

Pet Nutrition Desk Reference

The Nutro Company
1550 West McEwen Drive, First Floor
Franklin, TN 37067
1-800-833-5330

Preston R. Buff, PhD, PAS, Dipl. ACAN
Rebecca A. Carter, PhD



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Chapter 1

Natural Eating Behavior of Dogs and Cats

Throughout history humans have interacted with dogs and cats in various ways, including protection, rodent control, hunting and companionship. From archaeological evidence, it is believed dogs were the first animal to be domesticated by humans around 14,000 years ago¹. Remains of cats dating back 6,000 years ago have been found in Cyprus, indicating domestication of cats is more recent than dogs.

Dogs and Their Wild Cousins

Domestic dogs (*C. familiaris*) are categorized phylogenetically in the family *Canidae* and the genus *Canis* along with wolves (*C. rufus*, *C. lupus*), jackals (*C. aureus*, *C. mesomelas*, *C. adustus*, *C. simensis*), coyote (*C. latrans*) and dingo (*C. familiaris dingo*). It has been argued that these species should not be categorized as separate species, as they can all interbreed and produce viable offspring. Dogs and their wild cousins possess many common characteristics, such as communication by facial expressions, body postures, tail-wagging, howling and yelping¹. However, there are many differences in the behavior of dogs and wolves. Wolves have a greater awareness of their environment and react more quickly to stress, which improves the chance of survival in the wild.³ Dogs, on the other hand, are more docile, less fearful and have a greater tolerance for stress³. The differences in the behavior of dogs are most likely related to centuries of domestication and accessibility of food from humans.

Dogs retain many aspects of wild feeding behavior, such as the ability to consume their daily energy need in a matter of minutes from one meal. Wolves have the capacity to eat as much as 17 percent of their body weight in animal protein during a single meal⁴. Some breeds of dogs also retain a similar capability, but not to the same degree as wolves. Dog breeds such as beagles and foxhounds that are kept in packs will generally gorge when food is offered. Labrador retrievers have a tendency to overeat as well when given the opportunity. Other dogs, such as some toy and giant breeds, are more finicky and do not possess the natural instinct to consume large amounts of food when it is available. These differences between breeds indicate that feeding behavior has been altered by domestication.¹

In nature, the primary component of the diet of canines is animal protein, but canines can obtain nutrient requirements from vegetable sources as well. Feral dogs are known to hunt in packs, similar to wild canines, and eat a wide variety of foods. The diet of wolves consists primarily of animal protein and they typically hunt larger prey, such as elk, and eat the highly nutritious organs first followed by muscle tissue⁵. Feral dogs typically hunt small prey and forage on berries and some plants⁶. Jackals often raid stores of cultivated fruit and consume large quantities of grass⁷. Wild canines and feral dogs must exert a considerable amount of energy to acquire food,

and thus consume foods that are more easily available in the environment in which they live. Domestic dogs are reliant on humans to provide them with all of their nutritional needs. Generally, this food is provided in a form of a complete and balanced commercially prepared pet food.

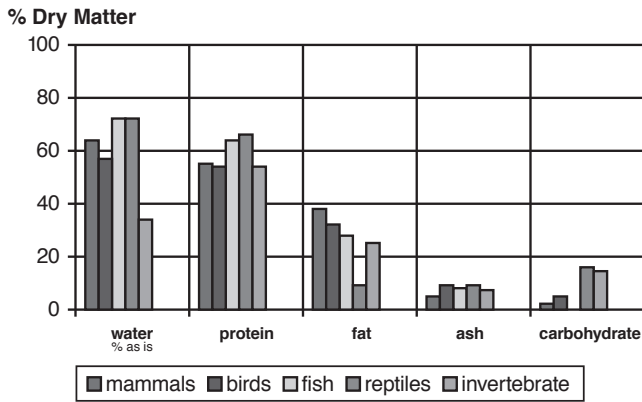
Cats and Their Wild Cousins

Domestic cats (*Felis catus*) are categorized phylogenetically in the family *Felidae* and the genus *Felis* along with 38 other species. These species can be classified into eight major lineages, which are ocelot, pantherine, caracal, puma, Asian leopard, baycat, lynx and domestic cat. Through DNA analysis, it has been found the domestic cat (*Felis catus*) is most closely related to the European wildcat (*F. silvestris*), the African wildcat (*F. libyca*) and the sand cat (*F. nigripes*)². These species of wild cats closely resemble the domestic cat in appearance, and African wildcats have been kept as pets⁸. Many of the behavioral signs observed in domestic cats, such as purring, meowing, hissing and spitting, have been observed in most wild species².

Cats have evolved as specialized hunters, using sound and vision to locate their prey. Cats have a highly developed sense of hearing and can respond to higher pitched sounds than dogs, using over 20 muscles to control their ears, which swivel independently⁹. Cats can even locate prey by sound alone, such as scratching noises or high-pitched calls, and can distinguish between mice and shrews². Once a cat has identified the prey by sound, it then hones in on the movement of its prey through its keen sense of sight. Domestic cats are considered to be generalist resident predators, meaning they hunt a variety of prey in a limited area¹⁰. Cats will scavenge to some degree, including acceptance of household food items they have not caught or killed. House cats that eat a complete and balanced pet food will hunt when they have the opportunity, as this is their natural instinct.

The natural diet of feral cats consists primarily of small mammals, birds, fish, reptiles and invertebrates. The macronutrient concentration of the feral cat diet consists primarily of protein and fat with little carbohydrate (Figure 1). Research conducted at The Waltham Centre for Pet Nutrition has identified a preferred macronutrient profile (MNP: relative amounts of protein, fat and carbohydrate) for cat diets. The data shows that cats aim to source 50% of their calories from protein, 40% from fat and 10% from carbohydrate. These findings are relevant in terms of increasing food intake and preference, as this closely resembles the nutrient composition of the cat's natural diet.

Figure 1. Macronutrient concentration of prey consumed by feral cats.



Summary

The relationship of humans with dogs and cats has evolved from primarily protection and pest control to that of loving companions. In recent times, dogs and cats have transitioned from living outdoors, eating scraps and hunting to living indoors and eating pet foods specifically formulated for their specific needs. Many pet owners want to provide the best nutrition to enhance the health of their pets and choose to feed as nature intended. The remaining chapters focus on the nutrient needs of pets and how these can be met naturally.

References:

- ¹J Serpell, Ed. 1995. *The Domestic Dog: Its Evolution, Behavior, and Interactions with People*. Cambridge University Press.
- ²Turner, D.C. & P Bateson, P., Eds. 1988 *The Domestic Cat: The Biology of its Behavior*. Cambridge University Press.
- ³Hemmer, H. 1990. *Domestication: The Decline of Environmental Appreciation*. Cambridge University Press.
- ⁴Young, S.P. 1944. *The Wolves of North America. Part I*. Washington, D.C. American Wildlife Institute.
- ⁵Stahler, D.R., D.W. Smith and D.S. Guemsey. 2006. "Foraging and Feeding Ecology of Gray Wolf (*Canis lupus*): Lessons from Yellowstone National Park, Wyoming, USA," *The Journal of Nutrition*. 136: 1923S–1926S.
- ⁶Boitani, L. and P. Ciucci. 1995. "Comparative Social Ecology of Feral Dogs and Wolves," *Ethology, Ecology & Evolution* 7: 49–72.
- ⁷Ewer, R.F. 1973. *The Carnivores*. London: Weidenfield & Nicolson.
- ⁸Smithers, R.H.N. 1968. "Cat of the Pharaohs," *Animal Kingdom* 61: 16–23.
- ⁹Tabor, R. 1983. *The Wild Life of the Domestic Cat*. London: Arrow Books.
- ¹⁰Andersson, M. and Erlinge, S. 1977. "Influence of Predation on Rodent Populations," *Oikos* 29: 591–597.

Chapter 2

Digestive Physiology and Nutrient Requirements of Dogs and Cats

All living things have specific nutrient requirements, and those requirements differ between species. Thus, the nutrient requirements for humans are different than those of dogs and cats. Complete and balanced pet foods are designed to meet the specific requirement for pets during specific life stages. This chapter will identify the nutrients and discuss the purpose of each one.

Digestive Physiology of Dogs and Cats

Digestion is the breaking down of food by mechanical, chemical and microbial processes to a form that can be utilized by the pet. The process starts with mastication (chewing) to mechanically break down food into small particles. Saliva is produced by glands in the mouths of dogs and cats, which acts as a buffer and aids to lubricate food particles as they descend through the esophagus to the stomach. Both dogs and cats lack enzyme α -amylase that initiates starch digestion in the mouth, which limits the amount of carbohydrate breakdown by saliva. The stomach temporarily stores food and regulates the flow of food into the small intestine. Digestive fluids are secreted into the stomach and small intestine to break down food particles by chemical processes. Most of the enzymatic digestion occurs in the small intestine, breaking food down into the nutrient components. These nutrients are then absorbed into the body through the small intestine. Some nutrients are not absorbed by the small intestine and remain in the material that is then passed into the large intestine. The large intestine serves as an environment for microbial fermentation. This is where fiber is converted into short chain fatty acids by the microorganisms. Water and electrolytes are the main nutrients absorbed by the large intestine. Dogs and cats need an optimal balance of soluble and insoluble fiber in their diet to maintain the environment of the large intestine. This balance of fiber enables beneficial microorganisms to thrive in the large intestine, which promotes healthy digestion and optimal stool quality.

Physiological Differences of Dogs and Cats

Dogs have a keen sense of smell up to 10,000 times more sensitive than humans. This enables dogs to find prey and determine if a food source is rancid. Dogs have 42 teeth designed for cutting, tearing and grinding, which enables them to eat a wider variety of foods. The enamel of dogs' teeth is approximately five times thinner than that of humans. Dogs have fewer taste buds than humans and can taste bitter and sweet, but not salty flavors. They have limited salivary amylase, which limits the amount of carbohydrate breakdown by saliva. The pH of the dogs' saliva is more alkaline than humans. Their stomach is very expandable and designed to cope with large meals. This is a result of the evolution of

canines, which has enabled their survival by hunting large prey and eating infrequent meals. The stomach pH is more acidic than in humans, which is beneficial for digestion of bones and destruction of harmful bacteria. Transit time through the intestine is 12–30 hours compared with 30 hours to five days in humans. Bacterial fermentation takes place in the large intestine to break down fiber.

The cat is an obligate carnivore, and therefore must have animal protein in its diet. Cats have 30 teeth, all sharp and designed for cutting and tearing. There is no sideways movement of the jaw and they do not have teeth designed for grinding. This limits the type of food cats can eat. The enamel of cats' teeth is approximately 10 times thinner than that of humans. Cats have even fewer taste buds than dogs and they have non-functional sugar taste receptors. Cats do not produce salivary amylase, which means they do not begin carbohydrate breakdown in the mouth. The cat's stomach is designed for many small meals at intervals throughout the day, requiring them to frequently catch and consume small prey. This is why cats are more active hunters. Their stomach pH is more acidic than humans for digestion of bones and destruction of harmful bacteria. Transit time through the intestine is 12–24 hours compared with 30 hours to five days in humans. The small intestine is well suited to digesting proteins and fats. Cats are not able to down-regulate protein digesting enzymes, and therefore need a protein-rich diet that is supplied through many small meals throughout the day. Bacterial fermentation takes place in the large intestine to break down fiber. However, the fermentation capacity of cats is limited compared to humans and dogs.

Essential Nutrients

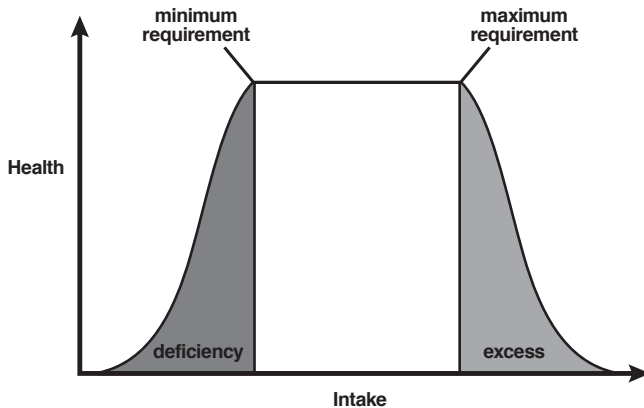
Essential nutrients are those required by the animal that either cannot be synthesized by the body or cannot be synthesized in adequate amounts for good health. Essential nutrients are supplied by complete, balanced nutrition.

Complete and Balanced Nutrition

Cats and dogs require about 40 essential nutrients, each in the right form and in the right amount (balanced) to deliver complete nutrition. Complete and balanced nutrition delivers the right amount of every essential nutrient within the daily calorie needs of the cat or dog, whether the pet food format is wet, dry or semi-moist. Manufacturing a complete and balanced food for cats and dogs is a science in itself and requires expertise at all stages of production. This includes sourcing raw materials, blending the vitamin and mineral mixes, understanding the role of processing for each pet food format, and knowledge of the nutrient and energy requirements of cats and dogs. Each essential nutrient has a recommended minimum daily requirement that has been defined through many years of research, but for some

nutrients work continues to further refine these levels. Where appropriate, a maximum daily intake has also been defined. To deliver complete and balanced nutrition, each essential nutrient should fall within the minimum and, where appropriate, maximum levels required by cats and dogs (Figure 2).

Figure 2. Recommended daily nutrient intake



Nutrient requirements of cats and dogs

National Research Council (NRC)¹

The NRC committee consists of key academic experts in the field of companion animal nutrition who define the nutrient requirements of cats and dogs. The most recent NRC guidelines on these requirements were produced in 2006. The NRC guidelines influence all other nutritional standards—although there are examples of differences between the NRC and other nutritional agencies.

Association of American Feed Control Officials (AAFCO)²

AAFCO guidelines are written by invited experts from the industry and academia. Compliance with these guidelines is a legal requirement in most states in the USA. Although AAFCO produces an official publication every year, it does not change the nutritional requirements for dogs and cats annually.

The Waltham Centre for Pet Nutrition³

The Waltham Centre for Pet Nutrition produces guidelines for The Nutro Company using external and internal knowledge. These are solely produced for internal use by The Nutro Company and Mars Petcare associates. The WALTHAM® guidelines are updated every two years with the latest scientific knowledge.

Energy Requirements

Dogs and cats have specific energy requirements depending on lifestage and daily activity level. Energy is not a nutrient, but it does result from the breakdown of nutrients, including protein, fats and carbohydrates. Energy is expressed either in kilocalories (kcal) or kilojoules (kJ). Fat delivers

approximately double the amount of energy per gram as protein and carbohydrate. Dogs and cats need energy to maintain normal metabolic function. Manufactured pet foods are formulated to meet specific energy requirements by having the correct balance of energy to nutrient content. Pet food feeding guidelines, are based on the kilocalories provided by the food and use energy requirement equations to calculate how much food should be fed to pets of various sizes, ages and activity levels. Owners should always use the feeding guidelines as the foundation for estimating how much food to offer their pets, adjusting the amount according to individual pet requirements based on body condition.

Macronutrients and Micronutrients

Macronutrients are defined as the nutrients needed in larger amounts on a daily basis. Macronutrients include water, protein, fat and carbohydrates. Micronutrients are those nutrients needed in much smaller amounts on a daily basis. Micronutrients include vitamins and minerals.

Water

Water is a major constituent of an animal's body (75% at birth and 60% in adult life). It is the most important nutrient for life and plays a part in all major physiological functions. Cats have a reputation for drinking little because they are able to concentrate their urine, perhaps as a result of being descended from desert animals. However, if the urine concentration is too high, it increases the risk of crystal and stone formation within the urinary tract.

Cats and dogs must have free access to drinking water at all times. Water has many essential functions for life. Water is the medium for transporting nutrients and waste through the body. It is required for most metabolic processes and regulation of body temperature. Water acts to lubricate the joints, the eyes and the inner ear (for the transmission of sound). There are three sources of water: drinking water, food (dry food contains up to 10% water and wet food around 80% water) and metabolic water. Dogs and cats fed wet food will drink far less water than pets fed dry food due to the higher water content and by-product of metabolic processes. Free access to clean drinking water helps prevent dehydration, the signs of which are dry skin that lacks elasticity, a higher heart rate and high fever. Body water loss of more than 10% can have serious health implications. Increased intake can be a sign of diabetes mellitus or kidney disease.

Protein

Proteins are made up of amino acids, in predefined chains that determine their roles within the body. Amino acids, which are produced by the breakdown of dietary proteins in the digestive tract, are used by the body to synthesize new proteins. Proteins are used by the body to build and repair organs and tissues, transport molecules, send messages from one organ to another (hormones) and help combat disease (antibodies).

Good sources of proteins are animal products (meat, poultry and fish) and some vegetable products (rice gluten, rice and pea protein). Some physiological conditions require more protein than others; for example growth, gestation, lactation or physical activity are demanding in terms of protein utilization. Dogs and cats use 30–35% of dietary protein to maintain skin and coat health.

Amino Acids

Amino acids are the building blocks of proteins and their derivatives. Proteins include a total of 20 different amino acids, only 11 (cats) or 10 (dogs) of which are essential (Table 1). “Essential” means they cannot be produced by the body, so these amino acids must be provided in the diet. Amino acids are required by the body to ensure healthy physiological function. Without essential amino acids, the growth of kittens and puppies will be slow and health may be compromised. In adult animals, processes such as nitrogenous waste elimination and hemoglobin synthesis will be disrupted. All dietary proteins of animal or plant origin are composed of a series of chemically bound interlinked amino acids. Dietary proteins of “high biological value” are those that combine good digestibility and a high content of essential amino acids, such as egg, meat (including organ meats such as heart, kidney, liver and lung), poultry, fish proteins and cereal glutes. The absence of any of the essential amino acids from the diet stops the synthesis of essential proteins. Under these conditions, the animal then breaks down body tissue to provide the required amino acids, seriously compromising health.

Table 1: Essential amino acids for dogs and cats

Amino Acid	Primary Function
Methionine & Cysteine	Key components of hair and skin proteins (keratins)
Taurine (essential for cats)	Healthy eyesight, healthy heart, natural antioxidant
Arginine	Growth and urea production
Lysine	Synthesis of all proteins
Phenylalanine & Tyrosine	Thyroid and adrenal function, hair pigmentation
Leucine, isoleucine, valine	Synthesis of muscle protein
Histidine	Structural protein
Threonine	Energy production
Tryptophan	Hormone production

Methionine and Cysteine

Methionine and cysteine are sulfur amino acids important for the synthesis of the hair and skin proteins, keratins. The keratin synthesis needed to maintain skin and hair can account for up to 30% of an adult dog’s daily protein requirement. Methionine is essential within the diet. Cysteine can be

synthesized from methionine. However, if cysteine is provided in sufficient quantities, it helps free up methionine for other functions. The metabolism of sulfur amino acids produces sulfuric acid, which is eliminated through the urine. A carnivore’s natural diet, rich in sulfur amino acids, therefore tends to produce acidic urine. Methionine and cysteine are particularly abundant in fish and egg proteins, as well as casein. Wheat and maize glutes are also rich sources. A deficiency of methionine and cysteine can result in hair loss, slow hair growth and a generally dry and brittle appearance of hair.

Taurine

Taurine is only essential for cats as, unlike dogs, they cannot synthesize it themselves. Taurine was discovered in 1826 in the bile of cattle (*Bos taurus*), hence its name. It is a sulfur amino acid found in most animal tissue. Unlike other essential amino acids, it does not have any role in protein synthesis. Taurine enables the liver to synthesize bile salts. It also works by regulating calcium flow into and out of the cells and has a role in healthy cardiac function. Taurine is required for healthy reproduction, healthy eyesight and hearing. It is an important antioxidant, and plays a role as a precursor for the synthesis of complex fats (glycosphingolipids), supporting the barrier function of the skin. Animal protein sources, in particular the organs (e.g. heart, kidney, liver), are the main natural sources of taurine. For reasons yet to be fully understood, wet cat food requires twice the level of taurine supplementation of dry food, to allow the cat to absorb adequate levels of the nutrient. Taurine deficiency can result in feline central retinal degeneration (FCRD) and subsequent blindness, inadequate immune response, poor growth and poor reproductive function, including decreased live birth rate and congenital birth defects.

Arginine

Arginine is important for the synthesis of urea from ammonia. In the absence of arginine, cats rapidly develop clinical signs of ammonia intoxication (hyperammonaemia), which include vomiting, hypersalivation and nerve problems. This deficiency may prove fatal within hours if left untreated. In addition to its involvement in the excretion of ammonia, arginine plays a role in blood vessel relaxation and the release of several hormones. Arginine is abundant in meat, including organs, and in gelatin. Arginine-free diets are associated with excessive salivation, muscle tremors, vomiting and death. In the long term, marginal arginine deficiency can lead to cataract development. Signs of deficiency tend to be more severe in cats than dogs. As ammonia is produced from the breakdown of protein, more arginine is required for higher protein diets.

Lysine

Lysine is often the first limiting amino acid in the diet, which means it has the greatest risk of being deficient if a pet food is not carefully formulated. Lysine is an essential amino

acid used for the synthesis of proteins. Lysine is sensitive to heat, and during pet food processing it undergoes a chemical reaction with sugar (Maillard reaction), thought to be important for generating flavors and aromas. Lysine is abundant in animal sources, especially muscle tissue. Deficiency can lead to reduced food intake and weight loss. Too much lysine in puppies can cause signs of arginine deficiency.

Phenylalanine and Tyrosine

Phenylalanine and tyrosine are aromatic amino acids (so named because of their carbon ring structure) that are vital for the production of pheomelanins (yellow to red pigments) and eumelanin (brown to black pigments), which define the color of an animal's coat. Of the aromatic amino acids, only phenylalanine is considered to be essential. Tyrosine is either provided directly in the diet or synthesized from phenylalanine. However, if tyrosine is provided in sufficient quantities, it helps free up phenylalanine for other functions. Phenylalanine is essential for the production of thyroid hormones and other key metabolites. Besides its role in hair and iris pigmentation, tyrosine is also a dopamine, noradrenalin and adrenalin precursor. These molecules are required for the proper functioning of the brain and in reproduction. Phenylalanine is found in most animal protein sources such as beef, pork, poultry and fish. Rice is the only vegetable source to contain useful quantities of tyrosine. Signs of deficiency include neurological dysfunction, uncoordinated gait and hyperactivity in cats. In dogs, signs include weight loss and reduced food intake, and reddening of black coats.

Branched Chain Amino Acids (BCAA)

Leucine, isoleucine and valine constitute the class of branched chain amino acids (BCAA) within the essential amino acid family. The body is unable to produce these amino acids in sufficient amounts quickly, and therefore a dietary source is required. Leucine, isoleucine and valine stimulate the synthesis of proteins and slow their breakdown in the muscles, and therefore help increase lean muscle mass and help prevent muscle wasting. The effectiveness of BCAA in both these actions appears to diminish with age. Leucine, isoleucine and valine are commonly found in muscle, including beef, lamb and poultry. Deficiency of any of the BCAA can result in weight loss and lethargy. Deficiency of isoleucine in particular can result in rough coat, lesions on the paws and an uncoordinated gait.

Histidine

Histidine was first isolated in 1896, and acts as a precursor for a number of important compounds. Besides its structural function in proteins, histidine is a precursor for a number of neurological compounds such as histamine. Animal protein is a good source of histidine. It is present in particularly high concentrations in blood as well. Histidine deficiency can result in weight loss and refusal to eat. In cats, even a marginal deficiency over a long period of time can result in cataracts.

Threonine

Threonine is an alpha amino acid and is the only essential amino acid to contain an alcohol group within its structure. Threonine acts as a precursor for a number of metabolically active molecules including pyruvate, involved in the production of energy. Beef, lamb, poultry, fish and pork are all good dietary sources of threonine. Threonine deficiency can result in weight loss and refusal to eat in both cats and dogs. In cats, even a marginal deficiency can result in nervous system problems.

Tryptophan

Tryptophan was first isolated in 1901 and is a precursor of many important metabolic molecules. Tryptophan acts as the precursor of niacin synthesis in dogs. Although cats do have the ability to synthesize niacin from tryptophan, the activity of the enzyme picolinic carboxylase diverts tryptophan away from this function. Tryptophan also acts as the precursor of serotonin and melatonin. Poultry and fish are excellent sources of tryptophan. Tryptophan deficiency can result in refusal to eat and weight loss.

Fats

Fats are a rich source of energy, providing more than twice as much energy per gram than protein or carbohydrate. In terms of nutrition, fats deliver essential fatty acids and provide the necessary environment for absorption of fat-soluble vitamins in the gut. Fats (and oils) from both animal and vegetable origins provide various sources of essential fatty acids. Ingredients such as poultry fat, fish and seed oils are used to deliver these nutrients. Fatty acids are required for a number of processes in the body, including maintenance of a healthy skin and coat, a strong immune system and reproductive function.

Fatty Acids

Fatty acids are the main constituent of fats and consist of a carbon chain varying in length and chemical structure. Saturated and unsaturated fatty acids are named according to the absence or presence, respectively, of at least one double bond within the carbon chain. Saturated long-chain fatty acids are used exclusively for energy within the body, while the role of polyunsaturated fatty acids (PUFAs) is more diverse. Fatty acids are termed essential when they cannot be generated within the body. The omega-3 and omega-6 groups of PUFAs represent the key essential fatty acids in mammalian nutrition. Vegetable oils (e.g. sunflower and linseed), and animal fats (e.g. fish oil and beef tallow) are good sources of fatty acids. Deficiency of fatty acids can result in fat-soluble vitamin deficiency (vitamins A, D, E and K) and poor skin and coat condition.

Omega-3 Fatty Acids

Eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and alpha linolenic acid (ALA) form the omega-3 family of PUFAs. There is evidence to suggest omega-3 PUFAs are required in the diet of gestating animals for normal embryonic

growth and development. However, in the adult cat and dog, there is insufficient evidence to support an absolute minimum requirement of omega-3 PUFAs in the diet. While not essential for adult cats and dogs, omega-3 fatty acids can provide a number of functional benefits, including improving skin and coat condition and acting as anti-inflammatory agents. In the aging animal, omega-3 PUFAs can help prevent deterioration of cognitive function by improving brain oxygenation. Rich sources of ALA include flaxseed oil, whereas the most abundant source of DHA and EPA is marine fish oil. Alternatively, EPA and DHA can also be found in phytoplankton and single cell algae. Excess omega-3 PUFAs can lead to impairment of immune function in dogs.

Omega-6 Fatty Acids

Arachidonic acid and linoleic acid are essential fatty acids belonging to the omega-6 family of PUFAs. Dogs can synthesize arachidonic acid from dietary linoleic acid, but cats are unable to carry out this conversion step, making arachidonic acid an essential nutrient in the diet of cats. Omega-6 fatty acids are essential for healthy reproduction, as they are involved in the synthesis of prostaglandins. Prostaglandins are hormone-like compounds that regulate a number of reproductive processes, including ovulation and parturition. Arachidonic acid can be found in animal fats, such as poultry fat. Linoleic acid can be found in vegetable oils, such as sunflower oil. A deficiency in omega-6 fatty acids can cause poor reproductive performance, poor skin and coat condition resulting in dry, irritated, flaky skin and a dull appearance of the coat.

Carbohydrates

Cats and dogs can synthesize their own blood glucose from amino acids. Carbohydrate, therefore is not an essential macronutrient. However, if carbohydrates are provided in the diet of cats and dogs, they can be utilized. Carbohydrates are used in pet foods as sources of energy and dietary fiber, and levels tend to be higher in dry pet food than in wet pet food. Carbohydrates are molecules composed of carbon, oxygen and hydrogen that have certain chemical characteristics in common. Carbohydrates are predominantly of plant origin, with the exception of blood glucose, glycogen in the muscles and liver, and milk lactose.

Absorbable Carbohydrate

This form is immediately useable by the body. Glucose is the most common dietary unit of absorbable carbohydrate, but is usually present as a component of more complex, digestible carbohydrates.

Digestible Carbohydrate

These are mainly starch, predominantly from plant origin. They are broken down by enzymes into absorbable carbohydrates.

Fermentable Carbohydrate

These are utilized by bacteria in the gut and may be broken down into a form useable by the body. Fermentable carbohydrates may be classed as prebiotics if they are specifically used by gut bacteria beneficial to the host. An example is pectin.

Non-fermentable Carbohydrate

These are commonly known as fibers. This category of carbohydrate passes through the body undigested (e.g. lignin) and serves to add bulk to the bowel contents.

Sugars

The term sugar refers to some absorbable (e.g. glucose and fructose) and some digestible carbohydrates (e.g. lactose and sucrose). When provided in the diet, sugars provide energy. In prepared pet foods, dietary sugar can react with lysine during processing, enhancing flavors and aromas. Although not essential, sugars can be used as an energy source when provided in the diet. While lactose in the mother's milk acts as an energy source for young puppies or kittens, a digestive enzyme, lactase, is necessary to make it biologically available. Lactase disappears once the animal stops feeding on milk, often leading to a limited ability to digest lactose as an adult. Sugars are naturally found in most fruits, cereals, roots and potatoes. When fed in excess, sugars may cause diarrhea and small intestinal bacterial overgrowth.

Starch

Starch is a digestible carbohydrate, composed of thousands of glucose molecules linked together by simple chemical bonds. Although not essential, dietary starch is utilized as an energy source. Starch molecules are broken down by digestive enzymes into glucose molecules that are absorbed in the small intestine. Cooking starch increases the gelatinization, making it easier to digest. Starch is common in plants and is used to store energy (in a similar way to fats in animals). Common sources include rice, corn, wheat, barley and potato. As starch is not an essential nutrient, cats and dogs cannot develop a nutritional deficiency if it is absent from the diet. However, poorly cooked starch, or high dietary levels may cause diarrhea.

Fiber

Most soluble fibers are fermentable (e.g. fructooligosaccharides [FOS] and pectin) and most insoluble fibers are non-fermentable (e.g. lignin and cellulose). However, an exception is psyllium, which is a soluble but non-fermentable fiber. The role of fiber varies according to type. Non-fermentable fibers, such as lignin, act as bulk within the digestive tract, regulating digestive transit. Intestinal transit must be slow enough to allow efficient absorption of nutrients but not so slow that constipation occurs. The right level of dietary fiber can help to optimize intestinal transit time. Some fermentable fibers, such as FOS and mannanoligosaccharides (MOS), can

improve the health of the digestive tract by providing food for beneficial bacteria. These specific fibers are known as prebiotics (not to be confused with probiotics that are live bacteria beneficial to gut health). Not all fermentable fibers have a prebiotic effect, if they do not provide nutrients for a particular bacteria. Most fiber is plant-based, and common examples include beet pulp, cellulose, alfalfa, gums and pectin. As fibers are not essential nutrients for cats and dogs, they cannot develop a deficiency. However, too little or too much fiber can compromise feces quality.

Vitamins

The word “vitamin” is derived from the words “vital” and “amine,” as these compounds are vital for life. Thiamin was the first vitamin to be named. By extension, other substances that play a similar role are also referred to as vitamins. The vitamins are split into two families: vitamins that are soluble in fats (vitamins A, D, E, K; Table 2) and vitamins that are soluble in water (B vitamins; Table 3). If consumed excessively, fat soluble vitamins accumulate in the body and can become toxic, whereas excess water-soluble vitamins are passed out in the urine. Vitamins are provided through various ingredients and can be added to pet food in pre-prepared vitamin mixes. Each vitamin is involved in several different functions.

Table 2: Essential fat soluble vitamins for dogs and cats

Vitamin	Key Function
Vitamin A	Vision, skin
Vitamin D	Calcium and phosphorus metabolism
Vitamin E	Antioxidant
Vitamin K	Blood clotting

Table 3: Essential water soluble vitamins for dogs and cats

Vitamin	Key Function
Thiamin–B1	Nervous system
Riboflavin–B2	Skin
Niacin–B3	Skin, cell energy
Pantothenic acid–B5	Growth, skin
Pyridoxine–B6	Cell energy
Biotin–B7	Skin, hair
Folic acid–B9	Nervous system development
Cobalamin–B12	Formation of blood cells
Choline	Synthesis of phospholipids

Vitamin A (Retinol)

Vitamin A was isolated in 1913 and its chemical structure was mapped in 1931. It is a long chain alcohol that is soluble in fat. It is absorbed in the small intestine and stored in the liver. Dogs can synthesize vitamin A from beta carotene, but cats lack the required enzyme to do this. Both cats and dogs are

adapted to process large amounts of vitamin A. Vitamin A is required for healthy vision, in particular adaptation to darkness. It is also involved in the synthesis of reproductive hormones and other proteins, as well as regulating the growth of skin cells and the production of sebum. Good sources of dietary vitamin A are liver, fish and eggs. Vitamin A deficiency can result in eye problems, dry skin, reproductive anomalies and greater sensitivity to infections and pulmonary complications. High levels of vitamin A can result in joint abnormalities and poor reproductive performance.

Vitamin D (Cholecalciferol)

The benefit of fish liver oil for prevention of rickets was discovered in 1782, but vitamin D was not isolated until 1932. Humans and herbivores synthesize this vitamin from skin sterols in the presence of sunlight. However, this process is absent in cats and dogs, meaning vitamin D must be provided in the diet. To be active in the body, ingested vitamin D must be modified in the liver and kidney. Vitamin D plays an essential role in the regulation of calcium and phosphorus metabolism by increasing their intestinal absorption, optimizing calcium incorporation into bone and reducing the loss of calcium and phosphorus in the urine. Meat and vegetables are almost completely lacking in vitamin D. Good sources include oily fish (sardines, tuna) and liver. Vitamin D deficiency can cause rickets (rare in dogs and cats), weight loss and osteomalacia (joint and muscle pain, bone fractures). Excessive intake of vitamin D can cause lower bone turnover and ossification in dogs, resulting in excessive bone mineralization. In the cat, excess vitamin D can cause mineral deposits in the soft tissues, hypocalcaemia, depression, vomiting and lethargy. Effects are most pronounced in puppies and kittens, resulting in bone abnormalities and calcification of soft tissues.

Vitamin E (Alpha Tocopherol)

Vitamin E was discovered in 1920 and was isolated in 1936. It was not until the 1980s that its antioxidant potential was discovered. Vitamin E is a generic term that covers several substances. Alpha tocopherol is the most common form and has the greatest biological activity. Vitamin E is stored in fat tissue, within the liver and muscles. Diets high in polyunsaturated fatty acids require more vitamin E to prevent fatty liver disease. Vitamin E helps to protect the cell membranes from free radical damage and strengthens the immune system. Free radicals are produced by cells through normal metabolism, and consequently contribute to the aging process. Free radicals are also produced as a result of external factors that affect the body such as exercise, pollution and sunlight. Free radicals can contribute to cell death. The most important sources of vitamin E are of vegetable origin and include oils, grains and cereals. Vitamin E is also found in some animal products, such as liver. Signs of deficiency in dogs and cats include muscle weakness, reproductive failure, retinal degeneration and discoloration of adipose tissue. Excess vitamin E in cats has been shown

to prolong blood-clotting time. Vitamin E is the least toxic fat-soluble vitamin.

Vitamin K (Menaquinone-7 – MK-7)

The existence of a dietary factor that prevented hemorrhaging was proven in 1929, but Vitamin K was not isolated until 1936. Vitamin K is now known to be a group of several similar fat soluble substances that enable blood clotting through complex biochemical pathways. The vitamin K group includes co-factors for many enzymes, meaning that vitamin K has to be present to enable enzyme activity. As a consequence, it is essential for some blood coagulation processes. It also has a role in protein metabolism and helping calcium incorporation into bone. Vitamin K is usually stored in the liver. The intestinal bacteria of cats and dogs produce vitamin K. However, this process may not provide the full daily requirement in all circumstances, so a dietary source is required. The main sources of vitamin K are liver, meat and vegetables such as spinach. A vitamin K deficiency can result in digestive, nasal, skin and cerebral hemorrhaging due to inadequate blood clotting processes. In time, these often minor hemorrhages can lead to anemia (lack of the red cells that transport oxygen in the blood).

Thiamin (Vitamin B1)

Thiamin was the first vitamin to be discovered. Signs of thiamin deficiency, or beriberi, were observed in humans as early as 2600 BC, but it was only in 1885 that its nutritional origin was proven. It was not until 1910 that thiamin deficiency was identified as the cause of the disease. This vitamin is soluble in water and concentrated in the heart, the liver, the kidneys and the brain. Thiamin is involved in many complex biochemical reactions that help generate energy for the cell. It is essential for healthy functioning of the nervous system, where it assists in transmission of sensory impulses. Yeast and wheat germ have the highest thiamin content, but it is also found in meat, bran and cereals. Thiamin deficiency can cause beriberi in humans and animals as shown by fatigue, muscle weakness, problems with gait and vision, seizures and ultimately death.

Riboflavin (Vitamin B2)

Riboflavin was discovered in 1937, but its importance for the prevention of a number of diseases was only fully understood in the 1980s. Riboflavin is water-soluble and very sensitive to light. Riboflavin, along with niacin, is involved in energy production, and also contributes to skin and coat health. It is very common in nature, found in yeast, liver and eggs. A deficiency can produce skin changes around the eyes and the abdomen.

Niacin (Vitamin B3)

Niacin is also known as vitamin PP and nicotinic acid. Along with other B vitamins, niacin helps protect the skin by promoting the synthesis of skin fats, particularly ceramides, to

help limit skin dehydration. In dogs, some niacin is synthesized from tryptophan, an essential amino acid, but not enough to meet full daily requirements. Cats have a very limited capacity to do this, and therefore niacin must be supplied within the diet. Present in most foods, niacin exists in large amounts in meat, fish and cereal. In humans, deficiency results in pellagra—a serious disease that combines skin, digestive, psychiatric and hematological disorders. In dogs, a deficiency can cause dermatitis around the abdomen and hind legs.

Pantothenic Acid (Vitamin B5)

The discovery of pantothenic acid's key role in the energy production of cells won Fritz Lipmann the 1953 Nobel Prize for chemistry. As an element in coenzyme A, pantothenic acid is involved in almost every metabolic process. In synergy with other B vitamins (niacin and choline) it helps protect the skin by promoting the synthesis of skin fats. This vitamin's name comes from the Greek word "pantos," which means "found everywhere." The main sources are meat, tripe and eggs. Given that pantothenic acid is very common in food, deficiencies are very rare and symptoms general.

Pyridoxine (Vitamin B6)

Pyridoxine was discovered in the mid 20th century and its many roles in the body are still being studied. As a coenzyme, it plays multiple roles in different metabolic pathways, especially those of amino acids. Its sources include yeast, wheat germ and meat. A pyridoxine deficiency can cause skin, nerve and blood disorders.

Biotin (Vitamin B7)

Also known as vitamin H, biotin is one of the most important vitamins for a glossy coat and healthy skin in animals, as well as being directly involved in the healthy functioning of the nervous system. Discovered at the turn of the last century during research into "egg white disease"—where eating large quantities of raw egg whites caused skin lesions, hair loss and neuromuscular disorders—biotin was found to be present in yeasts which are inhibited by an antibiotin in the raw egg whites. In the dog, biotin is produced by intestinal bacteria, meaning dietary sources are only required in the presence of anti-bacterial agents. In cats, a dietary source is required. Biotin is involved in breaking down glucose, fatty acids and some amino acids, as well as being essential for the synthesis of some other fatty acids. Biotin is also essential for skin and coat health. It is found in large amounts in liver and kidneys.

Folic Acid (Vitamin B9)

Folic acid is involved in the development of the tissues of the nervous system. Stored in the liver, folic acid is essential for fast cell multiplication (e.g. in the fetus) and is involved in the synthesis of essential DNA components. In the dog, some folic acid is produced by intestinal bacteria. However, it is not known whether this is sufficient for daily requirements, and

therefore a dietary source is required. Cats require a dietary source of folic acid. Yeast is a good source of folic acid, along with liver and green vegetables, such as spinach. A deficiency can cause malformation (such as spina bifida) in the fetus. Folic acid supplementation in gestating bitches helps reduce the incidence of cleft palate in newborn puppies. Folic acid also helps prevent anemia.

Cobalamin (Vitamin B12)

Cobalamin was isolated in the middle of the 20th century through the anti-anemic benefits of liver. It is the only vitamin that incorporates a mineral (cobalt) in its composition. It is a coenzyme in many essential biochemical reactions, and also plays a primary role in the synthesis of proteins and the production of red cells. Cobalamin is only found in animal products (liver, kidney, heart, lung, fish and meat). Deficiencies are caused through reduced absorption as a consequence of aging, vegetarian diets, digestive diseases and certain forms of cancer; and must be compensated for via the diet.

Choline

Choline is not a vitamin in the true sense of the word because all animals are able to synthesize it to some degree. The body is able to synthesize choline in the liver, but production is not always sufficient to cover requirements, and it must be added to the diet. Choline works to build cell membranes, and plays a role in protecting the skin from dehydration. Combined with phosphorus, choline becomes lecithin and forms part of the cell membranes and blood lipoproteins. Choline is also a component of acetylcholine, a very important mediator for nerve transmission. Choline is abundant in meat, including liver and heart, eggs and soy. Choline is required to prevent the pathological accumulation of fatty acids in the liver.

Minerals

Minerals are inorganic nutrients within the diet. When a food is analyzed for energy all nutrients other than minerals are removed. The remaining material is made up of dietary minerals, and is commonly referred to as “ash.” Those minerals required at relatively high levels within the diet are called macrominerals (calcium, phosphorus, potassium, sodium, magnesium and chloride; Table 4). Microminerals (sometimes referred to as trace elements) are required in far lower amounts, but are essential for the healthy functioning of the body (iron, zinc, manganese, copper, iodine and selenium; Table 5). Minerals may be present naturally within the ingredients commonly used in prepared pet foods. However, they may also be added as purified salts such as iron sulfate, zinc oxide, manganese oxide, copper sulfate, sodium selenite, calcium iodate. Bioavailability of minerals varies between the salts, which is considered when formulating mineral supplements for use in pet foods. The bioavailability of minerals can be improved by binding the mineral to a protein through the process of chelating. These chelated minerals are more readily

absorbed and are more useable to the pet. Some examples of chelated minerals are zinc proteinate, copper proteinate and manganese proteinate.

Table 4: Essential macrominerals

Mineral	Key Function
Calcium	Ossification of bones
Phosphorus	Energy Transfer
Potassium	Cellular ion balance
Sodium	Cellular ion balance
Magnesium	Sensory impulses
Chloride	Acid base balance

Table 5: Essential microminerals

Mineral	Key Function
Iron	Synthesis of hemoglobin
Zinc	Skin and coat health
Manganese	Formation of cartilage and skin
Copper	Synthesis of skin pigments
Iodine	Functioning of the thyroid gland
Selenium	Antioxidant

Calcium (Ca)

Calcium is the fifth most abundant element in the Earth’s crust and in sea water. Calcium intake must be balanced with phosphorus (P) for healthy bone growth and maintenance. Calcium plays two fundamental roles in the body. Over 90% of calcium found in the body is retained in the bones and teeth where, along with phosphorus, it is responsible for making these structures rigid. Calcium also plays a role in transfer of information between the cells and in the transmission of nerve impulses. Calcium is found in the bones of mammals, birds and fish. Dairy products also contain significant amounts of calcium. Vegetables such as broccoli and cabbage are moderately good sources. Common mineral salts include calcium carbonate, calcium sulfate and calcium phosphate. Lactation and growth require higher dietary levels of calcium than other lifestages. Signs of deficiency include compromised growth, while excess calcium results in bone abnormalities and osteochondrosis.

Phosphorus (P)

The word phosphorus means “light bearing.” The substance was discovered in 1669 by a German alchemist who released phosphorus in the form of a vapor that glowed in the dark. Phosphorus has multiple roles, each equally important. A large proportion (over 80%) of phosphorus found in the body is retained in the bones and teeth where, together with calcium, it is responsible for making these structures rigid. It is a constituent of cell membranes and is required for energy production.

Phosphorus is a structural component of DNA and RNA, the molecules that carry the cell's genetic code. Phosphorus is found in the bones of mammals, birds and fish. Meat is also rich in phosphorus. Phosphorus deficiency can result in slow growth, poor appetite and bone deformities. The maximum amount of phosphorus in a diet is usually governed by the level of calcium and maintenance of the calcium:phosphorus ratio. However, aging cats may demonstrate sub-clinical renal insufficiency and may be more susceptible to the effects of excess phosphorus.

Potassium (K)

Potassium is an alkaline mineral that oxidizes rapidly in air and is very reactive with water. This mineral was first isolated from potash (a type of stone), hence its name. It is the eighth most abundant mineral in the body. Potassium is the most abundant cation (positively charged ion) found inside the cell. It is essential for the correct functioning of the cell, and together with sodium, this mineral is responsible for maintaining the acid-base balance. Potassium is also responsible for nerve impulse transmission and plays an important role in energy metabolism. Potassium is commonly found in vegetables, meat, fish and eggs. Common mineral salts include potassium bicarbonate, potassium chloride and potassium sulfate. Although potassium deficiency is rare, restlessness and muscle paralysis have been reported in potassium-deficient puppies. Diarrhea can cause significant potassium losses resulting in deficiency if the condition persists.

Sodium (Na)

Sodium is a soft, silvery-white, highly reactive mineral, first isolated by Sir Humphrey Davy in 1807. This mineral is essential for healthy functioning of cells. Together with potassium, it maintains acid-base balance, and is also responsible for maintaining osmotic pressure between the inside and outside of the cell. It plays a major role in cellular energy metabolism, and is involved in nerve impulse generation and transmission. Sodium is important for regulation of water balance, the sensation of thirst and urinary concentration. Sodium usually occurs naturally in the form of sodium chloride (table salt). Vegetables are usually low in sodium, while unprocessed meats are around three times higher. Other common mineral salts include sodium phosphate and sodium carbonate, sodium bicarbonate and sodium tripolyphosphate (STPP). Sodium deficiency is rare in cats and dogs. Symptoms include restlessness, increased heart rate, reduced water consumption and increased urine output. Very high levels of sodium intake have been shown to cause vomiting and dry mucous membranes.

Magnesium (Mg)

Magnesium is an abundant intracellular cation and is involved in more than 300 metabolic processes. Magnesium plays a role in energy metabolism, DNA and RNA metabolism,

protein synthesis, and muscle and nerve cell membrane function. Magnesium is also, like calcium and phosphorus, an important constituent of bones and teeth. Magnesium is found in the bones of mammals, birds and fish. Magnesium deficiency can result in the appearance of nervous problems, including hyperextension of the joints, paralysis, hypertension and loss of appetite. Excess dietary magnesium has been linked with struvite bladder stone formation in cats.

Chloride (Cl)

Chloride is the most prevalent negatively charged ion in the extracellular fluid of animals. Chloride is important in maintaining the concentration of extracellular fluid and plays a role in acid-base balance. Chloride is found in limited concentrations in most foods. Therefore, diets must be supplemented with chloride-containing salts e.g. sodium chloride (table salt). Signs of deficiency include weakness, failure to grow and symptoms similar to potassium deficiency. Excess chloride can result in altered calcium and potassium levels in the blood and metabolic acidosis.

Iron (Fe)

Iron is the most prevalent trace element (micromineral) in the body, comprising about 0.005% of total weight. Iron is a vital component of hemoglobin, the molecule that transports oxygen around the body in red blood cells, and of myoglobin, which does the same job in muscle. Iron has many enzymatic functions, especially with respect to cellular respiration. Liver, meat, fish and green vegetables, such as broccoli and spinach, are rich natural sources of iron. Carbonate and oxide sources of iron are poorly available forms of this mineral. Iron deficiency can result in poor growth, pale mucous membranes, diarrhea and anemia. High levels of iron can cause marginal deficiencies in manganese, copper and zinc. Very high levels of iron can result in vomiting and diarrhea.

Zinc (Zn)

Zinc is present in most tissues throughout the body in relatively low concentrations. Zinc is the cofactor for around 200 enzymes involved in cell replication, carbohydrate and protein metabolism and membrane structure. It is essential for the transport of vitamin A in the blood, and plays an important role in reproduction. It is also crucial for collagen and keratin synthesis, and is therefore a fundamental element involved in skin and coat health and wound healing. Whole grain cereals and meat are rich natural sources of zinc. Zinc can also be found in mineral salts, such as zinc sulfate and zinc oxide. Zinc deficiency can result in poor growth and skin lesions on areas of wear, such as foot pads. Excess zinc can also cause seizures in cats. If the zinc level in the diet is high, the copper and iron levels should be increased above minimum requirements to avoid marginal deficiencies due to competing absorption sites within the body.

Manganese (Mn)

Manganese occurs in small amounts within animal tissues. An adult dog may have a total body content of only 3–15mg manganese. Manganese plays an active role in the correct functioning of the mitochondria, and is important for the formation of bone and joint cartilage and neurological function. Manganese plays a structural role in many enzymes. Cereals and mineral salts are good sources of manganese. Meat does contain manganese, but in lower amounts than other sources. A deficiency of manganese can result in shortening and bowing of the front legs during growth. In adult dog lameness, enlarged joints and poor locomotion have been reported. Manganese deficiency can have profound effects during reproduction, including delayed estrus, poor conception rates, still births and low birth rates. Prolonged manganese excess can result in iron deficiency.

Copper (Cu)

Dogs and cats contain a very small amount of copper. In 1984, Meyer reported a total body content of copper to be 7.3 mg per kg body weight in young dogs. Copper facilitates the intestinal absorption of iron, and its incorporation into hemoglobin. It is an active element in many enzymes and plays an important role in reducing cellular damage caused by free radicals. Copper is involved in the synthesis of collagen in the tendons and the myelin within the nervous system. Copper also participates in the synthesis of melanin, which is a hair pigment. Foods that have a high copper content include meat (lamb, pork, duck) and protein-rich grains (peas, lentils, soy). Copper may be added to pet food in the form of mineral salts, however copper oxide is a poorly available form of this mineral, and thus copper proteinate is often used to meet the copper requirements. Copper deficiency can result in anemia, loss of hair pigmentation and hyperextension of the lower limb.

Iodine (I)

Iodine is by far the heaviest mineral that is essential for cats and dogs but is required in very small amounts. It is an essential constituent of thyroid hormones, which are important for growth, development and the regulation of metabolic rate. Sea salt, seaweed flour and fish are common sources of iodine. Signs of deficiency include goiter, hair loss, dry coat and weight gain due to altered thyroid gland activity. In cats, excess iodine has been shown to decrease thyroxine (a thyroid hormone) levels, leading to similar symptoms to those seen in deficiency.

Selenium (Se)

Selenium is an essential micromineral, first classified in 1817. It is widely distributed in animal tissues, yet is present in only very small amounts in any given organ or tissue. Selenium acts as an antioxidant and plays a vital role in reducing cellular damage caused by free radicals. Selenium plays a support role in immune response. Selenium is found in inorganic mineral salts and fish. Low quantities can be found in meat, liver

and kidneys. Selenium deficiency can result in refusal to eat, depression, difficulty breathing and coma. Selenium excess can occur in diets containing high levels of fish. Symptoms include refusal to eat and poor bodyweight gain.

Summary

Dogs and cats must have sufficient amounts of all of the essential nutrients in the correct balance every day to maintain the proper level of health. To ensure these are provided in all of the foods that The Nutro Company makes, we employ a staff of dedicated Nutritionists, Veterinarians and Scientists. We formulate our foods with high quality natural ingredients to meet the needs of your pets.

References:

- ¹*Nutrient Requirements of Dogs and Cats*. 2006. The National Academies Press. Washington, DC.
- ²Association of American Feed Control Officials Incorporated. 2010 Official Publication
- ³The Waltham Centre for Pet Nutrition, Waltham-on-the-Wolds, Leicestershire, England

Chapter 3

Ingredients in Pet Food

Nutrients are supplied in pet food by various ingredients, which are added at different levels to meet the nutrient requirements of pets. Meat products and vegetable protein products are added as a source of protein to supply certain amino acids. Grains and starches are added to meet the energy requirements. Plant fiber is added to help regulate the digestive tract and to provide a nutrient source for the microorganisms of the digestive tract. Fats and oils are added to supply essential fatty acids, as well as energy. Complete and balanced pet foods are fortified with vitamins and minerals to meet the nutrient needs of pets. In addition to supplying nutrients, some ingredients offer additional health benefits. The availability of nutrients in the ingredients and the digestibility of those nutrients affect the quality of the pet foods. Pet food ingredients used by The Nutro Company, including definitions, are listed in Appendix 1. Additional pet food ingredients and definitions are listed in Appendix 2.

Protein Sources

Protein is delivered in pet food from meat, fish, dairy, egg and plant sources. Natural sources of meat protein are fresh meat (beef, lamb, pork and chicken) meat meal and meat by-product meal. Fresh meat is the least processed meat protein ingredient and has the lowest protein density. This is due to the high concentration of water in fresh meat, which is mostly cooked out when making dry pet food. For example, a dry pet food that contains 25% fresh meat, which consists of 75% water, would result in 6–7% protein in the dry food from this fresh meat.

Meat meal is made from meat that has had the water and most of the fat removed from a cooking process. The result is a dry, concentrated source of protein. Meat meals are labeled on packages to indicate the source of protein, such as lamb meal or beef meal. Poultry meals, such as chicken meal, are made from meat that has been cooked to remove the water and most of the fat. Meat by-product and poultry by-product meals are similar to meat meals except they may also contain other animal tissues, such as viscera, chicken heads and chicken feet. The source of meat by-product meals are typically labeled on the package. If the source of animal protein is mixed, such as containing both beef and pork, the pet food label may just read meat meal. Knowing the source of the protein is beneficial for pets that may have allergies or intolerances to certain types of proteins.

Fish protein sources used in pet foods are fresh fish, frozen fish, fish meals or fish by-products. Fresh fish is the least stable and typically the least likely to be used in making pet food. The location of the manufacturing facility must be in close proximity to the source of fresh fish. The more common form of fish used in pet food is frozen fish. Fresh fish and frozen fish are labeled on the pet food according to the type of fish, such

as tuna or salmon. Fish meal is made from cleaned fish that is ground and cooked to remove the water and some of the fat to produce a concentrated protein source. These meals can be labeled on pet food according to the type of fish, such as tuna meal or salmon meal. If the fish meal is made from a mix of different types of fish, then it appears on the label as fish meal. Fish by-products are cleaned portions of fish, such as heads, fins, tail ends, skin, bone and viscera, and are labeled as fish by-product on the pet food.

Nearly 80% of the protein in cows' milk is in the form of casein. Milk protein is typically delivered in pet food from ingredients such as whey, which is produced from the making of cheese. Whey is typically dried to remove the water and concentrate the nutrients.

Egg protein is considered to be the most ideal protein, due to its amino acid profile and its digestibility. Egg product contains the yolk and white of eggs, without the shells, and is often dried or used in liquid or frozen form.

Plant protein sources are typically supplied by glens, meals or protein isolates. Gluten is the result of removing the starch component of grains to leave a protein-rich portion. Some examples would be corn gluten meal, wheat gluten and rice gluten. Soybean meal is a common plant protein source used in some pet foods. Soybean meal is made by removing the oil from the soybeans by solvent extraction, leaving a protein-rich meal. Protein isolates are typically from ingredients, such as potatoes or peas, that have had the starch component removed, resulting in a highly concentrated protein source. These are typically labeled on pet food as potato protein, pea protein or named protein isolate.

Novel proteins come from protein sources that pets have not historically eaten. These types of proteins are used in foods designed for pets that have sensitivities to certain types of proteins. Novel protein sources may include venison, duck, pea protein and potato protein. Additionally, proteins can be put through a process called hydrolyzation, which breaks the protein into smaller fragments so the body does not recognize it as an allergen. These appear on the pet food label as hydrolyzed protein, such as hydrolyzed pea protein.

Specific amino acids can be added to pet foods to supplement protein sources that may be lacking certain types of amino acids. One example would be adding taurine to a vegetarian pet food that does not have animal protein, as taurine is required for cats and is beneficial for dogs. Pure amino acids are synthesized from other compounds and can not be considered natural. These forms of amino acids can be utilized by the pet in the same way as amino acids from natural protein sources.

There are many sources of proteins used in pet foods, but not all protein sources are the same when it comes to amino acids (see Chapter 2). When evaluating protein sources, each one has a specific amino acid profile. All species have

certain requirements for amino acids in different amounts that are needed daily. Dogs and cats have different requirements than humans. When complete and balanced pet foods are formulated at The Nutro Company, these requirements are taken into consideration with the amino acid profile of each protein source. Animal protein sources have more of the amino acids dogs and cats require, and the amino acid profile more closely meets their requirements. Plant protein sources are typically low in arginine and do not contain taurine, both of which are essential to cats and are beneficial to dogs.

Carbohydrate Sources

Carbohydrate is a term that covers molecules that are composed of carbon, oxygen and hydrogen. These are further divided into starch, sugar and fiber. Carbohydrates are not essential nutrients for dogs or cats. In fact, dogs and cats in the wild consume very little carbohydrates. However, both dogs and cats can utilize certain types of carbohydrates (sugar and starch) for quick energy. In pet foods, these types of carbohydrates are typically provided by grains. Common grains include rice, oats, corn, wheat and barley. At The Nutro Company, we use whole brown rice and whole rice, as they are one of the most digestible grains available. Other carbohydrate sources are starches, such as potato starch and wheat starch, which are highly digestible and rapidly utilized for energy. Fiber is classified as fermentable and non-fermentable. Many fiber sources contain both fermentable and non-fermentable components, such as beet pulp and chicory. Other fiber sources, such as cellulose and pectin, are non-fermentable. It is a common misconception that fiber is added to pet food as “filler.” A certain amount of fiber is needed in order to aid in the digestion of other nutrients. Fibers regulate transit time in the digestive track, and act as prebiotics to support the healthy bacteria in the intestine.

Fat Sources

Fats and oils provide energy and essential fatty acids to the diet. Each type of fat or oil is comprised of different amounts of fatty acids. Marine fish oils, such as menhaden fish oil, are rich in omega-3 fatty acids. Oils from plant sources, such as sunflower oil, vegetable oil and soybean oil, are rich in omega-6 fatty acids. Animal fat and poultry fat are a rich source of conjugated fatty acids, such as linoleic acid. The Nutro Company uses a variety of different fats and oils to meet the nutrient requirement of fatty acids, and to provide added benefits to the overall health of pets.

Vitamin Sources

Fruits, meats, vegetables and grains all contain vitamins. However, to ensure nutrient requirements are met, at The Nutro Company we fortify our complete and balanced pet foods with vitamins.

Mineral Sources

Most animal and plant ingredient sources contain minerals. Additionally, minerals that come from mined sources are added to pet food. To ensure the nutrient requirements of dogs and cats are met, at The Nutro Company we fortify our complete and balanced pet foods with minerals. Some forms of minerals are poorly absorbed, and thus chelated forms are used, such as copper proteinate, zinc proteinate and manganese proteinate.

Natural Ingredients

Ingredients that are derived from animal, plant or mined sources can legally be labeled on pet food as natural. Ingredients that are not natural are those that are chemically synthesized or contain an additive that is chemically synthesized. At The Nutro Company, we believe the best way to deliver nutrients to your pet is through natural ingredients. We use carefully processed ingredients to ensure our products meet our quality standards when pets consume them.

Preservatives

Preservatives are added to ingredients and to pet foods to ensure the food maintains its freshness. Fats and oils will go through an oxidation process, which results in a rancid product. Pet food manufacturers add preservatives to reduce the amount of this degradation. Chemical preservatives such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and ethoxyquin are used by some pet food companies. At The Nutro Company, we only use mixed tocopherols, which are natural antioxidants and a source of vitamin E, to stabilize our pet food.

Ingredient Labeling

All pet food companies must conform to the laws of each state in which they are sold by providing specific information on the package label. This includes the brand name, product name, a purpose statement, guaranteed analysis, list of ingredients, directions for use, nutritional adequacy, the name and address of manufacturer and a quantity statement. An example of the brand name would be NUTRO® and the product name would be NATURAL CHOICE® Lamb Meal & Rice Dog Food. The purpose statement would indicate the species for which the food is intended and the classification, such as adult maintenance. The guaranteed analysis must list the amounts of the legally required nutrients, such as protein, fat, fiber and moisture. The list of ingredients must contain all of the ingredients in descending order, and the terms used must conform to the term's definition by law. The feeding directions must include an amount per weight of dog or cat and include the frequency of feeding. If the product is complete and balanced, it must state for what life stage the product supports. If a product is labeled as “light,” “lite” or “reduced calorie,” it must conform to legal limits of calorie content. The name and address of the manufacturer or the distributor must be printed on the package. The quantity of pet food in the package must be labeled.

Functional Ingredients

Functional ingredients provide added health benefits beyond meeting basic nutritional requirements. At The Nutro Company, we use specific ingredients and combinations of ingredients to provide certain added benefits. We add patented levels of linoleic acid and zinc for a healthy skin and coat. We use a unique blend of antioxidants for a healthy immune system. We use natural sources of glucosamine and chondroitin to help promote healthy joints. We use a patented blend of protein, fat and carbohydrate, which is the ideal nutrient balance to deliver nutrients at the levels that cats naturally prefer, developed by The Waltham Centre for Pet Nutrition. We add the omega-3 fatty acids EPA and DHA for healthy brain development and cognitive function. Among the functional ingredients, we use ingredients known as superfoods, which contain natural phytochemicals that provide added health benefits. The benefits of our ULTRASSENTIAL® Superfood Blend include: strong immune system from antioxidant-rich fruits and vegetables; lean muscle mass from high-quality protein with essential amino acids; healthy skin and coat from ingredients rich in omega-3 and -6 fatty acids; heart health from high-quality proteins, fruits and vegetables; sharp vision from beta carotene; joint health from natural sources of glucosamine and chondroitin; cognitive development from EPA and DHA; and strong teeth and bones from optimal calcium levels for growing puppies. At The Nutro Company, we implement the latest science combined with natural sources of nutrition to provide a lifetime of health for your pet. We are continuously conducting research at The Waltham Centre for Pet Nutrition to find new advances in science that deliver the best nutrition to your pet naturally.

Chapter 4

Manufactured Pet Food

As has been shown in the previous chapters, essential nutrition is a complex subject. Although dogs, cats and humans share some common traits, there are many notable physiological differences, causing unique dietary requirements for each species. Most of these differences are due to the unique and specialized adaptations of cats and dogs. One way to ensure all essential nutrient requirements are met is to feed a complete and balanced manufactured diet. Wet, dry and semi-moist diets are all carefully designed to provide the right nutrients in the right amounts according to lifestage, including puppy, kitten, adult or senior. Decades of scientific research and expertise are incorporated into most reputable brands of manufactured pet food, offering owners a reliable and consistent product of guaranteed quality and a high level of safety.

Many cats and dogs around the world are still fed home-prepared diets made from human foods and table scraps. Diets that are suitable for humans rarely deliver enough nutrients for dogs or cats without excessive overfeeding. It is very hard to make a complete and balanced pet food at home. Most home-prepared diets are incomplete and may impair the health and vitality of pets¹. They have been linked to increased risk of obesity and other health issues. Home-prepared raw food diets may have the additional risk, both to pets and owners, of being contaminated with parasites and bacteria. Some common human food ingredients can be toxic to cats and dogs, including chocolate, grapes, raisins and onions.

Dry Pet Food

All NUTRO[®] dry pet foods start with a blend of ingredients that are ground and cooked using water, steam, heat and pressure. Ingredients like chicken meal, lamb meal, poultry fat and ground rice provide a combination of essential nutrients, including protein, fat, vitamins and minerals. After the pet food is extruded, it is dried and coated with fat, oils and natural flavors to prevent rancidity and promote palatability. The dry pet food is then poured into bags, sealed, tested and stored before shipment to customers and consumers. Throughout this process, multiple quality checks are in place to make sure every bag we sell is safe and nutritious.

Canned Pet Food

All NUTRO[®] canned products start with frozen meat, such as chicken, turkey or lamb. The meat is kept frozen to retain freshness and make the best product possible. The meat is mixed with carbohydrates, such as rice, vegetables such as peas and carrots, and tasty gravy fortified with essential vitamins and minerals. Next, cans and trays are filled and sealed to prepare for cooking. Heat and pressure are maintained during the canning process to prevent harmful organisms and bacteria from causing food spoilage and health concerns. After the products are cooked, they are shelf stable and ready for the pet to enjoy.

Crunchy Treats

All NUTRO[®] crunchy treats start with a blend of wholesome ingredients that are ground and cooked using water, steam, heat and pressure. Ingredients like chicken meal, lamb meal, poultry fat and whole brown rice provide a combination of essential nutrients, including protein, fat, vitamins and minerals. After the crunchy treats are extruded, they are dried, and in some cases coated with fat, oils and natural flavors to prevent rancidity and promote palatability. Upon cooling down to ambient temperature, the crunchy treats are then packed, sealed, tested and stored before shipment to customers and consumers. Throughout this process, multiple quality checks are in place to make sure every bag we sell is safe and nutritious.

Baked Biscuits

All NUTRO[®] baked biscuits start with a blend of dry ingredients that are mixed with water, fat and flavors to make the dough. Ingredients like chicken meal, lamb meal, poultry fat and ground rice provide a combination of essential nutrients, including protein, fat, vitamins and minerals. After the dough is given its specific shape, it is baked. The baked biscuit is cooled to ambient temperature, packed, sealed, tested and stored before shipment to customers and consumers. Throughout this process, multiple quality checks are in place to make sure every bag we sell is safe and nutritious.

Semi-Moist/Soft Treats

All NUTRO[®] semi-moist/soft treats start with separate blends of dry and liquid ingredients that are cooked together using water, steam, heat and pressure. Ingredients like chicken, lamb, chicken meal, lamb meal, poultry fat and whole brown rice provide a combination of essential nutrients, including protein, fat, vitamins and minerals. After the soft and moist treats are extruded and formed into their characteristic shapes, they are baked to create a firmer texture. Upon cutting and cooling to ambient temperature, the semi-moist treats are packed, sealed, tested and stored before shipment to customers and consumers. Throughout this process, multiple quality checks are in place to make sure every bag we sell is safe and nutritious.

References:

¹Streiff, EL, B. Zwischenberger, R. F. Butterwick, et al., 2002. "A Comparison of the Nutritional Adequacy of Home-Prepared and Commercial Diets for Dogs." *J. Nutr.* 132:1698S–1700S

Appendix 1; The Nutro Company Ingredients

INGREDIENT	DEFINITION/FUNCTION
Ascorbic Acid	Ascorbic acid is a source of Vitamin C, which is an anti-oxidant that neutralizes free radicals.
Alpha-linolenic acid	Alpha-linolenic acid is an Omega-3 fatty acid which improves skin and coat condition and acts as an anti-inflammatory agent.
Barley Malt	Barley grain that has been through the malting process of soaking in water and kiln drying. Barley malt enhances the flavor.
Basil	Basil is a natural herb that has been shown to have antioxidant properties in the oil of the plant. This herb enhances the flavor of foods.
Beef	Beef is a source of protein and adds flavor to a diet. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Beef Broth	Beef broth is made from cooking beef. The broth adds beef flavor that pets love.
Beef Liver	Beef liver is a high quality source of protein that is rich in vitamins and minerals. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Beef Meal	Beef meal is made from beef that is cooked to remove water and fat, leaving a dry, highly concentrated source of high quality protein and minerals, such as calcium. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system. Calcium helps promote strong teeth and bones.
Beta Carotene	Beta carotene is a member of the carotenoids family, which is found in highly pigmented plants and vegetables such as carrots and pumpkins. Beta carotene is converted in dogs to Vitamin A, which is required for healthy vision.
Biotin	Biotin is one of the B vitamins. It is one of the most important vitamins for a glossy coat and healthy skin. Biotin is directly involved in the healthy functioning of the nervous system.
Brewers Dried Yeast	Brewers dried yeast is a protein source that adds additional flavor. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Brewers Rice	An easily digestible, nutrient-rich grain that has been milled, which improves its digestibility. Brewers rice provides balanced nutrition for your pet in the form of energy.
Calcium Carbonate	Calcium carbonate is a natural source of calcium. Calcium is used by the body in large amounts, as it is required for many biological functions. Calcium helps promote strong teeth and bones.
Calcium Iodate	Calcium iodate is a source of calcium and iodine. Both are essential nutrients. Calcium is needed for strong bones and teeth. Iodine is needed for proper thyroid function, which regulates growth, development and metabolic rate.
Calcium Pantothenate	Calcium pantothenate is a source of pantothenic acid, a B vitamin that is involved in almost every metabolic process in the body.
Caramel Color	Caramel color is the dark brown material resulting from the carefully controlled heat treatment of food-grade carbohydrates. Carmel color enhances the flavor of our food and it is a taste that dogs love.
Carrageenan	Carrageenan is a seaweed extract used to thicken and modify the texture of foods. It is used in pet foods and human foods such as ice cream.
Carrots	Whole carrots and pieces obtained from the processing of carrots for human consumption. A source of carbohydrates and fiber that is rich in beta carotene.
Celery	Celery is a vegetable that adds fiber to the diet.
Celery Seed	Celery seed is from the celery plant and it enhances the flavor of foods.
Cheese	Cheese is a source of essential fatty acids, vitamins and minerals. Cheese enhances the flavor and is a taste that pets love.

Chicken	Chicken is a source of high-quality protein and adds flavor to a diet. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Chicken Broth	Chicken broth is made from cooking chicken. The broth adds chicken flavor that pets love.
Chicken Giblets	Chicken giblets include heart, liver and gizzard, which are excellent sources of protein. Similar to the giblets that are used to make gravy for humans. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Chicken Liver	Chicken liver is an excellent source of protein that is rich in vitamins and minerals. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Chicken Meal	Chicken meal is made from whole chicken that's cooked to remove the water and fat—leaving a dry, highly concentrated source of high-quality protein and minerals such as calcium. Also provides a natural source of glucosamine and chondroitin. Excludes chicken heads, feet and intestines.
Chicory Pulp	Chicory pulp is a source of fiber that helps support healthy digestion.
Choline Chloride	Choline chloride is a source of choline, a vitamin that works to build cell membranes.
Chondroitin	Chondroitin helps maintain healthy joints and supports mobility.
Cinnamon	Cinnamon is a spice from the bark of cinnamon trees. Cinnamon enhances the flavor of fruits, especially apples. Cinnamon provides flavor and aroma to our treats. Scientific research has shown that it acts as an antioxidant.
Cod	Cod is an ocean fish that is an excellent protein source and adds flavor that pets love. Cod is rich in Omega-3 fatty acids, which help support healthy skin and coat.
Copper Proteinate	Copper proteinate is a source of copper, which is chelated with amino acids to improve the bioavailability. Copper is a mineral that has many roles, including reducing cellular damage caused by free radicals, synthesis of hemoglobin and the synthesis of collagen.
Copper Sulfate	Copper sulfate is a source of copper, which is a mineral that has many roles, including reducing cellular damage caused by free radicals, synthesis of hemoglobin and the synthesis of collagen.
Corn Gluten Meal	Excellent source of protein that is highly digestible. Corn gluten meal is also a source of sulfur amino acids which are important for skin and coat health. It is also a good source of antioxidants like lutein.
Crab Meat	Crab meat is a source of protein that is rich in omega-3 fatty acids, and helps support healthy skin and coat.
Cranberry Powder	This delicious, natural source of vitamin C helps keep your best friend's immune system strong.
d-Calcium Pantothenate	d-Calcium pantothenate is a source of pantothenic acid, a B vitamin that is involved in almost every metabolic process in the body.
Defluorinated Phosphate	Defluorinated phosphate is a source of phosphorus in which the fluorine has been removed. It is an essential nutrient that is required for healthy bones and teeth.
Dicalcium Phosphate	Dicalcium phosphate is a source of calcium and phosphorus. Both are essential nutrients that are required for healthy bones and teeth.
DL-Methionine	DL-Methionine is an essential amino acid that helps maintain urinary tract health.
Dried Apples	Dried apples are a carbohydrate source that adds flavor.
Dried Blueberries	This popular berry is packed with antioxidants to help maintain a strong immune system, a healthy heart and sharp mind.
Dried Carrots	Dried carrots are rich in carotenoids, which have antioxidant properties and support a strong immune system.
Dried Cherries	Dried cherries are rich in vitamin C, which acts as a natural antioxidant to support a strong immune system.
Dried Chicory Root	Chicory root is a source of fiber that helps support healthy digestion.

Dried Cranberries	This deliciously, natural source of vitamin C helps keep your best friend's immune system strong.
Dried Egg Product	Dried egg that is free of shells. Egg provides one of the highest-quality proteins in a highly digestible form. Eggs also provide a good source of antioxidants like lutein, the pigment that provides yellow color to the yolk.
Dried Kelp and Dried Kelp Meal	Kelp is an ocean plant that is rich in iodine. Iodine is needed for proper thyroid function, which regulates growth, development and metabolic rate.
Dried Plain Beet Pulp	A source of natural fiber from sugar beets that have had the sugar removed. Beet pulp aids in healthy digestion and promotes good stool quality.
Dried Vegetable Fiber	A source of natural fiber from vegetables that have had the starch and water removed. Vegetable fiber aids in healthy digestion and promotes good stool quality.
Dried Whey	Dried whey is a dairy product, which is a source of protein, fat and lactose (milk sugar). Whey protein has a high biological value.
Dried Yeast	Dried yeast is an excellent source of protein and adds flavor to our products. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Duck	Duck is a novel source of protein, which may benefit pets with sensitive skin and stomachs.
Egg Product	Egg that is free of shells. Egg provides one of the highest-quality proteins in a highly digestible form. Eggs also provide a good source of antioxidants like lutein, the pigment that provides yellow color to the yolk.
Enriched Macaroni (Durum Semolina Enriched with Niacin and other vitamins/minerals)	Enriched macaroni is a pasta that is a highly digestible source of energy, which is enriched with niacin and other vitamins/minerals. Niacin is a B vitamin that is essential for healthy skin.
Ethylenediamine Dihydriodide	Ethylenediamine dihydriodide is a source of iodine. Iodine is needed for proper thyroid function, which regulates growth, development and metabolic rate.
Feeding Oatmeal	Feeding oatmeal is made from dehulled rolled oats and is an energy source.
Ferrous Sulfate	A source of iron, a vital component of hemoglobin, the molecule that transports oxygen.
Fish Broth	Fish broth is made from cooking fish. The broth adds fish flavor that pets love.
Fish Oil	Rich in unsaturated fatty acids that support skin and coat health, cognitive function and joint health.
Flax Seed Meal	Ground whole seeds from the flax plant. Flaxseed is a good source of omega-3 fatty acids (alpha-linolenic acid) for a healthy hair coat and also provides a good source of fiber for digestive health.
Flaxseed	Whole seeds from the flax plant, which are ground. Flaxseed is a good source of omega-3 fatty acids (alpha-linolenic acid) for a healthy hair coat and also provides a good source of fiber for digestive health.
Folic Acid	Folic acid is a B vitamin that is involved in the development of tissues of the nervous system.
Food Starch	Food starch is a natural source of energy from the starch of grains.
Garlic Flavor	Garlic flavor adds to the tastiness of our products.
Garlic Spice	The garlic spice we use in our pet foods adds to the flavor of the product.
Gelatin	Gelatin is a source of natural protein that adds structure to moist treats.
Glucosamine	Glucosamine helps maintain healthy joints and supports mobility.
Ground Rice	Ground, milled and polished rice grains. Excludes the bran, germ and hulls. Provides an excellent source of energy through highly digestible carbohydrates.
Ground Whole Wheat	Ground whole wheat is made from grinding wheat grain. It is a natural source of energy and fiber.
Guar Gum	Guar gum is made from guar beans which are ground. Guar gum is used to thicken sauces and gravy.
Herring	Herring is a cold water fish that is rich in EPA and DHA, which are omega-3 fatty acids that support healthy cognitive function.

Herring Meal	Herring meal is a concentrated source of protein from herring, which is a cold water fish that is rich in the omega-3 fatty acids EPA and DHA.
Inositol	Inositol is a vitamin-like substance, which is a constituent of phospholipids and is involved in signal transduction.
Iron Oxide	Iron oxide is a source of iron. Iron a vital component of hemoglobin, the molecule that transports oxygen.
Iron Sulfate	Iron sulfate is a source of iron. Iron a vital component of hemoglobin, the molecule that transports oxygen.
Lamb	Lamb is an excellent source of protein that dogs love. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Lamb Broth	Lamb broth is made from cooking lamb. The broth adds lamb flavor that dogs love.
Lamb Liver	Lamb liver is a high-quality source of protein that is rich in vitamins and minerals. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Lamb Meal	Lamb meal is made from real lamb that's cooked to remove the water and fat—leaving a dry, highly concentrated source of high-quality, highly digestible protein for lean muscles. It also provides essential vitamins and minerals such as vitamin B12 and selenium.
L-Ascorbyl-2-Polyphosphate	A source of vitamin C, which is an antioxidant that neutralizes free radicals.
L-Carnitine	A naturally occurring amino acid which plays a vital role in the metabolism of fat.
Lecithin	Lecithin is a naturally occurring phospholipid, and is an excellent source of choline. Choline is a vitamin that works to build cell membranes.
Liver	Liver is a high-quality source of protein that is rich in vitamins and minerals. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
L-Lysine	Lysine is an essential amino acid needed for synthesis of proteins in the body.
L-Lysine Monohydrochloride	A source of lysine which is an essential amino acid needed for synthesis of proteins in the body.
Mackerel	Mackerel is an ocean fish that is an excellent protein source. Mackerel is rich in omega-3 and omega-6 fatty acids that support a strong immune system and cognitive function.
Magnesium Stearate	A source of magnesium. Magnesium is an essential mineral that plays a role in energy metabolism, DNA and RNA metabolism, protein synthesis, muscle and nerve cell membrane function.
Manganese Proteinate	A source of manganese, which is chelated with amino acids to improve the bioavailability. Manganese is a mineral that has a vital role in the proper function of cells within the body. It is necessary for the formation of bone and joint cartilage and neurological function.
Manganese Sulfate	A source of manganese. Manganese is a mineral that has a vital role in the proper function of cells within the body. It is necessary for the formation of bone and joint cartilage and neurological function.
Manganous Oxide	A source of manganese. Manganese is a mineral that has a vital role in the proper function of cells within the body. It is necessary for the formation of bone and joint cartilage and neurological function.
Manganous Sulfate	A source of manganese. Manganese is a mineral that has a vital role in the proper function of cells within the body. It is necessary for the formation of bone and joint cartilage and neurological function.
Menadione Sodium Bisulfite Complex	A source of vitamin K activity, which is required for many enzymes to function properly in the body.
Menhaden Fish Oil	Menhaden fish oil is a rich source of omega-3 and omega-6 fatty acids that support a strong immune system and cognitive function.
Mixed Tocopherols	Mixed tocopherols are a source of vitamin E, which is an antioxidant that helps protect cells in the body.

Molasses	Molasses is a natural sweetener that enhances flavor.
Monocalcium Phosphate	Monocalcium phosphate is a source of calcium and phosphorus. Calcium is used by the body in large amounts as it is required for many biological functions. Phosphorus is needed by the body for energy production. Calcium and phosphorus help promote strong teeth and bones.
Monosodium Phosphate	Monosodium phosphate is a source of sodium and phosphorus. Sodium is essential for healthy functioning cells and maintains acid base balance with potassium in the body. Phosphorus is needed by the body for energy production.
Natural Flavors	A proprietary flavor system comprising natural sources of flavors that pet's love.
Natural Smoke Flavor	Natural smoke flavor is added to provide a smoky flavor to our products.
Niacin	Niacin is a B vitamin that protects the skin by promoting the synthesis of skin fats, to help limit skin dehydration.
Niacin Supplement	Niacin is a B vitamin that protects the skin by promoting the synthesis of skin fats, to help limit skin dehydration.
Niacinamide	Niacinamide is a form of niacin. Niacin is a B vitamin that protects the skin by promoting the synthesis of skin fats, to help limit skin dehydration.
Oat Bran	Oat bran is the outer hard layer of the oat grain. Oat bran is rich in fiber and essential fatty acids.
Oat Fiber	Oat fiber is a more concentrated source of dietary fiber than oat bran. Oat fiber supports healthy digestion.
Oatmeal	A grain that provides an excellent source of dietary fiber consisting of both insoluble and soluble fiber to support digestive health.
Oats	A grain that provides an excellent source of dietary fiber consisting of both insoluble and soluble fiber to support digestive health.
Parsley	Parsley is an herb that enhances the flavor of our products.
Pasta (Semolina Wheat enriched with Niacin and other vitamins/minerals)	Pasta that is a highly digestible source of energy, which is enriched with niacin and other vitamins/minerals. Niacin is a B vitamin that is essential for healthy skin.
Pea Protein	Pea protein is a concentrated protein source. Pea protein is a novel protein source that may benefit pets with sensitive skin and stomachs.
Peas	Peas are a vegetable that are rich in vitamins and minerals.
Peppers	Peppers are a vegetable that add a flavor to our products.
Phosphoric Acid	Phosphoric acid is added to provide an optimal pH of the product.
Pork Plasma	Pork plasma is a protein source that helps maintain the texture of our products.
Potassium Carbonate	A source of potassium, which is a mineral that is essential for the correct functioning of cells in the body. It is responsible for maintaining the acid base balance in the body.
Potassium Chloride	A source of potassium, which is a mineral that is essential for the correct functioning of cells in the body. It is responsible for maintaining the acid base balance in the body.
Potassium Iodide	A source of potassium and iodine. Potassium is a mineral that is essential for the correct functioning of cells in the body. Potassium is responsible for maintaining the acid base balance in the body. Iodine is a component of thyroid hormone which is important for growth, development and the regulation of metabolic rate.
Potassium Sorbate	Potassium sorbate is used as a mold inhibitor in moist treats.
Potato Protein	Potato protein is a concentrated protein source. Potato protein is a novel protein source which may reduce digestive upset in pets with sensitive stomachs.
Potato Starch	Potato starch is a natural source of energy from the starch of potatoes.
Potatoes and Dried Potato	Potatoes are a good source of energy and are rich in vitamins and minerals.
Poultry Fat	Provides essential fatty acids like linoleic acid for a healthy skin and coat. Also serves as a concentrated source of energy and flavor.
Powdered Cellulose	Powdered cellulose is a natural source of fiber that supports healthy digestion.

Propylene Glycol	Propylene glycol is added to maintain the moistness of semi-moist treats.
Pyridoxine Hydrochloride	A source of pyridoxine, also known as vitamin B6, a B vitamin that has many roles in metabolism.
Red Peppers	Red peppers are a vegetable that add a flavor to our products.
Riboflavin	Riboflavin, also known as vitamin B2, is a B vitamin that contributes to skin and coat health.
Riboflavin Supplement	A source of riboflavin, also known as vitamin B2, is a B vitamin that contributes to skin and coat health.
Rice	An easily digestible, nutrient-rich grain. Rice provides balanced nutrition for your pet in the form of energy.
Rice Bran	The combination of the bran layer and germ of the rice. Rice bran provides many different nutrients including dietary fiber for digestive health and antioxidants to support the immune system.
Rice Flour	Finely ground meal from the milling of rice, which consists primarily of the starch and gluten fractions. Rice flour provides an excellent source of highly digestible carbohydrates for quick energy.
Rice Gluten	Rice gluten is a protein and carbohydrate source that is made from removing most of the starch from the grain.
Rice Protein Concentrate	Rice protein concentrate is a concentrated protein source made from rice. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Rosemary and Rosemary Extract	Rosemary is a natural herb that enhances the flavor of foods.
Salmon	Salmon is an ocean fish that is an excellent protein source. Salmon is rich in omega-3 and omega-6 fatty acids that support a strong immune system and cognitive function.
Salmon Broth	Salmon broth is made from cooking salmon. The broth adds salmon flavor that pets love.
Salmon Meal	Salmon meal is made from real salmon that's cooked to remove the water and fat—leaving a dry, highly concentrated source of protein and natural antioxidants. It is also a great source of long-chained omega-3 fatty acids like DHA and EPA which are important for cognitive function and joint health.
Salmon Protein Concentrate	Salmon protein concentrate is a concentrated protein source made from salmon. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Salt (Sodium Chloride)	Salt is a combination of the two minerals sodium and chloride. Sodium is essential for healthy functioning of cells and maintains the acid base balance in the body with potassium. Chloride has a role in maintaining the fluid balance in the body and helps maintain acid base balance.
Selenium	Selenium is an essential mineral that is needed in small amounts. Selenium plays a vital role in reducing cellular damage and supports the immune response.
Shrimp	Shrimp is a high-quality protein source and it adds flavor that pets love. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Sodium Acid Pyrophosphate	An acid source that is added to leaven baked goods. This helps our biscuit dough to rise and provide the crunchy texture that dogs love, which helps clean teeth.
Sodium Alginate	Sodium alginate is added to thicken our sauces and gravies.
Sodium Ascorbate	Sodium ascorbate is a source of vitamin C, which is an anti-oxidant that neutralizes free radicals in the body.
Sodium Bicarbonate	Sodium bicarbonate is a source of sodium. Sodium is essential for healthy functioning cells and maintains acid base balance in the body with potassium.
Sodium Carbonate	Sodium carbonate is a source of sodium. Sodium is essential for healthy functioning cells and maintains acid base balance in the body with potassium.
Sodium Metabisulfite	Sodium metabisulfite is added to condition biscuit dough to provide texture.

Sodium Phosphate	Sodium phosphate is a source of sodium and phosphorus. Sodium is essential for healthy functioning cells and maintains acid base balance in the body with potassium. Phosphorus is needed by the body for energy production.
Sodium Selenite	A source of sodium and selenium. Sodium is essential for healthy functioning cells and maintains acid base balance in the body with potassium. Selenium plays a vital role in reducing cellular damage caused by free radicals and a support role in immune response.
Sodium Tripolyphosphate	Sodium tripolyphosphate is a source of sodium and phosphorus. Sodium is essential for healthy functioning cells and maintains acid base balance in the body with potassium. Phosphorus is needed by the body for energy production.
Soy Grits	Soy grits are a natural source of protein and carbohydrates made from soybeans. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system. Carbohydrates provide a source of readily available energy.
Soy Protein Concentrate	Soy protein concentrate is a concentrated protein source made from soy. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Soybean Oil	Oil that is pressed from soybeans. Soybean oil provides a source of both omega-6 and -3 fatty acids to support many health systems, including skin and coat, joint and cognitive.
Starch	Starch is a natural source of energy from the starch of grains and vegetables.
Sunflower Oil	Oil that is pressed from sunflower seeds. Sunflower oil is a good source of the omega-6 fatty acid, linoleic acid which is a key nutritional driver for hair coat softness and shine.
Sweet Potatoes	Sweet potatoes are a natural energy source that are rich in vitamins and minerals.
Taurine	An essential amino acid for cats. Taurine provides added health benefits for dogs as a natural antioxidant as well as for healthy eyesight, heart health and hearing.
Tetrapotassium Pyrophosphate	Tetrapotassium pyrophosphate is added to condition biscuit dough to provide a texture that helps clean teeth.
Thiamine Mononitrate	Thiamine, also known as vitamin B1, is a B vitamin that is involved in many complex biochemical reactions that help generate energy for cells.
Thyme	Thyme is an herb that enhances the flavor of our products.
Tomato	A vegetable packed with vitamin C and antioxidants, tomatoes help support a strong immune system and a healthy heart.
Tomato Flakes	Tomato flakes are a dehydrated form of tomatoes. Packed with vitamin C and antioxidants, tomatoes help support a strong immune system and a healthy heart.
Tomato Paste	Tomato paste is a concentrated form of tomatoes. Packed with vitamin C and antioxidants, tomatoes help support a strong immune system and a healthy heart.
Tomato Pomace	A dried mixture of tomatoes packed with vitamin C and antioxidants, tomatoes help support a strong immune system and a healthy heart.
Tricalcium Phosphate	A source of calcium and phosphorus. Both are essential nutrients that are required for healthy bones and teeth. Tricalcium phosphate is added to aid in emulsifying canned products.
Tuna	Tuna is an ocean fish that is an excellent source of protein and is a flavor that pets love. Tuna is rich in omega-3 fatty acids that help support healthy skin and coat.
Tuna Meal	Tuna meal is made from real tuna that's cooked to remove the water and fat—leaving a dry, highly concentrated source of protein and natural antioxidants. Tuna is rich in omega-3 fatty acids that help support healthy skin and coat.
Turkey	Turkey is an excellent source of protein that adds flavor that pets love. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Turkey Broth	Turkey broth is made from cooking turkey. The broth adds turkey flavor that pets love.

Veal	Veal is a high-quality source of protein that adds flavor to the diet. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Venison	Venison is a novel high-quality protein source. Venison may benefit pets with sensitive skin and stomachs.
Venison Meal	Venison meal is made from real venison that's cooked to remove the water and fat—leaving a dry, highly concentrated source of high-quality, highly digestible protein for lean muscles. Venison is a novel high-quality protein source. Venison may benefit pets with sensitive skin and stomachs.
Vitamin A Acetate	Vitamin A acetate is a source of vitamin A, which is required for healthy vision.
Vitamin A Supplement	A source of vitamin A, which is required for healthy vision.
Vitamin B12 Supplement	A source of vitamin B12 activity, also known as cobalamin, plays a role in the synthesis of protein in the body and the production of red blood cells.
Vitamin D3 Supplement	A source of vitamin D3 activity which plays a role in optimizing calcium incorporation into bone and reduces calcium and phosphorus loss in urine.
Vitamin E Supplement	A source of vitamin E activity which is an important antioxidant that protects cells from free radicals.
Water	Water is the most important nutrient for life. Water is needed for all functions of the body and it must be consumed every day.
Wheat Flour	Finely ground meal from the milling of wheat. Consists primarily of the starch and gluten fractions. These provide an excellent source of highly digestible carbohydrates for quick energy.
Wheat Gluten	Wheat gluten is a protein and carbohydrate source that is made from removing most of the starch from the grain.
Wheat Starch	Wheat starch is a natural source of energy from the starch of wheat grain.
Whitefish	Whitefish is an excellent protein source and adds flavor that pets love. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Whole Brown Rice	An easily digestible, nutrient-rich grain. Brown rice provides balanced nutrition for your pet in the form of energy.
Whole Rice	An easily digestible, nutrient-rich grain. Rice provides balanced nutrition for your pet in the form of energy.
Xanthan Gum	Xanthan gum is added to thicken our sauces and gravies.
Yeast Culture	Yeast culture is an excellent source of protein and adds flavor to our products. Protein is an essential nutrient that helps promote strong muscles, aids in tissue repair, provides energy and helps support a healthy immune system.
Yucca Schidigera Extract	Yucca schidigera extract adds flavor to our products and aids in reducing stool odor.
Zinc Oxide	Zinc oxide is a source of zinc, which is a fundamental element involved in skin and coat health, and wound healing.
Zinc Proteinate	A source of zinc which is chelated with amino acids to improve the bioavailability. Zinc is a fundamental element involved in skin and coat health, and wound healing.
Zinc Sulfate	Zinc is a fundamental element involved in skin and coat health, and wound healing.

Appendix 2; Additional pet food ingredients*

INGREDIENT	DEFINITION/FUNCTION
Animal by-product meal	Rendered product from animal tissues, exclusive of hair, hoof, horn, hide, manure, stomach and rumen contents.
Animal Fat	Obtained from the tissues of mammals and/or poultry in the commercial processes of rendering or extracting.
Brewers dried grains	Dried extracted residue of barley malt alone or in mixture with other cereal grain or grain products resulting from the manufacture of wort or beer and may contain pulverized dried spent hops in a small amount.
Butylated hydroxyl anisole (BHA)	Chemical preservative.
Butylated hydroxytoluene (BHT)	Chemical preservative.
Corn grits	Medium-sized hard, flinty portions of ground corn containing little or none of the bran or germ.
Corn meal	The entire corn kernel, ground or chopped. May also be called ground corn.
Chicken fat	Provides essential fatty acids like linoleic acid for a healthy skin and coat. Also serves as a concentrated source of energy and flavor.
Chicken flavor	Chicken flavor is added to increase palatability of products.
Ethoxyquin	Chemical preservative.
Fructo-oligosaccharides	A fermentable fiber used to maintain healthy gut function.
Ground whole grain sorghum	The entire product made by grinding the grains of grain sorghum.
Ground whole grain corn	The entire corn kernel, ground.
Iodized salt	Table salt (sodium chloride) with added iodine, an essential mineral needed for proper thyroid function, which regulates growth, development and metabolic rate. Sodium is essential for healthy functioning of cells and maintains the acid base balance in the body with potassium. Chloride has a role in maintaining the fluid balance in the body and helps maintain acid base balance.
Meat	Clean flesh derived from slaughtered mammals, limited to skeletal muscle or tongue, diaphragm, heart or esophagus; with or without fat, skin, sinew, nerves or blood vessels.
Meat by-products	Non-rendered, clean parts (other than meat) derived from slaughtered mammals. Includes lungs, spleen, kidneys, brain, livers, blood, bone, partially defatted low temperature fatty tissue, and stomachs and intestines freed of their contents.
Meat meal	Rendered product from mammal tissues, exclusive of blood, hair, hoof, horn, hide, manure, stomach and rumen contents.
Meat and bone meal	Rendered product from mammal tissues, including bone, exclusive of blood, hair, hoof, horn, hide, manure, stomach and rumen contents.
Meat protein isolate	Produced by separating the meat protein from fresh, clean, unadulterated bones by heat processing followed by low temperature drying to preserve function and nutrient. Characterized by a fresh, meaty aroma.
Poultry by-products	Non-rendered clean parts of carcasses of slaughtered poultry, such as heads, feet, viscera, free from fecal content and foreign matter.
Poultry by-product meal	Ground, rendered, clean parts of the carcass of slaughtered poultry, such as necks, feet, undeveloped eggs, and intestines; does not contain feathers.
Poultry meal	Dry rendered product from clean flesh and skin, with or without bone, exclusive of feathers, heads, feet, and entrails.
Soybean meal	Obtained by grinding the product after removal of most of the oil from soybeans.
Soybean mill run	Composed of soybean hulls and some bean meats, obtained from the production of dehulled soybean meal.

*Ingredients listed in Appendix 2 constitute a partial list of approved ingredients. The entire list is published in Association of American Feed Control Officials Incorporated. 2010 Official Publication ©/™ Trademarks 2010 © The Nutro Company.

