient itself. Examples include plant toxins, biotoxins, certain metals, and allergens. On the other hand, extrinsic hazards are not found naturally in the ingredient but arise as contaminants due to other factors, such as the environment, manufacturing, or if added in excess quantities. These include mycotoxins, heavy metals, pesticide residues, veterinary drug residues, and the excessive delivery of essential nutrients. Examples under each category are given in **Table 1**.

Regulatory agencies like the US FDA and the EU have set strict guidelines for many of these hazards, making chemical food safety control measures vital for ensuring the safety of pets and compliance with regulations.

The management of food hazards is conducted through an internationally recognized system known as Hazard Analysis Critical Control Points (HACCP). This food safety system focuses on systematically identifying hazards throughout the production process and controlling them based on a risk assessment approach. In pet food, chemical hazards are primarily introduced through ingredients, except for process contaminants (undesirable chemical compounds generated during manufacturing of food). Therefore, a thorough risk assessment process for ingredients is essential to eliminate potential hazards.

Ensuring the safety and quality of ingredients starts with the supplier. Rigorous steps are taken prior to approval of a supplier for a particular ingredient. Factors such as the sourcing or production location, manufacturing steps, safety and quality practices at the manufacturing facility, and the transportation method of the ingredient are all important considerations in identifying the hazards. For plant-based ingredients such as cereals and grains, knowledge of the geographical location of cultivation, the weather patterns and its changes, harvesting and storage practices, etc. helps in determining the potential for mycotoxin hazards and addressing them very early in the production process.

Prior to approval of a new ingredient or supplier, a thorough audit of the facility and their processes is necessary. Extensive and broad analytical testing, including panels of mycotoxins, heavy metals, pesticide residues, and other identified hazards (in Table 1), depending on the nature of the ingredient, is crucial for establishing baseline levels and evaluating the supplier's quality control measures. Cross-referencing test results performed by the manufacturer with those performed by the vendor enhances confidence in the supplier. Once the levels of inherent compounds and contaminants are confirmed to be within safe limits, the vendor is approved. However, continuous monitoring

Of Note

- Quality control is an important aspect of producing high-quality pet food. Food safety is a key component of quality and is non-negotiable.
- Chemical hazards can be classified into two main categories: intrinsic and extrinsic.
- Chemical food safety is critical to ensure that so called "chemical hazards" are controlled in pet food and requires scrutiny of ingredient usage to guarantee absolute safety for pets, ultimately supporting their health and well-being.

Table 1. Potential intrinsic and extrinsic chemical hazards that are avoided and/or minimized in pet food through strict quality control practices

Intrinsic	Extrinsic
▪ **Plant toxins (examples)** –Glycoalkaloids from green potatoes (concentrated by potato protein process) –Cyanide from cassava –Erucic acid/glucosinolates from older rapeseed varieties –Quinolizidine alkaloids from *Lupinus albus* (lupins) ▪ **Metals** –Iodine from seaweed –Fluoride in krill ▪ **Unknowns** –Unknown toxin	▪ **Mycotoxins** (Aflatoxin, DON, OTA, ZEA, T-2/HT-2) ▪ **Heavy Metals** (Pb, Hg, As, Cd) ▪ **Other metals of concern** (F, Cr) –Required but concern if in excess (Se, Fe, I, Zn, Cu) ▪ **Pesticide residues** (insecticides, herbicides, fungicides) ▪ **Veterinary drug residues** (feed additives, antibiotics, growth promotants) –Ionophores (monensin, lasalocid, salinomycin, etc.) ▪ **Deficient or excess vitamins and minerals** –Vitamin D excess, Thiamine deficiency ▪ **Environmental residues** (dioxins, PBDEs, radionuclides, etc.) ▪ **Packaging migrants** (BPA) ▪ **Biogenic amines** (histamine) ▪ **Process contaminants** (acrylamide, furans, PAHs, HAAs)

of identified hazards and regular vendor audits are essential to ensure ongoing control of hazards and maintain supplier trust.

Before sourcing vitamin and mineral premixes, steps are taken to ensure that there is no cross contamination with ionophores or coccidiostats at the manufacturing facility. Assessing storage practices, production workflow, and cleaning processes and ensuring separate production lines help mitigate risks surrounding drug carryover and contamination concerns.

Some ingredient components or their usage levels may not be appropriate for all animal species due to differences in metabolic physiology. To determine a safe allowable dose or inclusion level in a finished product, it is necessary to consider how the active components are absorbed, metabolized, and eliminated in each specific species. Reviewing existing toxicity and pharmacokinetic data aids in establishing safe levels of consumption of specific potential chemical hazards. It is important that chemical hazards are avoided because many pets consume the same diet or diets for years. Additionally, the levels of contaminants in ingredients are carefully monitored to ensure that their final concentrations in the finished product do not exceed internal or external guidelines for safety.

In summary, chemical food safety is critical to ensure that chemical hazards are controlled in pet food. The scrutiny of ingredient usage based on intrinsic and extrinsic risks is essential to guarantee that the levels utilized are safe for pets, ultimately supporting their health and well-being.

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