Nutrition and Disease Management for Veterinary Technicians and Nurses

SECOND EDITION

Ann Wortinger | Kara Burns

with website

WILEY Blackwell

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By Ann Wortinger and Kara M. Burns

WILEY

Editorial offices:
1606 Golden Aspen Drive, Suites 103 and 104, Ames, Iowa 50014-8300, USA
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK
9600 Garsington Road, Oxford, OX4 2DQ, UK

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Preface

Nutrition is an area of veterinary medicine that is very easy for the technician to have an active role in. Many of the commercial food producers have even concentrated on educating technicians on nutrition. There are nutrition tracks at most national conferences, as well as on-line learning programs.

As with any other area of education, you still need to know the basics to understand what is being taught, and unfortunately this is often not addressed for technicians. While chemistry, microbiology and math are required at most schools, even these do not adequately address basic animal nutrition. We all are taught the basic nutrients in a diet: water, protein, fats and carbohydrates, but how do they work together, what happens to them inside the body and what changes occur with aging or disease?

So where does this leave a technician who wants to know more about nutrition, who wants to really understand what is going on inside the animal? Usually they start by going through the available veterinary nutrition books, if you aren't overwhelmed and terrified by the first chapter it's a miracle. These books are often more detailed than a technician needs or wants to know; you tend to get lost in these details and miss the basic points. If you go to human nutrition books, these do not address the unique nutritional needs of our most common species, dogs, cats, horses, birds and pocket pets, though they can often address basic nutrition in a less technical manner. Some people enroll in an online program, but the basics are still often missing from these and referencing these later on can be difficult. I love having reference books available whenever I have a question or need clarification on a point of interest, and I often have questions and need clarification. Many commercial food producers also provide technical helplines, but you still need to understand the basics before you can ask for clarification!

I have plowed through nutrition books from the very basic pet owner books to the extremely technical veterinary books; all of them have something to offer, but will you read long enough to understand it? I was very fortunate to have a number of veterinarians who were willing to explain the points I didn't understand, to correct me when I misunderstood a concept and to direct me to areas that I may find interesting. Without them, I would have had a much more difficult time understanding and utilizing nutrition in our day-to-day practice. After all, that is the ultimate goal of nutrition isn't it?

My goal in writing this book was to provide a book for a technician that was both relevant and technical but understandable and usable. This is not a dummied down version of a veterinary nutrition book, but one that focuses on the unique interests of technicians and how we use nutrition in practice and at home. For the second edition I have asked my good friend and partner in nutrition, Kara Burns to provide her spin on disease management and alternate species nutrition. I am very excited to have Kara helping to improve the second edition.

The book is organized into five sections. The first section addresses the basics of nutrition by looking at energy and nutrients, how the individual nutrients of water, carbohydrates, fats, proteins, vitamins and minerals are utilized by the body, digestions and absorption of these nutrients and finally energy balance. Section 2 covers nutritional requirements for cats and dogs by going through the history and regulation of pets food, understanding how to read pet food labels, understanding nutrient content and types of foods and how they differ, and evaluating raw food diets, preservatives and homemade diets. Section 3 covers different feeding regimens, body condition scoring both definition and use, and takes feeding from pregnancy and lactation through neonatal, growth and adult maintenance feeding and into geriatrics. Section 3 also covers feeding for performance animals, special feeding requirement for cats, nutrition myths, the use of nutritional support and assisted feeding techniques. Section 4 is new and covers nutritional management of disease, looking at GI disease, hepatic disease, weight management, FLUTD and others. The final section, also new, addresses the feeding management of other species, including horses, birds, and pocket pets. Each section will build on the information covered in previous sections, allowing for practical use of the information learned.

My cats and chickens are not thrilled when I start calculating caloric intake, nutrient distribution or metabolizable energy. I am sure that Kara's varied pet population feels much the same way, but they too will ultimately benefit from our knowledge, as have innumerable clients, patients, co-workers and students.

My hope is that through this book you to will come to appreciate the important role nutrition plays in veterinary medicine, both through prevention and therapeutic use. You will have a better understanding of basic digestion, nutrient use by the body and how food can affect our patients from the pre-natal period through their death (hopefully many years down the line). And lastly that you will bring nutrition into your practice and use it to improve the quality of care that is provided to your patients. Nutrition is an ever-evolving field in veterinary medicine, and I hope this book serves as a stepping stone for future learning. Kara and I love veterinary nutrition and we hope that you will come to love it too!

Ann Wortinger

Acknowledgments

Working on this second edition has been challenging on many fronts. I changed jobs half way through, continued with my speaking schedule, had a son get married and my youngest child graduated and moved out. Enough activities to distract the most hardy of writers.

By adding Kara Burns as cowriter, we have been able to expand the chapters and information provided, allowing both of us to further spread the nutrition word! As many of you know, Kara and I were on the organizing committee for the Veterinary Technician Specialty in Nutrition, and are now on the Executive committee for the VTS (Nutrition). A labor of love for both of us!

My feline editorial staff has changed since the last edition, Cheyenne-Abyssinian extraordinaire has been replaced by Dusty, our blind Detroit stray; we also lost Daisy much too soon and added Poppy a TNR rescue. Lily and Rose helped to train my new recruits in what is expected of a feline editorial staff at our house. You ladies had the unfailing ability to know exactly which book or article I was currently working out of, or would need next. You very kindly marked it with your furry bodies. Supervision was conducted from the back of my chair, when needed, and Dusty needed to be taught that crossing the keyboard was not the way to get across my desk. How does anyone work without a feline editorial staff?

Ann Wortinger

Writing *Nutrition and Disease Management for Veterinary Technicians and Nurses, Second Edition* with Ann Wortinger has been the realization of a dream. I do not believe there are two people with more passion for nutrition than Ann and myself. We both see the value of proper nutrition and the foundation for health that proper nutrition provides to veterinary patients. Thank you, Ann, for adding me as an author and for your friendship!

Thank you to the love of my life Ellen Lowery, DVM, PhD, MBA. You make my life complete and give me the courage to pursue all of my dreams. Thank you for your encouragement and support in this endeavor and for constantly supporting my desire to write this book!

My parents, Bernard "Red" and Marilyn Burns instilled in me a love of all animals. Additionally, I saw the power of nutrition first hand as my father dealt with Type 1 diabetes his entire life, eventually succumbing to complications of the disease. Veterinary nutrition fell naturally into place from these experiences.

I have an expansive editorial staff that has contributed their supervisory abilities along this writing journey. Felines Prancer, O'Malley, and Oreo have been consistently knocking all references off of my desk in an obvious attempt to keep me from sitting in one place for too long. Whenever I had a writing "block," I would sit back and watch our horses, Socks and Eddie, running through the pasture – what an awesome sight. All six of our birds would take turns providing beautiful sounds to help the writing process. And yes – Pudge and Fribble, the reigning "Best Dogs Ever" (Fribble has the additional title of "cutest dogever") were with me every step of the way. Thank you all for bringing such joy to my life.

Kara M. Burns

About the companion website

This book is accompanied by a companion website:

www.wiley.com/go/wortinger/nutrition

The website includes:

- Cases for self-study and review
- Review questions and answers
- The figures from the book in PowerPoint

SECTION 1

Basics of Nutrition

1 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.[1,2] Plants are able to convert solar energy from the sun into carbohydrates thorough 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.[1,2]

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.[1,2] 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.[1,2] Nonessential nutrients can be synthesized by the body and can be 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 with 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 of 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] 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.[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 the other processes.[2] 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.[2] Without the energy supplied through the diet, these reactions would not occur and death would follow.[2]

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.[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 as last resort amino acids from body protein.[2] 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.[4]

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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).[4] 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.[4]

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.[1,2]

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.[1,2]

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.[1,2] 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.[4]

The ME of a diet or food ingredient depends on both the nutrient composition of the food and the animal consuming it.[1,2] 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.[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 very time-consuming and expensive and requires access to large numbers of test animals.[1,2] 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.[5] Manufactures 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.[1,2] 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.

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/per 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]

Table 1.2 Example of nutrient density and nutrient distribution

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

Nutrient distribution:
Protein 21 gr/96.25 gr/100 kcal = 22%
(21÷96.25) × 100 = 22%
Fat 23.8 gr/96.25 gr/100 kcal = 25%
(23.8÷96.25) × 100 = 25%
Carbs 51.45 gr/96.25 gr/100 kcal = 53%
(51.45÷96.25) × 100 = 53%

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

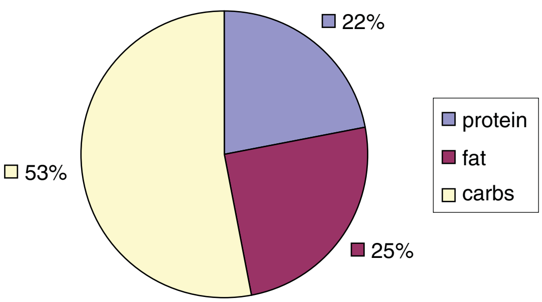

Table 1.3 Examples of nutrient density and caloric distribution

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%

Source: From P Roudebush DS Dzanis, J Debraekeleer, RG Brown (2000) Pet food labels. In MS Hand, CD Thatcher, RI Remillard, P Roudebush (eds), *Small Animal Clinical Nutrition* (4th edn), p. 155, Marceline, MO: Walsworth Publishing for Mark Morris Institute.

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).[6] 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).[1,2]

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.[1,2,7] 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

Table 1.4 Calculating nutrients as a percentage of metabolizable energy

Total calories in 100 grams of food
Protein = 3.5 kcal/gram × grams in food
Fat = 8.5 kcal/gram × grams in food
Carbohydrate = 3.5 kcal/gram × 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) × 100 = % ME
Fat = (fat calories/100 gram divided by total calories/100 gram) × 100 = % ME
Carbohydrate = (carbohydrate calories/100 gram divided by total calories) × 100 = % ME

Source: From: LP Case, DP Carey, DA Hirakawa, *et al*. (2000) Energy and water. In Gross *et al.* (2nd edn), *Canine and Feline Nutrition*, pp. 3–14, St Louis, MO: Mosby; KL Gross, KL Wedekind, CS Cowell *et al*. (2000). Nutrients. In MS Hand, CD Thatcher, RL Remillard *et al*. (eds), *Small Animal Clinical Nutrition* (4th edn), pp. 21–36, Marceline, MO: Walsworth Publishing Mark Morris Institute

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.)

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 1.3 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.

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2 Water

Introduction

Water is the single most important nutrient in terms of survivability. Animals can live for weeks without any food, using their own body fat and muscle for energy production, but a loss of only 10% of their body water can result in death.[1−3] It is also one of three nutrients that do not contribute any calories to the diet.

Within the body, water functions as a solvent that facilitates cellular functions and as a transport medium for nutrients and the end products of cellular metabolism. Water is able to absorb much of the heat that is generated during metabolic reactions with a minimal increase in temperature. Water also helps to transport heat away from the working organs through the blood.[1,2]

Water is an essential component in normal digestion because it is necessary for hydrolysis, the splitting of larger molecules into smaller ones through the addition of water.[1,2] Examples of hydrolysis would include lipase, an enzyme that hydrolyzes fats, amylase an enzyme that hydrolyzes amyloid, a complex carbohydrate and peptidase an enzyme that hydrolyzes peptides, complex groups of amino acids.[4] Elimination of waste products through the kidneys also requires a large amount of water, which acts as both a solvent for the toxic metabolites and as a carrier medium.[1,2]

Water is involved in regulating oncotic pressure that helps the body to maintain its shape; one manifestation of loss of oncotic pressure is seen with dehydration with loss of skin elasticity. Water is found in all the body fluids as well as helping to lubricate the joints and eyes, provides protective cushioning for the nervous system and aids in gas exchange in respiration by keeping the alveoli moist and expanded.[2]

Water accounts for the largest proportion of any of the nutrients in an animal's body, varying from 40% to 80% of the total amount. The percent of water varies with species, condition and age.[1,2] Generally, lean body mass contains 70–80% water and 20–25% protein, with adipose tissue containing 10–15% water and 75–80% fat. The younger and leaner the animal is, the more water it contains. The fatter the animal, the lower the animal's water content.[2]

Water Quality

Because of water's role as a solvent, the potential exists that other substances can enter the animal's body that hadn't been planned for. Salinity (water's salt content), nitrates, nitrites, inorganic chemicals and microbial contamination are examples of only a few contaminants that can be found in water supplies.[5] Routine measurement of water quality looks at these dissolved solids with a reading of total parts per million (ppm) and is reported as "total dissolved solids" (TDS). Water containing less than 5000 ppm TDS is generally considered acceptable for consumption. A level above 7000 ppm is considered unsuitable for livestock and poultry consumption.[5] Human recommendations are less than 500 ppm of TDS, and this is considered a better recommendation for companion animals.

For anyone with access to city water, TDS testing is done through the local public health department. For those persons using well water or other sources of water, having a commercial analytical laboratory screen the water for TDS, pesticide residues and other chemicals would be recommended.[2]

Water Loss

Water is lost in a number of ways. Obligatory loss from the kidneys is the minimum amount of water required by the body to rid itself of the daily load of urinary waste

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products. Facultative loss is the remaining portion of the urine that is excreted in response to the normal water reabsorption rate of the kidneys and to mechanisms responsible for maintaining proper water balance in the body. Fecal water accounts for a much smaller portion of the water lost.[1] A third route of water loss is through evaporation from the lungs during respiration. Water can also be lost through perspiration, but this is only a very small portion of water loss for most companion animals. In dogs and cats evaporative and perspiration water loss are very important for the regulation of normal body temperature during hot weather.[1]

Water Gains

Daily water consumption must compensate for these continual losses. The total water intake daily comes from three possible sources: water present in the food, metabolic water and drinking water.[1]

The amount of water found in the diet depends on the type of food being fed; dry food can have a moisture content as low as 7%, with some canned foods being as high as 84%. Within limits, increasing the water content of a food increases the diets acceptability to the animal.[1]

Metabolic water is the water that is produced during oxidation of the energy-containing nutrients of the body. Oxygen combines with the hydrogen atoms removed from the carbohydrates, proteins, and fats in the food during digestion to produce water molecules.[1,6] The metabolism of fat produces the greatest amount of metabolic water on a weight basis, and protein catabolism produces the smallest amount.[1] Metabolic water accounts for a fairly insignificant portion of the water intake, being only 5–10% of the daily total intake.[1,5]

The most significant source of water intake is voluntary drinking. Numerous factors can affect an animal's voluntary oral intake including ambient temperature, type of diet being fed, level of exercise, physiologic state and health.[1,6] Water intake increases with an increase in ambient temperature and increasing exercise because of evaporative loss through the lungs due to panting to cool the body. The amount of food being fed can also affect water intake: as the calories increase so does the amount of waste products that the body needs to get rid of, increasing the amount of urine produced. If this increase in calories results in weight gain, there will also be an increased loss due to panting to help with thermoregulation.[1,6]

Voluntary Oral Intake

The type of diet being fed as well as the composition can dramatically affect voluntary oral intake of water. A study on dogs found that when the test animals were fed a diet containing 73% moisture, they obtained only 38% of their daily water needs from drinking water. When they were abruptly switched to a diet containing only 7% water, voluntary oral intake immediately increased to 95% or more of the total daily intake.[1] When cats are fed only canned food, their voluntary oral intake is likewise very low, in fact when cats are fed a food with very high water content; cats can maintain normal water balance with no additional drinking water.[6] This could be seen with liquid or gruel recovery diets as well as some commercial canned diets with a high amount of sauce.

Water requirements are related to maintaining appropriate water balance in the animal. Dogs and cats meet the majority of their water requirements through water included in food and voluntary oral intake. As a general guideline, the daily water requirement, expressed in ml/day for dogs and cats is roughly equivalent to the daily energy requirement (DER) in kcal/day. For dogs this is 1.6 × the resting energy requirement (RER), for cats 1.2 × RER.[2,5]

Domestic cats, descendents of desert animals, normally form more concentrated urine than do dogs. Actual water requirements for cats may be less than those for dogs. Water needs can best be met though access to clean, fresh water at all times.[2,5,6] Dogs will show thirst and drink voluntarily when body water decreases by 4% or less, cats do not voluntarily drink until they lose as much as 8% of their body water. In addition, cats that are fed dry food diets will typically consume less water per day than those fed canned food diets.[6]

If fresh, palatable, clean water is available and proper amounts of a balance diet are being fed, most dogs and cats are able to accurately self-regulate their water balance through voluntary oral intake.[1,2,6] Normally, thirst ensures that water intake meets or exceeds the body's requirements. Inadequate water intake can reduce appetite, reduces production on a number of levels including growth, lactation, reproduction and physical activity.[2]

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3 Carbohydrates

Introduction

Carbohydrates are the major energy-containing part of plants, making up between 60% and 90% of their dry-matter weight.[1] This class of nutrients is made up of the elements carbon, hydrogen and oxygen, and is classified as monosaccharides, disaccharides, oligosaccharides or polysaccharides and have the generally formula of $(CH_2O)_{n}$.[1,2] The hydrogen and oxygen are usually present in the same ratio as that found in water (H_2O) giving rise to the name carbohydrate or hydrated carbon.[3]

Carbohydrates are not an essential nutrient, but rather provide energy for the essential systems to do their jobs. In those species where fiber is not easily digested, the nondigestible carbohydrates found in fiber can be important for normal gastrointestinal function and health.[4]

As a nutrient, carbohydrates act primarily as an energy source, allowing amino acids and fatty acids to be used for building and maintenance of the body. When more carbohydrates are consumed than are needed by the body for energy, it may be converted into body fat and stored, or serve as starting materials for the metabolism of other compounds.[3,4]

Monosaccharides

Monosaccharides are also called simple sugars, and are the simplest form of carbohydrates, being composed of sugar units containing between 3 and 7 carbon atoms.[1,2] The chief monosaccharides are glucose, fructose (fruit sugar), and galactose (milk sugar).[1,2] Monosaccharides can combine with one another to form polymers, and these can be enormous molecules containing many thousands of individual monosaccharide units.[3]

Glucose is a moderately sweet simple sugar found in commercially prepared corn syrup and sweet fruits such as grapes and berries. It is also the chief end product of starch digestion and glycogen hydrolysis in the body. Glucose is the form of carbohydrate found circulating in the blood stream and is the primary form of carbohydrate used by the body's cells for energy.[1] Glucose is a 6 carbon ring in the shape of a hexagon, onto which the hydrogen and oxygen compounds are attached. This 6 carbon configuration gives the monosaccharides their other name of hexoses. Glucose is also known as dextrose (Figure 3.1).[5]

Fructose, commonly called fruit sugar, is a very sweet sugar found in honey, ripe fruits and some vegetables. It is also formed from the digestion or hydrolysis of the disaccharide sucrose.[1] Fructose is also a 6 carbon sugar but the structure differs from glucose in that 2 of the carbons are outside of the ring structure giving the molecule a pentagon shape (Figure 3.2).[5]

Galactose is not found in a free form in foods. However, it makes up 50% of the disaccharide lactose, which is found in the milk of all mammals.[1] It has the same number and kinds of atoms as glucose, with only the position of 1 OH group being slightly different (Figure 3.3).[5]

Disaccharides

Disaccharides are made up of two monosaccharide units linked together. Lactose, the sugar found in mammalian milk, contains a molecule of glucose and a molecule of galactose. This is the only carbohydrate of animal origin.[1,2] Lactose intolerance, as seen in some adult animals, is caused by a deficiency of the enzyme beta-galactosidase. This deficiency prevents the glucose and galactose molecules from separating, making this a nondigestible carbohydrate.[3] Sucrose, commonly called table sugar, contains a molecule of glucose linked to a molecule of fructose. This is the most common sugar

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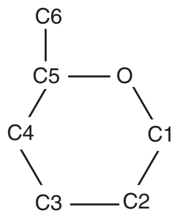

Figure 3.1 6 carbon hexagon glucose.

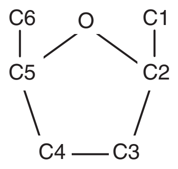

Figure 3.2 6 carbon pentagon fructose.

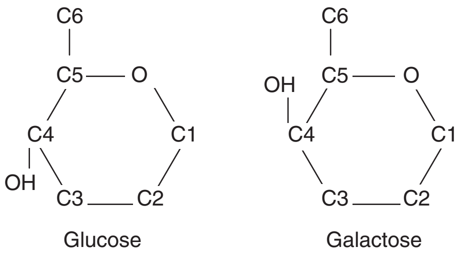

Figure 3.3 Glucose and galactose molecules.

found in plants.[1,2] Maltose is formed by linking two glucose molecules. This is produced whenever a starch molecule is broken down. This can be seen during digestion or during the fermentation process that yields alcohol. Maltose is a minor constitute of only a few foods.[5]

Oligosaccharides

Oligosaccharides are carbohydrates made up of 3–10 monosaccharide units making them polymers. These units may be the same or a mix of different monosaccharides. They are often difficult to digest and if found in quantity as with some plant materials, may be associated with gastrointestinal disturbances or flatulence.[2,3] Those that contain fructose are called fructooligosaccharides (FOS), but there are many other oligosaccharides found in plants.[2] FOS's in the diet improve intestinal flora, increase nitrogen digestion and retention, improve stool quality and reduce fecal odors.[1]

This class of carbohydrates is used commonly for their prebiotic effects. A prebiotic is defined as "nondigestible food ingredients that selectively stimulate a limited number of bacteria in the colon to improve the host health."[6] This healthful effect is seen because these fibers are resistant to the breakdown by enzymes in the host intestines, but are able to be broken down by certain gut bacteria helping to support the limited growth of these bacteria. Prebiotic fibers are thought to reduce fecal odor by modifying fecal concentration of certain digestive by-products and improve immune function by influencing gut-associated immune cells.[6]

Polysaccharides

Polysaccharides consist of many thousands of monosaccharide units. They are found widely in plants being used for cell wall material (cellulose) and energy storage (starch in the form of amyloid and amylopectin for plants and glycogen for animals).[1,3] Cereal grains such as corn, wheat, sorghum, barley and rice are the major ingredients in pet foods that provide starch.[1] Complex carbohydrates of plant origin other than starch are referred to as dietary fiber, or nonstarch polysaccharides. These include cellulose, hemicellulose, pectin, and the plant gums and mucilages.[1,3] Plant fibers differ from starches and glycogen in that their monosaccharide units have a different bonding configuration (beta bonds instead of alpha bonds). These bonds resist digestion by the gastrointestinal enzymes of most monogastrics, making their energy unavailable for absorption in the small intestine (Figure 3.4).[1]

Certain microbes found in the large intestine of dogs and cats are able to break down fiber to varying degrees, even though the animal themselves are unable to break down the fiber.[1] This bacterial fermentation produces short-chain fatty acids (SCFAs) and other end products. The SCFAs that are produced in the greatest numbers are acetate, propionate and butyrate.[1] These SCFAs are a significant energy source for the enterocytes of the small intestine and colonocytes of the large intestine.[1] Fiber in the diet also functions as an aid in the proper functioning of the gastrointestinal tract and as a dietary diluent that decreases the total energy density of the diet.[1]