Small Animal Clinical Nutrition: An Iterative Process

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"Things should be made as simple as possible, but not simpler."
Albert Einstein

CLINICAL IMPORTANCE

The public has become increasingly more aware of the importance of nutrition to health during the past four decades as a result of the growing recognition that food is associated with disease processes such as coronary artery disease, hypertension, obesity, diabetes mellitus and cancer. *Healthy People 2010* is a comprehensive set of disease prevention and health promotion objectives for the United States. *Healthy People 2010* uses 10 leading health indicators that reflect the major health concerns in the nation at the beginning of the 21st century. These indicators were selected based on their importance as public health issues and their ability to motivate action and provide data to measure progress against specific goals. One of the focus areas is nutrition, especially overweight/obesity conditions (Healthy People 2010).

The discipline of veterinary nutrition and its relationship to the practice of veterinary medicine have benefited from these changes. Food animal veterinarians have long recognized that no aspect of the production enterprise has more impact on health and production than nutrition; many health problems are associated with inadequate feeding programs. Food animal veterinarians recognize that optimizing feeding programs improves food animal health and productivity and, as a result, the economic status of producers. Food animal veterinarians who provide their clients with high-quality production medicine programs become unbiased nutritional consultants.

Similarly, small animal practitioners must improve their nutritional counseling skills because they cannot truly meet their patients' health needs without optimizing nutrition. Small animal veterinarians can improve the quality of medicine delivered to their patients by knowledgeably and systematically addressing the nutritional aspects of each case, whether the goal is treating or preventing disease. Veterinarians must emphasize health maintenance and wellness strategies for companion animals to provide the most beneficial service. Total disease prevention requires lifelong dedication to proper nutrition, immunizations, dental care and parasite control programs. Nutritional factors are a cornerstone in maximizing health, performance, longevity and disease prevention. Nutritional counseling and intervention, however, are beneficial only if done properly.

Veterinarians and their health care teams have considerable influence on the foods clients feed their pets. A study conducted by *Veterinary Economics* in 1990 found that 87% of veterinarians felt that offering nutritional services improved their practices (Gants, 1990). Ninety-four percent of these veterinarians said that their clients were somewhat or very receptive to nutrition-related information. A 1995 study conducted by the American Animal Hospital Association found that 54% of pet owners interviewed sought veterinary advice on pet foods at least once and 43% had received a recommendation from their veterinarian on which manufacturer's pet food to feed their puppies or kittens. Seventy percent of the latter group fed the brand of food recommended by their veterinarian (AAHA, 1995).

The word *recommend* means to counsel or advise (American Heritage Dictionary). The implication is that the advice proceeds from actual knowledge of the subject. Veterinarians should know how food needs vary with each lifestage, with mental, physical and environmental stresses and with diseases. Causes and effects of dietary imbalances should be considered so that the resulting disorders can be prevented or diagnosed and treated. Veterinarians should also be familiar with the various pet foods available to help clients choose the most appropriate ones. Veterinarians also need to understand the benefits and shortcomings of various feeding methods. After a feeding plan has been instituted, veterinarians need the skills to monitor the program to assess and reassess outcomes and to modify the feeding plan when necessary. The primary goal of this chapter is to provide practicing veterinarians, veterinary technicians and students with the basic problem-solving processes needed to successfully manage the nutrition of companion animal patients.

The Two-Step Iterative Process of Clinical Nutrition

A brief review of instructional systems design (ISD) is in order to better understand iterative (repetitive) processes. ISD emerged after World War II as a set of recognized standard procedures used to develop well-structured materials in response to the need for more efficient training techniques (Moore and Kearsley, 1996). ISD embodies various perspectives on learning, teaching, systems theory, behavioral psychology, communications and information theory. The ISD model breaks instruction into a series of phases or steps with defined procedures; a defined service or product must be delivered at each step. Steps include: 1) design, 2) development, 3) implementation, 4) evaluation and 5) analysis. Then, the process
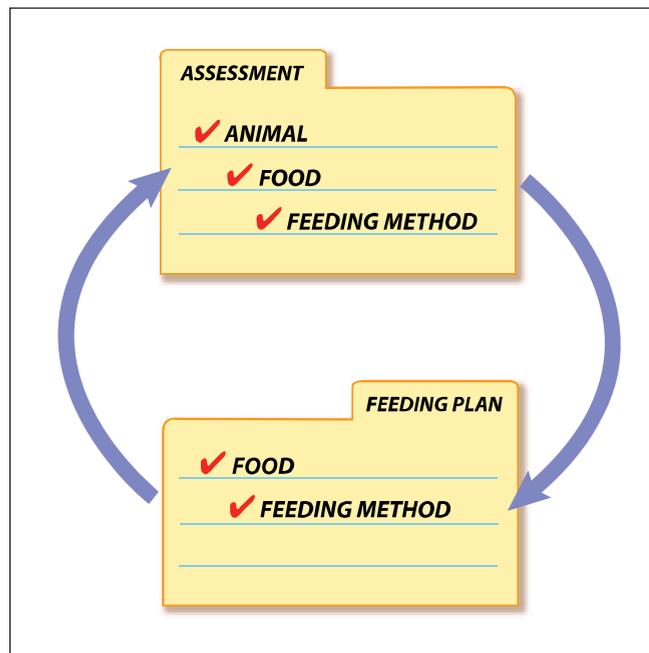
Figure 1-1. The two-step process of veterinary clinical nutrition.

repeats itself as a continuous loop and may involve many cycles. The American College of Veterinary Nutrition (ACVN) has recommended that nutrition problem solving include assessment of the patient, the food and the feeding method (Bauer et al, 1995).

Figure 1-1 depicts the iterative process used in this book. The first step is patient assessment, which allows the determination of the patient's key nutritional factors and their levels (the concept of key nutritional factors is described below). Determination of the key nutritional factors is the basis for the second step: the feeding plan. The feeding plan includes recommendations for food and feeding methods. If assessment of the current food and feeding methods indicates that they are appropriate, the current feeding plan can remain in place. However, if the assessment indicates otherwise, a new feeding plan should be formulated and implemented.

After a suitable period of time (the length of which depends on the patient's condition), the two-step process is repeated to determine the appropriateness or effectiveness of the new feeding plan. Thus, the patient is reassessed and, if necessary, a new feeding plan is developed and implemented. This is the iterative or repetitive part of the process. Any number of iterations of the two-step process can occur, depending on the needs of each patient. A critically ill patient may need to be reassessed every few hours, whereas a normal adult dog or cat may be reassessed annually. The subsequent reassessment of the patient at each cycle is also referred to as monitoring. This information is discussed under the heading of reassessment in the chapters that deal with patient assessment and feeding plans.

PATIENT ASSESSMENT

The goal of patient assessment is to establish a dog's or cat's key nutritional factors and their target levels in light of its physiologic or disease condition. The patient's key nutritional factors are the benchmark for assessing the animal's food and selecting a food. Assessment of dogs and cats to determine their key nutritional factor status should be a structured process that includes: 1) review of the history and medical record, 2) physical examination and 3) laboratory tests and other diagnostic procedures (Remillard and Thatcher, 1989). These first three steps determine the patient's physiologic state and medical diagnosis and are the basis for the fourth step, which is the determination of the key nutritional factors and the estimation of their target levels.

Obtain an Accurate History and Review the Medical Record

Obtaining the animal's history and reviewing the medical record help determine the nutritional status of the patient. The signalment is part of the history and defines the patient's physiologic state and includes: 1) species, 2) breed, 3) age, 4) gender, 5) reproductive status, 6) activity level and 7) environment.

A complete history should also include questions about the pet's weight and therapies (medical, surgical, etc.) that may affect appetite, nutrient metabolism or both. An accurate

description of the current feeding plan, including the animal's food, eating and drinking habits and feeding methods should be obtained from the client. Intakes of treats and nutritional supplements should be recorded.

Review of the medical record provides objective historical information and documents the pet's previous health status, health maintenance procedures that were performed and medications that were prescribed. Veterinarians should evaluate this information to determine if any of these factors are related to the animal's current nutritional status. This review permits early nutritional intervention in the treatment of established malnutrition (under- or overnutrition) and in the prevention of malnutrition in individuals at risk (**Box 1-1**).

A patient's food is usually changed because of altered requirements or alterations in nutrient intake, digestion, absorption, metabolism, excretion or a combination of these factors. Knowledge of normal nutritional physiology and of diseases and their nutritional pathophysiology is important to identify patients at risk for malnutrition. The history and medical record are tools to help identify these risks.

Conduct a Physical Examination

A thorough physical examination can help define an animal's nutritional status and identify diseases that may have a nutritional component. Physical findings should be recorded in the patient's medical record. Veterinarians should examine each body system for problems that are responsive to nutritional intervention. An animal's body condition will likely reflect abnormalities of major organ systems.

Body condition can be subjectively assessed by a process called body condition scoring. In general, this process assesses a patient's fat stores and, to a lesser extent, muscle mass. Fat cover is evaluated over the ribs, down the topline, around the tailbase and ventrally along the abdomen. Body condition score (BCS) descriptors have been developed with respect to the species (dogs and cats) and age of the patient (**Figures 1-2** and **1-3**). Score descriptors vary due to the structural differences between species and between young and adult pets. The scores range from 1 to 5 with 1 being very thin and 5 being grossly obese. A body condition score of 3/5 is generally referred to as being ideal. An "ideal" body condition, however, depends on the dog's or cat's lifestage, lifestyle and intended use. For example, a BCS of 2/5 to 2.5/5 may be desirable for a racing greyhound, whereas a BCS of 3.5/5 might be better for a pregnant queen at the end of its first trimester to help support the upcoming lactation. A BCS of 2.5/5 to 3/5 is probably ideal for most mature dogs and cats for optimal health and resultant longevity. Thus, overall, an ideal BCS is a range of numbers rather than simply a "3/5."

Body condition scoring reasonably estimates an animal's body composition. Studies assessing scorer repeatability and variations between scorers have found agreement between 80 to 90% of the measurements (LaFlamme et al, 1994; Graham et al, 1982; Croxton and Stollard, 1976; Burkholder, 1994). Research with cats found a correlation of 0.9 or higher between BCS and body composition predicted from morphometry (LaFlamme, 1993). Veterinarians should routinely assign BCSs, obtain body weights and record both in the medical record.

The patient's body weight can be compared with breed standards (Appendix 14) or with the animal's previous body weight from the medical record. The patient's pre-illness body weight or usual body weight during health can serve as a standard for determining the effect of illness on body weight. A history of rapid weight loss and a reduced BCS may indicate a catabolic condition with a marked loss of lean tissue, dehydration or both. A history of progressive weight gain and an increased BCS may indicate an anabolic condition with an excessive accumulation of fat, water or both.

Conduct Necessary Laboratory Tests and Other Diagnostics

No single laboratory test or other diagnostic procedure can accurately assess a patient's nutritional status. Routine complete blood counts, urinalyses and biochemistry profiles, however, can provide insight into the presence of metabolic disorders and other diseases. Albumin concentration, lymphocyte count, packed cell volume and serum total protein values may serve as general indicators of nutritional status. Other chapters in this textbook will discuss specific laboratory tests and other diagnostic procedures that may help assess healthy and sick patients.

Serum protein concentrations in people provide an estimate of long- and short-term changes in nutritional status and correlate with morbidity and mortality (Giner et al, 1996). For example, low serum albumin concentrations may indicate protein depletion due to chronic undernutrition or protein loss. Shorter half-life serum protein concentrations such as prealbumin, transferrin, retinol-binding protein and fibronectin are used in human medicine to assess short-term changes in nutritional status. However, these tests have not been routinely available in veterinary medicine. Although not used widely, serum creatine kinase concentrations are elevated in anorectic cats and decline after 48 hours of nutritional support. Serum

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Box 1-1. Malnutrition Includes Excesses.

Malnutrition is defined as any disorder of nutrition with inadequate or unbalanced nutrition. Many veterinarians and animal owners think only of nutritional deficiencies when they hear the term malnutrition. Muscle wasting and a distended abdomen in a starving third-world child or a heavily parasitized puppy is often our first mental image of malnutrition. In first-world societies, however, malnutrition is usually due to overnutrition or excessive intake of nutrients. Obesity due to consumption of excessive levels of fat and calories is a common example of malnutrition in people and their pets. Another example of malnutrition due to unbalanced nutrition is developmental orthopedic disease seen in rapidly growing large- and giant-breed puppies as a result of excessive calcium and energy intake. Malnutrition due to either nutrient deficiencies or excesses can be harmful to dogs and cats.

BCS 1. Very thin ▶
The ribs are easily palpable with no fat cover. The tailbase has a promi-nent raised bony structure with no tissue between the skin and bone. The bony prominences are easily felt with no overlying fat. Dogs over six months of age have a severe abdominal tuck when viewed from the side and an accentuated hourglass shape when viewed from above.
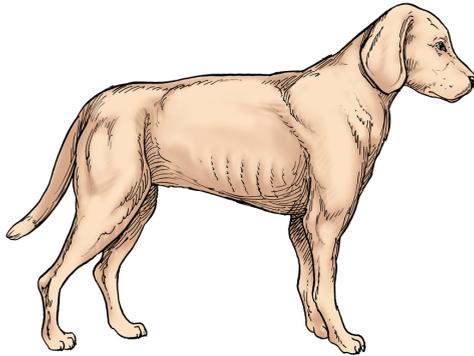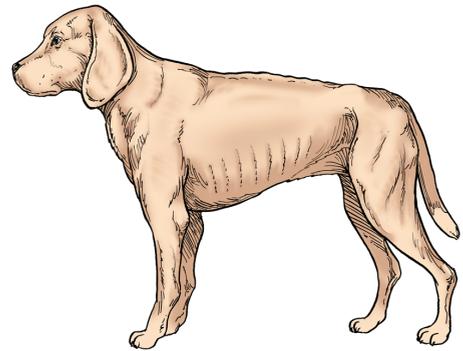
◀ BCS 2. Underweight
The ribs are easily palpable with minimal fat cover. The tailbase has a raised bony structure with little tissue between the skin and bone. The bony prominences are easily felt with minimal overlying fat. Dogs over six months of age have an abdominal tuck when viewed from the side and a marked hourglass shape when viewed from above.

BCS 3. Ideal ▶
The ribs are palpable with a slight fat cover. The tailbase has a smooth contour or some thickening. The bony structures are palpable under a thin layer of fat between the skin and bone. The bony prominences are easily felt under minimal amounts of overlying fat. Dogs over six months of age have a slight abdominal tuck when viewed from the side and a well-propor-tioned lumbar waist when viewed from above.
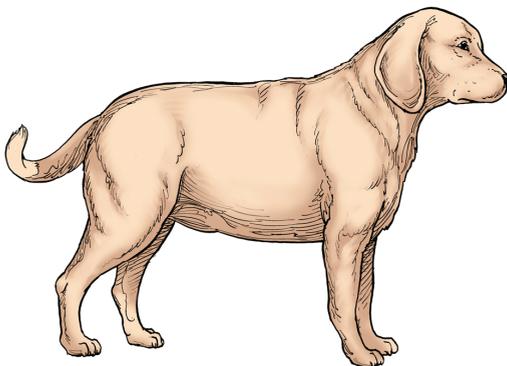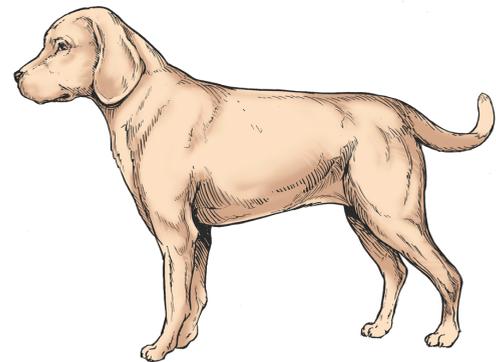
◀ BCS 4. Overweight
The ribs are difficult to feel with moderate fat cover. The tailbase has some thickening with moderate amounts of tissue between the skin and bone. The bony structures can still be palpated. The bony prominences are covered by a moderate layer of fat. Dogs over six months of age have little or no abdominal tuck or waist when viewed from the side. The back is slightly broadened when viewed from above.

BCS 5. Obese ▶
The ribs are very difficult to feel under a thick fat cover. The tailbase appears thickened and is difficult to feel under a prominent layer of fat. The bony prominences are covered by a moderate to thick layer of fat. Dogs over six months of age have a pendulous ventral bulge and no waist when viewed from the side due to extensive fat deposits. The back is markedly broadened when viewed from above. A trough may form when epaxial areas bulge dorsally.
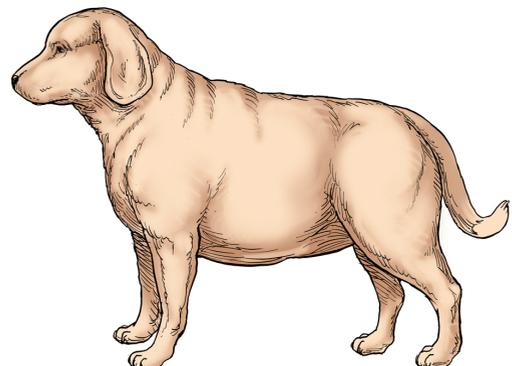
Figure 1-2. Body condition score (BCS) descriptors for dogs in a five-point system.

BCS 1. Very thin ▶
The ribs are easily palpable with no fat cover. The bony prominences are easily felt with no overlying fat. Cats over six months of age have a severe abdominal tuck when viewed from the side and an accentuated hourglass shape when viewed from above.
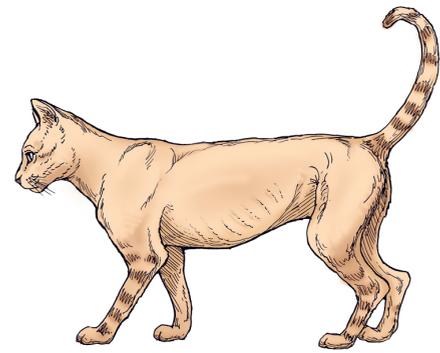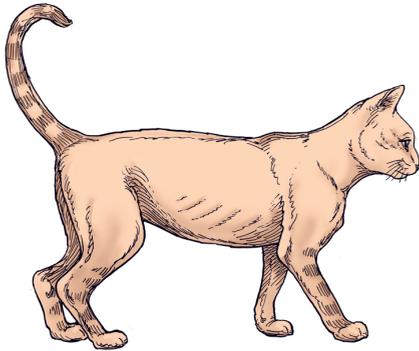
◀ **BCS 2. Underweight**
The ribs are easily palpable with minimal fat cover. The bony prominences are easily felt with minimal overlying fat. Cats over six months of age have an abdominal tuck when viewed from the side and a marked hourglass shape when viewed from above.

BCS 3. Ideal ▶
The ribs are palpable with a slight fat cover. The bony prominences are easily felt under a slight amount of overlying fat. Cats over six months of age have an abdominal tuck when viewed from the side and a well-proportioned lumbar waist when viewed from above.

◀ **BCS 4. Overweight**
The ribs are difficult to feel with moderate fat cover. The bony structures can still be palpated. The bony prominences are covered by a moderate layer of fat. Cats over six months of age have little or no abdominal tuck or waist when viewed from the side. The back is slightly broadened when viewed from above. A moderate abdominal fat pad is present.
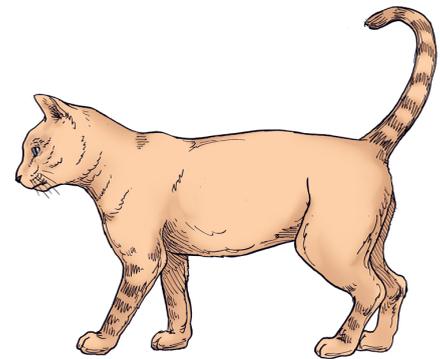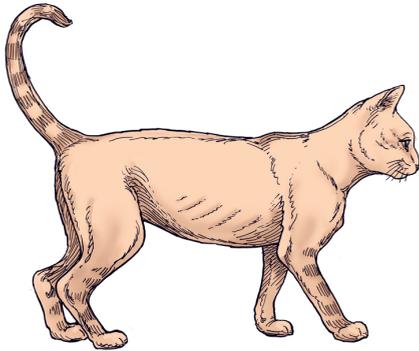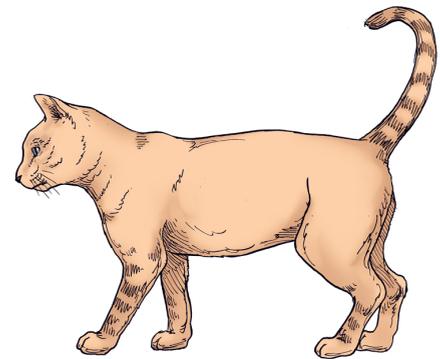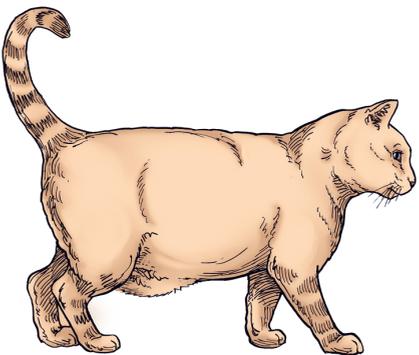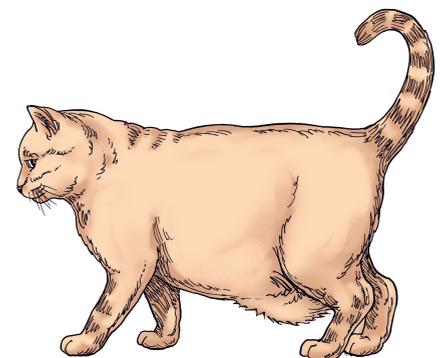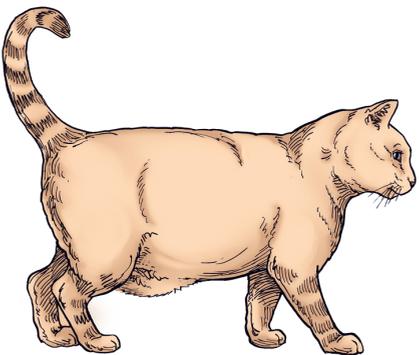
BCS 5. Obese ▶
The ribs are very difficult to feel under a thick fat cover. The bony prominences are covered by a moderate to thick layer of fat. Cats over six months of age have a pendulous ventral bulge and no waist when viewed from the side due to extensive fat deposits. The back is markedly broadened when viewed from above. A marked abdominal fat pad is present. Fat deposits may be found on the limbs and face.
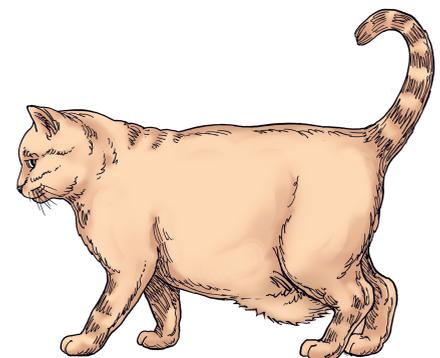
Figure 1-3. Body condition score (BCS) descriptors for cats in a five-point system.

creatine kinase concentrations may become a useful marker for assessing and monitoring nutritional status in animals (Fascetti et al, 1997).

Results of a single measurement or test must be interpreted cautiously, because over- or under-hydration can alter concentrations of these proteins. Diagnostics such as radiography and ultrasonography, including echocardiography, may be indicated to further characterize the health status of patients. Results of laboratory and diagnostic tests should always be viewed in the context of findings from the history, physical examination and the patient's medical record.

Determine the Key Nutritional Factors and Their Target Levels

The concept of key nutritional factors is fundamental to the practical application of clinical nutrition used in this text. However, to better understand the basis for this concept, a brief review of nutrient requirements vs. nutrient allowances precedes the description of key nutritional factors.

Researchers traditionally have used normal dogs and cats to determine nutrient requirements. In the United States, the primary sources for minimum nutrient requirements of healthy dogs and cats are the National Research Council (NRC) Nutrient Requirement bulletins published in 1985 and 1986, respectively and recently updated as a combined edition (NRC, 1985; NRC, 1986; NRC, 2006). The requirements published in 1985 and 1986 were determined by feeding dogs and cats purified diets rather than commercially available foods. These NRC values, therefore, were minimum nutrient requirements that had to be extrapolated to the types of foods normally fed to dogs and cats. In 1993 and 1994, the Association of American Feed Control Officials (AAFCO) published recommended nutrient profiles for dog and cat foods, respectively (Nutrient Profiles for Dog Foods, 1993; Nutrient Profiles for Cat Foods, 1994). These nutrient profiles have been republished yearly and are the official source for nutrient profiles for commercial dog and cat foods in the United States.

The AAFCO nutrient profiles include safety factors similar to those in the recommended dietary allowances (RDAs) that have been established for people (NRC, 1989). These safety factors compensate for changes in a food's nutrient availability due to ingredient and processing variables and for individual differences in nutrient requirements within dog and cat populations. Because of these safety factors, the term "allowance" is better suited to describe AAFCO values than "requirements." AAFCO values are adequate to meet the known nutrient needs of almost all healthy dogs and cats and are a better source of feeding recommendations for most dogs and cats than are minimum requirements. The earlier NRC bulletins published for dogs and cats in 1974 and 1978, respectively, also included safety factors and therefore were actually "allowances." Besides recommendations for lower limits, AAFCO prescribes upper limits for certain nutrients with the obvious implication that some nutrient excesses can be harmful. As with RDAs for people, AAFCO allowances for pet food nutrient profiles are not necessarily optimal.

Instead of separate dog and cat editions, the recently updated NRC includes information about both species. It provides nutrient requirements in three formats: minimum requirement, adequate intake and recommended allowance (2006). Minimum requirement is defined as the minimal concentration or amount of a maximally available nutrient that will support a defined physiologic state. Adequate intake is defined as the concentration or amount of a nutrient demonstrated to support a defined physiologic state when no minimum requirement has been demonstrated. Recommended allowance is defined as the concentration or amount of a nutrient in a diet formulated to support a given physiologic state. The recommended allowance is based on the minimum requirement with consideration for the normal variation in bioavailability of the nutrient in typical-quality feed ingredients. If no minimum requirement is available, the recommended allowance is based on adequate intake. Like the old editions, the more recent NRC edition also includes safe upper limit levels for a nutrient when data are available (NRC, 2006).

Neither NRC nor AAFCO has established nutrient profiles for geriatric dogs and cats and those with specific disease processes.

Key Nutritional Factors

Key nutritional factors encompass nutrients of concern and other food characteristics. The concept of nutrients of concern greatly simplifies the approach to clinical nutrition because most commercial pet foods sold in the United States provide at least AAFCO allowances of all nutrients. Thus, if a commercial food is fed, veterinarians and their health care teams need only to understand and focus on delivering the target levels for a few nutrients (nutrients of concern) rather than the 40 plus nutrients currently recognized for cats and dogs (NRC, 2006).

Nutrients of concern encompass nutritional risk factors for disease treatment and prevention as well as nutrients that are key to optimizing normal physiologic processes such as growth, gestation, lactation and physical work. The following elements must be considered in determining key nutritional factors and their target levels: 1) the patient's lifestage and physiologic state, 2) environmental conditions such as temperature, housing and pet-to-pet competition, 3) the nature of any disease or injury, 4) the known nutrient losses through skin, urine and gastrointestinal tract, 5) the interactions of medications and nutrients, if applicable, 6) the known capacity of the body to store certain nutrients and 7) the interrelationships of various nutrients.

Besides requiring specific levels of certain nutrients, some patients have other food-related needs. These needs might include management of acute or chronic systemic acid-base balance, maintenance of a specific urinary pH range, certain kibble texture, a specific range of digestibility or osmolality, avoidance of certain protein sources and presence of specific ingredients. Some nutrients and ingredients that are added to foods provide other non-nutritive functions that can be important to health and performance. Thus, specific food characteristics or factors other than the nutrient content may

be important to consider. Information about such food characteristics should be available from product manufacturers. Pet food labels contain addresses and toll-free phone numbers of the manufacturer.

Chapters 12 through 24 determine and list key nutritional factors and their target levels for healthy dogs and cats. The key nutritional factors and their target levels for dogs and cats with specific disease complexes can be found in Chapters 25 through 68. For convenience, these chapters also contain levels of key nutritional factors in commercial foods typically marketed for use in patients with various medical conditions. Regardless of which nutrients are considered as key nutritional factors, the reader should understand the various ways nutrient needs are expressed. **Box 1-2** describes the methods and units for expressing an animal's nutrient needs.

In summary, the primary goal of patient assessment is to establish the patient's key nutritional factor needs. The key nutritional factors are the benchmark for assessing the adequacy of a patient's food. Additionally, the results of patient assessment are the basis for determining an appropriate feeding method.

FEEDING PLAN

The feeding plan can be developed after the key nutritional factor needs have been determined. The feeding plan includes what food or foods to feed and which feeding methods to use. Thus, the first step is to assess the current food and to select the best food to feed.

Assess and Select the Food
The primary components of food assessment should include: 1) evaluation of the current food's key nutritional factor content relative to the patient's needs (determined during Patient Assessment, above) and 2) determination whether or not feeding tests or clinical trials were conducted.

Determine the Food's Key Nutritional Factor Content
The key nutritional factors and their levels for most of the commonly used commercial foods are listed in the food tables in the individual chapters. In most instances, these profiles will provide the necessary information. If the key nutritional factor information of the food in question is not listed in the food tables, the manufacturer should be contacted for that information. Pet food labels contain addresses and toll-free phone numbers of the manufacturer.

Although much less convenient, there are other ways to determine most of a food's key nutritional factor content. Many, if not most, key nutritional factors are nutrients. **Box 1-3** describes various ways to determine the nutrient content of a food. **Box 1-2** describes methods and units used in expressing the nutrient content of food.

Key Nutritional Factor Comparison
Comparing a food's key nutritional factor content with the patient's needs will help identify any significant imbalances in

the food being fed. If the patient's current food is adequate (key nutritional factors in balance with the patient's needs) then the food currently being fed can continue to be fed. However, if important excesses or deficiencies exist, the patient's current food must be "balanced."

There are numerous approaches to balancing foods. Some are rather extensive (**Boxes 1-4** and **1-5**). This section will review the most practical methods including: 1) food replacement and 2) simple mathematical ration balancing (Pearson square). Alternatively, veterinarians can contact a veterinary nutritionist who accepts referrals. Both the ACVN and the European College of Veterinary Nutrition (ECVN) have diplomates who do referral work. Contact the executive director of the ACVN to obtain a list of diplomates who do nutrition referral work. Contact information for the executive director can be found in the AVMA Directory or online at www.ACVN.org.

When comparing a food's key nutritional factor nutrient content with a patient's needs, methods of expressing nutrient content of the food and nutrient requirements of the animal must be compatible (same units). In this textbook, compatible units are used in the food tables for comparing the food's key nutritional factor content and the patient's target values. See **Box 1-2** for more details about how food content and animal needs are expressed.

Food Replacement
If food assessment indicates that an animal's key nutritional factor requirements are not being met, the most practical way to balance a food is to simply select a different food (i.e., one that does a better job of meeting the patient's requirements). The most likely application of this method occurs when one commercial food is substituted for another. If homemade foods are being used, they can be replaced by appropriate commercial foods or another homemade food if other recipes are available (Chapter 10).

The process is straightforward and simple. The nutrient content of other foods is evaluated to see which food most closely meets the animal's requirements. Assuming comparable palatability, the most acceptable food replaces the previous food. **Case 1-3** demonstrates food replacement. This process is greatly facilitated by the food tables in the feeding healthy dog and cat chapters (Chapters 12 through 17 for dogs and 19 through 24 for cats) and the feeding clinically ill patient chapters (Chapters 25 through 68). These tables list the key nutritional factor targets and the key nutritional factor contents of commercial foods commonly marketed for patients at various lifestages and those having specific diseases.

Changing foods for most healthy dogs and cats is of minor consequence. Some owners switch their pets from one food to another daily. Most dogs and cats tolerate these changes. However, vomiting, diarrhea, belching, flatulence or a combination of signs may occur with sudden, rapid switching of foods, probably because of ingredient differences. It is prudent, therefore, to recommend that owners change their pet's food over the course of at least three days. A seven-day period is even

Box 1-2. Typical Methods and Units for Expressing a Patient's Nutrient Needs and a Food's Nutrient Content and Methods for Conversion to the Same Units.

When comparing a patient's nutrient requirements to a food's nutrient content to determine adequacy of the food, the same quantifying units must be used to make the comparison meaningful. The units used for expressing food nutrient content and patient nutrient requirements are compared in **Table 1**.

PATIENT'S NUTRIENT NEEDS
The three methods for expressing an animal's nutrient needs are: 1) dry matter, energy density defined and 2) energy basis and 3) absolute basis.

Dry matter basis, energy density defined is the percentage or quantity of a nutrient in the food's dry matter that is needed by the animal. This measure is the most common method of expressing an animal's nutrient needs. It describes what is required in a food and indicates an animal's nutrient needs. Dry matter refers to that weight of the food remaining when the water content is subtracted. (**Tables 2** and **3** demonstrate methods of calculating dry matter.) Dry matter values are most meaningful if the energy density of the food's dry matter is specified because most animals eat, or are fed, to meet their energy requirements.

Energy basis refers to the quantities of nutrients per animal's energy requirement. Units of measure are typically nutrient amounts per 100 kcal or 1 MJ metabolizable energy (ME). Occasionally an animal's protein, fat and digestible (soluble) carbohydrate needs are expressed as a percentage of the animal's total energy needs (**Table 4**).

Absolute basis refers to the unit measure (usually weight) of a nutrient that is needed by an animal in a 24-hour period. These needs are expressed as quantities per kg of body weight per day.

FOOD'S NUTRIENT CONTENT
Although there are three methods for expressing an animal's nutrient needs, there are four methods for expressing a food's nutrient content: 1) as fed basis, 2) dry matter basis, 3) dry matter basis, energy density defined and 4) energy basis.

As fed basis simply refers to the quantity of nutrients in a food as it is fed. This method ignores moisture and energy content. The units of measure are percentages or quantities of nutrients per unit weight (kg) of food.

Dry matter is that weight of the food remaining after the water content has been subtracted from the as fed amount. Dry matter basis, therefore, is the amount of nutrients in the food's dry matter. It accounts for variability in water content but not variability in energy density. The units of measure are percentages or quantities of nutrients per unit weight (kg) of food dry matter. The usefulness of dry matter basis is limited because the energy density of individual foods can vary widely. This consideration will be further explained below (dry matter basis, energy density defined). **Tables 2** and **3** show the conversion from as fed basis to dry matter basis.

Dry matter basis, energy density defined is the same as dry matter but specifies a food's energy density, thus accounting for potential variability. The units of measure are the same as those used with dry matter basis but are further qualified by expressing the energy density of the food. For example, recommended nutrient values for canine and feline foods are based on an energy density of 3.5 and 4.0 kcal ME/g (14.64 and 16.74 kJ ME/g) of food dry matter, respectively. Dry matter basis, energy density defined is probably the most widely used method of expressing a food's nutrient content.

Energy basis refers simply to the amount of nutrients per 100 kcal or 1 megajoule ME of food. Occasionally, a food's protein, fat and digestible carbohydrate content is expressed as a percentage of the food's total energy content (**Table 4**).

Both dry matter basis, energy density defined and energy basis are reasonably accurate methods of expressing a food's nutrient content. However, even these methods have limitations.

Animals require less food to meet their energy requirements when foods with higher energy densities are fed. Under these circumstances, the concentrations of the other nutrients in the food need to be increased proportionally, to ensure the animal receives the minimum amount of all nutrients needed in a smaller amount of food.

When foods with lower energy densities are fed, a lower concentration of the other nutrients may be required, assuming the dog or cat could eat, or would be fed, enough of the food to meet its energy requirement. In these instances, the nutrient levels need to be decreased proportionately, so that the animal would not receive toxic levels of nutrients in a larger amount of food.

Foods of low energy density, particularly those low in fat and high in fiber, are usually intended for animals that have a tendency to be overweight. These animals should be fed fewer calories than animals with normal body weights and body condition scores. The nutrient content of foods in this category should not be corrected for their lower energy density. During weight loss, there is a disproportionately lower energy intake relative to the non-energy nutrients. Although these animals require fewer calories to lose weight, as far as is known, their requirement for other nutrients has not changed. Thus, they are essentially being fed the same amount of dry matter but fewer calories. On an energy basis (g/kcal), the food's nutrient values will be higher than if the animal had normal energy requirements.

On the other end of the spectrum are situations in which foods of high energy density are fed to animals with an unusually high need for energy-providing nutrients relative to non-energy nutrients. A working sled dog is an example. In this case, on an energy basis, the food's non-energy nutrient content could be lower than if the animal had normal energy needs.

CONVERTING TO SAME UNITS
Comparing food on an as fed basis to an animal's requirement on an absolute basis requires: 1) mathematical calculation and 2) either the energy density of the food or the amounts of the energy-supplying nutrients in the food. **Table 5** provides an example of such a calculation.

When using dry matter basis, energy density defined to compare foods or to compare foods with animal requirements, the energy densities must be the same for the comparisons to be meaningful. **Table 6** shows how to convert to the same energy density. In some cases it will be desirable to convert food nutrient content on an as fed basis to dry matter basis, energy density defined (**Case 1-1**).

Box 1-2 continued

Table 1. Comparisons of methods to express food nutrient content and animal requirements/allowances for nutritional assessment of food.

Food nutrient content (units)
As fed basis (% or amount of nutrient/kg food)
Dry matter basis (% or amount of nutrient/kg of food dry matter)
Dry matter basis, energy density defined (% or amount of nutrient/kg of food dry matter, at a specified energy density)
Energy basis (amount of nutrient/100 kcal or 1 megajoule ME of food's energy content)

Dog/cat requirements/allowances (units)
Absolute basis (amount of nutrient/kg animal)
Dry matter basis, energy density defined (% or amount of nutrient/kg of food dry matter, at a specified energy density)
Energy basis (amount of nutrient/100 kcal or 1 megajoule ME of animal's energy requirement)

Table 2. How to convert from as fed basis to dry matter basis.

Step 1. Obtain the food's dry matter content by subtracting the water content from the as fed amount of the food.

> **Example A:** If a moist food contains 75% water, 25% of the food is dry matter:
>   100% as fed – 75% water = 25% food dry matter

> **Example B:** If a dry food contains 10% water, 90% of the food is dry matter:
>   100% as fed – 10% water = 90% food dry matter

Step 2. Convert the percentage as fed nutrient content of the food to a dry matter basis by dividing the percentage of the nutrient content on an as fed basis by the percentage dry matter.

> **Example A:** If the moist food above contained 10% protein on an as fed basis, on a dry matter basis it would contain 40% protein:
>   10% protein as fed basis ÷ 25% dry matter = 40% protein dry matter basis

> **Example B:** If the dry food above contained 18% protein on an as fed basis, on a dry matter basis, it would contain 20% protein:
>   18% protein as fed basis ÷ 90% dry matter = 20% protein dry matter basis

Table 3. Shorthand method for converting from as fed basis to dry matter basis.

A less accurate, shorthand method for converting from an as fed basis to a dry matter basis is to simply multiply the percentage nutrient content on an as fed basis by four for moist foods or add 10% for dry foods. This method is based on the assumption that moist foods contain approximately 75% water and dry foods contain approximately 10% water. Check the guaranteed analysis on the product label.

> **Example A:** If a moist food contains 10% protein on an as fed basis, on a dry matter basis it would contain 40% protein:
>   10% protein as fed basis x 4 (factor for moist foods) = 40% protein dry matter basis*

> **Example B:** If a dry food contains 18% protein on an as fed basis, on a dry matter basis it would contain 20% protein:
>   18% protein as fed basis + 10% (factor for dry food) = approximately 20% protein dry matter basis*

*Compare these results with those obtained in **Table 2** for moist and dry foods with the same moisture content.

Table 4. How to determine the protein, fat and carbohydrate content as a percent of the food's total energy content.

Practically speaking, the available energy in foods for dogs and cats is provided by digestible carbohydrates, protein and fat; dietary fiber provides little if any energy to these species. Occasionally an animal's need for, or a food's content of, any or all of these three nutrients is expressed in terms of the fraction of the total energy they provide. The method is simply another way to express the relative amounts of these three nutrients. The following example demonstrates how to calculate the percentage of kcal and kJ from protein, fat and digestible carbohydrate of a pet food.

Nutrient	%	kcal/g of nutrient	kJ/g of nutrient	kcal/g of food**	kJ/g of food**
Protein	22	3.5*	14.64*	0.77	3.22
Fat	9	8.5*	35.56*	0.77	3.20
Digestible carbohydrate	51	3.5*	14.64*	1.79	7.47
Total	-	-	-	3.33	13.89

% kcal from protein = 0.77 ÷ 3.33 = 23.1
% kJ from protein = 3.22 ÷ 13.89 = 23.2
% kcal from fat = 0.77 ÷ 3.33 = 23.1
% kJ from fat = 3.20 ÷ 13.89 = 23.0
% kcal from digestible carbohydrate = 1.79 ÷ 3.33 = 53.8
% kJ from digestible carbohydrate = 7.47 ÷ 13.89 = 53.8

*"Modified" Atwater values.
See **Box 1-6, Table 3 for a more detailed explanation for calculation of energy density of pet foods.

Table 5. Example illustrating the mathematical process required to compare a food's nutrient content on an as fed basis to an animal's needs on an absolute basis.

Example: If an intact male cat weighing 4.5 kg requires 31 mg of magnesium (Mg) per day (recommended allowance) and the cat's food as fed contains 0.12% Mg, 20% fat, 35% protein and 27% digestible carbohydrate, does the cat receive adequate amounts of Mg? The answer is calculated as follows:

1) First find out how much food is to be fed. Because animals are fed to meet their energy requirements, the first step is to determine the energy density of the food, if it is unknown. This is done by calculating the amount of energy provided by each of the energy-supplying nutrients. Using the "modified" Atwater energy values of 3.5, 8.5 and 3.5 kcal metabolizable energy (ME)/g (14.64, 35.56 and 14.64 kJ ME/g) for protein, fat and digestible carbohydrate respectively (See **Box 1-6**, **Table 2**), multiply the percentage of each nutrient in the food (as fed basis) by 1 g of food. Then multiply the answer by the energy density of each nutrient. The sum of the three separate energy values is the energy density of the food.

In kcal ME/g of food:
35% protein x 1 g food x 3.5 kcal ME/g
= 1.23 kcal ME/g from protein

20% fat x 1 g food x 8.5 kcal ME/g
= 1.70 kcal ME/g from fat

27% digestible carbohydrate x 1 g food x 3.5 kcal ME/g
= 0.95 kcal ME/g from carbohydrate

Sum
3.88 kcal ME/g food (total)

2) The next step is to determine the daily energy requirement (DER) of the animal. Multiply the formula for resting energy requirement (RER) by the appropriate modifier for maintenance of an adult cat (**Box 6, Table 1**).

RER (kcal ME/day) = 70(BW$_{kg}$)$^{0.75}$
RER (kJ ME/day) = 293(BW$_{kg}$)$^{0.75}$

= 70(4.5 BW$_{kg}$)$^{0.75}$ = 216 kcal ME/day
= 293(4.5 BW$_{kg}$)$^{0.75}$ = 904 kJ ME/day

Modifier for feline adult maintenance = 1.4 x RER = DER
Modifier for feline adult maintenance = 1.4 x RER = DER

DER (kcal ME/day) = 1.4 x 216 kcal ME = 302 kcal ME
DER (kJ ME/day) = 1.4 x 904 kJ ME = 1,266 kJ ME

3) Determine the amount of food to be fed by dividing the cat's energy requirement by the energy density of the food.
302 kcal ME/day ÷ 3.88 kcal ME/g = 78 g food/day
1,266 kJ ME/day ÷ 16.18 kJ ME/g = 78 g food/day

4) Determine the amount of Mg provided by the food by multiplying the amount of food fed by the percentage of Mg in the food.
78 g food x 0.12% Mg = 0.090 g (90 mg) Mg
The amount of Mg provided by the food (90 mg) compared with the animal's requirement of 31 mg indicates more than an adequate (threefold) amount of Mg.

Table 6. How to convert to the same energy density.

Correcting energy densities in order to make valid nutrient comparisons, either between foods or between a food and an animal's requirement, is based on the assumption that the relationship between nutrient content and energy density is directly proportional. A simple ratio can be established to generate a multi-

plier that converts the units of the animal's requirements to those of the food; then the animal's requirement and the food's nutrient content can be compared. The multiplier is obtained by dividing the energy density of the food by the requirement energy density.

Example: Is a food that provides 0.72% potassium and 4 kcal (16.74 kJ)/g, on a dry matter (DM) basis, adequate for canine adult maintenance?
1) The requirement for potassium is 0.6% DM basis in an adult dog food that provides 3.5 kcal (14.64 kJ)/g.

2) Convert the requirement to the same energy density as the food by generating the multiplier.
    Multiplier
      = Food energy density ÷ requirement energy density
      = 4.0 kcal (16.74 kJ)/g DM ÷ 3.5 kcal (14.64 kJ)/g DM
      = 1.14

3) To obtain the equivalent nutrient requirement for a food providing 4 kcal (14.74 kJ)/g, on a DM basis, multiply the requirement by the multiplier.
    Equivalent nutrient requirement
      = 1.14 x 0.06% potassium
      = 0.68% potassium, 4 kcal (14.74 kJ)/g, on a DM basis

4) The amount of potassium in the food (0.72%) is compared to the animal's equivalent nutrient requirement (0.68%) and is found to be adequate.

5) The multiplier obtained above (1.14) can be used to convert the other nutrient requirements to the same basis as the food to compare the adequacy of their levels, if desired.

After the energy densities of the food and the animal's needs are converted to the same units, the comparison is simple.

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better, as owners increase the proportion of new food and decrease the proportion of old food (**Table 1-1**). Nearly all pets readily tolerate a seven-day transition period. A much longer transitional period is recommended in cases in which the food change is known to be significant, the pet has demonstrated a poor tolerance to such changes in the past or food refusal is expected (**Table 1-1**). For example, a long transition schedule is likely to be needed for an old cat recently diagnosed with kidney disease when the food must be switched from a highly palatable grocery "gourmet" food to an appropriate veterinary therapeutic food.

Table 1-1. Recommended short- and long-term food transition schedules for dogs and cats.

Short schedule*	Long schedule**		Food percentages	
Dogs and cats (days)	Dogs (days)	Cats (weeks)	Previous food	New food
1,2	1-3	1	75	25
3,4	4-6	2	50	50
5,6	7-9	3	25	75
7	10	4	0	100

*Recommended for most healthy dogs and cats.
**Recommended for situations in which the food change is known to be significant, the dog or cat has demonstrated low tolerance to such changes in the past or food refusal is anticipated.

Simple Mathematical Ration Balancing (Pearson Square)

The Pearson square is another useful diet balancing tool. This handy method can be used to combine any two foods, supplements or ingredients to yield a mixture with a desired nutrient content. **Figure 1-4** shows how the Pearson square method is used to balance a diet. Here's how to use the Pearson square:

• A small square is drawn and the desired nutrient concentration of the proposed mixture is written in the middle of the square.
• The nutrient concentration of one component of the mixture is written at the upper left corner of the square.
• The nutrient concentration of the other component of the mixture is written at the lower left corner of the square.
• The nutrient values at the corners are subtracted from those in the center of the square. The smaller number is always subtracted from the larger and the differences written diagonally at the right corners of the square.
• The differences are added together and the sum is written below each difference as the denominator of a fraction.
• The fractions are converted to percentages. These percentages are the proportion of each component of the mixture in the corners directly to the left. When combined in those percentages, the constituent components will yield a mixture

Box 1-3. Four Ways to Determine the Nutrient Content of a Food.

The nutrient content of a food can be determined one of four ways:
1) Obtain the target values from the manufacturers of commercially prepared foods.
2) Order a laboratory analysis.
3) Calculate the content based on the published values for the ingredients.
4) Use the information found in the label guaranteed analysis and typical analysis (Chapter 9).

Only the first three are recommended because of the severe limitations of label guarantees and typical analyses.

Most pet food manufacturers, upon request, will supply target values for the nutrient content of their products. This approach is simple and inexpensive. Although these values usually reflect actual average nutrient levels, occasionally they vary significantly from actual values, thus this method is not always accurate. No laws govern the accuracy of target nutrient levels. In most instances, however, these values will be adequate.

The basic laboratory analysis is the proximate analysis (Figure 5-3), which provides the percentage moisture, crude protein, crude fat, ash and crude fiber in a food and allows calculation of the digestible carbohydrate fraction (also referred to as the nitrogen-free extract [NFE]). Most commercial laboratories will also conduct more expansive nutrient analyses including amino acids, fatty acids, minerals, vitamins and various fiber fractions. Analysis of food samples for nutrient content is very straightforward and usually accurate. Limitations include proper sampling, the potential issue of analytical variance for certain nutrients and the expense and time involved for a complete analysis.

Calculations require nutrient contents of ingredients and a formula for the food in question. Published average nutrient contents of ingredients can be obtained from NRC nutrient requirement booklets and listings of average nutrient contents of human foods. This approach would likely be used for determining the nutrient content of a homemade food. One limitation of this method is the time and knowledge required to do such calculations. Another limitation is accuracy (i.e., how closely the published average nutrient content of the ingredients represents the ingredient's actual nutrient content). Values can vary markedly.

The use of guaranteed analyses (United States and Canada) or typical analyses (Europe) listed on the label of commercially prepared foods as a means of establishing nutrient content has severe limitations:

In the case of guaranteed analysis, the quantities listed are minimums or maximums only.

It is only necessary to list a fraction of the nutrients in the food (e.g., guaranteed analysis only requires crude protein, crude fat, crude fiber and moisture; typical analysis only requires crude protein, crude fat, crude fiber, ash and moisture if more than 14%).

Guaranteed analysis values are not the nutrient content of the food. They are a guarantee by the manufacturer that the food contains not more, or less, than the stated amount. Label guarantees can provide a general idea of the nutrient content for a limited number of nutrients and the classification of the food (growth-type food, maintenance food, etc.).

Use caution when using guaranteed and typical analyses to compare specific nutrient levels between foods. When such comparisons are made, be sure to compare similar forms of foods (i.e., dry to dry or moist to moist). Label guarantees are listed on an as fed basis. Different forms of food can be compared if the foods are converted to the same moisture or energy content (**Tables 2, 3** and **6** in **Box 1-2**).

Box 1-4. Computerized Food Evaluation/Balancing Programs.

There are two categories of food evaluation/balancing software programs listed below. The category entitled "Veterinary Clinical Nutrition Software" is a special application designed for use by veterinarians and veterinary nutritionists. It contains commercial pet food and human food nutrient data that enable users to select foods and make feeding and weight-loss feeding plans for individual patients. Additional tools for automatic formulation of homemade pet foods from recipes are also available.

A cautionary reminder: software programs are tools intended to make the mathematical work of food evaluation/balancing/formulation easier and faster. Their accuracy depends entirely on the accuracy of the databases from which they are working and they do not account for nutrient availability regarding ingredient sourcing and cooking, nor do they ensure a palatable food.

Veterinary Clinical Nutrition Software Programs

Davis Veterinary Medical
   Consulting, PC
707 Fourth Street, Suite 307
Davis, CA 95616
Phone: (530) 756- 3862 or
(888) 346-6362
Fax: (530) 756-3863
E-mail:
info@dvmconsulting.com
www.balanceit.com
Balance IT

Commercial Formulation Software Programs

Creative Formulation
   Concepts, LLC
1831 Forest Drive, Suite H
Annapolis, MD 21401
Phone: (410) 267-5540
Fax: (410) 267-5542)
http://creativeformulation.com
Concept5

Feedsoft Formulation
14001 Dallas Parkway,
Suite 1200

Dallas, TX 75240
Phone: (866) 363-7843
Fax: (972) 231-9096
http://feedsoft.com

Agricultural Software
   Consultants, Inc.
2726-600 Shelter Island Drive
San Diego, CA 92106
Phone: (619) 226-2600
Fax: (619) 226-7900
Mixit-Win 5

Format International, Ltd.
Format House

Poole Road
Woking
Surrey England GU21 6DY
Phone: +44 (0)1483 726081
Fax: +44 (0)1483 722827
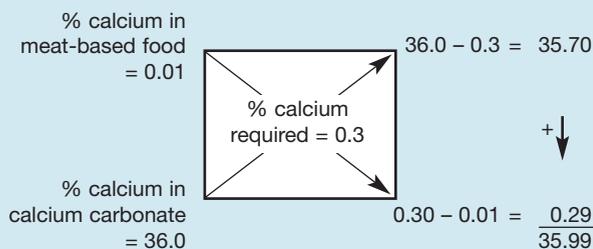www.format-international.com
New Century

Format International, Inc.
10715 Kahlmeyer Drive
St. Louis, MO 63132
Phone: (888) 628-5683
Fax: (314) 428-4102
www.format-international.com
New Century

Box 1-5. Food Formulation and Extensive Food Balancing.

It is not the intention of this book to teach complete food formulation or extensive food balancing. Few practitioners need to know how to formulate balanced foods from scratch. Nutrient requirement information is readily available; however, accurate/relevant ingredient nutrient databases, an understanding of the availability of nutrients in various ingredients, knowledge of the effect of cooking on nutrient availability and knowledge of all of these variables on palatability are complex issues. Such information is not readily available, and usually requires assimilation by a team of experts, including veterinarians, nutritionists and food scientists to ensure proper formulation of complete and balanced foods.

Fortunately, numerous complete pet food options are readily available from commercial pet food manufacturers. Many homemade food recipes have also been published. Be sure to obtain homemade food recipes from reliable sources as discussed in Chapter 10.

As an example, the Pearson square can be used to solve the following problem: How much calcium carbonate containing 36% calcium must be added to a meat-based food to increase its calcium content from 0.01% to 0.3% on an as fed basis? Assume you are making 5 kg of the mixture. The problem is set up and worked as follows:

% calcium in meat-based food = 0.01

% calcium required = 0.3

% calcium in calcium carbonate = 36.0

$36.0 - 0.3 = 35.70$

$0.30 - 0.01 = 0.29$

$\overline{35.99}$

The final step converts fraction to percentages by dividing the numerator of the fractions by the denominator and multiplying by 100.
   Meat-based food: (35.70 ÷ 35.99) x 100 = 99.19%
   Calcium carbonate: (0.29 ÷ 35.99) x 100 = 0.81%
If the total mixture is 5 kg, then 99.19% (4.96 kg) should be a meat-based food and 0.81% (0.04 kg, or 40 g) should be calcium carbonate.

Figure 1-4. Example of how to use the Pearson square.

having the same concentration as the number in the center of the square.

Feeding Tests and Clinical Trials

Evaluation of the product label of commercial foods can provide feeding test information. Determining if a food has been evaluated in clinical trials is a more complicated matter and is covered in Chapter 9 and in various clinical chapters.

Whether or not commercial foods for healthy pets have been animal tested can usually be determined from the nutritional adequacy statement on the product's label (Chapter 9). Published clinical trials and case reports for commercial veterinary therapeutic foods can be obtained from the product's manufacturer. As mentioned above, manufacturers' addresses and toll-free phone numbers are found on pet food labels. However, some brands of these products have passed regulatory agency (AAFCO) prescribed feeding tests although the product label may not include such information.

Commercial pet foods that have undergone AAFCO-prescribed or similar feeding tests provide reasonable assurance of nutrient availability and sufficient palatability to ensure acceptability (i.e., food intake sufficient to meet nutrient needs). Feeding tests also provide some assurance that a product will adequately support certain functions such as gestation, lactation and growth. However, even controlled animal testing is not infallible.

In the United States, the AAFCO testing protocol for adult maintenance lasts six months, requires only eight animals per group and monitors a limited number of parameters (Chapter 9). Passing such tests does not ensure the food will be effective in preventing long-term nutrition/health problems or detect problems with prevalence rates less than 15%. Likewise, these protocols are not intended to ensure optimal growth or maximize physical activity. Besides feeding tests, AAFCO prescribes other methods to assure nutritional adequacy (Chapter 9). Thus, in addition to meeting AAFCO requirements, the food should be evaluated to ensure that key nutritional factors are at levels appropriate for promotion of long-term health or for optimal performance. Few, if any, homemade recipes have been animal tested according to prescribed feeding protocols.

Although not considered feeding tests, the personal observations of veterinarians and pet owners about the performance of specific foods or recipes can be valuable. Such experiences are, in a sense, uncontrolled feeding tests. Through experience, veterinarians and pet owners form impressions about a food's value in disease management, its ability to support various lifestages and work, its palatability, resultant stool quality and skin and coat benefits. Limitations of personal observations include the lack of controls and the length of time it takes (months to years) to gather sufficient information about a wide variety of products. Also, some commercial products are continuously improved; therefore, yesterday's product does not necessarily reflect the capabilities of the "same" product today. However, personal observations can augment controlled feeding tests such as published clinical trials and regulatory agency prescribed feeding protocols for healthy pets.

Physical Evaluation of the Food

Conducting a physical evaluation of the food is of limited usefulness. It can provide information about a food's consistency and whether or not there are extraneous materials in the food. It can also determine package quality, which may or may not reflect product quality. Physical evaluation of the food is probably most useful for assessing whether or not the food has spoiled (Chapter 11).

Box 1-6. A Method for Calculating the Food Dosage Estimate.

Calculations to estimate food dosage are based on the assumption that if a food contains the proper proportions of nutrients relative to its energy density, and is fed to meet an animal's energy requirement, then the animal's requirements for non-energy nutrients will automatically be met. This calculation has three steps:
1) Estimate the energy requirement of the animal (**Table 1**).
2) Determine the energy density of the food (kcal or kJ ME/g food, as fed basis). Sources include product labels, product literature, contacting the product's customer service department by phone or e-mail (phone numbers or e-mail addresses can often be found on the product label). The energy density can be calculated using Atwater values (**Tables 2** and **3**).
3) Divide the energy requirement of the patient by the energy density of the food to determine the daily amount to feed (food dosage).

Table 1. Calculation of energy requirements.

Calculation of daily energy requirement (DER) is based on the resting energy requirement (RER) for the animal modified by a factor to account for normal activity or production (e.g., growth, gestation, lactation, work). RER is a function of metabolic body size. RER is calculated by raising the animal's body weight in kg to the 0.75 power. The average RER for mammals is about 70 kcal/day/kg metabolic body size: RER (kcal/day) = $70(BW_{kg})^{0.75}$ or $30(BW_{kg})$ + 70 (if the animal weighs between 2 and 45 kg). RER values can also be obtained from Table 5-2, Part 3. Expressed in kJ, the average RER for mammals is about $293(BW_{kg})^{0.75}$. These energy requirements should be used as guidelines, starting points or estimates of energy requirements for individual animals and not as absolute requirements.

Feline DER
Maintenance (0.8 to 1.8 x RER)
Neutered adult	= 1.2-1.4 x RER
Intact adult	= 1.4-1.6 x RER
Inactive/obese prone	= 1.0 x RER
Weight loss	= 0.8 x RER
Senior adult (7-11 years)	= 1.1-1.4 x RER
Very old adult (>11 years)	= 1.1-1.6 x RER
Critical care	= 1.0 x RER
Weight gain	= 1.2-1.8 x RER at ideal weight

Gestation
Energy requirement increases linearly during gestation in cats. Energy intake should be increased to 1.6 x RER at breeding and gradually increased through gestation to 2 x RER at parturition. Free-choice feeding of pregnant queens is also recommended.

Lactation
Lactation is nutritionally demanding and the physiologic and nutritional equivalent of heavy work. Recommend 2 to 6 x RER (depending on number of kittens nursing) or free-choice feeding. The following table may also be used to estimate the DER of lactating queens:

Weeks of lactation DER
Weeks 1-2	RER + 30% per kitten
Week 3	RER + 45% per kitten
Week 4	RER + 55% per kitten
Week 5	RER + 65% per kitten
Week 6	RER + 90% per kitten

Growth
Daily energy intake for growing kittens should be about 2.5 x RER. Free-choice feeding is recommended.

Canine DER
Maintenance (1.0 to 1.8 x RER)
Neutered adult	= 1.6 x RER
Intact adult	= 1.8 x RER
Inactive/obese prone	= 1.2-1.4 x RER
Weight loss	= 1.0 x RER
Critical care	= 1.0 x RER
Weight gain	= 1.2-1.8 x RER at ideal weight

Work
Light work	= 1.6-2.0 x RER
Moderate work	= 2.0-5.0 x RER
Heavy work	= 5.0-11.0 x RER

Gestation
First 42 days: feed as an intact adult.
Last 21 days: use 3 x RER. (This quantity may need to be increased to maintain normal body condition for some dogs, especially larger breeds.)

Lactation
Lactation is nutritionally demanding and the physiologic and nutritional equivalent of heavy work.
Recommend 4 to 8 x RER (depending on number of puppies nursing) or free-choice feeding.
The following table may also be used to estimate the DER of lactating bitches:

Puppies (No.)	DER
1	3.0 x RER
2	3.5 x RER
3-4	4.0 x RER
5-6	5.0 x RER
7-8	5.5 x RER
9	≥6.0 x RER

Growth
Daily energy intake for growing puppies should be 3 x RER from weaning until four months of age.
At four months of age energy intake should be reduced to 2 x RER until the puppy reaches adult size.

Table 2. Energy available from protein, fat and digestible carbohydrate (nitrogen-free extract).

Metabolizable energy (kcal/g)
Species	Crude protein	Crude fat	Digestible carbohydrate
All*	4.4 x digest.*	9.4 x digest.*	4.15 x digest.*
Dogs and cats**	3.5**	8.5**	3.5**

Metabolizable energy (kJ/g)
Species	Crude protein	Crude fat	Digestible carbohydrate
All*	18.41 x digest.*	39.33 x digest.*	17.36 x digest.*
Dogs and cats**	14.64**	35.56**	14.64**

Key: digest. = digestibility
*The most accurate value to use when the digestibility of the three nutrients is known. (Adapted from Lewis et al, 1987)
**"Modified" Atwater values (Dog Food Nutrient Profiles and Cat Food Nutrient Profiles). Association of American Feed Control Officials 2007.

Table 3. Example calculation of caloric density of a pet food.*

Analysis			Metabolizable energy (kcal)		
	%		kcal/g of nutrient**		kcal/g of food
Protein	22	x	3.5	=	0.77
Fat	9	x	8.5	=	0.77
Fiber***	3	x	0	=	0
Moisture	10	x	0	=	0
Ash***	5	x	0	=	0
Digestible carbohydrate[†]	51	x	3.5	=	1.79
Total					**3.32[††]**

Analysis			Metabolizable energy (kJ)		
	%		kJ/g of nutrient**		kJ/g of food
Protein	22	x	14.64	=	3.22
Fat	9	x	35.56	=	3.20
Fiber***	3	x	0	=	0
Moisture	10	x	0	=	0
Ash***	5	x	0	=	0
Digestible carbohydrate[†]	51	x	14.64	=	7.47
Total					**13.89[††]**

3.33 kcal/g (13.89 kJ/g) x amount of food/measuring cup = kcal/measuring cup[†††]

*As fed basis.
From **Table 1-8.
***If not available, these may be estimated as 3% fiber and 9% ash in dry foods, 1% fiber and 6% ash in soft-moist foods and 1% fiber and 2.5% ash in moist foods.
[†]Percent digestible carbohydrate (nitrogen-free extract) usually is not stated but can be calculated on an as fed basis by subtracting the percent protein, fat, fiber, moisture and ash from 100.
[††]If the nutrient percentages were obtained from the label guarantee, multiply the food's caloric density by 1.2 for moist pet foods and 1.1 for semi-moist and dry pet foods. In this example, 3.33 (13.89 kJ) x 1.1 = 3.66 kcal (15.28 kJ)/g of dry food.
[†††]An 8-oz. (volume) measuring cup holds 3 to 3.5 oz. by weight (85 to 100 g) of most dry pet foods or 3.5 to 5 oz. by weight (100 to 150 g) of most semi-moist pet foods. It is more accurate to use the average weight of three individual measuring cups of food in determining kcal or kJ/cup.

Label Evaluation

The ingredient panel of the pet food label provides general information about which ingredients were used and their relative amounts. The ingredients used in the product are listed in descending order by weight in many countries. The ingredient panel can be useful if specific ingredients are contraindicated for certain animals or an owner has an ingredient concern. However, the quality of the ingredients cannot be determined from the label and there is much misinformation and, as a result, misunderstandings about pet food ingredients (Chapter 8). As mentioned above, the presence or absence of specific protein sources or other ingredients in a food can be obtained from the product label.

Depending on the country, product labels will also provide information that indicates by what means the product has been shown to be nutritionally adequate (Chapter 9).

Assess and Determine the Feeding Method

Feeding methods relate directly to the physiologic or disease state of the animal and the food or foods being fed. Thus, the information obtained by assessing the animal and the food is fundamental to assessing the feeding method. There are at least three things to consider regarding feeding methods: 1) feeding route, 2) amount fed and 3) how the food is offered (when, where, by whom and how often). In addition, feeding factors that affect compliance should be considered, such as whether or not the animal has access to other foods and who provides the food.

Feeding Route

Whether or not the feeding route is appropriate depends on the animal's condition. Although most animals are able to feed themselves, orphans and some critical care patients may require assistance. Assisted-feeding methods are described in detail in Chapters 25 and 26. Assisted-feeding methods include enteral feeding by syringe or tube (several approaches) and parenteral feeding.

Amount Fed

The nutrient needs of an animal are met by a combination of the nutrient levels in the food and the amount of food offered and eaten. Even if a food has an appropriate nutrient profile, significant over- or undernutrition could result if too much or too little is consumed. Thus, it is important to know if the amount being consumed is appropriate.

The amount of food offered should be determined when taking the patient's history. Although many animals are fed free choice, owners should still be able to provide a reasonable estimate of the actual amount being consumed. The owner may need to return home and measure the amount the pet consumes to provide an accurate report or estimate the amount based on the purchasing frequency of bags or cans. The amount actually being consumed can then be compared with the amount that should be fed. If the animal in question has a normal BCS (3/5) and no history of weight changes, the amount fed is probably appropriate. Exceptions to this generalization include growing animals, animals that are gestating or lactating and hunting dogs and other canine athletes early in the athletic event season.

The appropriate amount to feed can be difficult to determine precisely, but can be estimated. For most commercial pet foods, food dosage estimates can be found in the feeding guidelines on the product label. However, food dosages can be calculated if guidelines are unavailable. The precision of feeding guidelines or calculated food dosages is limited because the efficiency of food use varies among individuals because of differences in physical activity, metabolism, body condition, insulative charac-

teristics of the coat and external environment. Even when environmental conditions and physical activity are similar, sizable individual differences can exist.

Figure 1-5 contains data generated from several controlled studies about the amount of food (energy content standardized) consumed by mature, non-reproducing dogs and cats kept in kennels or runs under similar environmental conditions while maintaining body weight. The total amount of energy needed by dogs and cats for maintenance, even under similar environmental conditions can vary two- to threefold. Even when the extremes are excluded (the top and bottom 2.5%), the amount of energy needed varied more than twofold (Lewis et al, 1987). Therefore, a commercial product's amount to feed guideline or a calculated food dosage should only be considered an estimate or a starting point that may very likely need adjustment.

Calculations to estimate food dosage are based on the assumption that if a food contains the proper proportions of nutrients relative to its energy density, and is fed to meet an animal's energy requirement, then the animal's requirements for non-energy nutrients will be met automatically. This is an important concept. Box 1-6 demonstrates the method for calculating food dosage estimates. Case 1-2 includes an example of a food dosage problem.

How the Food is Offered

The amount fed is usually offered in one of three ways: 1) free-choice feeding (dogs and cats), 2) food-restricted meal feeding (dogs and cats) and 3) time-restricted meal feeding (dogs). The number of feedings per day must be considered when the last two methods are used.

Free-choice feeding (also referred to as ad libitum or self feeding) is a method in which more food than the dog or cat will consume is always available; therefore, the animal can eat as much as it wants, whenever it chooses. The major advantage of free-choice feeding is that it is quick and easy. All that is necessary is to ensure that reasonably fresh food is always available.

Free-choice feeding is the method of choice during lactation. Free-choice feeding also has a quieting effect in a kennel and timid dogs have a better chance of getting their share if dogs are fed in a group.

Disadvantages include: 1) anorectic animals may not be noticed for several days, especially if two or more animals are fed together, 2) if food is always available, some dogs and cats will continuously overeat and may become obese (such animals should be meal fed) and 3) moist foods and moistened dry foods left at room temperature for prolonged periods can spoil and are inappropriate for free-choice feeding (Chapter 11).

When changing a dog from meal feeding to free-choice feeding, first feed it the amount of the food it is used to receiving at a meal. After this food has been consumed and the dog's appetite has been somewhat satisfied, set out the food to be fed free choice. This transitioning method helps prevent engorgement by dogs unaccustomed to free-choice feeding. Engorgement is generally not a problem when transitioning cats to free-choice feeding. Although dogs and cats unaccustomed to free-choice feeding may overeat initially, they generally stop doing so within a few days, after they learn that food is always available. Avoid taking the food away at any time during this transition period. Each time food is taken away increases the difficulty in changing the animals to a free-choice feeding regimen.

With food-restricted meal feeding, the dog or cat is given a specific, but lesser, amount of food than it would eat if the amount offered were not restricted (i.e., free choice). Time-restricted meal feeding is a method in which the animal is given more food than it will consume within a specified period of time, generally five to 15 minutes. Time-restricted meal feeding is of limited usefulness with dogs and has little if any practical application in cats. Many dogs can eat an entire meal in less than two minutes. Both types of meal feeding are repeated at a specific frequency such as one or more times a day. Some people combine feeding methods, such as free-choice feeding a
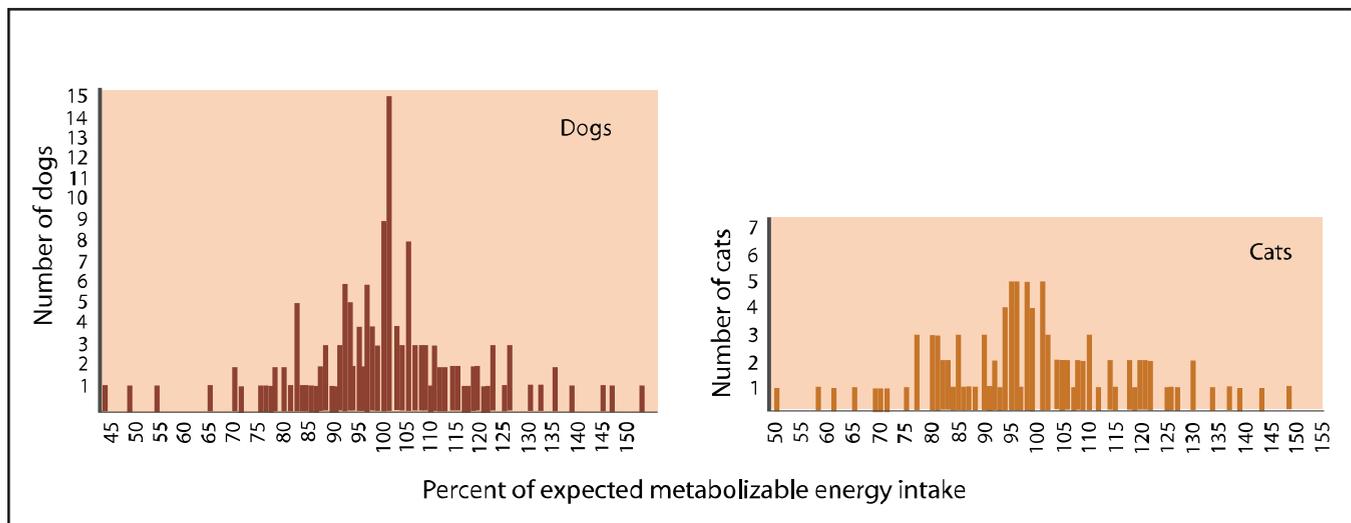
Figure 1-5. Variation in expected energy intake required to maintain optimal body weight in dogs and cats. Data were collected from 120 dogs and 76 cats kept under similar conditions and fed the amount of a variety of commercial pet foods necessary to maintain body weight (Adapted from Lewis et al, 1987).

dry or semi-moist food and meal feeding a moist food or other foods such as meat or table scraps.

Food consumption resulting from frequent meal and free-choice feeding has several advantages. Small meals fed frequently throughout the day result in a greater loss of energy due to an increase in daily meal-induced heat production. Also, providing frequent small meals generally result in greater total food intake than does less frequent feeding (Mugford and Thorne, 1980). Frequent feeding of small meals benefits animals with dysfunctional ingestion, digestion, absorption or use of nutrients.

Frequent feeding is also desirable in normal animals that require a high food intake. Puppies and kittens less than six months old, some dogs engaged in heavy work (high levels of physical activity), dogs and cats experiencing ambient temperature extremes, bitches and queens during the last month of gestation and during lactation should be fed at least three times per day to ensure that their nutritional needs are met. These animals may require one and one-half to four times as much food per unit of body weight than most normal adult dogs and cats. A reduced frequency might limit total food intake in these situations. Also, more frequent feeding during periods of variable appetite suppression, such as occurs with psychologic stress or high ambient temperatures, helps ensure adequate food intake.

Most clinically normal adult dogs that are not lactating, working or experiencing stress will have a sufficient appetite and physical capacity to consume all of the food required daily in a single 10-minute period (assuming food of typical nutrient density [about 3.5 kcal/g or 14.64 kJ/g dry matter]). Cats are less likely to eat their entire meal in one 10-minute sitting, but once-a-day feeding is adequate for most healthy adults. Although many dogs and cats are fed once daily without noticeable detrimental effects, at least twice daily feeding is generally recommended.

In summary, how the food is provided and how often it is fed depend on the animal's condition and in some cases the lifestyle of the owner. Each animal's situation will dictate which feeding method is most desirable (free choice, time-restricted meal feeding or food-restricted meal feeding). For many physiologic and disease conditions this consideration will not be important. For others it will be very important. Recommendations for the best method of providing the food and the number of times per day the food is offered are included in each individual chapter.

Compliance

Owner compliance is necessary for effective clinical nutrition. Feeding methods should reinforce or enable compliance. Enabling compliance includes limiting access to other foods and knowing who provides the food. An animal from a multi-pet household may have access to the other pets' food. If so, such access needs to be denied or limited. Restriction can be difficult in some homes. In such cases the veterinary health care team and pet owner may need to compromise.

Compliance can be eroded if everyone in the family does not support the feeding plan. Whoever feeds the pet must understand the consequences when the wrong foods are fed or even the right foods are fed in the wrong amounts. Client education is essential for the successful outcome of any feeding plan. Specific client education must be provided for feeding healthy pets and for those with specific disease problems. Both oral and written instructions encourage compliance with feeding plans.

Veterinarians and their health care teams should actively involve clients in the formulation of the feeding plan to ensure commitment to the plan. The hospital staff should strive to uncover issues that clients may have about the feeding plan and negotiate mutually acceptable solutions. Open communication about the client's and the health care team's objectives, concerns and shared responsibilities is necessary for successful implementation of the feeding plan. Authoritarian approaches are unlikely to be effective because they discount the high degree of independent decision making that clients have based on their own perceptions of nutrition. Veterinarians and their health care teams can guide clients and enable them to make informed decisions. For more about compliance see Chapter 3.

REASSESSMENT

Finally, monitoring, or reassessing the animal, should be performed at appropriate intervals to evaluate the effectiveness of the feeding plan. For patients undergoing intensive care, reassessment may need to be done every few hours, whereas pets in a health maintenance program could be reassessed annually. Reassessment signals the initiation of the iterative step of the clinical nutrition process. Involving the client in an action plan is an essential component of the veterinarian-client relationship. The reader is referred to the remaining chapters of this book for information about specific feeding plans and practices according to nutritional needs of pets in health and in specific diseases.

REFERENCES

The references for this chapter can be found at www.markmorris.org.

CASE 1-1

Calcium Supplementation in a Great Dane Puppy

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Patient Assessment

A 10-week-old male Great Dane puppy weighing 15 kg was examined as part of its routine health maintenance procedures. The results of a physical examination were normal. The puppy's body condition score was 3/5.

Assess the Food and Feeding Method

The puppy is fed a dry lamb and rice-based commercial food. The owner feeds the puppy four 8-oz. measuring cups of food daily. The owner also provides eight calcium tablets daily as a supplement to "ensure enough calcium." A phone call to the pet food company's customer service department determined that the food's calcium content is 2.3% and that it provides 3.6 kcal/g (15.1 kJ/g) on an as fed basis (10% moisture). The customer service department also indicates that the food density is 94 g/cup. Product literature included with the calcium tablets indicates that each tablet provides 0.5 g of calcium carbonate, and that calcium carbonate contains 36% calcium (0% moisture). The owner asked if this is enough calcium for the puppy.

Questions

1. How many g of food and how many g of calcium carbonate are being fed (dry matter [DM])?
2. Determine the total amount of calcium (DM) provided by the food and supplement.
3. Determine the percentage of calcium in the DM of the combined food and supplement.
4. Convert the energy density on an as fed basis to DM.
5. Does the combination of the food and supplement meet the calcium requirement for a giant-breed puppy?

Answers and Discussion

1. Four cups x 94 g/cup = 376 g of food. Because the two components being evaluated have differing moisture contents (food = 90% DM and calcium carbonate tablets = 100% DM), it is advisable to convert the food to DM at this point: 376 g of food on an as fed basis x 90% DM = 338 g food DM.

    The owner feeds eight calcium tablets daily. The calcium carbonate source has no moisture so as fed basis equals DM: eight calcium tablets x 0.5 g calcium carbonate per tablet = 4 g calcium carbonate (as fed and DM).

2. According to the manufacturer, the food provides 2.3% calcium on an as fed basis. To convert this to DM, divide the as fed percentage by the DM percentage: 2.3% calcium as fed basis ÷ 90% DM = 2.6% calcium DM.

    We have already determined that the calcium tablets provide 4 g calcium carbonate and that calcium carbonate contains 36% calcium. To determine how much calcium is provided by each component, multiply the amount of each component being fed by the amount of calcium in each component and add them:

    338 g food dry matter x 2.6% calcium = 8.8 g calcium
    4 g calcium carbonate x 36% calcium = 1.4 g calcium
                                           10.2 g total
                                           calcium (DM)

3. Total food DM is the sum of the two components:

    338 g food DM + 4 g calcium carbonate DM =
            342 g total food DM
    10.2 g total calcium (DM) ÷ 342 g total food DM =
            3.0% calcium

4. We need to consider the effect of the supplemental calcium source on the energy density of the food and convert the energy density to DM. In this case, we ignore any dilutional effect the 4 g of calcium carbonate has on the energy density of the food because it would be inconsequential (4 g ÷ 342 g = 1%). To convert 3.6 kcal ME/g (15.06 kJ ME/g) as fed to DM, as described previ-

ously, divide the as fed basis by the DM percentage:

3.6 kcal ME/g as fed ÷ 90% DM = 4 kcal ME/g (DM), or
15.06 kJ ME/g as fed ÷ 90% DM = 16.74 kJ ME/g (DM)
    Thus, the total food contains 3.0% DM calcium and provides 4 kcal ME/g (16.74 kJ) DM.

5. To compare a food's nutrient content with a recommended target level requires that the energy density of the food and that specified for the target level be similar or the same. Calcium is a key nutritional factor (nutrient of concern) for large- and giant-breed puppies. Calcium levels in foods intended for large- and giant-breed growth should not exceed 1.2% DM in foods that provide <3.8 kcal ME/g (<15.90 kJ) **(Chapter 33).** As described above, the conversion is made by generating a multiplier that converts the requirement to the same energy density as the food. This is done by dividing the food energy density by the requirement energy density and multiplying the requirement by the multiplier: 4 kcal ME/g ÷ 3.6 kcal ME/g = 1.1 (multiplier), or 16.74 kJ ME/g ÷ 15.06 kJ ME/g = 1.1 or 1.1 x 1.2% maximum = 1.32% maximum.

In this case, the combined food and supplement are providing excessive calcium for this giant-breed puppy (3% in food vs. 1.32% maximum recommended) (Chapter 33).

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CASE 1-2

Food Dosage Estimate for a Lactating Queen

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Patient Assessment
A 4-kg, three-year-old queen is presented for weight loss. The cat is nursing five, three-week-old kittens. The queen's body condition score is 2/5 and the patient record indicates the cat has lost 1 kg since its postpartum checkup.

Assess the Food and Feeding Method
The cat is being fed one cup of a commercial dry food daily, free choice. The food is suitably balanced for feline lactation. The energy density of the food is 535 kcal metabolizable energy (ME)/cup (2,238 kJ ME/cup) on an as fed basis.

Questions
1. What is this queen's estimated daily energy requirement (DER)?
2. What should the food dosage be based on this queen's DER?

Answers and Discussion
1. Resting energy requirement (RER) (kcal ME/day) = $70(BW_{kg})^{0.75}$
    = $70(4 \text{ kg})^{0.75}$ = 70(2.83) = 198 kcal ME/day, or
    = $293(4 \text{ kg})^{0.75}$ = 293(2.83) = 829 kJ ME/day
    Modifier for adult feline = 1.5 x RER = DER
    DER = 1.5 x 198 kcal ME/day = 297 kcal ME/day, or
    1.5 x 829 kJ ME/day = 1,243.5 kJ ME/day
    Modifier for feline lactation = (1 + 0.25[number kittens nursing]) x DER
    = [1 + 0.25(5)] x 297 kcal ME/day
    = 2.25 x 297 kcal ME/day = 668 kcal ME/day, or
    2.25 x 1,243.5 kJ ME/day = 2,798 kJ ME/day
2. The food being fed has a nutrient profile that is satisfactory for feline lactation. The energy density of the food is 535 kcal (2,238 kJ) ME/cup. Divide the energy requirement by the energy density of the food to determine how much to feed the cat:
    668 kcal ME/day requirement ÷ 535 kcal ME/cup = 1.25 cups/day, or
    2,798 kJ ME/day requirement ÷ 2,238 kJ ME/cup = 1.25 cups/day
    According to these calculations the cat is being underfed. The amount offered free choice should be increased by at least 25%.

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CASE 1-3

Altering the Food and Feeding Method for a Young Rottweiler

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Patient Assessment

A four-month-old, female Rottweiler was examined for diarrhea of five days' duration. The puppy had escaped from a fenced yard on trash pickup day and the owners suspected it had eaten garbage. The puppy appeared bright and alert, weighed 18 kg and had a body condition score of 3/5. The results of the physical examination were normal except for fluid-filled intestines on abdominal palpation. The owners described the stools as being small volume but frequent (eight to 10/day) and liquid with some bright red blood and mucus. A fecal examination was negative for intestinal parasites.

Assess the Food and Feeding Method

The puppy was fed a commercial dry puppy food three times per day until its escape. The puppy still had a good appetite, but seemed to be drinking more than usual amounts of water. On Day 1 of the diarrheic episode, the veterinarian examined the puppy and asked the owner to feed a moist commercial veterinary therapeutic food (poultry, egg and rice based) with moderate fat (13%) and low fiber (<1%) (Prescription Diet i/d Canine[a]). However, the diarrhea had not resolved after feeding the food for three days.

Question

What is the appropriate food and feeding method for this patient with large bowel diarrhea?

Answer and Discussion

The food was replaced with a moist commercial veterinary therapeutic food that contained 13% fat and 12% crude fiber on a dry matter basis (Prescription Diet w/d Canine[a]). The owners were instructed to feed the puppy at its estimated resting energy requirement (805 kcal [3,368 kJ]/day) with two cans of the new food divided into four meals per day for one to two days; then to feed at the estimated daily energy requirement (1,600 kcal/day [6,694 kJ]) with four cans of the new food divided into three to four meals per day for another two days. The owners were instructed to return for a recheck if the puppy did not have a normal stool by the fourth day. If the puppy's stool was normal, the owners were instructed to transition the food back to the original puppy food using the short schedule outlined in **Table 1-1.**

Progress Notes

No stool was produced within the first 24 hours of feeding the higher fiber food. By the end of the second day the dog had a normal bowel movement with no blood or mucus. The owners continued to feed the higher fiber food for another two days as instructed. The puppy was then switched back to the dry puppy food over seven days with no problems.

Endnote

a. Hill's Pet Nutrition Inc., Topeka, KS, USA.

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