Nutrients and Energy

Introduction

Animals, unlike plants, are unable to generate their own energy, and require a balanced diet to grow normally, maintain health once they are mature, reproduce, and perform physical work. Plants are able to convert solar energy from the sun into carbohydrates through a process called 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.

Nutrients

For animals, energy is provided in the diet through nutrients. Nutrients are components of the diet that have specific functions within the body and contribute to growth, tissue maintenance and optimal health. Essential nutrients are those components that cannot be synthesized by the body at a rate adequate to meet the body’s needs, so they must be included in the diet. These nutrients are used as structural components as with bone and muscle, enhancing or being involved in metabolism, transporting substances such as oxygen and electrolytes, maintaining normal body temperature and supplying energy. Nonessential nutrients can be synthesized by the body and can be obtained either through production by the body or through the diet. 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 with energy needs always being the first requirement to be met in an animal’s diet. After energy needs have been met, nutrients become available for other metabolic functions. Approximately 50–80% of the dry matter of a dog’s or cat’s diet is used for energy. The body obtains energy from nutrients by oxidation of the chemical bonds found in proteins, carbohydrates and fats.

Oxidation is the process of a substance combining with oxygen resulting in the loss of electrons. This oxidation occurs during digestion, absorption and transport of nutrients into the body’s cells. The most important 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.

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. ATP and other energy-trapping compounds pick up part of the energy released from one process and transfer it to the other processes. This energy is used for pumping ions, molecular synthesis and to activate contractile proteins, these three processes essentially describe the total use of energy by the animal. Without the energy supplied through the diet, these reactions would not occur and death would follow.

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

Energy represents the capacity to do work. This is measured most commonly in the United States as a calorie. A calorie is the amount of heat that is required to increase the temperature of 1 kilogram of water from 14.5 °C to 15.5 °C (or 1 °C). As this unit of measure is very small indeed, we commonly use the term kilocalorie (1000 calories). When we look at food labels, this is the unit that is being referenced, a kilocalorie, or kcal.

Although kcal is what is used in the United States, a joule is the SI unit measure of energy. 1 kcal = 4.184 joules. As with calories, a joule is a small unit of measure, and kilojoule (1,000,000 J) and megajoule (1000 J) are the units most commonly used in animal nutrition.

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 a food; some of it is lost during digestion and assimilation of nutrients as well as in urine, feces, respiration and production of heat.

Digestible Energy

Digestible energy (DE) refers to the energy available for absorption across the intestinal mucosa; the energy lost is that 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.

When GE values are readjusted for digestibility and urinary losses, ME values of 3.5 kilocalories/g are assigned to proteins and carbohydrates and 8.5 kilocalories/g to fats; these values are called Modified Atwater factors. These were developed by AAFCO to produce an equation that would more accurately reflect the digestibility of commercial pet foods, which tend to have lower digestibility than typical human foods.

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

Three possible methods can be used to determine the ME in a diet: direct determination using feeding trials and total collection methods, calculation from analyzed levels of protein, carbohydrates and fats in the diet, and extrapolation of data collected from other species.

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 very time-consuming and expensive and requires access to large numbers of test animals. The American Association of Feed Control Officials (AAFCO), the government body that oversees pet food production, has certain requirements for feeding trials; in general they require a minimum of 8 animals for a maintenance diet, at least 1 year of age, being fed the food in question for a minimum of 26 weeks. The food consumption is measured and recorded daily, individual body weights should be recorded at the beginning, weekly and at the end, and a minimum data base of blood work is required at the beginning and end of the study. All animals are to be given a complete physical exam by a veterinarian at the beginning and end of the study; they should be evaluated for general health, body and hair condition with comments recorded. A number of animals, not to exceed 25% (2 animals), may be removed for nonnutrition related reasons only during the first two weeks of the study. A necropsy will be conducted on any animal that dies during the study. There are additional conditions for foods used during pregnancy, lactation or growth. Manufacturers of some of the premium pet foods routinely measure the ME of their formulated pet foods and ingredients through the use of controlled feeding trials. Feeding trials are obviously a time-consuming and expensive way to test ME in pet foods, but are also the most accurate method and have the greatest potential to expose any deficiencies or excesses in a particular food.
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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

Calculation Method

ME values can also be determined using the calculation method. This involves the use of 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 losses of energy.1,2 The method does not account for digestibility or quality of ingredients, therefore excesses or deficiencies may not be apparent. ME is calculated using standard values for each nutrient, when the actual energy provided by each nutrient may be different from the standard.

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

When direct data is not available for particular food ingredients in a particular species, data from other species can be used. 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 that use calculation methods or extrapolation methods may be a little vague in how the certification is obtained (Table 1.1).

Energy Density

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 ME per kg or pound of the food.1,2 The energy density must be high enough for the animal to be able 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 a normal body weight and growth rate is the criteria used to determine the appropriate quantity of food to be fed.

Because energy intake determines total food intake, it is especially important that diets are properly 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 levels of energy containing nutrients in a food in terms of ME rather than as a percentage of the food’s weight (Table 1.2).1,2

Expressing nutrient content as units per 1000 kcal of ME is called nutrient density.1,2 Remember, fats contain almost three times the energy of proteins or carbohydrates and may only be a small portion of the diet’s weight, but supply a majority of the calories. If you look only at weight, a diet may look low fat, but in fact be just the opposite.

When evaluating different diets, it’s important to look at the caloric distribution of a food as well as nutrient density, rather than the percentage of the food’s weight, typically expressed as dry matter (DM). This will allow you to compare foods of differing moisture or energy contents. This method is somewhat limited when compared to the use of 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 (Table 1.3 and 1.4).1,2
Excess energy intake is much more common in dogs and cats than is energy deficiency. The current estimates given by the American Veterinary Medical Association (AVMA) show that in excess of 40% of dogs and cats are overweight (10–15% above their desired body weight) and 25% of dogs are seen as obese (20–25% above their desired body weight). Excessive energy intake has been shown to have several detrimental effects on dogs during growth, especially those of the large and giant breeds. Feeding growing puppies to attain maximal growth rate appears to be a significant contributing factor in the development of skeletal disorders such as osteochondrosis and hip dysplasia (Figure 1.1).

Excessive energy intake during growth also affects the total number of fat cells the animal has, meaning that if the animal over-consumes during its growth phase, this can contribute to the development of obesity later in life. Once a fat cell has been formed, it will never go away, and research has shown that the individual cells produce hormones that help it to retain its stored fat. Obesity had been linked to the development of orthopedic problems later in life as well as increasing the incidence of diabetes, hyperlipidemia, pancreatitis and heart failure. A study conducted by Nestlé 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 (Figures 1.2 and 1.3).8

Inadequate energy intake results in reduced growth rate and compromised development of young dogs and cats and in weight loss and muscle wasting in adult animals. In healthy animals, this is most commonly seen in hard-working dogs, pregnant or lactating females that are being fed a diet that is too low in energy density.1,2 This can also be seen in sick animals that are either unable or unwilling to eat, or those whose disease process cause energy loss or increased energy use.9

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, with permission.)

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.)

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.

Table 1.4 Calculating nutrients as a percentage of metabolizable energy

| Total calories in 100 grams of food | Protein = 3.5 kcal/gram x grams in food |
| Fat = 8.5 kcal/gram x grams in food |
| Carbohydrate = 3.5 kcal/gram x grams in food |
| Total calories/100 gram = protein calorie + fat calorie + carbohydrate calorie |

Percentage of ME contributed by each nutrient (caloric distribution)

| Protein = (protein calories/100 gram divided by total calories/100 gram) x 100 = % ME |
| Fat = (fat calories/100 gram divided by total calories/100 gram) x 100 = % ME |
| Carbohydrate = (carbohydrate calories/100 gram divided by total calories) x 100 = % ME |

References