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Nutrients and Energy

Introduction

Animals, unlike plants, cannot generate their own energy and require a balanced diet to grow normally, maintain health once they are mature, reproduce and perform physical work.[1,2] Plants can convert solar energy from the sun into carbohydrates through photosynthesis, but they too require water, vitamins and minerals for optimal growth and production. Animals, in turn, either eat plants or eat other animals that eat plants to obtain their energy.[1,2]

Nutrients

For animals, energy is provided in the diet through nutrients. Nutrients are components of the diet with specific functions within the body and contribute to growth, tissue maintenance and optimal health.[1,2] Essential nutrients are those components that the body cannot synthesize at a rate adequate to meet its needs, so they must be included in the diet. These nutrients are used as structural components in bone and muscle, enhancing or being involved in metabolism, transporting substances such as oxygen and electrolytes, maintaining normal body temperature and supplying energy.[1,2] Nonessential nutrients can be synthesized by the body and obtained either through production by the body or through the diet.[1,2] Nutrients are further divided into six major categories: water, carbohydrates, proteins, fats, vitamins and minerals.

Energy is not one of the major nutrients, but after water, it is the most critical component of the diet, energy needs always being the first requirement to be met in an animal's diet.[1,2] After energy needs have been met, nutrients become available for other metabolic functions.[1,2] Approximately 50–80% of the dry matter (DM) in a dog's or cat's diet is used for energy.[1,2] The body obtains energy from nutrients by oxidation of the chemical bonds found in proteins, carbohydrates and fats.[2]

Oxidation is the process of a substance combining with oxygen, resulting in the loss of electrons.[3] This oxidation occurs during digestion, absorption and transport of nutrients into the body's cells.[2] An essential energy-containing compound produced during this oxidative process is adenosine triphosphate (ATP), a common high-energy compound composed of a purine (adenosine), a sugar (ribose) and three phosphate groups.[2,3]

The biochemical reactions that occur within the body either use or release energy. Anabolic reactions require energy for completion, and catabolic reactions release energy upon completion.[2] ATP and other energy-trapping compounds pick up part of the energy released from one process and transfer it to other processes.[2] This energy is used for pumping ions, molecular synthesis and activating contractile proteins. These three processes essentially describe the total use of energy by the animal.[2] Without the energy supplied

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through the diet, these reactions would not occur, and death would follow.[2]

ATP is a usable form of energy for the body but not a good form of energy storage because it is used quickly after being produced.[2] Glycogen and triglycerides are longer-term storage forms of energy.[2] In fasting animals, when the body needs energy, it uses stored glycogen first, stored fat second, and finally, amino acids from body protein as a last resort.[2] The triglycerides found in fats cannot be converted into glucose. Only the glycerol backbone can be utilized for this purpose. For proteins/amino acids, they must undergo gluconeogenesis to be converted into usable glucose.[4]

Measures of Energy

Energy is the capacity to do work. This is measured most commonly in the United States as a calorie. A calorie is the amount of heat required to increase 1 g of water from 14.5 to 15.5 °C (or 1 °C) in a bomb calorimeter.[4,10] As this unit of measure is very small, we commonly use the term kilocalorie (1000 cal). When looking at food labels, this is the unit that is being referenced, a kilocalorie or kcal.

Although kcal is used in the United States, a joule is the International System of Units (abbreviated SI) unit measure of energy. 1 kcal = 4.184 J. As with calories, a joule is a small unit of measure, and megajoule (1,000,000 J, 10^6, abbreviated MJ) and kilojoule (1000 J, 10^3, abbreviated KJ) are the units most commonly used in animal nutrition.[4,10] For small animal nutrition, the kilojoule is used most. For large animal nutrition, the megajoule is used.

Gross Energy

The total amount of potential energy contained within a diet is called gross energy (GE). GE in food is determined by burning the food in a bomb calorimeter and measuring the total amount of heat produced. Unfortunately, animals are not able to use 100% of the energy contained in food. Some are lost during digestion and assimilation of nutrients and in urine, feces, respiration and heat production.[1,2]

Digestible Energy

Digestible energy (DE) refers to the energy available for absorption across the intestinal mucosa, the energy lost is found in the feces. Metabolizable energy (ME) is the amount of energy actually available to the tissue for use. The energy lost is that found in the feces and urine. ME is the value most often used to express the energy content in pet foods.[1,2]

When GE values are readjusted for digestibility and urinary losses, ME values of 3.5 kcal/g are assigned to proteins and carbohydrates and 8.5 kcal/g to fats. These values are called modified Atwater factors.[1,2] These were developed by American Association of Feed Control Officials (AAFCO) to produce an equation that would more accurately reflect the digestibility of commercial pet foods, which tend to have a lower digestibility than typical human foods.[4]

The ME of a diet or food ingredient depends on its nutrient composition and the animal consuming it.[1,2] If a dog and horse eat the same high-fiber diet, the horse will have a higher ME value due to its better fiber digestion ability than a dog. These differences in digestion can also be seen between dogs and cats, though not to the same extent as with an herbivore.

There are three methods to determine the ME in a diet: direct determination using feeding trials and total collection methods, calculation from analyzed protein levels, carbohydrates, and fats in the diet and extrapolating data collected from other species.[1,2]

Feeding Trials

Feeding trials using the species of concern are the most accurate method of determining a food's ME content. However, this can be time-consuming and expensive and requires access to large numbers of test animals.[1,2] The

AAFCO, the government body that oversees pet food production, has specific requirements for feeding trials; in general, they require a minimum of eight animals for a maintenance diet, at least 1 year of age, being fed the food in question for a minimum of 26 weeks. Food consumption is measured and recorded daily. Individual body weights should be recorded at the beginning, weekly and end, and a minimum database of blood work is required at the beginning and end of the study. A veterinarian must give all animals a complete physical exam at the beginning and end of the study; they are evaluated for general health, body and hair condition with comments recorded. Animals, not to exceed 25% (2 animals), may be removed for non-nutrition-related reasons only during the first two weeks of the study. A necropsy is conducted on any animal that dies during the study. There are additional conditions for foods used during pregnancy, lactation or growth.[5] Manufacturers of some of the premium pet foods routinely measure the ME of their formulated diets and ingredients through the use of controlled feeding trials.[1,2] Feeding trials are a time-consuming and expensive way to test ME in pet foods. Still, it is also the most accurate method and has the greatest potential to expose any deficiencies or excesses in a particular diet.

Calculation Method

ME values can also be determined using the calculation method. This involves using mathematical formulas to estimate a food's ME from its analyzed protein, carbohydrate and fat content. The formulas used for dog and cat diets have constants that account for fecal and urinary energy losses.[1,2] The method does not account for the digestibility or quality of ingredients. Therefore, excesses or deficiencies may not be apparent. ME is calculated using standard values for each nutrient. But each nutrient's actual energy may be different from the standard (see Table 1.1).

Table 1.1 Examples of AAFCO certification claims.

1. Animal feeding trials using AAFCO's procedures substantiate that … provides complete and balanced nutrition for maintenance.
2. This product is formulated to meet the nutritional levels established by the AAFCO dog food profile for adult dogs.
3. Animal feeding tests using AAFCO's procedures substantiate that … provides complete and balanced nutrition for all life stages of cats.
4. …is formulated to meet nutritional levels established by the AAFCO cat food nutrient profiles for growth and maintenance.[1,2]

Actual GE for triglycerides ranges from 6.5 to 9.5 kcal/g, proteins range from 4.0 to 8.3 kcal/g and carbohydrates range from 3.7 to 4.3 kcal/g. The standard values assigned to these nutrients are triglycerides 9.4 kcal/g, proteins 5.65 kcal/g and carbohydrates 4.15 kcal/g.[4] These values reflect GE rather than the modified Atwater numbers typically assigned when doing pet food calculations. GE does not account for fecal or urinary losses in a diet or the energy used during digestion.[4]

Data from other species can be used when direct data is not available for particular food ingredients in a particular species. This is especially common with cat food ingredients. The species most often used for comparison is the pig. Although this method of estimating ME is not as accurate as direct measurement, data collected from swine experiments have been reported to correlate well with values from other species with simple stomachs.[1,2]

The method used to attain AAFCO certification is required to be listed on the product label. Most companies that use feeding trials clearly state this; those using calculation methods or extrapolation methods may be a little vague in how the certification is obtained (see Table 1.2).[1,2]

Energy Density

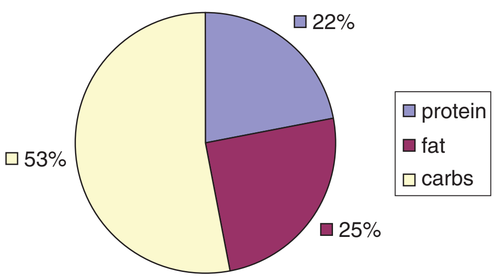
The energy density of a pet food refers to the number of kilocalories provided in a given weight or volume. In the United States, energy density is expressed as kilocalories (kcal) of

Table 1.2 Example of nutrient density and nutrient distribution.

Nutrient density:
Protein 21 g/96.25 g/100 kcal
Fat 23.8 g/96.25 g/100 kcal
Carbs 51.45 g/96.25 g/100 kcal

Nutrient distribution:
Protein 21 g/96.25 g/100 kcal = 22%
$(21 \div 96.25) \times 100 = 22\%$
Fat 23.8 g/96.25 g/100 kcal = 25%
$(23.8 \div 96.25) \times 100 = 25\%$
Carbs 51.45 g/96.25 g/100 kcal = 53%
$(51.45 \div 96.25) \times 100 = 53\%$

Calorie calculation:
Protein 22% of 100 kcal = 22 kcal/96.25 g of food
Fat 25% of 100 kcal = 25 kcal/96.25 g of food
Carbs 53% of 100 kcal = 53 kcal/96.25 g of food



ME per kg or pound of food.[1,2] The energy density must be high enough for the animal to consume enough food to meet its daily energy requirements. Energy density will be the primary factor that determines the amount of food eaten each day.[1,2] The ability to maintain normal body weight and growth rate is the criteria used to determine the appropriate quantity of food fed.

Because energy intake determines total food intake, diets must be appropriately balanced so that requirements for all other nutrients are met at the same time that energy requirements are met.[1,2] For this reason, it is more appropriate to express nutrient energy levels in a diet in terms of ME than as a percentage of the food's weight or DM (see Table 1.3).[1,2]

Expressing nutrient content as units per 1000 kcal of ME is called nutrient density.[1,2]

Table 1.3 Examples of nutrient density and caloric distribution.

Dog food for growth, dry:
Calories (ME): 4491 kcal/kg, 485 kcal/cup
Caloric distribution:
Protein 29%
Fat 46%
Carbohydrate 25%

Dog food for maintenance, canned:
Calories (ME): 1108 kcal/kg, 409 kcal/can
Caloric distribution:
Protein 34%
Fat 58%
Carbohydrate 8%

Cat food for maintenance, dry:
Calories (ME): 4490 kcal/kg, 459 kcal/cup
Caloric distribution:
Protein 29%
Fat 47%
Carbohydrate 24%

Cat food, hairball formula, dry:
Calories (ME): 3692 kcal/kg, 280 kcal/cup
Caloric distribution:
Protein 30%
Fat 29%
Carbohydrate 41%

Therapeutic recovery diet, canned:
Calories (ME): 2000 kcal/kg, 340 kcal/can
2.14 kcal/ml-canine
2.11 kcal/ml-feline
Caloric distribution:
Protein 29%
Fat 66%
Carbohydrate 5%

Remember, fats contain almost three times the energy of proteins or carbohydrates and may only be a small portion of the weight of the diet but supply most of the calories. If looking only at weight, a diet may look low in fat, but be just the opposite.

When evaluating different diets, it is important to look at the caloric distribution and nutrient density rather than the percentage of the food's weight, typically expressed as DM. This will allow you to compare foods of differing moisture or energy contents. This method is somewhat limited compared to

Table 1.4 Calculating nutrients as a percentage of metabolizable energy.

Total calories in 100 g of food

Protein = 3.5 kcal/g × grams in food
Fat = 8.5 kcal/g × grams in food
Carbohydrate = 3.5 kcal/g × grams in food
Total calories/100 g = protein calorie + fat calorie + carbohydrate calorie

Percentage of ME contributed by each nutrient (caloric distribution)

Protein = (protein calories/100 g divided by total calories/100 g) × 100 = %ME
Fat = (fat calories/100 g divided by total calories/100 g) × 100 = %ME
Carbohydrate = (carbohydrate calories/100 g divided by total calories) × 100 = %ME

nutrient density because caloric distribution only considers the energy-containing nutrients of the food. The AAFCO requires that the energy value of a pet food be expressed in kcal of ME (see Table 1.4).[1,2]

Excess energy intake is much more common in dogs and cats than energy deficiency. The current estimates given by the American Veterinary Medical Association (AVMA) show that greater than 50% of dogs and cats are overweight (10–15% above their desired body weight) or obese (20–25% above their desired body weight)[6] Excessive energy intake has been shown to have several detrimental effects on dogs during growth, especially those of large and giant breeds. Feeding growing puppies to attain a maximal growth rate appears to be a significant contributing factor in developing skeletal disorders such as osteochondrosis and hip dysplasia (see Figures 1.1 and 1.2).[1,2]

Excessive energy intake during growth also affects the total number of fat cells the animal has. If the animals overconsume during their growth phase, this can contribute to obesity later in life. Once a fat cell has been formed, it will never go away, and research has shown that individual cells produce hormones that help them retain their stored fat.[1,2,7] Obesity has been linked to the development of orthopedic problems later in life and increased diabetes, hyperlipidemia, pancreatitis and heart failure. A study conducted by Nestle Purina demonstrated that by simply reducing the amount of food fed to a controlled group of Labradors by 25%, they, on average, lived 1.5 years longer than their pair mate, had less incidence of orthopedic problems, cancer and metabolic diseases (see Figure 1.3).[8]

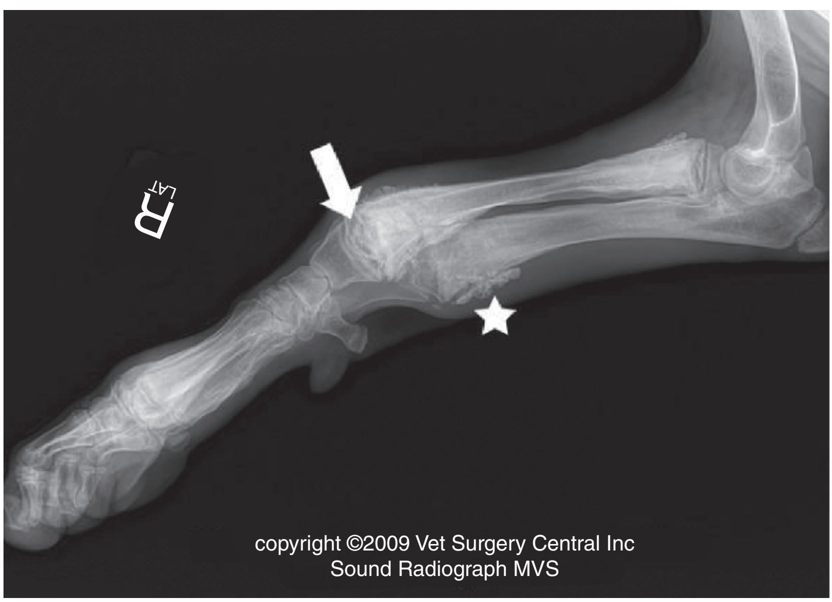


Figure 1.1 Radiograph of a Great Dane puppy with hypertrophic osteodystrophy due to overnutrition. This X-ray shows a line of lucency where destruction of the bone has occurred adjacent to the growth plates in the distal ulna. New bone production can also be seen outside of the bones. (Courtesy of Dr. Dan Degner.)

Figure 1.2 A Great Dane puppy showing the joint enlargement seen with hypertrophic osteodystrophy due to overnutrition. (Courtesy of Dr. Dan Degner, with permission.)

Inadequate energy intake results in reduced growth rate and compromised development in young dogs and cats and weight loss and muscle wasting in adult animals. In healthy animals, this is most commonly seen in hardworking dogs and pregnant or lactating females fed a diet too low in energy density.[1,2]

Figure 1.3 Weight loss secondary to diabetes mellitus. A common complication of this disease is weight loss due to lack of glucose utilization by the cells, causing protein catabolism of the muscle to meet the body's energy requirements with the decreased energy availability.

Weight loss is also seen in sick animals that are either unable or unwilling to eat adequate amounts of food or whose disease process causes energy loss or increased energy use.[9]

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