Chapter 20

Feeding Young Adult Cats: Before Middle Age

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"In a cat's eyes, all things belong to cats."
English Proverb

INTRODUCTION

Cats generally reach adulthood between 10 to 12 months of age and, not uncommonly, live up to 20 years or more. The span of time from 12 months to death represents the total adult life of cats. After approximately six to eight years of age, however, there is an increasing prevalence of age-related diseases and onset of mild behavioral, physical and metabolic changes related to aging. In this chapter, the term "young adult" refers to non-reproducing cats one to six or seven years of age. The term "mature adult" (Chapter 21) refers to cats seven or eight years of age (beginning of middle age) and older.

The feeding goals for young adult pet cats include ensuring that the food fed and the feeding methods used will help maximize health, longevity and quality of life (disease prevention). Nutritional requirements for young adult cats tend to be the most broadly defined of any lifestage. This is partly because healthy young adult cats have the greatest ability to tolerate or compensate for metabolic and physiologic perturbations. Most regulated commercial foods provide all the necessary nutrients in amounts that avoid deficiencies (Chapters 5 and 6). To achieve the feeding goals described above, however, nutritional recommendations must go beyond simple prevention of nutrient deficiencies.

Nutritional recommendations for people who live in affluent societies include advice about nutrients, non-nutrient food ingredients and caloric intake guidelines for the prevention of important diseases such as obesity, diabetes mellitus, cardiovascular diseases, cancer, Alzheimer's disease and others. Although much remains to be learned in terms of the role of nutrients in feline disease prevention, optimal nutrient recommendations for young adult cats should also include recommendations based on our current understanding of nutrient and non-nutrient ingredients and feeding guidelines to help prevent important diseases of cats. **Table 20-1** lists relevant health issues for young adult cats that have a known nutritional association and which may be positively influenced by feeding for disease prevention.

PATIENT ASSESSMENT

The purpose of assessing the patient is to confirm the feeding goals, recognize risk factors for diseases (**Table 20-1**) and become acquainted with the associated key nutritional factors.

Table 20-1. Important diseases for adult cats that have nutritional associations.

Disease/health concern	Incidence/prevalence/mortality/pet owner concern	References*
Dental disease	Most prevalent disease; numerous associated health issues	Lund et al, 1999
Obesity	Approximate 30% prevalence; numerous associated health issues; neutered and indoor cats are at increased risk	Lund et al, 1999
FLUTD	0.85 to 1.5% per year incidence; 3% prevalence; most common reason cat owners seek veterinary care; kidney/urinary diseases are the most common cat owner concerns	Lawler et al, 1985; Lund et al, 1999; Willeberg, 1984; Westropp et al, 2005; Hostutler et al, 2005; Anon, Vet Economics, 2005; MAF, 2005
Kidney disease	Second leading cause of non-accidental death; kidney/urinary diseases are the most common cat owner concerns	Polzin et al, 2005; Ross et al, 2006; MAF, 1998, 2005
Cancer	Leading cause of non-accidental death	MAF, 1998
Arthritis	Incidence in general population unknown, but 22% in cats over one year of age in one study; overweight cats are three times likelier to have arthritis	Godfrey, 2005; Scarlett and Donoghue, 1998

Key: FLUTD = feline lower urinary tract disease.

*The references for **Table 20-1** can be found at www.markmorris.org.

Table 20-2. Factors to consider during nutritional assessment.

Signalment	Dietary history	Weight history	Physical examination	Diagnostic studies
Activity level	Adverse food reactions	Current weight	Body condition	Albumin
Age	Amount eaten	Ideal weight	Bone structure	Creatine kinase
Breed	Amount offered	Percent weight change	Coat condition	Hematocrit
Disease status	Appetite (interest)	Rate of change	Eyes	Hemoglobin
Environment	Brand fed	Usual weight	Hydration	Lymphocyte count
Gender	Feeding method		Muscle mass	Potassium
Reproductive status	Feeding schedule		Oral health	Prothrombin time
Use	Food aversions		Skin condition	Serum urea nitrogen
	Food storage		Strength/activity	Sodium
	Food form (e.g., dry, moist)			
	Nutritional losses			
	Previous foods			
	Supplements			
	Treats			
	Water availability			

(See below.) Assessment includes the complete evaluation of the patient and its environment (**Table 20-2**). Information from the signalment (age, breed, gender and neuter status), history and physical examination should be incorporated into nutritional recommendations.

History and Physical Examination

Key features from the signalment and history include the age, gender, activity level, weight history, environment (indoor vs. outdoor) and hunting history. Differences in these factors influence energy requirements and risks for certain diseases. The initial dietary history for healthy young adult cats should establish the brand, type and amount of foods fed regularly, including treats, table foods and nutritional supplements. The feeding method (including the amount fed) and appetite should be noted as well as any recent changes in body weight and stool quality. The extent of the evaluation depends on preliminary findings. A more detailed dietary history may be required if significant abnormalities are uncovered during the history or physical examination (e.g., anorexia, unexplained weight loss, poor diet, etc.). A detailed dietary history should evaluate the factors listed in **Table 20-2**.

If the dietary history is perceived to be incomplete, it may prove useful to have owners continue to feed and medicate their cat as usual and record amounts, types and brands of all foods and supplements given for one to two weeks. Such dietary records help better define nutrient intake, nutritional problems and errors in feeding management.

A thorough physical examination should include a systematic evaluation of each body system. Special attention should be given to the oral cavity, hydration status, skin and coat condition, body weight and body condition score (BCS) (Chapter 1). Careful observation is needed to assess lean body mass, muscle tone and body composition. Apparent loss of lean body mass may indicate recent weight loss, nutritional deficiency or disease, even in obese cats. For example, a study of 57 cats with neoplasia documented that fat mass was reduced in 60% of the patients and muscle mass was reduced in 91% (Baez et al, 2007). Any physical abnormalities should be correlated to the signalment and history to pinpoint issues that require further exploration. Important diseases or health issues that have either a direct or indirect nutritional association include the condi-

tions listed in **Table 20-1**. Some of these data come from epidemiologic studies. Unfortunately, this type of study can only show an association and cannot prove causality. Most of the time these conditions won't be present and the focus will be on their prevention.

Age

Aging in healthy cats is associated with metabolic changes that affect nutritional recommendations. Overlaid on these changes are the concerns of age-associated diseases. There are specific nutrient and/or ingredient considerations for foods intended for young adult cats, especially with respect to weight control, lower urinary tract health, dental health, cancer, arthritis and subclinical kidney disease (VPI Pet Insurance, 2007; Ross et al, 2006; Lund et al, 2005, 1999; Godfrey, 2005; Polzin et al, 2005) (**Table 20-1**).

Breed

Although different breeds of cats may have varying nutritional requirements, the variation is less pronounced than that of dog breeds. Certain feline breeds (e.g., Abyssinians) are noted for their lively, rambunctious disposition, whereas others (e.g., Persians or ragdolls) tend to be quiet and tranquil (Pugnetti, 1983). Thus, disposition affects energy requirements among breeds. In the future, it is possible that other nutritional variances may be elucidated with continued research into specific requirements of different cat breeds. Currently, some commercial foods are marketed for various cat breeds, but no published data exist to support specific nutrient requirements by breed.

Gender/Neuter Status

Small differences in body composition and energy intake between male and female adult cats have been reported (Jewell et al, 1996). The differences in energy intake appear to be due to gender-related differences in lean body mass (Jewell et al, 1996; Klausen et al, 1997). Risk factors for certain diseases vary by gender; however, these differences are less than the individual variation between cats and rarely warrant a gender-specific nutritional plan. Exceptions include reproducing (Chapter 22) and neutered cats.

Neutering increases the risk of overweight and obesity. Neutered cats are more likely to be overweight than intact cats of either sex (Lund et al, 2005; Scarlett et al, 1994; Root, 1995; Flynn et al, 1996). Chapter 27 reviews probable mechanisms.

Nutritional counseling should be provided to owners at the time that cats are brought to the veterinarian for neutering. Although most cats are apparently able to maintain a healthy BCS (2.5/5 to 3.5/5) after neutering, feeding controlled amounts of low-energy foods reduces the risk for obesity (Scarlett et al, 1994) and should be a routine postneutering recommendation (Laflamme, 2006). Kittens neutered at less than six months of age should be fed foods designed for growth until they reach skeletal maturity (between eight and 10 months of age). Many foods designed for growing kittens are energy dense; therefore, portion control and regular monitoring of body condition is recommended.

Environment/Activity Level

The daily energy requirement (DER) for cats may be markedly altered when ambient temperatures deviate significantly from their thermoneutral zone (NRC, 2006). Behavioral responses usually compensate for minor deviations in temperature with little effect on a cat's water or energy needs. Temperatures low enough to cause shivering (5 to 8°C [41 to 46.4°F]), however, can increase a cat's DER to 2 to 5 x resting energy requirement (RER) (Hensel and Banet, 1982; Precht et al, 1973).

Cats kept in hot environments (>38°C [>100.4°F]) may initially reduce food intake by 15 to 40%; however, as respiratory rate and grooming behavior increase and panting begins, the requirements for calories and water increase. Water is critically important to prevent heat stress in hot environments. Heat-stressed cats pant and wet their coats with saliva to maximize cooling via evaporative water loss. Dehydrated cats have a 50% reduction in ability to use evaporative water loss for thermoregulation (Doris and Baker, 1981). Significant elevations of core body temperature may occur with loss of evaporative cooling. Owners should be advised to monitor body condition and adjust feeding protocols as needed to meet these changing demands.

Cats thrive in ambient conditions of low humidity and warm temperatures (Pedersen, 1991). National Institutes of Health (NIH) and United States Department of Agriculture (USDA) guidelines for feline housing recommend humidity between 30 to 70%, room temperatures between 18 to 29°C (64.4 to 84.2°F) and 10 to 15 air exchanges/hour (ventilation) (Guide for the Care and Use of Laboratory Animals, 1996; APHIS, 1985). Practical options to the NIH and USDA recommendations are temperatures between 10 to 29.5°C (50 to 85°F) and humidity levels between 10 to 50% (Pedersen and Wastlhuber, 1991). Energy requirements change very little within these ranges.

Multi-cat environments refer to individual households with two or more cats; however, the definition also includes catteries, shelters and research institutions. Cats are solitary animals; therefore, multi-cat environments can lead to social and psychological stress, particularly if there is overcrowding (Hart and Pedersen, 1991). Households with more than five cats appear to be at increased risk for problems typically associated with multi-cat households including changes in food intake, behavioral problems and infectious diseases such as feline leukemia (Beaver, 1992).

The combination of chronic stress, overcrowding, poor ventilation and inadequate nutrition makes infectious diseases very difficult to control. Unsanitary litter boxes can result in elevated environmental ammonia concentrations that impair health (Pedersen and Wastlhuber, 1991). Stress levels in multi-cat environments may be reduced by modifying the environment to include safe outdoor areas (See Box 27-8 for cat-proof fencing.), multilevel indoor and outdoor resting areas, visual barriers and quiet hiding spots where cats can retreat from unwanted social interactions.

Stressed cats may exhibit partial or complete anorexia. Less

Table 20-3. Key nutritional factors for foods for young adult cats.

Factors	Recommended food levels*	
	Normal weight	Inactive/ obese prone
Energy density (kcal ME/g)	4.0-5.0	3.3-3.8
Energy density (kJ ME/g)	16.7-20.9	13.8-15.9
Fat (%)	10-30	9-17
Fiber (%)	<5	5-15
Protein (%)	30-45	30-45
Phosphorus (%)	0.5-0.8	0.5-0.8
Sodium (%)	0.2-0.6	0.2-0.6
Chloride (%)	1.5 x Na	1.5 x Na
Magnesium (%)	0.04-0.1	0.04-0.1
Average urinary pH	6.2-6.4	6.2-6.4
Antioxidants		
Vitamin E (IU/kg)	≥500	≥500
Vitamin C (mg/kg)	100-200	100-200
Selenium (mg/kg)	0.5-1.3	0.5-1.3
VOHC Seal of Acceptance	Plaque control	Plaque control

Key: ME = metabolizable energy, VOHC = Veterinary Oral Health Council (Chapter 47).
*Dry matter basis. Concentrations presume an energy density of 4.0 kcal/g. Levels should be corrected for foods with higher energy densities. Adjustment is unnecessary for foods with lower energy densities.

commonly, overeating and resultant weight gains are reported consequences of stress (Beaver, 1992). Short-term bouts of anorexia (i.e., one to three days) have little overall effect on otherwise healthy young adult cats, although metabolic changes are evident by the third day of fasting (Biourge et al, 1994; Pazak, 1997). A prolonged reduction in food intake in healthy cats or short-term food deprivation in sick cats can lead to undernourishment and increased risk of hepatic lipidosis.

Challenges associated with feeding cats in a multi-cat environment include difficulty in monitoring food and water intake, ensuring all cats have unfettered access to food and providing specialized foods to individual cats. Obtaining accurate dietary histories and achieving good dietary compliance for cats from multi-cat households can be challenging for veterinarians and owners. However, modification of feeding and management practices can alleviate many problems.

Activity level is one of the key determinants of DER. By nature, cats do not participate in heavy work or endurance-type activities, thus the variation in energy requirement between active and sedentary cats is small compared with that of dogs. Nevertheless, twofold differences in energy requirement have been observed between active and sedentary cats (Earle and Smith, 1991; Finke and Lutschaunig, 1995).

Most, but not all cats confined indoors are minimally active. Although most indoor cats have "run of the house," some indoor housing includes confinement to small areas (e.g., caging in hospitals, kennels, animal shelters or catteries). Activity is markedly limited under these circumstances as reflected by lower energy requirements. Thus, sedentary, inactive and caged cats often have DERs very near or even below the average RER (0.8 to 1.2 x RER) or 40 to 60 kcal/kg body weight/day (167 to 251 kJ/kg body weight/day) (Flynn et al, 1996; Earle and Smith, 1991) and may be as low as 24 kcal/kg body weight/day (100 kJ/kg body weight/day) (Hoenig et al, 2007). Therefore, indoor cats have an increased prevalence of overweight and obesity. They also are more likely to have hairballs and calcium oxalate urolithiasis (Lund et al, 1999).

Cats housed outdoors have less protection from the environment and temperature fluctuations and are presumably more active than indoor cats. As a result, the optimal food and feeding methods may differ for outdoor cats. Cats allowed unlimited activity may have energy needs 10 to 15% above average (Miller and Allison, 1958). Very active cats may expend markedly more energy than other cats. For example, the energy requirement of Abyssinian cats has been reported as 79 kcal/kg body weight/day (330 kJ/kg body weight/day), or 1.6 x RER, which is 30% greater than that required by the average adult housecat (Finke and Lutschaunig, 1995).

Both food selection (i.e., energy content) and amount fed should match activity levels and are important to prevent overweight or obesity.

Laboratory and Other Clinical Information

Laboratory analyses provide limited insight into nutritional status but can be very helpful in excluding disease processes. Special diagnostic tests (e.g., plasma aminograms, clotting profiles, urinary clearance ratios and hormone assays) may help assess specific disease processes or specific deficiencies such as Vitamin K deficiency. Fecal analysis for intestinal parasites is routinely performed for healthy young adult cats, although malnutrition from intestinal parasitism occurs rarely.

Key Nutritional Factors

Table 20-3 summarizes key nutritional factors for young adult cats. The sections that follow review key nutritional factors in more detail.

Water

Although water is the most important nutrient for cats, a definitive water requirement has been not established because: 1) cats adjust water intake to the dry matter (DM) content of the food and 2) the water requirement of cats varies with physiologic and environmental conditions. Generally, cats need 1 ml water/kcal metabolizable energy (ME) requirement. In practice, adult cats should have unlimited access to fresh water. Although cats conserve total body water by forming highly concentrated urine, such concentrated urine is undesirable in the prevention and treatment of feline lower urinary tract disease (FLUTD). Increased water intake is useful for managing urolithiasis by reducing the urinary concentration of urolith-forming minerals. To date, of all treatments evaluated, feeding moist food (>60% of calories) was the only one associated with a statistically significant decrease in recurrence of clinical signs in cats with feline idiopathic cystitis (FIC). Currently, FIC is the most common cause of FLUTD (Lekcharoensuk et al, 2001; Gerber et al, 2005) (Chapter 46). Feeding moist foods (vs. dry foods) increases water intake and urine volume in most cats (Gaskell, 1989), but unlike dogs, cats do not fully compensate for differences in food moisture content by altering free

water intake. When allowed free access to water, the total water intake of cats eating dry food is only half that of cats eating moist food (Burger et al, 1980; Seefeldt and Chapman, 1979).

Energy

Determination of DER for a population of cats results in a bell-shaped curve (Figure 1-5). Individual cats may have energy requirements 50% or more above or below the average requirement. This range is not surprising considering that the DER of a particular cat is influenced by differences in lean body mass, gender, neuter status, environmental temperature, genetic traits, housing and activity level. Despite the relative uniformity of size within the domestic cat population, there are size-associated differences in energy requirements. Generally, smaller cats consume more calories per kg body weight than larger cats (Earle and Smith, 1991; Finke and Lutschaunig, 1995). Thus, it is important to remember that calculated energy requirements are only estimates for individual cats. The true caloric requirement for an individual cat is what is needed to maintain an ideal body condition (BCS 2.5/5 to 3.5/5) and stable weight.

Data in the literature indicate that, under a variety of conditions, the DER of young adult cats ranges widely from 31 to 100 kcal/kg body weight/day (129 to 418 kJ/kg body weight/day) (NRC, 2006). However, the DER of average young adult pet cats is more likely to range between 40 to 75 kcal/kg body weight/day (167 to 314 kJ/kg body weight/day) or approximately 1.0 to 1.6 x RER, where RER in kcal = $70(BW_{kg})^{0.75}$ or RER in kJ = $293(BW_{kg})^{0.75}$. A simple linear formula can also be used to estimate RER for cats weighing more than 2 kg: RER is approximately 70 kcal + 30 kcal x BW_{kg} (293 kJ + 125.5 kJ x BW_{kg}) (Lewis et al, 1987). Table 5-2 lists RER values for body weights greater than 1.5 kg. Caloric requirements for active neutered cats are calculated using the lower end of the range (1.2 x RER), whereas the upper end of the range (1.4 to 1.6 x RER) is used for active and sexually intact cats. Most housecats are neutered and are minimally active (NRC, 2006) and, therefore, are more prone to overweight and obesity. Thus, it is prudent to use 1.0 x RER or 39 to 66 kcal/kg body weight/day [163 to 276 kJ/kg body weight/day]) (Earle and Smith, 1991) as a starting point for most housecats and increasing their energy intake, if necessary, to maintain ideal body condition. This same starting point, 1.0 x RER, is recommended when calculating the energy needed for maintenance at ideal body weight for an obese cat. Obese cats may require as few as 0.8 x RER or 44 to 54 kcal/kg ideal body weight (184 to 226 kJ/kg ideal body weight/day) to achieve an average weight loss of 1% of body weight per week (LaFlamme and Jackson, 1995) (Chapter 27). After obese cats have returned to their original lean weight, as few as 24 kcal/kg body weight (100 kJ/kg body weight) may be needed for maintenance (Hoenig et al, 2007). Controlling energy intake is important for managing and preventing obesity. Approximately 35% of adult cats seen by veterinarians in the United States are overweight or obese (Lund et al, 2005). The prevalence is highest in seven- to eight-year-old cats; nearly 50% of this age group are overweight or obese (BCS 4/5 or 5/5) (Scarlett et al, 1994; Lund et al, 1999). Obesity increases the risk of death in young to middle-aged cats 2.7 times above that of lean cats (Scarlett and Donoghue, 1997); thus, preventing obesity has important consequences for long-term health (Chapter 27). Risk factors associated with obesity include: 1) middle age, 2) male gender, 3) neutering, 4) low activity/indoor/apartment dwelling and 4) feeding high-fat, high-calorie foods free choice (Lund et al, 2005; Scarlett et al, 1994). Food digestibility and energy density may influence the risk for FLUTD. Energy-dense foods reduce overall DM intake. Lower DM intake decreases stool volume, which subsequently reduces fecal water loss. Both features reduce total magnesium intake and increase urine volume. Food intake should be controlled when feeding high-calorie foods. Excessive intake of calorically-dense foods coupled with free-choice feeding can induce obesity, also a risk factor for urolithiasis.

The recommended range of energy density in foods for inactive/obese-prone young adult cats is 3.3 to 3.8 kcal/g (13.8 to 15.9 kJ/g) (DM). The recommended range for foods for normal weight young adult cats is 4.0 to 5.0 kcal/g (16.7 to 20.9 kJ/g).

Fat

Cats use dietary fat for energy, as a source of essential fatty acids and to facilitate absorption of fat-soluble vitamins. A minimum requirement for fat has not been established for cats although foods containing less than 5% DM fat have been fed successfully to hyperlipidemic cats. The minimum recommended DM allowance of fat in adult cat foods is 9% (NRC, 2006). Fat levels above 9.0% DM are recommended for most cats. Fat enhances the palatability of food; cats prefer foods with levels near 25% DM fat vs. foods containing 10 or 50% DM fat (Kane et al, 1981). High-fat foods have been associated with an increased incidence of obesity in cats (Scarlett et al, 1994). Most cats do well when fed foods containing 10 to 30% DM fat. Cats prone to obesity, however, should be fed foods with lower levels of dietary fat (9 to 17% DM).

Current AAFCO allowances for the essential fatty acids, linoleic acid and arachidonic acid (AA), are appropriate for adult cats (2007). Therefore, commercial foods that have AAFCO label statements acknowledging that a food is appropriate for adult maintenance should provide adequate amounts of linoleic acid and AA. **Box 20-1** discusses the role of omega-3 (n-3) fatty acids in foods for adult cats.

Fiber

Although cats do not require dietary fiber, small amounts in commercial foods enhance stool quality and promote normal gastrointestinal (GI) function. The natural foods of cats typically contain less than 1% dietary fiber although much higher levels are well tolerated (Vondruska, 1987; Dimski and Buffington, 1991). Fiber concentrations less than 5% DM are recommended for normal young adult cats. Because increased levels of dietary fiber reduce energy density and can induce satiety, obese-prone cats may benefit from foods that contain from 5 to 15% DM crude fiber (Chapter 27). Fiber supplementation may also benefit cats that are prone to develop hairballs.

Box 20-1. The Emerging Role of Omega-3 Fatty Acids in Feline Nutrition.

Fatty acids of the omega-3 (n-3) series (linolenic acid, 18:3n-3) are probably required in the food of all animals. However, studies establishing requirements for omega-3 fatty acids in adult cats have not been performed. Cats would normally consume omega-3 fatty acids when eating the neural tissues of their prey. The role of omega-3 fatty acids in companion animal medicine has focused mostly on their pharmacologic-like properties and ability to modulate the immune response and inflammation associated with dermatitis, arthritis, cancer and obesity. Although these effects may benefit some animals, untoward effects are possible. In one study, cats developed increased bleeding times and decreased platelet function when fed foods supplemented with high levels of omega-3 fatty acids. However, no adverse effects were found in similar studies. The current understanding of omega-3 fatty acid metabolism in cats is limited; thus, aggressive omega-3 fatty acid supplementation should be used judiciously. The recommended dry matter allowance for omega-3 fatty acids in foods for healthy adult cats is 0.01% (total eicosapentaenoic and docosahexaenoic acids).

The Bibliography for **Box 20-1** can be found at www.markmorris.org.

Clinical evidence and field trials have demonstrated a reduction in the frequency of hairball vomiting with fiber supplementation (Hoffman and Tetrick, 2003; Dann et al, 2004).

Protein

The protein requirements of adult cats have generally been established using experimental foods containing essential amino acids at or above the minimum requirement for growth. From these studies, the National Research Council (2006) suggested the minimum protein requirement for adult cats is 16% and the minimum recommended allowance is 20% (DM, food energy content of 4 kcal/g [16.7 kJ/g]). Commercial foods prepared from natural ingredients and processed may have lower protein digestibility than the experimental foods used to establish these minimums. To provide a margin of safety and account for differences in protein quality, the Association of American Feed Control Officials (AAFCO) has suggested a minimum dietary protein level of 26% DM for adult maintenance (2007). Protein and amino acid requirements vary with the energy content of a food. The minimum protein allowance suggested by AAFCO is based on foods containing 4.0 kcal/g (16.7 kJ/g) DM and should be corrected for foods with energy densities greater than 4.5 kcal/g (18.8 kJ/g). (See Chapter 1 for the correction method.)

Meeting the minimum protein needs of cats is critical because they have minimal capacity to adapt to low levels of dietary protein. Protein in excess of the requirement is rapidly catabolized and used to provide energy and maintain blood glucose levels. Any excess energy will be stored as fat; therefore, there appears to be little benefit to feeding large excesses of protein to cats. Furthermore, dietary protein excess may increase proteinuria and the progression of subclinical renal disease (Adams et al, 1994; Brown et al, 1997; Ross, 1992). Similar to findings in people and dogs, the role of protein in the progression of renal disease in cats is controversial. There is, however, strong (Grade 1, [See Chapter 2]) evidence to support the recommendation to feed a veterinary therapeutic food designed for kidney disease to cats with serum creatinine concentrations in excess of 2 mg/dl (stage mid-II through IV chronic kidney disease [CKD]) (Polzin et al, 2008; Ross et al, 2006; Elliot et al, 2000). The point being that, among other things, these foods are typically lower in protein.

Although cats can be fed vegetable-based foods, most protein in the food should be derived from animal tissues. The amino acid profile of most animal tissues better reflects the nutritional requirements of cats. Moist products should list animal-based ingredients within the first two ingredients (excluding water), whereas dry products should list animal-based ingredients in the first three ingredients. The recommended DM protein allowance for both normal weight and inactive/obese-prone young adult cats is 30 to 45%. Current AAFCO allowances for taurine are appropriate for adult cats (2007). Foods that have AAFCO label statements acknowledging that a food is appropriate for adult maintenance should provide adequate amounts. Therefore, taurine, although a very important nutrient for cats, is considered an "other" nutritional factor and is discussed under that heading below.

Phosphorus

Dietary phosphorus levels of 0.5 to 0.8% DM are recommended for young adult cats. The minimum recommended allowance for phosphorus in foods for adult cats is 0.26% DM (NRC, 2006). Deficiencies of phosphorus are rare in cats fed commercial foods. Phosphorus excess appears to be of greater concern. Dietary phosphorus is a key nutrient in the management of two common feline diseases: struvite-mediated FLUTD and CKD. The mineral constituents of struvite are magnesium, ammonium and phosphate. Although the primary objectives for preventing FLUTD due to struvite precipitates are to increase urine volume, reduce urinary pH and, to a lesser extent, restrict dietary magnesium, limiting dietary phosphorus may be beneficial (Chapter 46). The kidneys excrete excess dietary phosphorus. The risk of clinically apparent struvite crystalluria and urolithiasis is highest in cats from two to five years of age. Controlling phosphorus intake in combination with appropriate reductions in dietary magnesium concentrations and urinary pH, and increasing water intake, if possible, should help reduce the risk of struvite-associated FLUTD in cats of this age group.

Excess dietary phosphorus is not considered a cause of renal damage but may accelerate the progression of renal disease towards failure and death (Ross et al, 1982). High levels of dietary phosphorus (1.2 to 1.8% DM) reduce creatinine clearance values and possibly reduce renal function in young, healthy cats (Pastoor et al, 1995). Excess phosphorus should be avoided in the early nutritional management of renal disease in cats

to decrease the renal excretory workload and avoid phosphorus retention (Chapter 37). The evidence for recommending a phosphorus-restricted food for cats with CKD, however, is weak. Studies in dogs on the specific effect of phosphorus intake on clinical outcome in induced CKD have shown that dietary phosphorus restriction slows progression and improves survival. Similar studies have not been reported in cats. Phosphorus restriction has been shown, however, to reduce renal mineralization in cats with induced CKD (Polzin et al, 2008). Dietary phosphorus may be reduced as low as 0.3% DM in cats with overt renal disease.

Sodium and Chloride

The minimum sodium requirement for adult cats is 0.065% DM; the minimum recommended allowance is not much greater (0.068%) (NRC, 2006). The average sodium content of prey is relatively low (i.e., approximately 0.25% DM in whole rat carcasses) (Vondruska, 1987). Sodium concentrations from 0.2 to 0.6% DM satisfy the needs of healthy young adult cats without providing excessive levels. In people, limiting sodium intake to levels that meet the requirement without significant excess reduces the risk of hypertension and is considered important to long-term health (Stamler, 1995). This same nutritional practice has been advocated for cats. In a study involving feline hypertension, nearly 50% of hypertensive cats fed a low-sodium food had a significant reduction in blood pressure (Littman, 1994). This response is similar to that seen in people in that not all people are "salt-sensitive." In cats, hypertension is commonly associated with diseases such as renal failure, hyperthyroidism and cardiac disease (Cowgill and Kallet, 1986; Kobayashi et al, 1990). High blood pressure has been associated with significant end-organ damage in hypertensive cats. Blindness, retinal hemorrhage, stroke, cardiac dilatation and murmurs and renal damage were common findings among cats studied (Littman, 1994). Thus, as it relates to cats with hypertension, avoiding excess sodium chloride seems prudent because: 1) hypertension has significant deleterious health effects, 2) diagnostics to detect hypertension are not commonly performed and 3) the medical conditions associated with hypertension are common in cats.

Dietary sodium chloride supplementation is used in commercial cat foods to reduce the occurrence of FLUTD by increasing water intake. Sodium chloride added at concentrations of 4% DM or greater markedly enhanced water intake and increased urine volume (Burger et al, 1980). Short-term studies have shown adult cats tolerate a wide range of dietary sodium intakes (i.e., 0.04 to 2.0%) (MacDonald et al, 1984; NRC, 2006; Burger et al, 1980). A longer-term study (three months) evaluated the safety of salt supplementation (0.35% vs. 1.1% sodium and 0.7% vs. 2.06% chloride, DM) in normal, obese, aged cats and cats with pre-existing CKD. In this study, none of the cats were hypertensive at the beginning of the study and blood pressure was unaffected when they were fed the high-salt food. Cats with pre-existing kidney disease fed the salt-supplemented food, however, experienced increased serum urea nitrogen, phosphorus and creatinine concentrations, suggesting progressive deterioration of renal function. Because apparently healthy cats can have a significant degree of undetected renal dysfunction when screened routinely with biochemistry profiles, it would follow that the risks associated with feeding high-sodium chloride foods to reduce the occurrence of FLUTD outweigh the benefits (Kirk et al, 2006).

Furthermore, in addition to possibly exacerbating hypertensive disorders and contributing to the progression of pre-existing renal disease, high dietary sodium levels reportedly enhance urinary calcium excretion (Osborne et al, 1992), particularly in cats with impaired renal function (Kirk et al, 2006). This may explain the common occurrence of calcium oxalate uroliths in cats with kidney disease. Thus, sodium excess, particularly in the form of sodium chloride, should be avoided in adult cats.

Chloride has been implicated more recently as a major determinant in the development of hypertension in salt-sensitive people. The interaction of sodium with chloride appears to cause the greatest increase in blood pressure compared with sodium combined with other anions (Kurtz et al, 1987) (Chapter 36). The minimum chloride requirement has been determined for kittens but not adult cats. The NRC recommended allowance for adult cats (0.096% DM) is based on kitten data (2006). Typically, dietary chloride recommendations are 1.5 times dietary sodium recommendations.

Magnesium

The minimum magnesium requirement for adult cats is 4.1 mg/100 kcal (9.7 mg/MJ or 0.016% DM) (Pastoor, 1993). The NRC minimum requirement is 0.02% (DM, 4 kcal/g) and the minimum recommended allowance is 0.04% (DM, 4 kcal ME/g [16.7 kJ/g]) (2006). Excessive magnesium restriction may be associated with the prevalence of calcium oxalate uroliths in cats (Thumchai et al, 1996). Therefore, excessive restriction of magnesium (i.e., <0.04% DM) is not recommended. For practical purposes, a magnesium content between 0.04 to 0.1% DM is recommended in foods for young adult cats (**Table 20-3**). These levels are similar to those found in the natural food of cats. Magnesium concentrations of 0.08% DM were measured in whole rat carcasses (Vondruska, 1987). Magnesium is an essential nutrient, but is also a major constituent of struvite crystals. To reduce the risk of FLUTD due to struvite, dietary magnesium concentrations should be less than 20 mg/100 kcal of food (<0.10% DM) and the food should be formulated to produce the appropriate urinary pH (Chapter 46).

Urinary pH

Food ingredients and feeding methods contribute to the urinary pH produced by cats. The normal urinary pH of cats eating mice and rats is 6.2 to 6.4 (Hand et al, 1988). Thus, 6.2 to 6.4 is considered the "normal acidic urinary pH" of cats fed a wild-type food and the recommended range for healthy young adult cats.

The risk of struvite precipitation and FLUTD is greatly reduced at urinary pH values less than 6.5 (Buffington, 1991). Many cats develop metabolic acidosis when the urinary pH

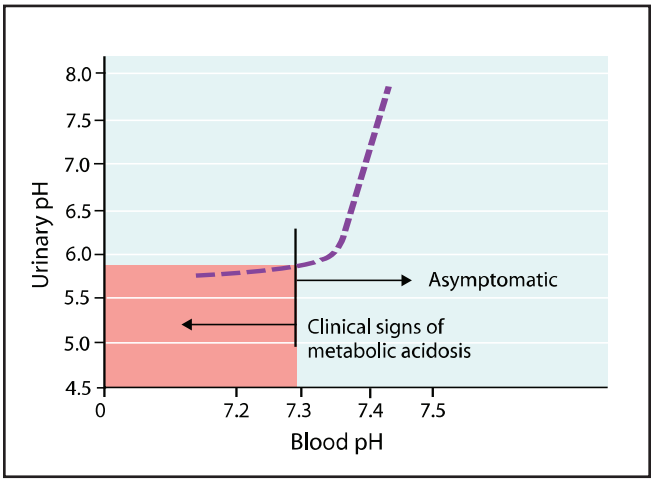

Figure 20-1. Correlation between urinary and blood pH in cats. Many cats develop metabolic acidosis when urinary pH is consistently less than 6.0. (Adapted from Allen TA, Bartges JW, Cowgill LD, et al. Colloquium on Urology. Feline Practice 1997; 25: 32.)

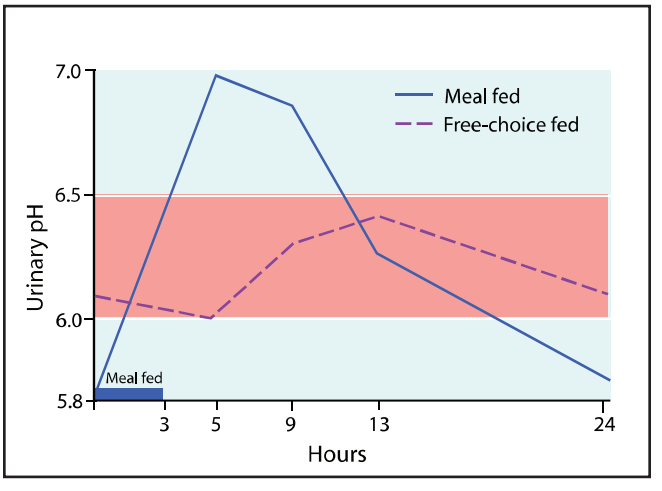

Figure 20-2. Effect of feeding method on urinary pH in cats. Note the significant increase in urinary pH after a single meal (meal fed). This effect is termed "postprandial alkaline tide." Food provided free choice modulates urinary pH by dampening the postprandial alkaline tide that occurs three to six hours following ingestion of larger meals. The shaded area represents the acceptable urinary pH range for adult cats. (Adapted from Taton GF, Hamar D, Lewis LD. Evaluation of ammonium chloride as a urinary acidifier in the cat. Journal of the American Veterinary Medical Association 1984; 184: 433-436.)

is less than 6.0 (**Figure 20-1**) (Dow et al, 1990). Metabolic acidosis may promote bone demineralization, urinary calcium and potassium loss (Ching et al, 1989, 1990) and increase the risk of calcium oxalate urolithiasis (Thumchai et al, 1996; Kirk et al, 1995). Free-choice food intake modulates urinary pH by dampening the postprandial alkaline tide that occurs three to six hours following larger meals. Meal feeding promotes a much greater alkaline tide and higher average urinary pH (**Figure 20-2**). Commercial foods commonly balance dietary cations and anions to achieve an appropriate urinary pH. Animal proteins, corn gluten meal, certain mineral salts, methionine and phosphoric acid are common ingredients that reduce urinary pH when added to feline foods (Hand et al, 1988).

Foods that produce average urinary pH values of 6.2 to 6.4 when fed free choice reduce the risk of struvite-mediated FLUTD, avoid metabolic acidosis and reduce the risk of calcium oxalate urolithiasis in most young adult cats.

Antioxidants

The body synthesizes many antioxidants (e.g., superoxide dismutase) but relies on food for others (e.g., vitamin E). Common food-source antioxidants include vitamins E and C, β-carotene and other carotenoids, selenium and thiols. Fruits and vegetables are good sources of flavonoids, polyphenols and anthocyanidins. The following discussion will focus on vitamins E and C and selenium as antioxidant key nutritional factors in foods for young adult cats because: 1) they are biologically important, 2) they act synergistically (e.g., vitamin C and selenium-containing glutathione peroxidase regenerate vitamin E after it has reacted with a free radical), 3) of safety concerns and 4) information regarding inclusion levels in pet foods is usually readily available.

The consequences of prolonged oxidative stress (i.e., free radical damage) to cell membranes, proteins and DNA contribute to and/or exacerbate a wide variety of degenerative diseases. A partial list includes cancer, diabetes mellitus, kidney and urinary tract disease, heart disease, liver disease, inflammatory bowel disease and cognitive dysfunction (Ames et al, 1993; Kesavulu et al, 2000; Ha and Le, 2000; Thamilselvan et al, 2000; Freeman et al, 1999; Cheng et al, 1999; Center, 1999; Knight, 1999).

The consequences of free radical damage to cells and tissues have also been associated with the effects of aging. Although aging is a complex, multifactorial process, one possible explanation for many of the degenerative changes is the free radical theory of aging (Harman, 1956). This theory proposes that free radicals produce cell damage and that age-dependent pathologic alterations may, at least in part, be the cumulative result of these changes. Examples of research supporting this theory include invertebrate studies that found the normal endogenous production of reactive oxygen species limits lifespan (Melov et al, 2000) and studies involving superoxide dismutase-deficient mice that died within the first week of life (Melov, 2000).

Many phenomena initiate free radical formation within the body. Although such things as environmental pollutants and radiation are direct and indirect sources of free radicals, the primary source is endogenous from normal oxidative metabolism in mitochondria. The body defends itself against the effects of free radicals through a complex of protective antioxidant compounds. These compounds protect biomolecules by scavenging free radical compounds, minimizing free radical production and binding metal ions that might increase the reactivity of poorly reactive compounds. Besides these classic mechanisms, many antioxidants exhibit second messenger regulatory function, cell cycle signaling and control of gene expression (Chapter 7 covers antioxidants in detail).

VITAMIN E

Vitamin E (α-tocopherol) is the main lipid-soluble antioxidant present in plasma, erythrocytes and tissues (NRC, 2006). It is transported in plasma proteins and partitions into membranes and fat storage sites where it is one of the most effective antioxidants for protecting polyunsaturated fatty acids (PUFAs) from oxidation. It functions as a chain-breaking antioxidant that prevents propagation of free radical damage in biologic membranes. Vitamin E inhibits lipid peroxidation by scavenging lipid peroxyl radicals much faster than these radicals can react with adjacent fatty acids or with membrane proteins (Gutteridge and Halliwell, 1994).

Research indicates that a level of vitamin E higher than the requirement confers specific biologic benefits. The minimum recommended allowance of vitamin E in foods (DM) for adult cats is 38 mg/kg (NRC, 2006). The concentration of vitamin E in a food necessary to protect against lipid peroxidation of PUFAs in cell membranes depends on the concentration of PUFAs in the food. Foods high in PUFAs, such as foods containing fish oils, may require four or more times increased vitamin E concentration to prevent steatitis (NRC, 2006). Besides helping to prevent chronic diseases associated with oxidative stress, increasing dietary intake of vitamin E to 272 and 552 IU/kg of food (DM) in aged cats improved immune function (Hayes et al, 1969; Hall et al, 2003; Meydani et al, 1998). Furthermore, increased vitamin E intake is also directly related to increased vitamin E content of skin in cats (and dogs), which may help prevent certain skin diseases (Jewell et al, 2002). No safe upper limit has been established for cats. One antioxidant biomarker study suggested that cat foods should contain 600 IU/kg DM for improved antioxidant function (Jewell et al, 2000). Based on these data, foods for young adult cats should contain at least 500 IU/kg DM.

VITAMIN C

Vitamin C (ascorbic acid) is the most powerful reducing agent available to cells. As such, it is important for regenerating oxidized vitamin E. Ascorbic acid also: 1) regenerates glutathione and flavonoids, 2) quenches free radicals intra- and extracellularly, 3) protects against free radical-mediated protein inactivation associated with oxidative bursts of neutrophils, 4) maintains transition metals in reduced form and 5) may quench free radical intermediates of carcinogen metabolism (Chapter 7). Dogs and cats can synthesize required amounts of vitamin C (Innes, 1931; Naismith, 1958) and, while not shown in cats, dogs can rapidly absorb supplemental vitamin C (Wang et al, 2001). In vitro studies, however, indicated that cats (and dogs) have from one-fourth to one-tenth the ability to synthesize vitamin C as other mammals (Chatterjee et al, 1975). Whether or not this finding translates to a reduced ability in vivo is unknown.

Excessive vitamin C supplementation can be a problem. In people, high vitamin C intake increased urine oxalate excretion and risk for urolithiasis (Massey et al, 2005). Vitamin C supplementation resulted in a small progressive reduction of urinary pH in cats and 1,000 mg vitamin C per day induced diarrhea in some cats (Kienzle and Maiwald, 1998). Moderate supplementation of foods with vitamin C (193 mg/kg of food, DM) did not appear to increase the risk of urinary oxalate production in healthy adult cats (Yu and Gross, 2005).

Foods for young adult cats should contain 100 to 200 mg vitamin C/kg DM. This is based on the recommendation for vitamin E and data that show that vitamin C regenerates vitamin E at about a 1:1 molar ratio (Barclay et al, 1985). Also, this range is not a risk for urinary oxalate production (Yu and Gross, 2005).

SELENIUM

Glutathione peroxidase is a selenium-containing antioxidant enzyme that defends tissues against oxidative stress by catalyzing the reduction of H_2O_2 and organic hydroperoxides and by regenerating vitamin E. The minimum recommended allowance for selenium in foods for adult cats is 0.3 mg/kg DM (NRC, 2006). The minimum requirement for selenium in foods for cats is 0.13 mg/kg DM (Wedekind et al, 2003, 2003a). Animal studies and clinical intervention trials in people have shown selenium to be anticarcinogenic at much higher levels (five to 10 times) than the recommended allowances for people or the minimum requirements for animals (Combs, 2001; Neve, 2002). Several mechanisms have been proposed for this effect, including enhanced antioxidant activity via glutathione peroxidase (Neve, 2002). Therefore, for increased antioxidant benefits, the recommended range of selenium for cat foods is 0.5 to 1.3 mg/kg DM. There are no data on which to base a safe upper limit of selenium for cats, but for regulatory purposes, a maximum of 2 mg/kg DM has been set for dog foods in the United States (AAFCO, 2007). In the absence of cat data, the safe upper limit for dogs may provide a working guideline for cat foods.

Texture

Food texture influences oral health (Chapter 47). Dry foods specifically designed to promote oral health can help reduce accumulation of dental plaque and calculus and the severity of gingivitis. If the labels of such foods carry the Veterinary Oral Health Council (VOHC) Seal of Acceptance, they have been successfully tested, according to specific protocols, to clinically reduce plaque (Chapter 47).

Generally, dry foods result in less plaque accumulation in cats than do moist and semi-moist foods (Logan, 1996; Studer and Stapley, 1973). This effect appears not to be clinically important because most cats eat dry foods and dental disease is the most prevalent disease of adult cats (Lund et al, 1999). Food texture also influences the palatability and acceptability of foods for cats. A sudden change in texture may result in reduced food intake or food refusal. Cats accustomed to eating only dry foods may refuse moist foods and vice versa.

Other Nutritional Factors

In addition to the key nutritional factors for commercial foods for young adult cats discussed above, the following nutritional

Table 20-4. Selected commercial foods for young adult cats (normal and inactive/obese prone) compared to recommended levels of key nutritional factors.*

Dry foods	Energy density (kcal/cup)**	Energy density (kcal ME/g)	Fat (%)	Fiber (%)	Protein (%)	P (%)	Na (%)
Recommended levels (normal body condition)	**–**	**4.0-5.0**	**10-30**	**<5**	**30-45**	**0.5-0.8**	**0.2-0.6**
Hill's Science Diet Adult Hairball Control Feline	339	4.1	22.1	8.1	34	0.69	0.31
Hill's Science Diet Adult Optimal Care Ocean Fish & Rice Recipe	488	4.3	22.7	1.2	34	0.72	0.27
Hill's Science Diet Adult Oral Care Feline	337	4.2	22.0	7.5	34.1	0.75	0.37
Hill's Science Diet Nature's Best Ocean Fish & Brown Rice Dinner Adult	470	4.3	20.6	1.2	33.9	0.74	0.33
Iams Eukanuba Adult Chicken Formula	436	4.4	23.6	1.4	38.5	0.99	0.55
Iams Original with Chicken Cat Food	368	4.1	17.3	1.8	37.3	1.06	0.50
Nutro Max Cat Adult Roasted Chicken Flavor	421	4.2	20.9	2.2	36.3	1.1	0.44
Nutro Natural Choice Complete Care Adult	452	4.3	22.0	2.7	37.4	1.1	0.44
Purina ONE Natural Blends Chicken & Oat Meal Formula	450	4.4	17.9	1.9	37.9	1.44	0.60
Purina ONE Total Nutrition Salmon & Tuna Flavor	430	4.4	15.7	1.8	37.9	1.29	0.52
Purina Pro Plan Indoor Care Turkey & Rice Formula	433	4.2	15.2	5.3	46.0	1.28	0.48
Royal Canin Adult Fit 32	351	4.2	16.5	8.1	35.2	1.12	0.66
Moist foods	**Energy density (kcal/can)****	**Energy density (kcal ME/g)**	**Fat (%)**	**Fiber (%)**	**Protein (%)**	**P (%)**	**Na (%)**
Recommended levels (normal body condition)	**–**	**4.0-5.0**	**10-30**	**<5**	**30-45**	**0.5-0.8**	**0.2-0.6**
Hill's Science Diet Adult Hairball Control Savory Chicken Entrée Minced	91/3 oz. 168/5.5 oz.	4.4	23.3	9.8	35.9	0.65	0.49
Hill's Science Diet Adult Indoor Cat Savory Chicken Entrée Minced	91/3 oz. 168/5.5 oz.	4.4	23.3	9.8	35.5	0.65	0.49
Hill's Science Diet Adult Optimal Care Gourmet Beef Entrée Minced	93/3 oz. 171/5.5 oz.	4.4	22	4.8	37.6	0.72	0.32
Nutro MAX Cat Gourmet Classics Adult Chicken & Liver Formula	169/5.5 oz.	4.6	29.8	2.1	42.6	1.28	0.64
Nutro Natural Choice Complete Care Adult Chicken & Liver Entrée	167/5.5 oz.	4.7	30.4	1.7	47.8	1.30	0.65
Purina Pro Plan Adult Cat Chicken & Rice Entrée in Gravy	78/3 oz.	3.9	15.1	0.4	59.1	0.95	1.38
Dry foods	**Energy density (kcal/cup)****	**Energy density (kcal ME/g)**	**Fat (%)**	**Fiber (%)**	**Protein (%)**	**P (%)**	**Na (%)**
Recommended levels (inactive/obese prone)	**–**	**3.3-3.8**	**9-17**	**5-15**	**30-45**	**0.5-0.8**	**0.2-0.6**
Hill's Science Diet Adult Hairball Control Light Feline	283	3.5	9.1	8.3	36	0.72	0.33
Hill's Science Diet Adult Indoor Cat	281	3.5	9.1	8.3	36	0.72	0.33
Hill's Science Diet Adult Light Feline	316	3.5	9.5	6.9	35.1	0.73	0.4
Hill's Science Diet Oral Care Adult Feline	337	4.2	22	7.5	34.1	0.75	0.37
Iams Eukanuba Adult Weight Control	315	3.9	14.4	1.8	34.7	0.99	0.54
Nutro Natural Choice Complete Care Indoor Weight Management	359	3.8	13.2	2.7	36.3	0.82	0.22
Nutro Natural Choice Complete Care Weight Management	308	3.8	13.2	3.3	37.4	1.10	0.44
Purina ONE Indoor Advantage Hairball & Healthy Weight Formula	416	4.1	11.7	3.8	42.9	1.42	0.45
Purina ONE Special Care Healthy Weight Formula	362	3.7	12.2	3.7	46.1	1.41	0.40
Purina Pro Plan Weight Management Formula	413	4.2	12.0	3.4	50.5	1.08	0.54
Royal Canin Indoor 27	324	4.0	14.3	7.5	29.7	1.08	0.70
Royal Canin Indoor Light 37	285	3.5	9.9	10.2	40.7	1.07	0.80
Moist foods	**Energy density (kcal/can)****	**Energy density (kcal ME/g)**	**Fat (%)**	**Fiber (%)**	**Protein (%)**	**P (%)**	**Na (%)**
Recommended levels (inactive/obese prone)	**–**	**3.3-3.8**	**9-17**	**5-15**	**30-45**	**0.5-0.8**	**0.2-0.6**
Hill's Science Diet Adult Indoor Cat Savory Seafood Entrée Minced	90/3 oz. 165/5.5 oz.	4.1	23	9.4	37.9	0.7	0.43
Hill's Science Diet Adult Light Liver & Chicken Entrée Minced	75/3 oz. 138/5.5 oz.	3.6	14.2	10.1	35.6	0.69	0.32
Nutro MAX Cat Gourmet Classics Lite with Chicken & Lamb	140/5.5 oz.	3.9	15.2	1.7	41.3	1.3	1.09

Key: ME = metabolizable energy, P = phosphorus, Na = sodium, Mg = magnesium, Se = selenium, VOHC = Veterinary Oral Health Council Seal of Acceptance (Chapter 47), na = information not available from manufacturer, g = grams.
*From manufacturers' published information or calculated from manufacturers' published as fed values; all values are on a dry matter basis unless otherwise stated.
**Energy density values are listed on an as fed basis and are useful for determining the amount to feed; cup = 8-oz. measuring cup.
To convert to kJ, multiply kcal by 4.184.

Mg (%) 0.04-0.1	Urinary pH 6.2-6.4	Vit. E (IU/kg) ≥500	Vit. C (mg/kg) 100-200	Se (mg/kg) 0.5-1.3	VOHC plaque (Yes/No) Yes
0.053	6.3	705	119	0.79	No
0.065	6.3	1,042	197	0.86	No
0.058	6.3	670	171	0.55	Yes
0.088	6.2	739	270	0.83	No
na	na	na	na	na	No
0.109	na	na	na	na	No
0.082	na	132	38	0.49	No
0.088	na	330	88	0.77	No
na	na	na	na	na	No
na	na	na	na	na	No
0.110	na	na	na	na	No
0.121	na	604	220	0.49	No

Mg (%) 0.04-0.1	Urinary pH 6.2-6.4	Vit. E (IU/kg) ≥500	Vit. C (mg/kg) 100-200	Se (mg/kg) 0.5-1.3	VOHC plaque (Yes/No) Yes
0.069	6.4	694	241	1.1	No
0.082	6.4	816	257	1.06	No
0.072	6.4	396	80	1.2	No
0.106	na	170	106	0.43	No
0.10	na	174	261	0.43	No
0.04	na	na	na	na	No

Mg (%) 0.04-0.1	Urinary pH 6.2-6.4	Vit. E (IU/kg) ≥500	Vit. C (mg/kg) 100-200	Se (mg/kg) 0.5-1.3	VOHC plaque (Yes/No) Yes
0.071	6.2-6.4	689	176	0.68	No
0.071	6.2	689	176	0.68	No
0.068	6.2	693	189	0.67	No
0.058	6.3	670	171	0.55	Yes
na	na	na	na	na	No
0.088	na	330	110	0.71	No
0.093	na	330	88	0.60	No
na	na	na	na	na	No
na	na	na	na	na	No
0.84	na	na	na	na	No
0.11	na	604	220	0.49	No
0.11	na	604	220	0.49	No

Mg (%) 0.04-0.1	Urinary pH 6.2-6.4	Vit. E (IU/kg) ≥500	Vit. C (mg/kg) 100-200	Se (mg/kg) 0.5-1.3	VOHC plaque (Yes/No) Yes
0.094	6.4	961	195	1.72	No
0.077	6.2	401	na	1.46	No
0.104	na	174	87	0.43	No

factors are of concern for young adult cats fed homemade foods (Chapter 10). Occasionally, these factors also become important for cats that are intentionally, or unintentionally, fed commercial dog foods.

Taurine

The AAFCO allowances for taurine are appropriate for adult cats (2007). Therefore, commercial cat foods that have AAFCO label statements acknowledging that a food is appropriate for adult maintenance should provide adequate amounts. However, sporadic cases of taurine depletion continue to be diagnosed. Therefore, dietary taurine concentrations should be evaluated in cats with signs of deficiency or disease (Chapter 19). The minimum recommended allowance for taurine in foods depends on the form of the food. Dry and moist foods should provide 0.1 and 0.17% DM taurine, respectively (NRC, 2006). Taurine is not required in commercial dog foods and is usually not added, yet another reason cats should not be fed dog foods.

Essential Fatty Acids

Signs of essential fatty acid deficiency in cats include fatty degeneration of the liver, kidneys and adrenal glands. Scaly skin, mild hyperkeratosis and hair loss have also been noted. Linoleic acid and α-linolenic acid are essential for normal membrane structure and function, including growth, lipid transport, maintenance of the epidermal permeability barrier and normal skin and coat (MacDonald et al, 1984a). Definitive studies about the essentiality of α-linolenic acid have not been conducted in cats. AA, on the other hand, is important for functions that rely on eicosanoid synthesis. In cats, AA deficiency is associated with impaired platelet aggregation, inflammatory skin lesions and reproductive failure in queens (MacDonald et al, 1984b, 1984c). Male cats are capable of converting linoleic acid to AA within the testes, resulting in normal spermatogenesis (MacDonald et al, 1984c). The minimum DM recommended allowances for linoleic acid and AA are 0.55 and 0.006%, respectively (NRC, 2006). The AAFCO allowances for linoleic acid and AA, however, are appropriate for adult cats (2007). Thus, provision of adequate amounts of these essential fatty acids via commercial foods is usually not a problem.

Calcium

Calcium deficiencies are uncommon in cats fed commercial foods. Most cases of calcium deficiency occur in cats fed only meats, in which the calcium concentration is excessively low, particularly relative to the moderately high phosphorus concentration. The recommended DM allowance for calcium in foods for growing kittens is 0.8% of the diet (NRC, 2006). Adult needs are typically less than those for growth. The recommended DM allowance for calcium in foods for adult cats is 0.29% (NRC, 2006). Typical commercial foods contain calcium levels well in excess of these guidelines.

Daily calcium intakes of 200 to 400 mg result when adult cats are fed foods with a calcium-phosphorus ratio of 0.9:1 to 1.1:1 (Scott and Scott, 1967). Although foods with much

broader ratios of calcium to phosphorus have been fed successfully, ratios near 1:1 calcium to phosphorus optimize the availability of phosphorus (Kienzle et al, 1998). When the calcium-phosphorus ratio is increased to 2:1, phosphorus availability declines by 41%. Calcium-phosphorus ratios between 0.9:1 to 1.5:1 appear optimal for most cat foods.

Potassium

The potassium requirement of cats varies with the dietary protein concentration and the effect of the food on urinary pH. High-protein foods and foods that result in an acidic urinary pH increase the potassium requirement (Hills et al, 1982; Ching et al, 1989, 1990; Dow et al, 1990; DiBartola et al, 1993). Previously recommended levels of 0.4% DM potassium (NRC, 1986) resulted in hypokalemia in adult cats and kittens when combined with dietary acidification. Dietary potassium levels in foods for adult cats should be at least 0.52% DM (NRC, 2006) and ideally between 0.6 to 1.0% DM to prevent hypokalemia. The current AAFCO allowance for potassium is 0.6% DM (2007). Therefore, foods that have AAFCO label statements acknowledging that a food is appropriate for adult maintenance should provide adequate amounts of potassium.

Negative potassium balance may occur in cats with certain metabolic abnormalities (e.g., renal insufficiency, renal tubular acidosis, diabetes mellitus and enteritis). Supplementation may be necessary to maintain normal potassium balance in cats with these conditions, even when they are fed a food containing 0.6% DM potassium.

FEEDING PLAN

Assess and Select the Food

After the nutritional status of the cat has been assessed and the key nutritional factors and their target levels have been determined, the adequacy of the food being fed can be assessed. The steps to assessing foods include: 1) determining if the nutritional adequacy of the food has been assured by a credible regulatory agency such as AAFCO and 2) comparing the food's key nutritional factors with recommended levels.

In the U.S., commercial foods approved by AAFCO will usually have a nutritional adequacy statement on the label (Chapter 9). Commercial cat foods that have received AAFCO or other credible regulatory approval provide reasonable assurance of nutritional adequacy. Few homemade recipes have been formulated according to such protocols. Even foods bearing nutritional adequacy statements, however, are not infallible. Nutritional adequacy statements do not assure the food will be effective in preventing certain important long-term health problems (**Table 20-1**). Therefore, in addition to having passed nutritional adequacy protocols, the food should be evaluated to ensure that the key nutritional factors are at levels appropriate for delivering the feeding goal of promoting long-term health through disease prevention. Besides providing recommended levels of key nutritional factors for young adult cats, **Table 20-4** lists key nutritional factor profiles for selected commercial foods. The manufacturer should be contacted if the food in question cannot be found in this table. Manufacturers' addresses, websites and toll-free customer service numbers are listed on pet food labels. If the manufacturer cannot provide the necessary information, consider switching to a food for which this information is available. Because of the propensity for developing food fixations, feeding a combination of food forms (dry and moist) is sometimes recommended. It is unnecessary to change foods if the food currently fed supplies the correct amounts of the key nutritional factors and the food has a nutritional adequacy statement appropriate for adult cats. However, a new food should be selected if discrepancies were determined. The new food should, as closely as possible, provide the recommended levels of the key nutritional factors.

Snacks are either human foods (table foods) or commercial treats and are offered to cats for a variety of reasons. Small amounts of snacks will not have an important effect on the overall food regimen. Excessive feeding of treats, however, can markedly affect the cumulative nutritional profile. Therefore, it is important to assess the impact of treats with respect to the dietary needs of individual cats. The impact of treats on daily nutrient intake depends on three factors: 1) the nutrient profile of the treat, 2) the number of treats provided daily and 3) the nutrient composition of the cat's regular food. Meeting nutrient requirements is not the primary goal of feeding treats; consequently, many commercial treats are not complete and balanced. Similarly, most table foods are not nutritionally complete and balanced and may contain high levels of fat or minerals. If snacks are fed, it is simplest to recommend commercial treats that best match the nutritional profile recommended for young adult cats. Generally, snacks should not be fed in excessive amounts (<10% of the total dietary regimen on a volume, weight or calorie basis). Otherwise, the nutritional composition of the snack and food should be combined and assessed as the total food regimen.

Assess and Determine the Feeding Method

Veterinarians should evaluate the feeding method, including how the food is fed, the feeding frequency and the amount of food offered. It is also useful to know how the food is prepared (e.g., heated, water added, etc.) and by whom and where the cat is fed. This information may help explain any apparent discrepancies between the dietary history and the physical findings and help identify risk factors associated with various feeding methods. For example, a thorough evaluation of an obese cat includes verification that an appropriate feeding method is being used (Chapters 1 and 27).

No single feeding method is optimal for all cats. The preferred method of feeding an individual cat is often determined by non-nutritional factors (i.e., food type, owner preference, owner schedule and feeding environment including whether there are other pets [cats, dogs] in the household). Nutritional considerations for selecting an appropriate feeding regimen include the cat's body condition, health status/disease risk factors and the food's energy density and palatability.

There are basically two ways to feed cats: 1) free choice in

Table 20-5. Advantages and disadvantages of various feeding methods for cats.

Methods	Advantages	Disadvantages	Food types
Free choice	Convenient Ensures adequate food availability Mimics natural feeding behavior Dampens postprandial alkaline tide (lower mean urinary pH)	Overconsumption leads to weight gain or obesity, unless a specific amount is fed Difficult to monitor appetite and food intake Moist food may spoil Less owner contact	Dry Semi moist
Meal fed*	Enhances human-animal bond Facilitates monitoring of appetite and food intake Enhanced control of food intake	Enhanced postprandial alkaline tide (higher mean urinary pH) Large meals may result in vomiting Less convenient Three or more meals for pregnant or nursing queens, kittens or debilitated cats	Dry Semi moist Moist
Combination**	Enhances human-animal bond (vs. free choice) Variable effect on urinary pH	Poor monitoring of appetite and food intake unless a specific amount is fed Poor control of food intake Less convenient than free choice Variable effect on urinary pH	Dry Semi moist Moist

*One or more individual feedings per day, one to two hour availability per feeding.
**Dry foods available free choice, moist foods meal fed one or more times daily.

which the food is continuously available and the cat eats as much as it wants whenever it wants and 2) meal feeding in which a specific amount of food is offered one or more times per day. Most cats tolerate once daily feeding with no problems; however, meal feeding at least twice daily is preferred. Cats should be allowed one to two hours to complete a measured meal; many cats will return for several small feedings before finishing the entire offering. Many owners use a combination of free-choice and meal-feeding methods. Usually, dry food is available throughout the day and supplemented with one or more meals of moist food. Free-choice or combination feeding accommodates the normal feeding behavior of cats by allowing them to eat several small meals spaced irregularly throughout the day and night (Kane et al, 1981a). Each feeding method has advantages and disadvantages that should be considered when making recommendations (**Table 20-5**).

Unless a specific amount of food is fed, the major disadvantage to combination feeding is the inability to accurately monitor and control food intake. Most obese-prone cats should be fed a measured quantity of food; however, some obese-prone cats can be fed low-calorie foods free choice. Food should be available at all times for underweight cats to encourage sufficient food intake.

Clean drinking water should always be available. Water intake can be encouraged by providing a source of fresh flowing water, such as from a water fountain, which many cats seem to enjoy and can be an important aid in reducing the risk for FLUTD. Chapter 46 provides other tips for increasing water intake in cats.

The amount fed is important because nutrient requirements are met, or exceeded, by a combination of nutrient levels in the food and the amount of food fed. Even if a food has an appropriate profile of key nutritional factors, significant malnutrition could result from feeding excessive or insufficient amounts. The amount fed is appropriate if the cat has an optimal BCS (2.5/5 to 3.5/5) (Chapter 1) and body weight is stable. The amount fed can be estimated by calculation (Table 5-2) or by referring to feeding guides on product labels or product information. These guides, however, usually represent population averages and thus may not be optimal for individual cats. **Table 20-6** summarizes the feeding plan for young adult cats.

Table 20-6. Feeding plan summary for young adult cats.

1. Select a food from **Table 20-4** that most closely matches the recommended levels of key nutritional factors; for foods not listed in **Table 20-4**, contact the manufacturer for key nutritional factor content.
2. The selected food should be approved by a credible regulatory agency (e.g., AAFCO).
3. Determine the preferred feeding method (**Table 20-5**); when the correct amount of food is fed, food-restricted feeding is least likely to result in obesity.
4. For food-restricted meal feeding, first, estimate the cat's DER by multiplying RER (Table 5-2) by an appropriate factor.
   Neutered adult = 1.2 to 1.4 x RER
   Intact adult = 1.4 to 1.6 x RER
   Inactive/obese-prone adult = 1.0 x RER (Most pet cats are minimally active)
5. Second, divide the cat's DER estimate by the food energy density (as fed) from **Table 20-4** or manufacturer's information. This calculation will determine the number of cups (dry food) or cans (moist food) to feed each day.
6. Remember, these DER calculations are estimates and should be used as guidelines or starting points for individual cats and not as absolute requirements. Body condition and body weight are used to refine the amount to feed.
7. Regularly monitor body condition, body weight and general health.

Key: AAFCO = Association of American Feed Control Officials, DER = daily energy requirement, RER = resting energy requirement, cup = 8-oz. measuring cup.

A reduction in the amount of food fed is usually necessary in normally active cats that are temporarily confined, such as during boarding, or if their environment changes permanently. These cats may become overweight if food intake is not adjusted accordingly. A normal decline in food intake should not be

confused with inappetence due to stress or disease. Domestic cats display a variety of feeding behaviors that may have nutritional or non-nutritional bases (Box 19-1). Some of these behaviors are worrisome to owners and considered abnormal, when in fact they are normal. Other behaviors may indicate an underlying disease.

Cats do not typically develop digestive problems associated with food changes; furthermore, food variety stimulates increased food intake (Mugford, 1977). Unfortunately, rapid changes in the food or feeding method can cause GI upsets or food refusal for some cats. Transitioning to a new food over four to seven days may be necessary to avoid food intolerances. To change to a new food, replace 25% of the old food with the new food on Day 1 and continue this incremental change daily until the change is complete on Day 4. A slower transition may be required for cats that have been historically sensitive to dietary changes, those with GI diseases and when the new food differs markedly from the old (e.g., low fat vs. high fat or raw meat vs. dry food).

Food and water bowls should be cleaned regularly with warm soapy water and rinsed well. Water fountains should be cleaned weekly and refilled with fresh water. Dishes used for moist foods need daily cleaning, whereas dry food feeders should be cleaned at least weekly. Many cats prefer shallow dishes, especially breeds with less prominent faces such as Persians. For multi-cat households, multiple feeding stations and individual feeding dishes, particularly if placed at different levels, allow timid and low-status cats to eat alone or away from dominant cats. These practices also benefit dominant cats by reducing tension and allowing time for dominant cats to eat quietly instead of defending food or constantly harassing cats of lower social status.

REASSESSMENT

Cats provided proper nutritional management are healthy and alert and have ideal body condition, stable weight and a clean, well-groomed, glossy coat. The owner should evaluate body condition every two to four weeks. Owners should monitor daily food and water intake and observe the cat's interest in its food and its appetite. Stools should be evaluated regularly because changes in frequency or character may signify nutritional problems or disease. Normal stools should be firm, well-formed and medium to dark brown. Any abnormalities should be investigated. The veterinarian should also conduct a nutritional assessment as part of the annual wellness visit.

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REFERENCES

The references for **Chapter 20** can be found at www.markmorris.org.

CASE 20-1

Elective Surgery in a Young Siamese Cat

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Patient Assessment

An 11-month-old female Siamese cat was presented for routine ovariohysterectomy. The owner obtained the cat from a friend as a young kitten. The cat had been healthy except for one episode of upper respiratory infection, flea infestation and tapeworm infection. The cat lived with the owner in an apartment and rarely went outdoors.

Physical examination revealed a normal young adult cat. Body weight was 3.2 kg with ideal body condition (body condition score [BCS] 3/5). A packed cell volume (normal), feline leukemia virus test (negative) and fecal flotation test (negative) were performed before surgery. The ovariohysterectomy was uneventfully and the cat was released to the owner's care the next day.

Assess the Food and Feeding Method

The cat was fed a dry commercial grocery brand food formulated for growing kittens (Purina Kitten Chow Dairy Flavor[a]) and several varieties of moist commercial grocery brand foods. The dry food was available free choice and a small portion of moist food was fed each evening when the owner returned from work. Tuna flavor cat treats were also offered daily. Dairy products were fed intermittently; the cat was allowed to lick bowls used for cereal and ice cream.

Questions

1. When should the owner stop feeding kitten food?
2. Will the ovariohysterectomy change the nutrient requirements for this young cat?
3. What are the key nutritional factors for a cat entering adulthood?
4. Outline an appropriate feeding plan.

Answers and Discussion

1. An 11-month-old cat has reached its adult size and is finishing the maturation process. Foods specifically formulated for growing cats are usually fed until approximately one year of age. At that time, the food can be slowly changed to one formulated for young adult cats.
2. Neutering markedly alters a cat's metabolism. Changes occur within three months of neutering and include decreased resting energy requirement (RER) (basal metabolic rate; approximate decline 27 to 33%) and less ability to regulate food intake. These changes make gonadectomy a risk factor for obesity. Neutered cats are more likely to become overweight than are intact cats of either gender. Therefore, neutered cats should be fed less energy than intact cats to reduce the risk for obesity.
3. Key nutritional factors for young adult cats include water, energy, protein, fat, minerals (phosphorus, sodium, chloride, magnesium), urinary pH, antioxidants and food texture. Foods that produce average urinary pH values of 6.2 to 6.4 when fed free choice reduce the risk of struvite urolithiasis and avoid metabolic acidosis in most adult cats. Food texture influences oral health. Dental disease is the most prevalent disease in cats one year old and older. Dry foods specifically designed to promote oral health are beneficial in reducing plaque and calculus accumulation and controlling gingivitis.
4. A food specifically formulated for young adult cats should be chosen based on appropriate levels of key nutritional factors. A commercial dry adult cat food or a combination of dry and moist adult cat foods can be used. The form(s) of food chosen will dictate the feeding method used; meal feeding rather than free-choice feeding helps control obesity. The owner should be informed that neutering might markedly decrease the energy requirements of the cat. An estimated daily energy requirement (DER) can be calculated as a target for the owner. The DER of average young adult cats is approximately 1.4 x RER (70 kcal/kg body weight/day [293 kJ/kg body weight/day]). Caloric requirements for neutered or inactive cats may be less than this amount, whereas active intact cats may require a higher energy intake. Treats should be eliminated or used sparingly. The owner should monitor body weight and condition every two to three months to determine if DER should be adjusted. Free-choice access to potable water is important.

Progress Notes

The veterinary technician discussed the metabolic and behavioral changes that result from ovariohysterectomy with the owner when the cat was discharged. Dry and moist formulations of a commercial food formulated for adult cats (Science Diet Feline Maintenance[b]) were sent home with the owner. The owner was instructed to mix the dry adult food with the remaining growth food. The moist adult food was dispensed to replace the other moist foods after they were fed. The estimated DER was 1.4 x RER = 230 kcal (962 kJ). Offering one-fourth cup dry food in the morning and giving two-thirds of a 5.5-oz. can of food in the evening would meet this DER. The owner was given a body condition scoring chart for cats, and she indicated her willingness to evaluate the cat regularly.

Endnotes

a. Ralston Purina Co., St. Louis, MO, USA.
b. Hill's Pet Nutrition, Inc., Topeka, KS, USA. This product is currently available as Science Diet Adult Original.

Bibliography

Buffington CA, Rogers QR, Morris JG. Effects of age and food deprivation on urine pH of cats. Veterinary Clinical Nutrition 1994; 1: 12-17.
Flynn MF, Hardie EM, Armstrong PJ. Effect of ovariohysterectomy on maintenance energy requirement in cats. Journal of the American Veterinary Medical Association 1996; 209: 1572-1581.
Lund EM, Armstrong PJ, Kirk CA et al. Prevalence and risk factors for obesity in adult cats from private U.S. veterinary practices. International Journal of Applied Research in Veterinary Medicine 2005; 3(2): 88-96.
Munday HS, Earle KE, Anderson P. Changes in the body composition of the domestic shorthaired cat during growth and development. Journal of Nutrition 1994; 124: 2622S-2623S.
NRC. (National Research Council). Nutrient Requirements of Cats. Washington, DC: National Academy Press, 1986.
Root MV. Early spay and neuter in the cat: Effect on development of obesity and metabolic rate. Veterinary Clinical Nutrition 1995; 2: 132-134.
Scarlett JM, Donoghue S, Saidla J, et al. Overweight cats: Prevalence and risk factors. International Journal of Obesity 1994; 18: S22-S28.