

1988

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Recommended Citation

Kantorosinski, S. and Morrison, W. B. (1988) "A Review of Feline Nutrition," *Iowa State University Veterinarian*: Vol. 50 : Iss. 2 , Article 6.

Available at: https://lib.dr.iastate.edu/iowastate_veterinarian/vol50/iss2/6

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A Review of Feline Nutrition

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The nutritional needs of the cat are quite specific and differ greatly from the nutritional requirements of other species, such as the dog. The cat evolved from a strict carnivore and has not had the chance through evolution to change much from its carnivorous nature. Therefore cats require a much higher protein intake than an omnivore, such as the dog. The cat's need for dietary taurine, arginine, preformed vitamin A, and high protein makes it characteristic and different from many other species. It is only in recent years that the nutritional peculiarities of the cat are beginning to be recognized and researched.

As occurs in other animal species, disease in cats may result from prolonged feeding of unbalanced diets. Diets composed of a single food item may result in deficiency disease or toxicity. It is not uncommon to see nutritional hyperparathyroidism in cattery kittens who are fed homemade diets of high meat content.¹ Deficiencies of one or more nutrients may result in diseases such as pansteatitis, malnutrition, and central retinal degeneration.^{2,3,4} Many of these conditions may be corrected with dietary alterations if the practitioner recognizes that the disease is nutritionally related.

The use of nutrition as part of the medical management of certain disease conditions is also increasingly being used. Management of feline urologic syndrome through alterations in diet is now accepted practice.^{4,5} Dietary alteration is used to prevent progression of renal destruction in kidney failure.^{4,6} So for the veterinary practitioner an understanding of feline nutrition is important in prevention of disease as well as treatment and management of disease.

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In this paper the general principles of feline nutrition will be reviewed. The nutritional needs which make the cat different from other species are highlighted. Certain diseases which have a nutritional basis are discussed so that they may be more easily recognized and considered as part of a differential diagnosis. Finally nutritional management as a component of the treatment for specific conditions such as feline urological syndrome, renal failure and anorexia is considered.

Protein

Protein is necessary in the diet of any animal to supply the essential amino acids, to supply the nitrogen necessary to synthesize those amino acids considered nonessential, and to supply nitrogen for the formation of purines, pyrimidines, heme, and creatinine.⁷ The cat and fox are two species known to require a higher protein intake than most other mammalian species. In fact, one author suggests that adult cats require almost five times the amount of protein as adult dogs.⁸ In the cat it seems that a fixed amount of dietary protein is always broken down for energy.^{6,7} After amino groups are removed from amino acids the resulting keto acids can be used for energy or glucose production. Unlike most other mammals the cat cannot adjust its catabolic enzymes to shifts in levels of dietary protein.^{6,7} These enzymes are always set to handle a medium to high level of dietary protein even though there may be too low a level of protein in the diet. Insufficient intake of protein may result in a deficiency of the essential amino acids as well. Deficiency of the essential amino acids leads to decreased food intake and weight loss.

There are varied values given for the amount of protein necessary in the feline diet. One source recommends 25 - 30% protein in the diet on a dry weight basis; that is, if the protein is of good

biologic value (70-90 biologic value).⁴ This would mean 25% of the calories in the diet would be supplied as protein. A much lower value of 12.5% is given by another source saying that if a satisfactory amino acid level could be met this diet could support body weight and nitrogen needs in adult cats.⁹ This value is still higher than that required by other mammals. The National Research Council (NRC) has recommended as a minimum 240 grams of protein/kg diet (on dry basis) for growing kittens, which is about 20% of a very palatable, high quality diet.⁷

Protein, like fat, increases the palatability of the diet. It is best to avoid protein from a single protein source because this frequently leads to an imbalance of amino acids as well as resulting in the cat becoming addicted to a single item diet. The most critical period for ascertaining that the cat has sufficient protein in the diet is just after weaning. The NRC recommends about 20% protein (on a dry basis), whereas, another source recommends 30-40% of the diet be protein during this critical period.^{4,7} The recommendation of the NRC is a minimum value and relates to a purified diet of high biologic value.

It is important to realize that all the amino acids ingested are not readily available to the body. Processing of foods may affect the digestibility of the food. For example, the digestibility of soybeans is increased during processing since the cooking inactivates trypsin inhibitors found in soybeans.⁷ On the other hand, the drying of meats can decrease the nutritive value of the protein.⁷ When protein is heated in the presence of reducing sugars the availability of amino acids is reduced.⁷ Also during storage, proteins in the presence of polyunsaturated lipids can be oxidized which reduces the levels of amino acids especially methionine, tryptophan, and histidine.⁷ Therefore, if the diet is composed of a high quality protein consider that about 80-90% is available; if it is made up of a low quality protein consider 60-70% available.^{7,10}

Of the essential amino acids there are two that distinguish the cat as being quite different from other mammalian species. Arginine, which most animals can synthesize to some degree in the kidney, is necessary in the diet of cats. Taurine, another amino acid, has received much attention in the literature since studies have shown a taurine deficiency frequently leads to central retinal degeneration in cats.^{3,11,12} Each of these amino acids will be discussed further.

Arginine is necessary for the conversion of ammonia to urea. If arginine is lacking or defi-

cient in the diet ammonia accumulates in the blood. Cats on arginine restricted diets have shown signs of hyperammonemia soon after a meal. The cats display any of the following signs: hyperactivity, hyperesthesia, ataxia, emesis, ptialism, apnea, cyanosis, and sometimes death. Since arginine is involved in the metabolism of the waste products of protein metabolism some say that the arginine requirement increases when a high protein diet is fed as compared to a diet where protein is near the minimum requirement level.⁸ Arginine deficient diets occur rarely under natural circumstances.

Cats are very sensitive to a dietary deficiency of taurine. Other species are able to make taurine from methionine whereas cats have a very limited ability to use methionine to synthesize taurine. In addition there is a constant loss of taurine in the conjugation of bile salts. Cats predominantly use taurine in conjugating bile salts, whereas, other mammals are able to use either taurine or glycine in bile salt conjugation. The demand for taurine is increased even more during growth as muscle mass increases. Most taurine in the body is found in three main tissues: bile, the retina, and the olfactory bulb.³ In one experiment cats fed a taurine-free diet for eleven months showed rapid decrease in their plasma taurine levels and about half showed central retinal degeneration.¹¹ Visual acuity in the cats did not appear to be affected. The lesions are in the central area of the retina and the normally bright yellow tapetum becomes dark and granular and later a hyper-reflective focal lesion develops as photoreceptor cells are lost.⁷ With chronic deficiency the entire fundus appears atrophied. Vision does not seem to be affected until retinal degeneration is advanced; therefore routine ophthalmoscopic exam on cats may be a good practice. Changing the diet to one with adequate taurine will not reverse the damage but it will help prevent further progression of the disease. Taurine is high in meat, seafood, and milk.¹² It is low in vegetables and most dog foods.¹² Cases of central retinal degeneration have occurred when cats were fed dog foods or when a diet had casein as the only source of protein. Reasons given for feeding cats dog food were the lower cost, some cats preferring dog food over cat food, and the instructions of veterinarians who felt dog food reduced the incidence of feline urolithiasis.¹² Since taurine is also found in the olfactory bulb in rather high levels it is suggested that smell or taste may also be affected but this is uncertain.³

Fat

Fat in the diet provides a concentrated source of energy. It is also essential for absorption of fat soluble vitamins, for providing the essential fatty acids, and increasing the palatability of the diet. Cats can tolerate and digest high levels of fat in the diet quite well.

Cats are influenced by the amount and source of dietary fat. Commercial canned cat foods tend to have a higher percentage of crude fat on a dry matter basis than dry commercial cat foods. Usually there is from 10-40% crude fat in canned diets as compared to 10-12% in dry diets. Many cats seem to prefer about 20-30% crude fat rather than a much lower or higher percentage. The type of fat is also important in palatability. Cats tend to prefer animal fats over vegetable fats. Diets high in levels of hydrogenated coconut oil were refused by many cats. The cats preferred hydrogenated beef tallow diets over high levels of hydrogenated coconut oil.⁷ Chicken and turkey fats are known to increase palatability. Commercial cat food manufacturers also learned that cats could be stimulated to eat diets with fat content at 4% on a dry basis if the fat was sprayed on the surface of pelleted foods.¹³

Since fat provides about 2.25 times the metabolizable energy as protein or carbohydrate, adding fat to the diet greatly alters the energy concentration of the diet. Concern is over the fact that cats will take in sufficient energy but not sufficient protein, vitamins, or minerals when a diet is supplemented with fat. If adjustments are not made in these other nutrients the result may be a cat that is malnourished due to a deficiency in one or more of these nutrients.

Fat is necessary in that it provides linoleic and arachidonic acids, the two fatty acids considered essential in cats. Most other mammals can convert linoleate to arachidonate by desaturation and elongation which occurs in the liver.¹⁴ The ability of the cat to convert linoleate to arachidonate is very minimal,⁷ so both fatty acids are considered essential in the cat diet. Linoleate is not simply a precursor to arachidonate but is in itself essential for certain body functions. If linoleate was deficient in the diet, scaly skin, enlarged fatty livers and loss of water transpidermally occurred. It is known that linoleate has a function in the structuring of membranes for proper growth, lipid transport, and normal skin and coat condition. Arachidonate also has a structural function and is a precursor to prostaglandin, PGE₂.¹⁵ It is neces-

sary for normal reproduction and blood platelet aggregation.

In one study male cats fed a diet deficient in the essential fatty acids for about two years showed extensive testicular degeneration.¹⁴ They found that if linoleate was included in the diet degeneration of the testes did not occur. When linoleate was supplied in the diet levels of arachidonate in the testes increased which was thought to be due to the conversion of some linoleate to arachidonate by the testes.¹⁴ The levels of arachidonate in the plasma did not increase even though it seemed apparent that the testes converted some linoleate to arachidonate.¹⁴ So it seems that linoleate can help prevent testicular degeneration in a cat consuming a diet deficient in arachidonate. In the female cat on an arachidonate free diet, adding linoleate to the diet did not help her reproductive function. She could not bear kittens unless a certain level of arachidonate was present.¹⁴

Sources of these essential fatty acids differ. The richest source of arachidonate is the lipid portion of organ meats.¹⁶ Warm water fish and shellfish are other good sources. Tuna oil contains arachidonate but it also contains a 22 carbon chain fatty acid which seems to interfere with arachidonate.¹⁶ The possibility of developing an arachidonate deficiency is greatest in cats fed dry cat foods since they have a lower fat content than commercial canned cat foods. Vegetable oils lack arachidonate and most rendered animal fats if limited to 10% fat in the diet would not provide the necessary arachidonate.¹⁶ A good source of linoleic acid is safflower oil. In one study cats on a diet deficient in these essential fatty acids developed severe fatty liver, fat in the kidneys, dystrophic mineralization of the adrenal glands, testicular degeneration, and hyperkeratosis of the skin.¹⁶ These deficiency signs disappeared when safflower oil (as a means of supplying linoleate) was added to the diet. In this same study some cats were fed diets containing hydrogenated coconut oil, safflower oil, and chicken fat and fatty livers developed despite the presence of high levels of linoleate. The fatty livers were thought to have resulted from the effects of the medium-chain triglycerides in hydrogenated coconut oil. The researcher suggests that hydrogenated coconut oil may have accentuated an essential fatty acid deficiency, which has also been shown to occur in rats eating high levels of hydrogenated coconut oil. The level of fat in the diet beyond what is necessary to supply these two essential fatty acids has not been demonstrated.⁷

Certain vitamins are fat soluble and require the presence of some fat in the diet for absorption. These fat soluble vitamins are A, D, E, and K.

Vitamins

The vitamin requirements of the cat are quite specific. Cats in general have a higher need for the B-complex vitamins than other animals. The values of minimum requirements of some B-vitamins are 2-8 times greater for cats than dogs. For example, vitamin B₆, pyridoxine, provides the prosthetic group of transaminases and since cats have a high transaminase level their requirement for B₆ may be four times that of the dog.⁶ Thiamine is a B-vitamin which has received attention due to its easy destruction during cooking and storage. High losses can occur when canned foods are processed. Up to eighty percent of thiamine can be lost in processing so manufacturers should supplement the food with several times the thiamine requirement to insure adequate levels after processing.⁷ Thiamine deficiency can also result from prolonged ingestion of uncooked fish which contains thiaminase. Thiamine deficiency is characterized by ataxia, cerebellar tremors, loss of righting in the air, and seizures.¹⁷ Cats with thiamine deficiency will tend to keep their head ventroflexed on the sternum when they are suspended by the hind limbs. Normally a cat put in this position will dorsoflex its head. Diagnosis can be confirmed by giving thiamine orally or intramuscularly and observing for improvement which usually occurs within a few hours.

Cats are also characterized by their inability to convert Beta-carotene to vitamin A.⁷ Cats must have preformed vitamin A in the diet, unlike many other mammals who have the ability to convert Beta-carotene to the needed vitamin A.⁷ This need for preformed vitamin A is part of the strict carnivorous nature of the cat. Considering that liver is one of the highest sources of the preformed vitamin, the cat as a carnivore, had no need to retain an ability to convert Beta-carotene to vitamin A since the diet in most cases provided an abundance of preformed vitamin A. Beta-carotene is found in many vegetables and is not toxic if consumed in large amounts. On the other hand, vitamin A consumed in large amounts in the diet is very toxic. Cats fed a diet consisting mainly of liver may be receiving toxic doses of vitamin A which frequently presents as skeletal demineralization. There may be extreme tenderness of joints especially of the cervical skeleton due to bony exostoses that develop along muscular insertions

of the cervical vertebrae, ribs and long bones.³ To avoid the possibility of hypervitaminosis no more than one ounce of liver a day should be fed to an adult cat.¹³ Since vitamin A is a fat soluble vitamin, excesses are not excreted but stored in the body, especially in the liver. Therefore, deficiency is rare.

Vitamin E is another fat soluble vitamin that deserves special attention since occasionally deficiencies occur. Diets high in polyunsaturated fatty acids as contained in fish oil may increase the vitamin E requirement three or four times.⁷ Vitamin E stabilizes the unsaturated lipids. When large amounts of unsaturated fatty acids are taken in without sufficient antioxidant (vitamin E) peroxidation of depot fat may occur and later fat necrosis.⁶ The adipose tissue becomes yellow to orange-brown in color and firm. This condition is called pansteatitis or yellow fat disease. Most commercial cat foods have vitamin E added but these additional quantities become insufficient if the owner is supplementing the commercial foods with high proportions of red tuna or some other fish. Some fish oils, such as cod liver oil, are very high in unsaturated fatty acids and low in antioxidants such as vitamin E. Clinical signs of pansteatitis which may be seen are anorexia, pyrexia, tenderness of palpation of the abdomen and thorax. Small nodules may be present in the subcutaneous tissues. Biopsy of the subcutaneous fat may show fat cell necrosis and infiltration by neutrophils. One case study alerts practitioners to the fact that pansteatitis can resemble feline infectious peritonitis in its clinical appearance.² An eight month old male Persian cat presented with ascites, anorexia, weight loss, low grade fever, and diarrhea. The condition progressed to a chronic debilitating disease resembling FIP in clinical appearance. The author stresses the importance of considering pansteatitis as a differential diagnosis when a cat presents with effusive abdominal disease and fever which is antibiotic resistant.² Other diseases on the differential list for these clinical signs should include toxoplasmosis and lymphosarcoma. Laboratory data should allow differentiation of these diseases. Pansteatitis can usually be treated successfully with alpha-tocopherol.

Minerals

Minerals are needed by the body to maintain acid-base balance, tissue structure, and osmotic pressure. They are also essential in the function of many enzyme systems. Even though minerals

in a food may meet the minimum requirements, the bioavailability must also be considered. Phytic acid and chitin can greatly reduce the availability of minerals in a feed. If the phosphorus in a diet is largely plant derived it should only be considered about 30% bioavailable since it is likely to be bound to phytate to a great degree.⁷ Zinc, a mineral component of many body enzymes, may need to be tripled in amount in a diet containing large amounts of phytate and fiber.⁷ In phytate-containing diets which contain excess calcium, zinc is bound in the gut in an insoluble zinc-calcium-phytate complex and therefore not available for absorption.⁷ Adding supplements of several different minerals to the diet may result in problems due to the interaction of different minerals. An excess of one mineral in the diet may decrease the absorption of another.⁷ For example, an excess of phosphorus in the diet lowers the bioavailability of iron.⁷ In the table of minimum requirements (Table 1) the NRC suggests that values of iron, copper, and iodine be multiplied by a factor of 1.3 to help correct for decreased bioavailability.⁷ Zinc and manganese should be multiplied by a factor of 1.5.⁷

Secondary hyperparathyroidism is a condition which results when the levels of calcium and phosphorus are altered in the body. Diets low in calcium or very high in phosphorus may lead to this disease.¹ It is essential that these minerals be maintained in a specific ratio in the diet. A calcium to phosphorus ratio of 1:1 to 2:1 is thought to be acceptable. Diets composed primarily of cardiac and skeletal muscle can upset this ratio greatly. Beef heart has a calcium to phosphorus ratio of 1:40.¹ Horsemeat has a ratio of 1:10.¹ The great excess of phosphorus in these foods can lead to inadequate absorption of calcium which results in a hypocalcemia. Hypocalcemia stimulates the parathyroids to release parathormone in an attempt to restore the serum calcium to normal levels. Parathormone acts on bone, kidneys, and the intestine in its attempt to increase the calcium and decrease the phosphorus levels. The adult cat has 18-40 grams of calcium in its skeleton and these stores can be used to restore serum calcium to a normal level.⁷ The increased serum parathormone causes more bone resorption which results in a loss of bony mass. Increasing numbers of cases of secondary hyperparathyroidism are seen in catteries where breeders believe high meat diets produce healthier and faster growing kittens. In some catteries this may occur when kittens are offered dry cat food free choice in addition to horsemeat,

and the kittens selectively eat the horsemeat. In the wild, cats would eat a predominantly meat diet but calcium would be provided when the bones of small rodents were also consumed.

Clinical signs of nutritional hyperparathyroidism are lameness, limping or reluctance to move.¹ There may also be signs of posterior paresis, bone and joint pain, and constipation.¹ Radiographic findings show loss of bone density, possibly pelvic deformities, and pathologic fractures especially of the vertebrae.¹ Serum calcium and phosphorus levels are usually within the normal range. Occasionally blood clotting times may be extended.

Formulating Diets For Cats

Formulating a diet requires that sufficient nutrients and energy be available to supply the needs of the animal depending on whether the needs are for growth, maintenance, pregnancy or lactation. The diet must be looked at in terms of its biologic value. This is determined by the edibility, digestibility, and metabolizability of the diet.⁴ If a cat consumes all the diet the food is considered one hundred percent edible. Digestibility is determined by measuring the amount of the nutrient, for example, protein eaten minus the amount of protein recovered in the feces.⁴ Metabolizable energy is the gross energy of the nutrient minus the energy of the feces and urine.⁴ From these measurements the biologic value is determined.

$$\text{Biologic Value} = \frac{\text{quantity of nutrients absorbed and retained}}{\text{quantity absorbed}}$$

The nutrient requirements of the National Research Council are listed in Table 1. These requirements are those for purified feline diets that have a very high bioavailability. The bioavailability of natural ingredients used in cat foods will vary from the purified diet. In general, protein digestibility and amino acid bioavailability of ingredients used in cat foods will not exceed 90%.⁷ If there is a high amount of collagen in the food, digestibility may only be 50%. The National Research Council hopes to correct for these differences in bioavailability by suggesting that their minimum values for concentration of amino acids be multiplied by a factor 1.3.⁷ They recommend that their minimum requirements for the B-vitamins in the table be multiplied by 1.6 to help extrapolate the figures in the table to practical diets.⁷ Thiamine requires additional precautions

due to loss during cooking and processing.

Just as important as the biological value of a diet are the different requirements of each stage of the life cycle: mainly growth, maintenance, reproduction and lactation. The NRC in its table has given the minimum requirements for growing kittens. Due to the fact that research into the area of feline nutrition has only begun to increase in recent years, knowledge in this area is still limited. The NRC has not set minimum requirements of nutrients for maintenance and reproduction. They believe that the minimum requirements listed for kittens are adequate for other stages if certain changes are made. For maintenance the levels of protein and methionine should be reduced as noted in the table, and for reproduction vitamin A and taurine levels should be increased. Energy requirements differ during the various stages of a cat's life. Miller and Allison recommend the following energy requirements for growing kittens and adult cats:

- 250 kcal/kg body weight at 5 weeks of age
- 100 kcal/kg body weight at 30 weeks of age
- 85 kcal/kg body weight at 50 weeks of age (active cat)

An inactive, confined cat may need only 70 kcal/kg body weight of energy per day.⁷ Energy requirements increase during gestation such that most researchers believe that queens require about 25% more energy especially in the later stages of pregnancy. It is not uncommon for queens to lose weight during lactation even though they have free access to a very palatable diet. In one study of ten lactating queens in the first six weeks postpartum energy requirements increased from 90 to 270 kcal metabolizable energy/kg maternal body weight.⁷

Feeding Behavior

The feeding behavior of the cat is also quite characteristic. Cats usually prefer to eat alone without competition from other cats or pets. It is suggested that if two cats are in a household, feed each in separate bowls which are placed at different areas of the room.¹³ If a dog is in the household it may be best to place the cat's bowl in some elevated location that the dog can not reach. The cat is an adaptable and opportunistic feeder which was required in its evolution from a wild carnivore. In the wild it had to stalk and capture its food so meals depended on the type of wildlife in the area. If wildlife caught was rather large in size it would mean that meals would be large and probably infrequent. If the area supplied an abundance of mice the cat would probably adapt to having small

meals frequently throughout the day. Domestic cats on a free-feeding method were usually found to nibble randomly throughout the day.¹⁸ Some would eat 10-20 small meals in a 24 hour period.

Most researchers agree that cats can regulate their caloric intake quite well no matter what type of food is available. Most cats will voluntarily restrict their energy intake to that energy which is needed by the body. One study found that cats fed varying diets were able to adjust their intake after a very short time so that mean intake at each meal remained constant.¹⁸ This occurred even when some meals were of low caloric density and required a bulky intake to satisfy caloric needs. It needed a cat can easily meet its energy needs on one large meal per day. It is important that meals be of good quality but not overly palatable.

Cat Foods

Selection of a well balanced commercial cat food is not as easy as it may seem. There are two main methods by which food is judged to be nutritionally adequate. The manufacturer may claim on the label that the food meets the standard requirements set by the NRC. This is one way in which the nutritional value of the diet can be assessed. But statements of the nutrient value of a diet tell nothing about the diet's palatability, bioavailability or protein quality. Feeding trials, which are a second method of judging the quality of a diet, are better indicators than NRC requirements.⁶ If a food is labeled "complete, perfect, a scientific or balanced ration for cats" it must meet the NRC requirements or have been proven in feed trials.⁴ Reading the nutritional statement on the label can be quite helpful. Also note the label for guarantees and analyses. There should be a guaranteed minimum percentage of protein and fat and guaranteed maximum percentage for fiber and water. These are minimums and maximums and do not necessarily indicate the quantity of these substances in the food. Economically it may not be recommended buying a canned food with greater than 75% moisture.⁴ If a canned food has less than 5% fat or if a dry food has less than 7% fat the caloric density may be considered too low.⁴ The list of ingredients on the food gives a general idea of what is in the food and whether vitamin and mineral supplements have been added. It is recommended that a good quality food be purchased rather than supplementing a poor quality diet. Cats frequently develop a preference for one type diet over another. These preferences develop

as a result of previous dietary experiences and are not due to a requirement for certain nutrients.

Commercial cat foods come in a variety of forms. There are canned ration, canned gourmet, semi-moist, and dry types of foods available. The digestibility of canned food is usually higher than that of dry foods. Canned foods have from 72-78% moisture. The canned ration type foods are many times labeled as nutritionally complete and they supply energy from protein, fat, and carbohydrates in fairly substantial quantities. The gourmet canned foods are designed to add variety to the diet but not formulated to act as a sole source of nutrients. They are frequently nutritionally incomplete and energy is supplied mostly through protein and fat. Gourmet canned foods are usually the most expensive type food and are highly palatable, such that cats seem to become addicted to one certain variety.

Semimoist cat foods are intermediate in moisture between the canned and dry foods. They contain less fat than canned foods and generally have more cereal than canned foods so more energy is supplied by carbohydrate and less by fat. Semimoist foods have products added to stabilize the product, maintain water levels, and prevent spoilage since refrigeration is not required. Such things as sugar, sodium chloride, sorbates, and propylene glycol may be added. To control bacterial growth, pH is maintained using phosphoric acid. Use of phosphoric acid may increase phosphorus levels in the food enough to lead to problems in cats susceptible to feline urologic syndrome.⁴

Dry foods are composed of 7-12% moisture and are mainly carbohydrate and protein with very low fat content. Dry foods have substantial quantities of cereal grains, milling by-products and soybeans added with poultry by-products, fish meal, "digest" and animal fat present to increase palatability. Crude protein is 28-36% on a dry matter basis, less than that in most canned foods but very similar to the content in the semimoist foods. Dry foods have the advantages of costing less, offering a wide variety of protein sources therefore, decreasing chances of cats becoming addicted and being easy to store and feed. Some nutrients may be destroyed in processing and later in post-processing oxidation.

"Digest" is frequently being used in dry cat foods. This is a liquid which is sprayed on the exterior of dry cat food to increase palatability by providing flavor and acidity. Cats seem to prefer

acid over neutral or alkaline foods. "Digest" is made by enzymatic breakdown of a variety of animal products such as poultry by-products, liver, fish, and beef lungs.⁴ The action of the enzyme is then stopped by adding an acid. Eventually the acid provided by the digest must be excreted by the kidney.

It can be seen that each of the commercial cat foods has its advantages and disadvantages. Some owners choose to feed their cat a homemade type diet. This, even though well intentioned, is not recommended since frequently the cat is fed one predominant food which leads to an imbalanced diet. One course recommends choosing a canned ration type food of a manufacturer which is labeled to provide complete and balanced nutrition.¹³ Otherwise it is suggested that a mixture of two or more types of foods be fed to provide the necessary nutrients. So, for example, feed one-half the energy requirement as a canned food and provide the remaining energy as a dry food. Also during periods when extra energy is needed such as growth, pregnancy and lactation it may be wise to provide a diet which is more energy dense. One study compared a dry cat food with 21% fat to a leading kitten diet with 12% fat. The diet with the higher fat content resulted in 10% higher birth weights, 40% greater kitten survival, and a 30% greater weight gain in kittens from birth to weaning.⁶

THE USE OF NUTRITION IN MANAGEMENT OF DISEASE

Feline Urologic Syndrome

Dysuria, hematuria, cystitis, and urinary tract obstruction are all signs which may be seen with feline urologic syndrome. The incidence of the syndrome is quite high. In fact, some statistics say that as high as one out of ten cats seen in veterinary hospitals have problems relating to FUS.⁷ The incidence seems fairly equal in males versus females, although most urinary obstructions occur in males. Without proper dietary or medical management it is estimated that 50-70% of all cases will have a recurrence.⁶ Various factors have been suggested as causes of FUS, such as: infection; alkaline urine; age of castration; endocrine imbalance; high ash in the diet; high dietary magnesium; phosphate or nitrogen; low water intake; obesity; dry cat foods; confinement; and less frequent urination.⁷ The cause is likely to be

several factors acting together and may not always be the same set of factors.

Urine pH is an important factor in urinary crystal formation. In the wild, cats normally produce an acid urine with a pH of 6.0-7.0 due to their high meat diet. The vegetable ingredients in cat foods frequently result in a neutral or more alkaline urine. After a meal, urine pH increases and remains elevated for one hour or more as a result of the "alkaline tide" phenomenon. Many researchers believe that the increase in alkalinity which normally occurs after eating plus the increase in minerals in the urine from food being digested may lead to a crystal formation in the urine and FUS. To minimize the crystal formation some researchers recommend keeping the urine pH below 6.6.⁷ Below a pH of 6.6 struvite crystals remain in solution; above a pH of 7.1 crystallization spontaneously occurs.⁷

Studies are being done to see whether it is better to feed a cat free choice or to feed 1-2 large meals per day. Feeding free choice usually means the cat is eating 10-20 small meals a day and with each meal the urine pH rises and remains elevated for a short period. If one or two large meals are fed, the urine pH increases to a greater degree with each large meal and remains elevated for a longer period. The question is whether one situation is more conducive to stone formation than the other. Remember that in regard to urine pH several factors are involved, not only is the feeding interval important but also the type of food fed and the mineral composition of the diet.

The majority of cases of FUS have calculi, microcalculi, or crystals present in the urinary tract.⁶ Bacteria and viral infections are rarely involved and when a urinary tract infection is present it is thought to be secondary and not a cause of FUS. In 81.9% of the cases of FUS the calculi are composed of struvite.⁶ Struvite contains magnesium, ammonium and phosphate. The urine of a cat is usually quite high in ammonia and phosphorus due to its high protein diet. The levels of magnesium and phosphorus in the urine relate closely to the intake of these minerals in the diet. Three factors seem to be important in calculi formation.⁶ The first factor being a high concentration of these calculi-forming constituents in the urine. Secondly is the pH of the urine which should be favorable for crystal formation. The third factor important in calculi formation is that urine be in the urinary tract for a prolonged time. Calculi may cause an urethral obstruction or irritate the urinary tract leading to mucus secretion and forma-

tion of a mucoid plug causing urethral obstruction.

The mineral content of the urine is an important factor in urinary crystal formation. The minerals in urine can be influenced by diet, efficiency of digestion, urine volume, and kidney functioning.⁵ Altering diet is one way to change the mineral content of the urine. Most commercial cat foods that are made with soybean meal and bone meal are high in magnesium. Most cat foods on the market are 4-18 times the minimum magnesium levels recommended by the NRC due to the type of ingredients used in making the food.⁶ Realize that magnesium levels in the food can closely relate to urinary magnesium concentration but there are several precautions to be considered. For one, the magnesium in the food may not be highly bioavailable and much less is absorbed and utilized than expected.

The caloric density of the food is very important. Dry cat foods on a dry matter basis may contain the same level of magnesium as canned foods. Since the energy concentration of dry foods is less; cats must eat more dry foods to meet their needs and, therefore, get higher levels of magnesium.^{7,19}

High levels of ash in the diet are frequently associated with high levels of magnesium. But this is not always true since ash is considered to be all the noncombustible materials in a diet; so it not only includes magnesium but sodium chloride and calcium salts. Still some persons believe that if a cat is FUS susceptible the ash in the diet should be less than 5% on a dry matter basis.⁴ This statement can be made as long as the magnesium and phosphorus levels are also low in this low ash diet.

Urinary mineral levels cannot be considered without also considering urine pH. If urinary pH is near neutral and magnesium levels are high in the diet the incidence of FUS increases.⁷ If the urine pH is acid the high magnesium levels are usually of no problem. Also if urinary pH is high FUS may result with low urinary magnesium levels.⁶ So urinary magnesium concentration and urinary pH are related in the development of FUS.^{5,6,7}

Another factor in crystal formation is the length of time urine remains in the urinary tract. Cats are able to highly concentrate urine and go long intervals without voiding. Being a descendent of the desert cat of North Africa, cats can drink less water and concentrate urine to a greater degree than other mammals.⁶ The amount of water consumed is affected by salt intake, condition of

kidneys, age, and dry matter consumed.⁴ It was found that cats consume less water in relationship to dry matter on dry foods than on canned foods.⁴ Therefore, urine volume is also less. Water intake is not only an important consideration in FUS, but also in renal failure, and sulfonamide administration.⁴

Commercial dry cat foods have been considered a possible cause of FUS. They are higher in vegetable ingredients than most other types of foods and therefore, lead to a more neutral and even slightly alkaline urine. Dry cat foods have a similar magnesium level on a dry matter basis as canned foods but their lower caloric density requires a greater intake to meet energy needs. It was also mentioned that cats seem to consume less free water to dry matter on a dry food diet than a canned diet. Some researchers also believe that since dry foods tend to be higher in fiber more water is excreted in feces and therefore, less through formation of urine.⁶ These factors would lead one to suspect that cats on a dry food diet would have an increased incidence of FUS. Many studies do support this view.^{4,6,7} One study done with specific pathogen free cats on dry food diets did not find any association between a dry food diet and increased incidence of FUS.²⁰ Noteworthy in this study was the fact that cats were kept on a dry diet for only 4.5 months and then euthanized.

In summary, FUS seems to have a multifactorial etiology.²¹ Factors of urinary pH, urine mineral concentration, and length of time urine remains in the bladder are known to affect calculi formation. Since dietary changes can alter these factors and possibly lead to a decreased incidence and recurrence of FUS concentrating on nutritional management may be a good path to follow until further research is available. More study is needed using prospective clinical trials to assess the effect of diet alterations on FUS.

Renal Failure

Nutritional management is a very important part of managing renal failure. Proper dietary alterations can slow the progression of renal disease and decrease signs of uremia. The goal of dietary management should be to reduce the end-products of protein metabolism which are eliminated by the kidneys, such things as protein metabolites and phosphorus. Some suggest that in renal failure less than 25% of the calories in the diet should be from protein.⁴ Another source says protein should be adequate in amount to meet requirements but

reduced so as to maintain a blood urea nitrogen of less than 60 mg/dl.⁶ Reduced protein is recommended in patients showing clinical signs of uremia that are azotemic, hyperphosphatemic, and in moderate to severe renal failure.⁶ In patients not showing signs of uremia a low protein diet is controversial. Many sources recommend restricting dietary protein in all animals with reduced renal function regardless of the severity. Higher protein diets have been shown to increase glomerular filtration rate and renal blood flow which may be harmful and lead to further renal damage. Restricting protein in the diet not only reduces the wastes of protein metabolism, but may reduce progression of renal failure.⁶ A restricted protein diet also decreased dietary phosphorus and therefore, may decrease the risk of hyperparathyroidism and osteodystrophy. As chronic renal failure develops the kidney loses the ability to excrete phosphorus which leads to a high serum phosphorus level. As a result serum parathormone levels increase which may cause further damage to the renal tubules. To prevent the use of the body's own proteins for energy, make sure the animal is consuming sufficient calories in the diet. Feeding small meals several times a day instead of a single large meal may also help reduce catabolism of body protein. Make sure that plenty of drinking water is always available. If severe, proteinurea is present and the animal has hypoalbuminemia, it may be necessary to supplement each four ounces of food with one egg or two tablespoons of cottage cheese.⁴ If polyuria exists there may be excessive loss of B-vitamins in the urine so diets formulated for use in renal failure patients frequently are supplemented with B-vitamins. Proper dietary management in renal failure may slow progression of the disease and reduce uremic signs.

Hepatic Disease

The aims of dietary management in hepatic disease are to restore liver glycogen and reduce the workload on the liver.⁴ Energy provided in the form of starch or simple sugars is tolerated well. The liver helps in the metabolism of the wastes of protein breakdown, therefore, protein in the diet should be at a moderate level so the demands on the liver will be lessened. If the protein intake is too high in an animal with hepatic failure, encephalopathy may occur.⁶ Proteins in the diet should be of high biologic value such as eggs and liver. Insure that the diet provides adequate calories so that the body does not utilize body fat

and protein stores for energy. If bile salt excretion is impaired there is a decreased ability to use fats so restrict fats in the diet to less than 1.5%.⁴

Avoid use of medium chained triglycerides in hepatic failure since they are mainly metabolized in the liver. Certain fatty acids may also induce encephalopathy if the diseased liver cannot metabolize them.⁶ Ascites which occurs in liver failure may be due to portal hypertension which results in loss of vascular fluid and activation of the renin-aldosterone system.⁶ In this case, the ascites is not a result of hypoalbuminemia. Therefore, if ascites is present, a low sodium diet may be recommended. These measures will decrease the stress placed on a poorly functioning liver and help relieve some of the clinical signs of liver failure which may be present.

Anorexia

Infection, nutritional deficiencies, metabolic disorders and trauma frequently lead to anorexia in cats. If prolonged, anorexia may lead to hepatic lipidosis and jaundice.⁶ The aim is to maintain an intake of protein and energy to meet the needs of the body and to prevent the development of a fatty liver. The safest and easiest way to feed an animal is via the gastrointestinal tract. Feeding through the gut is less likely to lead to a fatty liver and increased production of secretory IgA improves resistance to infection.⁶ So if the gut is functional use it as the means of nutrient intake whenever possible. Appetite stimulation, force feeding and tube feeding are methods that can be used. If the gut is nonfunctional parenteral means must be used instead. To stimulate appetite warming the food enhances aroma and may help in encouraging the cat to eat. If nostrils are plugged, clean them. Being able to smell the food is very important in appetite stimulation. Providing a very palatable diet that is the same as the one provided in the animal's home environment may help. Force feeding may be used if it does not result in a high level of stress. It may work in a debilitated animal if done gently and with patience and reassurance. Cats that are stronger will usually fight this procedure. Tube feeding may be recommended since it is faster and less stressful than force feeding. Blend one-half can of a formulated, high energy diet and $\frac{3}{4}$ cup water together then strain the mixture through a kitchen strainer.⁶ Administer enough of the mixture to meet the cat's energy needs in two to three feedings per day. Another method which is occasionally used on a very temporary basis is to administer diazepam.

Most cats who are physically able to eat will when given 0.1-0.5 mg diazepam intravenously. Have food available at the time of injection. Then 1-2 mg is given orally to maintain appetite. This should not be used for more than two days. Anorexia is a very challenging problem but recognize that lack of nutrient intake of even a few days adversely affects the entire body. The body's ability to fight the disease or heal the trauma is lessened when nutrients are absent.

Obesity

Obesity is a problem in cats as it is in many other domestic species. Obese cats are frequently on a diet of gourmet canned foods and may refuse to eat other types of commercial foods. The owner may be supplementing the canned food with high caloric table scraps, and may be unaware that a problem even exists. Initially a good history must be taken including a good diet history of types of food eaten, amounts, and intervals of feeding. A complete physical exam should be done to rule out health problems. Since talking about obesity, even when it concerns a family pet, can be a very sensitive issue try and develop a rapport with the client. Explain that the incidence of certain diseases is increased in obese individuals. Since the success of the animal achieving its optimal body weight depends mainly on the efforts of the client, make sure the client is a part of the decision making. Determine an optimal body weight for the animal and estimate the time required to safely attain that weight. With the client set realistic short term goals, such as the goal for weight loss after one week. It is considered safe for a cat to lose about one-half pound the first week and about three pounds over twelve weeks.⁴ Initially try a diet which is 20-30% lower in calories than the previous diet.⁶ If this results in no weight loss or a minimal loss then change to a diet providing 65-70% of required calories to maintain a cat at its optimal body weight (about 35 calories/pound of optimal body weight/day).⁴ to lose one pound of body fat caloric intake must be decreased by 3500 kcal. A diet high in fiber and low in fat is recommended for weight loss, generally less than 10% fat (on dry basis) and greater than 15% fiber.⁶ It may be necessary to gradually introduce the new diet. With lots of client encouragement, patience and teaching the goal of weight loss can be achieved.

*Table composed by the National Research Council.

Table 1
Minimum Requirements for Growing Kittens
(units per kg of diet, dry basis)^a

Nutrient	Unit	Amount
Fat ^b		
Linoleic acid	g	5
Arachidonic acid	mg	200
Protein ^c (N x 6.25)	g	240
Arginine	g	10
Histidine	g	3
Isoleucine	g	5
Leucine	g	12
Lysine	g	8
Methionine plus cystine (total sulfur amino acids)	g	7.5
Methionine	g	4
Phenylalanine plus tyrosine	g	8.5
Phenylalanine	g	4
Taurine	mg	400
Threonine	g	7
Tryptophan	g	1.5
Valine	g	6
Minerals		
Calcium	g	8
Phosphorus	g	6
Magnesium	mg	400
Potassium ^d	g	4
Sodium	mg	500
Chloride	g	1.9
Iron	mg	80
Copper	mg	5
Iodine	ug	350
Zinc	mg	50
Manganese	mg	5
Selenium	ug	100
Vitamins		
Vitamin A (retinol)	mg	1
Vitamin D (Cholecalciferol)	ug	12.5
Vitamin E ^e (- tocopherol)	mg	30
Vitamin K ^f (phyloquinone)	ug	100
Thiamin	mg	5
Riboflavin	mg	4
Vitamin B ₆ (pyridoxine)	mg	4
Niacin	mg	40
Pantothenic acid	mg	5
Folacin (folic acid ^f)	ug	800
Biotin ^f	ug	70
Vitamin B ₁₂ (cyanocobalamin)	ug	20
Choline ^g	g	2.4
Myo-inositol ^h	-	-

^aBased on a diet with an ME concentration of 5.0 kcal/g dry matter fed to 10-to-20-week-old kittens. If dietary energy density is greater or lesser, it is assumed that these requirements should be increased or decreased proportionately. Nutrient requirement levels have been selected based on the most appropriate optimal response (i.e., growth, nitrogen retention, metabolite concentration or excretion, lack of abnormal clinical signs, etc.) of kittens fed a purified diet. Some of these requirements are known adequate amounts rather than minimum requirements. Since diet processing (such as extruding or retorting) may destroy or impair the availability of some nutrients, and since some nutrients, especially the trace minerals, are less available from some natural feedstuffs than from purified diets, increased

amounts of these nutrients should be included to ensure that the minimum requirements are met. The minimum requirements presented in this table assume availabilities similar to those present in purified diets.

^bNo requirement for fat is known apart from the need for essential fatty acids and as a carrier of fat-soluble vitamins. Some fat normally enhances the palatability of the diet.

^cAssuming that all the minimum essential amino acid requirements are met.

^dThe minimum potassium requirement increases with protein intake.

^eThis minimum should be adequate for a moderate to low-fat diet. It may be expected to increase three-to four-fold with a high PUFA diet, especially when fish oil is present.

^fThese vitamins may not be required in the diet unless antimicrobial agents or antivitamin compounds are present in the diet.

^gCholine is not essential in the diet but if this quantity of choline is not present the methionine requirement should be increased to provide the same quantity of methyl groups.

^hA dietary requirement for myo-inositol has not been demonstrated for the cat. However, almost all published studies in which purified diets have been used have included myo-inositol at 150 to 200 mg/kg diet and no studies have tested a myo-inositol-free diet.

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