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Sixth Annual Dr. Scholl Nutrition Conference - 1986

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Sixth Annual Dr. Scholl Conference
on the Nutrition of Captive Wild Animals

HAZARDS ASSOCIATED WITH FOOD PREPARATION AND STORAGE

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Food infections and intoxications, commonly referred to as food poisonings, have been a silent epidemic that has affected the zoo community as long as animal foods have been prepared. While food poisoning has been well documented in the human food industry throughout this century, it has only been in the past few years that the same diseases have been documented in zoos.

Food poisoning takes place when both raw and cooked foods are handled improperly. Foods exposed to harmful bacteria rarely produce either odor, color, or off flavor. Contaminated foods do not appear to be spoiled. In the past it was assumed these bacteria caused illness only in humans, but over the years these diseases have been identified in reptiles, pinnipeds, birds, hoofstock, as well as primates.

The symptoms of food poisoning vary from mild diarrhea to paralysis and death. Many of these diseases exhibit the same symptoms, and it can be difficult to identify them without proper culturing techniques. The bacteria causing food poisoning are divided into two categories: food infections and food intoxications.

FOOD INFECTIONS

Food-borne infections are illnesses caused by the ingestion of various bacteria. Salmonella, Shigella, Escherichia coli, Streptococcus, and Bacillus cereus are just a few. Symptoms of food infections often involve mild to severe gastroenteritis. Food infections are rarely fatal in healthy adults; however, consequences can be severe for weakened individuals and infants. Identified world-wide in a variety of hosts, the following descriptions highlight a few of the most prevalent diseases.

Salmonella

Salmonellosis is probably the most familiar food infection to zoo personnel. Salmonellae are gut-borne organisms with a wide range of hosts. Infections result from the ingestion of live bacteria and can persist for years allowing the infected individual to act as a carrier for the disease. Symptoms include nausea, vomiting, diarrhea, and low grade fever. Most zoos recognize salmonella as a problem, particularly in nursery areas. Zookeepers must keep in mind that humans act as carriers of the disease.

Campylobacter

Campylobacter jejuni is a bacteria which requires a special culturing technique in order to be isolated. The symptoms of this disease closely resemble salmonellosis.

Campylobacter has been isolated in a number of zoo animals including lowland gorillas, cheetahs, red pandas, flamingos, and crocodiles. Healthy adult Rhesus monkeys have been experimentally infected with a human strain of Campylobacter resulting in several days of mild illness. It has been estimated that up to twenty percent of the human population with symptoms of diarrhea carry this bacteria.

B. cereus

B. Cereus is found on raw rice. The spores of B. cereus can survive several hours in boiling water then germinate when the cooked rice is left at room temperature. Symptoms of this infection include nausea, diarrhea, and vomiting within two to fifteen hours of ingesting the bacteria. Cooked rice is common in many zoo diets since it is considered a safe food.

FOOD INTOXICATIONS

Food intoxications are diseases caused by the ingestion of toxins produced by bacteria, molds, plants, and insects. While plants and insects can be seen easily, toxic molds and bacteria are often undetected. Bacterial intoxications occur less frequently than infections but the symptoms are often more severe and result in severe gastroenteritis, paralysis and often death.

Botulism

Botulism is the disease caused by the ingestion of an enteroxin produced by the bacteria Clostridium botulinum. The symptoms include dizziness, blurred vision, paralysis, and death. C. botulinum is an anaerobic organism. Since it can grow only where there is no oxygen present, C. botulinum is found most often in stagnant pools and improperly prepared canned foods.

Staphylococcus

Staphylococcus aureaus is a salt tolerant organism often found on human skin. When transmitted to foods S. aureaus produces an enteroxin. Symptoms include sudden onset of salivation, nausea, abdominal cramps, diarrhea, vomiting and prostration.

Perfringens

Clostridium perfringens is bacteria which can grow with or without oxygen. Under anaerobic conditions the bacteria produces an enteroxin with symptoms similar to S. aureus. One documented case in Europe involved three African elephants that died when several abnormal factors contributed to an anaerobic condition of the rumen.

Most of these diseases can be transmitted from man to animal and back again. Perhaps many undiagnosed illnesses and deaths among zoo animals could be attributed to one of these diseases. As prevalent as these bacteria are, illnesses can be prevented through proper food management.

DISEASE PREVENTION

In order to control food-borne bacterial disease, management has two concerns: food storage and personal hygiene.

It is important to refrigerate cooked foods as quickly as possible. Cooked foods should also be handled as little as possible in order to prevent cross contamination. Meats should be kept at forty degrees Fahrenheit. Many bacteria will not grow as rapidly at that temperature. While freezing prevents bacterial growth, it does not kill the organisms and growth will resume when the food reaches room temperature. All foods should be kept in covered containers, and pests such as mice, roaches, and ants eliminated since they can transmit bacterial diseases.

Zoo personnel can be one of the greatest sources of food contamination. A bacterial infection causing minor intestinal distress for a keeper can be devastating to an infant, both animal and human.

In order to prevent contamination, ill employees must not be allowed to prepare foods or handle neonates. All employees should have cultures taken routinely to identify carriers. More simple measures include washing hands when leaving the restroom, washing hands between tasks, covering all cuts and abrasions to prevent cross contamination, and not allowing employees to smoke while preparing food.

Many common practices of the food and restaurant trade are applicable to food preparation in commissaries. More complete information on the prevention of food contamination can be obtained from a local USDA office or county extension service.

In addition useful references on food infection and intoxications include books by Riemann (1979) and Schnurrenberger and Hubbart (1981).

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FOOD-BORNE BACTERIAL DISEASE CAUSED BY UNCOOKED HORSEMEAT PRODUCTS

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During outbreaks of gastrointestinal disease or sudden death in a group of captive animals, there is a tendency to place the blame on "contaminated" food as the cause of the disease problems, yet proof of this contamination hypothesis is usually lacking. Only through a careful and systematic investigation of the problem can the food-borne link be proven. Samples of blood, feces, and vomitus from sick animals should be cultured for pathogenic bacteria. Portions of these samples should be be cultured for pathogenic bacteria. Portions of these samples should be labelled carefully and kept frozen so that they can later be screened for any suspected toxins. Thorough necropsies should be performed on any dead animals and specimens described previously taken for bacterial and toxicological studies. Samples of liver and kidney should also be taken from dead animals in suspected cases of toxicity. Most importantly, in order to prove that the food is the source of the disease, samples of the diet must be cultured and/or screened for toxins. Ideally, these samples are leftover food from the animals; food pans; if all food has been eaten, the same batch (or batches) of food that the animals were fed should be sampled. Sampling techniques and procedures are well described by Bryan (1985).

Any uncooked meat or meat by-product could potentially be the source of a large variety of bacterial infections and/or intoxications. This is especially true if the product has been handled improperly during processing. The focus of this paper is to discuss food-borne bacterial infections caused by two genera of bacteria that are commonly associated with horses--*Salmonella* and *Streptococcus*.

Salmonella

Salmonellae are gram-negative, rod-shaped bacteria that can colonize the intestinal tract of a wide variety of amphibians, reptiles, birds, and mammals--including man. The disease produced by these bacteria, salmonellosis, is usually characterized by a severe diarrhea that can be fatal. Under certain conditions, the organism can spread throughout the body, causing death before the onset of gastrointestinal signs.

Animals can also be carriers of *Salmonella*, without showing any signs of illness. Contamination of food by even microscopic amounts of feces from animals with salmonellosis or from carrier animals can result in the spread of

Salmonella.

Outbreaks of salmonellosis in zoos have been reported, especially among captive felids, and in many cases have been traced to the practice of feeding whole carcasses of dead animals, particularly poultry (Wallach and Boever, 1983). Horses can contract Salmonella infections and carry the bacteria; thus the potential for Salmonella-contamination of horsemeat products exists. Although uncooked horsemeat has been incriminated as a source of salmonellosis in domestic dogs (Rokey, 1986), I cannot find any reports of salmonellosis in zoo animals specifically linked to ingestion of horsemeat products. With proper processing and food-handling, the danger of transmitting Salmonella via horsemeat is probably minimal.

Streptococcus

Species in the genus Streptococcus are small, round gram-positive bacteria that tend to grow in pairs or chains of organisms. These bacteria colonize the skin and mucous membranes of many animals. Streptococci can be considered "parasites" since most species require animal-derived products for growth and are rarely found free in the environment (Gillespie and Timoney, 1981). These organisms are often relatively harmless and can be cultured from normal, healthy animals. However, under the proper conditions, some species of Strep. are definitely pathogenic and cause disease ranging from localized infections (e.g. mastitis) to generalized infection and death.

Streptococci can be identified to genus level by their size, shape, gram-positivity, and growth properties. They can be further characterized by the pattern of hemolysis (i.e., no hemolysis, alpha-hemolysis, or beta-hemolysis) they produce when growing on blood agar (Facklan and Carey, 1985). Since many streptococci are considered part of the normal bacterial flora of many animals, it is important to realize when an isolate from a sick (or dead) animal is significant. The policy we generally use at the National Zoo is that streptoccoci are significant when they are isolated as a pure culture and/or when they are beta-hemolytic.

From a practical standpoint, species identification of a Strep. is not necessary since streptococci are sensitive to many of the commonly used antibiotics, thus making streptococcal infections relatively easy to treat. However, for epidemiological purposes, significant isolates of Strep. should be speciated when possible. The next step in characterization of a Strep. is to determine to which Lancefield group the organisms belong, followed by species identification (Facklan and Carey, 1985). This requires special reagents and can be done at most large human hospitals and diagnostic laboratories.

There are four species of beta-hemolytic, Lancefield Group C streptococci (Facklan and Carey, 1985), three of which (Strep. equi, S. equisimilis, S. zooepidemicus) are commonly found growing on horses and therefore might be found in horsemeat products. Streptococcus equi is the causative agent of "equine strangles"--a respiratory and lymphatic infection of horses and other equids. This organism is highly adapted to the equid and rarely causes disease in other animals (Facklan and Carey, 1985, Gillespie and Timoney, 1981).

Strep equisimilis most commonly occurs in the reproductive tract of horses, but rarely causes disease problems in this species. It is also found in swine, where it can be a significant pathogen (Facklan and Carey, 1985, Gillespie and Timoney, 1981). Reports of infections in other animals are rare.

Strep zooepidemicus often grows in high numbers on the skin, oral cavity, and respiratory tract of equids. It is also widespread in other animals. This organism commonly infects wounds of horses and has caused septicemia in a variety of animals including horses, cattle, sheep, foxes, guinea pigs, and chickens (Facklan and Carey, 1985, Gillespie and Timoney, 1981). At the National Zoo, fatal septicemia caused by Strep zooepidemicus has been reported in brindled bandicoots (Isodon macrourus), a tree shrew (Tupaia glis) and an elephant shrew (Elephantulus rufescens) (Snow et al., 1984). All of these animals were fed a diet containing a commercially-available, uncooked horsemeat product. A summary of these cases follows.

In 1982, three brindled bandicoots were hand-raised at the National Zoo following the death of their dam. After weaning, these animals were separated and their diet was changed to that being given to adult bandicoots (which included uncooked horsemeat products) (Oftedal, pers. comm.). Shortly thereafter, one of the young bandicoots was found dead in its cage with bloody fluid emanating from its nose and mouth. On necropsy, many of its organs were edematous and bloody fluid was present in the lungs and thoracic cavity--findings suggestive of septicemia. Three days later, the second young bandicoot was found dead with similar post-mortem findings. Blood cultures from both bandicoots grew a beta-hemolytic Streptococcus which was sent out for speciation. Ten days after the second bandicoot died, the third juvenile bandicoot was found dead and again blood cultures resulted in a pure growth of beta-hemolytic streptococci. An unrelated adult bandicoot cagemate of the third juvenile died three days later after showing signs of lameness (from bite wounds); blood cultures were identical to the others. Microscopic examinations of tissues from all four bandicoots often revealed large numbers of streptococci within blood vessels throughout their bodies. When laboratory results identified the organism in each case as Strep. zooepidemicus, uncooked horsemeat from the same batch that was fed to the bandicoots was cultured and provided a very heavy growth of this organism. The diets of all remaining bandicoots were altered so that the horsemeat product was cooked and no further disease problems caused by Strep. zooepidemicus were encountered in this species.

In December 1982, an adult male tree shrew was found dead following 2 days of aggressive behavior towards it by its female cagemate. Gross necropsy findings on this animal were unremarkable, however, microscopic examination revealed a septicemia caused by gram-positive cocci. Blood cultures taken at necropsy and cultures of the horsemeat diet both resulted in a heavy growth of Strep. zooepidemicus in high numbers.

In April, 1983, an old male elephant shrew was found dead with no previous signs of illness. Gross and microscopic findings were similar to those described for the bandicoots. Blood and food cultures again grew Strep. zooepidemicus.

A review of more than 3,400 bacterial cultures performed at the National Zoo during the 5-year period 1982-86 revealed five other animals with lesions from which Group C, beta-hemolytic streptococci were isolated. All of these animals received uncooked horsemeat products as part of their diet. Strep. zooepidemicus was grown in pure culture from a subcutaneous abscess in a dwarf mongoose (Helogale parvula). Strep. equisimilus was cultured from an infected bite wound in a meerkat (Suricata suricatta). Strep. zooepidemicus was one of several bacteria isolated from the nasal cavity of a clouded leopard (Neofelis nebulosa) with a chronic sinus infection. A non-speciated Group C Strep was among the bacterial species cultured from a maned wolf (Chrysocyon brachyurus) with a uterine infection. In none of these 4 cases did the animal die as a result of the Strep. infection, however, in December 1986, Strep. zooepidemicus was isolated in pure culture from a dead, aged elephant shrew with lesions as described previously in this species.

Conclusion

In the cases described above, there are several factors which played a role in the establishment and severity of the streptococcal infections. All fatal infections occurred in either marsupials (i.e. bandicoots) or insectivores (tree shrew, elephant shrews), whereas localized infections occurred in carnivores. In their native habitats, the insectivores and marsupials would rarely, if ever, consume raw horsemeat and probably would not encounter high numbers of Strep. zooepidemicus. However, the carnivores are much more likely to be naturally exposed to this bacteria and thus perhaps their immune systems are better evolved to handle streptococci.

Infectious diseases are much more common in those animals with impaired or incompetent immunity such as the weak, the very old, the very young, or highly stressed animals. Both elephant shrews that died were old animals. The tree shrew and the adult bandicoot were stressed due to intra-specific aggression from cagemates. The juvenile bandicoots were relatively young and died during a highly stressful period of dietary change, separation from each other, and introduction to new animals.

The number of bacteria that an animal encounters in a food source is also a critical factor in determination of pathogenicity. As previously stated, high numbers of _Strep. zooepidemicus_ were cultured from the uncooked horsemeat on several occasions. Bacterial growth in meat is greatly influenced by food-handling techniques. Meat that is thawed at room temperature will have higher numbers of bacteria than if thawed within a refrigerator. Food that is eaten shortly after thawing contains much fewer bacteria than if it is allowed to sit several hours before consumption.

To minimize the dangers of bacterial disease transmission within meat diets, several steps can be taken. Good food handling procedures, including proper thawing techniques and thorough cleaning of food pans and preparation facilities, should be practiced. For animals that do not normally consume large amounts of raw meat, alternate protein sources or cooking of the meat would be beneficial. Minimizing stress for an animal will enhance its ability to resist all types of infectious diseases.

Diagnosing (and proving) cases of food-borne bacterial disease requires a complete investigative process. As the above cases illustrate, these diseases can be significant causes of illness and death in zoo animals. Fatal Group C _Strep_. infections in owl monkeys (_Aotus trivirgatus_) that received uncooked horsemeat at the Lincoln Park Zoo (Meehan, pers. comm.) demonstrate that these diseases are not unique to the National Zoo and may be more widespread than we realize.

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FILLING THE KNOWLEDGE GAP IN ZOO ANIMAL NUTRITION

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As nutritionists attempt to develop rational dietary programs for zoo animals, it becomes immediately apparent that the scope of our knowledge is dwarfed by a large degree of uncertainty. Not that rational diets can't be devised - they can. But considerable reliance must be placed on indirectly obtained information rather than on research with wild animals themselves. Many zoo animals are endangered, few representatives exist in either the wild or captivity, and it may never be possible to conduct research with certain target species. However, less endangered relatives are frequently available in sufficient numbers to justify studies that can improve the lives of both the study subjects and of related species.

Research in zoos is anathema to some who aren't familiar with scientific inquiry and who equate research with animal suffering. Zoo research should not and need not cause animals to suffer. Studies with wild animals should be conducted according to written protocols, reviewed and approved by individuals with oversight responsibility. But zoo research should be done. The frequency with which dietary problems are identified in necropsy reports makes such studies imperative.

An example of research that didn't involve animals at all but resulted in findings of great importance to captive primates began with identification of rickets in nursing young. These young primates were kept in an enclosed building with glass windows. They were totally dependent on their mother's milk for food, and it appeared that the vitamin D concentration in that milk was very low, despite oral vitamin D intakes by the lactating mothers. Baby primates of this species are exposed to sunlight in their wild ecosystem, but in captivity, behind glass, the solar ultraviolet wavelengths that result in cutaneous photobiogenesis of vitamin D did not reach them.

The research that corrected this problem involved a search for a plastic that would permit passage of the essential ultraviolet rays and still be strong enough to serve as a window or a skylight. Sample plastics were placed in a UV/VIS spectrophotometer and their transmission spectra determined. A plastic that demonstrated high transmissability in the 285-315 nm range was exposed to direct sunlight and weathering for 2 years and then retested. This plastic proved suitable as skylight material, retained its original transmission characteristics to a high degree, and permitted cutaneous photobiogenesis of vitamin D in animals confined indoors. As a consequence, the animal suffering that was seen prior to initiation of the research could be prevented and should not reoccur.

Many other important studies could be conducted in zoos without causing significant animal discomfort. Assessments of diet digestibility and determinations of vitamin status using blood assay techniques are two examples. Considering the need for information, the willingness of most university laboratories to cooperate, and the potential improvements in zoo animal welfare, all responsible zoos should encourage and support research for the benefit of their animal collections.

SPECIFICATIONS FOR FEEDS USED IN ZOO ANIMAL DIETS

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INTRODUCTION

As the feeding of zoo animals becomes more scientific and more objective, some of the techniques and methods used in formulating feeds for lab animals, pets and livestock can be applied to zoo animal diets. The purpose of this paper is to acquaint the reader with types of feed formulations and their applicability to zoo animal diets. The appendix contains two examples of formulations; Appendix A is an example of an open formula herbivore diet and Appendix B is an example of a closed formula primate diet. These diets have been used at the National Zoo since 1984. They are given as examples only and, for many reasons, may not represent appropriate formulations for feeding programs in other zoos.

ADVANTAGES AND DISADVANTAGES OF COMPETITIVE BIDDING

A contract award system involving competitive bidding is a common method for the purchasing of feeds. One advantage is that objective criteria are specified. Feeds are purchased under contract according to certain ingredient or nutrient specifications. This means that a shipment of feed can be rejected if the specifications are not satisfied. Under the worst circumstances, such specifications also protect the rights of the purchaser, should legal recourse be required to settle differences. Feeds are more likely to be uniform and consistent if feed specification criteria are carefully written than if specifications are vague or non-existent.

This system was also designed to avoid favoritism in the award process. Some zoo feed contracts involve hundreds of thousands of dollars. A competitive, lowest bid system helps assure impartiality in the award of contracts to individuals or companies. The system also helps the zoo to avoid high food costs. Expenses and profit margins must be carefully calculated by the feed supplier so that the bid submitted actually reflects a reasonable estimate. Bidding is competitive and companies are therefore less likely to inflate estimated costs of production and shipping, since each wishes to secure the contract.

A main disadvantage in this system of feed purchasing relates to the necessity of developing objective criteria. If you don't know or can't specify what you need, you probably won't get what you want. Writing specifications requires knowledge of nutrition, feeds, feed manufacturing and feed distribution. Most zoos don't have anyone on staff who is knowledgeable in these areas. Professional nutritionists in industry, in academia or in other zoos may be able to assist zoo staff in writing feed specifications. In some cases, nutritionists in feed companies will assist in developing specifications. However, this is likely only when the company has a high probability of being awarded the contract.

The main disadvantage of the system, however, relates to the difficulty in rewarding favorites. Good working relationships between zoo staff and feed manufacturers can be mutually beneficial. It is to the advantage of the zoo to deal with companies that provide good service and have responsive employees, yet the contract award system has no simple mechanism to reward such service. A supplier who consistently provides good quality fish or hay and who acts responsively if quality is questioned is an asset to a zoo commissary manager. Such relationships are rare and difficult to establish, yet they can be of great benefit in terms of food quality and consistency. In the case of manufactured feeds, company representatives may invest considerable time and effort in helping to develop feeds, yet that company may not be awarded the contract in subsequent years, even though expertise was contributed in initial product development.

In some instances, certain manufacturers can be excluded from bidding if justification for the exclusion is warranted. Justification could include a lack of response to complaints, late delivery of feeds or provision of feeds that do not meet specifications.

Feed specifications must be written in such a way to assure that feeds of inconsistent or inferior quality are not supplied. Amounts and types of feed ingredients that make up a formulated feed can be specified exactly (see Open Formula Feeds). If specifications are written too vaguely, the manufacturer may make substitutions in order to reduce manufacturing costs. For some feeds, ingredient substitutions may be acceptable, but should only be made with the knowledge of the zoo staff. For example, some substitutions may be necessary in response to scarcity or exorbitant cost of specific ingredients, due to poor growing conditions. Substitution of ingredients, such as including corn gluten meal instead of soybean meal, or animal fat instead of vegetable oil, may change the color, flavor or texture of a feed. This may lead to feed refusals with negative consequences for animal performance, behavior and management.

In some zoos, specifications have been written to justify using certain products. For example, information about a product may be taken from the label or from company-furnished information. Specifications can then be written so narrowly that other manufacturers are unable to bid. Zoo staff may feel this is a good way to assure consistency in feeds, by restricting the "bidding"to one company, but it is not legitimate since it defeats the purpose of the bid system.

DIET FORMULATION

Development of Nutrient, Ingredient and Quality Standards

The impetus for writing feed specifications may be a desire to improve the feeds used in zoo animal diets. For a variety of reasons, many commercially available dairy, beef, swine, poultry and horse diets are not suitable for use in zoo animal diets. The purchaser usually can obtain very limited information about the ingredients and nutrient levels in such diets. The limited information on feed tags and labels is usually insufficient to allow decisions about product adequacy, especially with regard to ingredient composition and micronutrient concentrations.

The nutrient levels specified in domestic animal diets are based upon known or estimated nutrient requirements. By contrast, the nutrient requirements of zoo animals are not well established. A nutritionist must therefore make assumptions and judgments about appropriate nutrient concentrations to include in feed formulations. Nutrient standards should be based on knowledge of animals' natural feeding habits and food selection in the wild, on gastrointestinal tract anatomy and physiology, and on desired performance objectives such as growth, lactation or maintenance. For example, a nutritionist may set minimum standards for protein, calcium, and phosphorus and maximum standards for iron, copper and sodium. It is not uncommon to specify that unusually high concentrations of some vitamins be included since some vitamins are labile. A level of 2,000 ppm of vitamin C in a dry primate diet may seem excessive, but since vitamin C may be destroyed under typical storage conditions, high levels of this nutrient should be included at the time of manufacture. A feed manufacturer must agree, if awarded the contract, that the product will comply with these standards.

Specifications may include the types of feed ingredients, such as alfalfa meal, soybean hulls and corn grain, as well as types of vitamin, mineral or amino acid supplements. A list of acceptable feed ingredients from which the diet can be made may be provided to the manufacturer. The quality of the ingredients may also be specified. For example, if soybean meal is to be used in the production of a pelleted feed, the manufacturer can be restricted to using soybean meal with a 48% protein content. The specifications may also state that contamination of the feed ingredients with foreign material (other grains, chaff or weed seeds) will be restricted to 2 to 3%, and that contamination due to mold, insect or rodent infestation will not be permitted.

The form of manufactured product, such as pellet, extruded biscuit or semi-moist cake, must also be included in the specifications. The physical dimensions of the product, such as the size of pellet or kibble, can also be specified. In addition, it is usually common to require the manufacturer to date the bag or feed shipment and provide some identification as to lot or production number. This information is important in establishing product shelf life and in tracking information about a product should a problem arise.

<u>Closed Formula Diets</u>

A closed formula diet is one in which the formula is 'closed' to the public, i.e. it is maintained as a trade secret by the manufacturer. The actual ingredient composition of the diet is not provided to the purchaser. Such formulations are developed by manufacturers to meet certain standards, established by animal nutritionists, but the actual quantities and ratios of ingredients used are not released. The specifications for closed formula products may state the exact quantities (or minimum/maximum levels) of some or many nutrients, but the way in which the manufacturer meets these nutrient standards is not predetermined. In such cases a list of acceptable feed ingredients may be specified by the purchaser. The producer may then select from among the listed ingredients in formulating the product. In practice, seasonal or regional restrictions on the availability of ingredients may restrict the manufacturer to a subset of the listed ingredients.

The evaluation of zoo animal diets requires knowledge of the characteristics of all feed items that are included in the diets. When commercial, closed formula products are included in zoo animal diets, there are usually many unknown nutrient values since specific concentrations of most nutrients will be unavailable. Detailed information concerning product specifications is considered to be proprietary by most companies. Such a policy is understandable because feed companies must compete for a share of the market. Revealing 'secret formulations' may mean giving away information that could ultimately end up in a competitor's feed mill. Some manufacturers may reveal information on a specific nutrient or ingredient in response to justifiable health concerns, but will rarely make available lists of all vitamins or minerals. Feed companies that handle small orders or that will make special order custom feeds are usually more willing to provide information on closed formula diets, although this varies considerably among companies.

One way to evaluate closed formula products is to have nutrient levels analyzed in a university or commercial laboratory. A quality control program can be established in which closed formula (and open formula) feeds are routinely screened for specific nutrients. However this is apt to be expensive ($40 to $60 per sample for proximate analysis, fiber fractions and some minerals; $60 to $120 per sample for some vitamins). Laboratory analysis of feeds on a routine basis will increase costs in the short term but is justified as an insurance against inadvertent use of products that do not contain appropriate or expected nutrient concentrations.

<u>Open Formula Diets</u>

An open formula diet is one in which the particular ingredients and ingredient amounts are specified, i.e. the formula is not a trade secret. Nutrient concentrations (or minimum/maximum values) are usually specified as well. Ingredient quality and amounts of acceptable foreign material are also of concern in open formula specifications.

Open formula diets are typically more expensive than closed formula diets since the manufacturer is not allowed to adjust freely the types or amounts of ingredients based on price or availability. However, there are usually minimal advertising or promotional costs for the manufacturer. Occasionally specifications are written to allow a limited number of substitutions, mainly to keep costs down. In open formula diets a nutritionist will usually include specifications for vitamin and mineral premixes to be certain that the product conforms to nutrient standards. The use of custom premixes may also add to costs. Periodic laboratory analysis of open formula feeds is important to verify that feeds contain the specified nutrient concentrations.

Knowledge of price and availability of feed ingredients and of various aspects of the milling process is essential for the successful formulation of open formula feeds. The production costs of such diets may become excessive if the specifications are unrealistic. For example, locally available feed ingredients should be used whenever possible to avoid high transportation costs associated with shipping ingredients over long distances. A formulation that may be inexpensive for a zoo in Illinois may be prohibitive for a zoo in Florida, due to the feed ingredients used for manufacture. It is also important to take into account the pelleting or extruding properties of feed ingredients. A successful product must have appropriate physical characteristics (e.g. pellet size and hardness), must withstand shipping and must be palatable to the animals to be fed.

Among the benefits of open formula diets are product consistency from batch to batch, known levels of individual ingredients, and clearly specified nutrient additions and/or nutrient concentrations. Even if the contract for a specific feed is awarded to a different manufacturer, product composition and consistency should not differ greatly. Another advantage is that modifications to the formulation can be made easily if a nutritionist believes that specific ingredients or nutrient amounts should be raised or lowered.

In general, open formula diets are cost effective when large quantities can be ordered, such as in zoos with large ungulate or bird collections. Most large feed mills are equipped to run batches of 2 tons or more at a time, and some require even larger orders. It is therefore impractical or impossible to have small batches of custom diets manufactured on a regular basis. Specifications can be written for feeds used in small amounts but for practical reasons these are usually of a closed formula type.Some specialty feed manufacturers have the capability and are willing to run small batches of custom (open formula) feeds (500 lbs. or less), but production costs are usually very high per pound of feed, such that the products become expensive.

CONCLUSION

There are many instances where commercially available pet and livestock feeds are inappropriate for use in zoo animal diets. 'Making do' with feeds best suited for domestic animals may be less expensive but may also represent an unnecessary risk to some animal species. Zoo animals are unique, and many are rare and irreplaceable. Whether open or closed formula diets are used depends on the nature of the collection, food budget and long-range objectives of a zoo's breeding program

The reasons for writing feed specifications for zoo animal diets should be obvious. Feed manufacturers and their nutritionists are usually willing to help in feed formulations and can represent a valuable resource in planning a zoo feeding program.

APPENDIX A

Open Formula Diet

SPECIFICATIONS FOR DRY FEEDS

National Zoological Park
Washington, DC 20008

A. Herbivore Breeder Diet (Open Formula)

1. This product shall be an open formula pelleted ration for use in feeding zoo herbivores, including monogastric and other nonruminant herbivores.

2. Ingredients: The manufacturer will be restricted to the following ingredients which will be incorporated into the product in the exact proportions specified:

International Feed No.	Ingredient	Percentage by weight
4-02-935	Corn, yellow, grain	32.4
1-00-023	Alfalfa meal, dehydrated (17% crude protein)	32.0
5-04-612	Soybean meal, dehulled (48% crude protein)	12.0
4-05-205	Wheat middlings	10.0
4-04-695	Molasses, cane, dried	10.0
4-07-983	Soybean oil	1.5
6-01-083	Mono-dicalcium phosphate (16% Ca, 21% P)	0.9
	Sodium chloride	0.5
	Vitamin and mineral premixes	0.5
	Sodium or calcium propionate	0.2

Supplemental vitamins and trace minerals shall be added to the ration via separate vitamin and mineral premixes. These premixes shall be formulated such that a minimum of one pound of each premix is required per ton of finished product. These supplemental premixes shall provide the following levels of fortification:

I. Vitamin premix

Vitamin	Fortification level per ton (2,000 lbs) of product	Source
Vitamin A	5,450,000 IU	Stabilized vitamin A palmitate or acetate
Vitamin D_3	454,000 IU	D activated animal sterol
Vitamin E	118,000 IU	d,l-alpha-tocopheryl acetate
Vitamin K	1.8 g	menadione activity
Thiamine	4.5 g	thiamine mononitrate
Riboflavin	3.6 g	riboflavin supplement
Niacin	36.3 g	niacin
Pyridoxine	5.5 g	pyridoxine hydrochloride
Biotin	0.18 g	biotin
Pantothenic acid	23.0 g	d-calcium pantothenate
Folic acid	2.7 g	folic acid
Vitamin B_{12}	30.0 mg	vitamin B_{12} supplement
Choline	700.0 g	choline chloride

II. Mineral premix

Element	Amount per Ton (of element, not compound)	Source
Iron	91.0 g	ferrous sulfate
Copper	6.4 g	copper oxide or sulfate
Zinc	74.0 g	zinc oxide or sulfate
Manganese	36.3 g	manganous oxide or carbonate
Iodine	0.64 g	penta-calcium ortho periodate or potassium iodate
Selenium	180 mg	sodium selenite
Cobalt	91 mg	cobalt carbonate or cobalt sulfate
Magnesium	360 g	magnesium oxide

3. Ingredient standards: Ingredients used in the manufacture of this ration will not be contaminated with any more than 3% of foreign materials such as other grains, weed seeds, chaff, etc. Nor will any mold, must or insect/rodent infestation be allowed. The average minimum nutrient concentrations of ingredients used in the manufacture of this product shall be equal to the values published in the National Academy of Sciences Publication 1684, "United States-Canadian Tables of Feed Composition". Contractors may be requested to provide a significant amount of data to show an effective ingredient quality control program is being followed.

4. Nutrient contents: The total calculated concentration of nutrients in the finished product from ingredients and from the fortifications at the time of manufacture should be as follows:

Crude protein	15.5%	Minimum
Crude fat	3.0%	"
Crude fiber	16.0%	Maximum
Calcium	0.6%	Minimum
Phosphorus	0.4%	"
Magnesium	0.2%	"
Potassium	0.8%	"
Sodium chloride	0.5%	"
Iron	100 ppm	"
Copper	7 ppm	"
Zinc	80 ppm	"
Manganese	40 ppm	"
Iodine	0.7 ppm	"
Selenium	0.2 ppm	"
Cobalt	0.1 ppm	"
Vitamin A	6,000 IU/kg	"
Vitamin D_3	500 IU/kg	"
Vitamin E	130 IU/kg	"
Vitamin K	2.0 ppm	"
Thiamine	5.0 ppm	"
Riboflavin	4.0 ppm	"
Niacin	40.0 ppm	"
Pyridoxine	6.0 ppm	"
Pantothenic acid	25.0 ppm	"
Biotin	0.2 ppm	"
Folic acid	3.0 ppm	"
Vitamin B_{12}	0.03 ppm	"
Choline	1,000 ppm	"

5. Form: The finished product shall be furnished in firmly pressed cylindrical pellets, 3/16" or 1/2" in diameter (as per directions of the National Zoological Park at the time of ordering), and packaged in 50 lb. double-walled bags that are clearly labeled with the name of the product, the name of the manufacturer, the net weight, the ingredients, the guaranteed analysis of the contents, the date of manufacturing, and the batch number under which it was processed. Codes or coding will not be acceptable for any markings specified herein.

6. Nutritional analysis: A sample of the initial and one subsequent batch (as requested by NZP) will be sent by the manufacturer to an independent laboratory for analysis of the following constituents: dry matter, crude fat, crude protein, crude fiber, ash, calcium and phosphorus. The results will be sent directly to the nutritionist at NZP, but the manufacturer will pay for these analyses.

Appendix B

Closed Formula Diet

SPECIFICATIONS FOR DRY FEEDS

National Zoological Park
Washington, DC 20008

B. Primate Feed (High Protein)

1. This product shall consist of extruded biscuits designed to be fed to both New World and Old World primates.

2. Ingredients: The manufacturer will be restricted to select ingredients from the following list for the formulation of this ration; however there is no intent to require the manufacturer to use all the ingredients that are listed:

Dried skim milk, Dehydrated alfalfa meal, Soybean meal, Ground yellow corn, Corn gluten meal, Fish meal, Animal liver meal, Oat groats, Ground wheat, Dried beet pulp, Dried bakery product, Wheat germ meal, Sugar (sucrose), Animal fat (preserved with BHA), Soybean oil, Brewers dried yeast, Irradiated dried yeast, D-activated animal sterol, Vitamin A palmitate, Vitamin A supplement, Vitamin B_{12} supplement, Vitamin E supplement, Menadione sodium bisulfite, Riboflavin supplement, Niacin, Calcium pantothenate, Folic acid, Choline chloride, Thiamine, Ascorbic acid, Pyridoxine hydrochloride, Steamed bone meal, Calcium carbonate, Dicalcium phosphate, Defluorinated phosphate, Salt, Iodized salt, Manganous oxide, Copper sulfate, Iron oxide, Iron carbonate, Manganese sulfate, Calcium iodate, Potassium iodate, Cobalt sulfate, Cobalt carbonate, Zinc oxide, Ethylene diamine dihydroiodide.

The manufacturer shall determine the amount of each ingredient used in the formulation of this ration that will ensure the nutrient contents specified in section 4, below, and that will be a palatable ration for primates.

3. Ingredient standards: Ingredients used in the manufacture of this ration will not be contaminated with any more than 3% of foreign materials such as other grains, weed seeds, chaff, etc. Nor will any mold, must, or insect/rodent infestation be allowed. Manufacturers may be required to provide a significant amount of data to show an effective ingredient quality control program is being followed.

4. Nutrient standards: The finished product at the time of manufacture shall conform to the following calculated standards:

Crude protein	24.00%	Minimum
Crude fat	5.00%	"
Crude fiber	4.00%	Maximum
Ash	6.75%	"
Amino Acids, % of Total Diet		
Arginine	1.50%	Minimum
Glycine	1.10%	"
Lysine	1.20%	"
Methionine	0.35%	"
Tryptophan	0.25%	"
Cystine	0.30%	"
Histidine	0.50%	"
Leucine	2.25%	"
Isoleucine	1.20%	"
Phenylalanine	1.20%	"
Threonine	0.85%	"
Valine	1.30%	"
Tyrosine	0.75%	"
Calcium	0.95%	"
Phosphorus	0.55%	"
Magnesium	0.10%	"
Potassium	0.90%	"
Sodium	0.34%	"
Chlorine	0.40%	"
Iron	275 ppm	"
Copper	13 ppm	"
Zinc	20 ppm	"
Manganese	40 ppm	"
Iodine	1.6 ppm	"
Cobalt	2.0 ppm	"
Vitamin A	20,000 IU/kg	"
Vitamin D_3	5,000 IU/kg	"
Vitamin E	100 IU/kg	"
Vitamin C	2,000 ppm	"
Thiamine	15 ppm	"

Riboflavin	10 ppm	"
Niacin	80 ppm	"
Pyridoxine	12 ppm	"
Pantothenic acid	40 ppm	"
Biotin	0.2 ppm	"
Folic acid	10 ppm	"
Vitamin B_{12}	0.03 ppm	"
Choline	1,500 ppm	"

5. Form: The finished product shall be furnished in extruded biscuits, 5/16" to 1/2" thick, 1"±1/4" wide, and 1 1/2" - 2" long. This product will be bagged in quantities of uniform weight and clearly labeled with the name of the product, the name of the manufacturer, the net weight, the ingredients, the guaranteed analysis of the contents, the date of manufacturing, and the batch number under which it was processed. Codes or coding will not be acceptable for any markings specified herein.

DEVELOPING AND TESTING A NEW PSITTACINE DIET

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INTRODUCTION

Proper nutritional management of psittaformes in zoos is necessary to achieve reproducing, self-sustaining populations. Unfortunately, there are few data available on natural diets of psittaformes to use as an information base in formulating captive diets. In addition, information on feed intake as well as nutrient composition of captive diets is limited. Health and reproductive problems still exist in captive psittaformes. Some of these health and reproduction problems seen in zoos may be a consequence of the current exotic bird feeding practices. Rickets and osteomalacia are prevalent (Anderson, 1983; Harrison, 1983). Other problems related to nutrition may include feather discoloration (Kray, 1985), feather loss (Altman, 1986), beak abnormalities (Altman, 1986), goiter (Altman, 1986), respiratory diseases (Altman, 1986) and obesity (Harrison, 1986; Lowenstine, 1986). After reviewing the current feeding practices and diets of several zoos, and identifying nutritional problems in captive psittaformes, we began developing and testing a new feed.

MORPHOLOGY AND ANATOMY OF PSITTAFORMES

An understanding of the morphology of the digestive tract is helpful in developing new diets. The overall morphology of the psittacine digestive tract is similar to that of other aves. However, psittacines have some unique morphological features that may influence diet formulation. For instance, the bill shape is stout and curved. It is a powerful bill which can easily crack seeds and hard fruits. Since the beak grows throughout life, psittacines, as well as other birds, trim the beak by biting on hard objects (McLelland, 1979). Beak trimming is especially important for psittacines since their beak contains a sensory organ which may become non-functional if the organ becomes overgrown by the beak (Gottschaldt, 1985).

Compared to other aves, the psittacine esophagus is very narrow (McLelland, 1979). This may limit psittacine's ability to swallow large items. Usually, the strong beak helps reduce food to a diameter which can pass through the esophagus. The crop is well developed and is transversely situated. The proventriculus is also small and the gizzard musculature is reduced. These changes in the proventriculus and gizzard are related to the extensive mastication that occurs in the buccal cavity. Psittacines lack a gallbladder and ceca, which is unusual but not unique in aves (McLelland, 1979). Lack of ceca certainly limits the extent of microbial digestion that could occur in psittacines.

The sensory systems and capabilities of any animal may provide insight in to the criteria used by that animal to select food. Birds seem to have olfactory capabilities but the limited knowledge base and lack of studies on psittacines prevents extrapolation to general or specific capabilities of psittacines (Bang and Wenzel, 1985). Color vision has also been suggested for other birds but has not been adequately investigated in psittacines (Martin, 1985).

As mentioned earlier, psittacine beaks contains an organ, the bill tip organ. This tactile organ is common in birds that use their bill to search, select and manipulate their food. There is an elaborate blood supply to the organ (Gottschaldt, 1985). The feel of a food is probably important in food choice for psittacines.

There are two types of taste receptors in birds. One type of taste receptor is "free" in the oral mucosa while the other type is closely associated with openings of the salivary glands. The receptors have also been termed solitary and glandular, respectively. Psittacines have a very high number of total taste receptors (Berkhoudt, 1985). There is some experimental evidence that psittacines can detect natural sugars in their water (Berkhoudt, 1985).

EVALUATING PSITTAFORME DIETS

One of the first steps in reviewing a feeding program or formulating new feeds is to estimate dietary requirements for the essential nutrients. For most species of non-domesticated animals, these levels have not been established. Therefore, one must extrapolate data from a National Research Council (1984) publication for a similar species and extract information from the literature (Roudybush et al., 1984; Grau and Roudybush, 1986; Roudybush and Grau, 1986). Once developed, these estimated nutrient requirements provide a basis for comparison of different diets. The working estimated nutrient requirements for psittacines are presented in Table 1.

Assessment of the nutrient composition of commercially available feeds is usually restricted to the limited information available on the label. Furthermore, certain label information is expressed as minimum or maximum concentrations, which may be misleading. Therefore, laboratory analyses are often necessary to establish nutrient levels in the feed. In some cases, there are discrepancies between label information and lab analyses that further complicate the problem.

A staple in many commercial and in-house zoo diets is seeds. There are several nutritional inadequacies of seed-based diets including no preformed vitamin A, imbalances and low levels, in relation to need, of calcium and phosphorus as well as other minerals and vitamins. There are high levels of fat (energy) in certain seeds that may promote obesity, especially in birds that have limited space for exercise and energy expenditure (Tables 2 and 3). The problems of seed-based diets are often exaggerated when seeds are offered as the sole food sources.

Many zoos currently feed mixed, cafeteria-style diets (e.g., seeds, nuts, fruits, vegetables, and supplements). There are some inherent problems in feeding these mixed diets (Allen, 1982). Nutrient levels in mixed bird diets, as offered, are often deficient in some nutrients and excessive in others. Deficient nutrients may include crude protein and specific amino acids, calcium, sodium, vitamin D, and vitamin A. Crude fat is often in excess. Most importantly, it is difficult to determine the exact nutrient intake because of disproportionate selection of specific items from the mix. Supplementation of mixed diets with assurance that the supplement is consumed is next to impossible. Moreover, supplementation may often be inadequate or inappropriate.

DEVELOPING AND TESTING A NEW DIET

The problems of feeding a captive population of psittacines prompted the development of a new diet. Several aspects were considered prior to formulation, including expected consumption (e.g., proportion of the dry matter intake), physical form (e.g., moist, semi-moist, pelleted, extruded), practicality (e.g., ease of feeding), feedstuffs to be used, and cost. Other considerations included factors that may influence acceptability of a new diet.

An extruded diet was produced in early 1986 (Table 4). This product was formulated to be fed as at least 50% of the birds' dry matter intake. The other 50% or less of diet dry matter was to consist of fruits, vegetables and a few seeds or nuts. Nutrient intakes (dry matter basis) from an offered mixed diet, including this extruded product, (Tables 5 and 6) were calculated for three Timneh gray parrots at the San Diego Zoo. Offered feed was weighed daily for nine weeks. Once per week, residual feed was collected after 24 hours and each individual item was re-weighed. Methodological problems that may alter data interpretation can include overnight changes in dry matter, and defecation and urination on the residual feed items. For each bird, the data were divided into the two high and two low days of consumption of the extruded diet. The mean high and low intakes of the offered extruded diet were 22% and 0.3% of the total diet dry matter, respectively, corresponding to 64% and 1.5% of the offered amount of extruded diet, respectively (N=6). Consumption of each item in the diet was calculated by difference between offered and residual amounts. The nutrient composition of the consumed diet was calculated for 47 nutrients with The Zoo Diet Analysis Program (Allen and Baer Associates, Inc. and Michigan State University Comparative Animal Nutrition Laboratory). Seven of the more important nutrients were selected for statistical analysis. Selected nutrient levels in the diet consumed were compared for high versus low days of intake of the extruded diet (Gill, 1978). High intake of the new diet significantly improved the nutrient levels in the consumed diet dry matter, for at least seven of these eight nutrients (Table 7).

Acceptability of the new product, as measured by the number of species consuming it (Table 8), and as measured by intake, appears to be good. Currently, two sizes of the extruded diet are being manufactured and tested at the San Diego Zoo. One size is approximately 2.7 cm by 0.8 cm and the other size is approximately 0.5 cm in diameter. Different sizes allow a greater diversity of species to which the diet can be offered.

CONCLUSIONS

Although this is only the first step in developing a new psittacine diet, the results have been encouraging. The results of our intake trials suggest that psittacines will not necessarily make nutritionally appropriate choices of food items. It is only through the laborious process of measuring intake that diet nutrient composition can be determined. It is also important to weigh animals to detect changes in body weight. Fine tuning of nutrient levels in this diet will be important for future improvement of animal growth and reproduction.

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Table 1. Working estimated nutrient requirements of psittacines (per 3222 kcal of dry matter).

Crude protein	20%	Thiamin	2 ppm
Linoleic acid	1.11%	Riboflavin	4 ppm
Lysine	0.94%	Vitamin B_6	5 ppm
Methionine	0.33%	Vitamin B_{12}	10 ppb
Cystine	0.33%	Niacin	30 ppm
Isoleucine	0.67%	Folate	622 ppb
Threonine	0.76%	Biotin	167 ppb
Tryptophan	0.19%	Choline	1444 ppm
Arginine	1.11%	Pantothenate	11.1 ppm
Calcium	0.89%	Vitamin A	4444 IU/kg
Phosphorus (avail.)	0.44%	Vitamin E	66.7 IU/kg
Sodium	0.17%	Vitamin D	556 IU/kg
Potassium	0.44%		
Magnesium	0.067%		
Iron	88.9 ppm		
Iodine	0.39 ppm		
Copper	8.89 ppm		
Manganese	66.7 ppm		
Selenium	0.17 ppm		
Zinc	44.4 ppm		

Table 2. Nutrient composition of selected common bird seeds (% of dry matter)[a].

Seed part	Dry matter	Crude protein	Crude fat	Carbo-hydrate	Crude fiber	Ash	Cal-ium	Phos-phorus
Canary								
Whole	92.7	20.2	4.1	31.6	33.4	5.8	0.06	0.16
Kernel	93.1	23.8	4.1	52.0	19.4	2.7	0.04	0.32
Hull	90.7	3.8	3.2	8.8	90.2	19.4	0.05	0.01
Hemp	93.6	26.7	34.8	1.5	41.7	5.4	0.12	0.32
Millet								
Whole	91.9	14.4	6.0	26.1	28.6	3.3	0.01	0.15
Kernel	91.9	15.0	4.0	58.0	18.5	0.8	0.01	0.40
Hull	93.8	6.5	4.0	0.9	97.0	10.7	0.01	0.06
Safflower								
Whole	94.8	21.2	40.7	4.7	36.7	2.6	0.11	0.34
Kernel	97.0	24.5	60.4	2.8	11.5	2.9	0.06	0.42
Hull	93.5	6.7	6.3	3.2	94.4	1.6	0.19	0.13
Sunflower								
Whole	96.0	19.8	36.2	1.7	46.0	2.9	0.11	0.33
Kernel	97.2	31.0	50.4	3.5	16.2	3.9	0.09	0.41
Hull	93.4	5.8	6.1	0.8	94.6	2.0	0.13	0.11

[a]Data from McDaniels, 1982.

Table 3. Proportion of kernal and hull[a].

Seed	% Hull	% Kernal
Canary	17.5	82.5
Millet	26.2	73.8
Safflower	40.0	60.0
Squash	28.9	71.1
Sunflower	42.0	58.0

[a]Data from McDaniels, L. Proximate analysis of common cage bird seeds and applications to the diet, University of California-Davis, Unpublished MS Thesis.

Table 4. Calculated levels of selected nutrients in a new psittacine diet (Formulation #1).

Nutrient	Calculated level (dry matter basis)
Crude protein (%)	29.9
Lysine (%)	1.49
Calcium (%)	1.37
Phosphorus (%)	0.80
Sodium (%)	0.27
Retinol (IU/kg)	4370
Vitamin E (IU/kg)	157
Vitamin D_3 (IU/kg)	900[a]

[a]As of July, 1986 1500 IU/kg Vitamin D_3

Table 5. Feed item composition of offered diet.

Item	Percent of dry matter
Extruded diet	19.3
Sunflower seeds	42.9
Safflower seeds	1.9
Peanuts	4.5
Corn	25.3
Carrots	0.6
Sweet potatoes	2.9
Celery	0.5
Oranges	1.3
Green beans	0.7
Spinach	0.3

Table 6. Selected nutrient levels of offered diet.

Nutrient	Calculated level (dry matter basis)
Crude protein (%)	22.0
Lysine (%)	0.79
Calcium (%)	0.36
Phosphorus (%)	0.50
Sodium (%)	0.09
Retinol (IU/kg)	844
Vitamin E (IU/kg)	40
Vitamin D_3 (IU/kg)	175

Table 7. Comparison of selected nutrient levels in diets with high or low intake of the extruded diet (Mean$\pm$SEM)[a].

Nutrient	High intakes	Low intakes
Crude protein	17.9$\pm$0.2	19.8$\pm$0.7
Lysine (%)	0.714$\pm$0.032	0.514$\pm$0.032
Calcium (%)	0.374$\pm$0.033	0.109$\pm$0.005
Phosphorus (%)	0.470$\pm$0.014	0.390$\pm$0.014
Sodium (%)	0.106$\pm$0.011	0.039$\pm$0.011
Retinol (IU/kg)	958$\pm$119	59$\pm$19
Vitamin E (IU/kg)	47$\pm$4	16$\pm$2
Vitamin D_3 (IU/kg)	198$\pm$25	13$\pm$4

[a]All means statistically different ($p<0.02$) except crude protein.

Table 8. Common names of species offered diet as of June, 1986.

Queen of Bavaria conures
Painted conures
Double yellow-headed amazon
Grand caymen amazon
Brown's rosella
Slender bill cockatoo
Citron crested cockatoo
Rose breasted cockatoo
Leadbeaders cockatoo
Red-tail black cockatoo
Hyacinthine macaws
Green wing macaws
Blue and gold macaws
Scarlet macaws
Derbyan parakeets
Thick-bill parrots
Timneh gray parrots
Blue crown hanging parrots
Pesquest parrots (diet soaked in nectar)
Eclectus parrots
Desmarest fig parrots

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HUMAN RESPIRATORY HAZARDS ASSOCIATED WITH FEEDING AND HUSBANDRY OF ZOO ANIMALS

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The primary health hazards associated with the feeding and husbandry of zoo animals would include exposure to airborne contaminants when handling animal waste, feed, forages and bedding material.

One of the primary gases associated with animal waste handling is ammonia. This gas is released from manure and urine especially during decomposition. Ammonia gas is an irritant which is colorless, lighter than air, and highly water soluble. It has a sharp pungent odor becoming detectable at levels as low as 5 ppm. Typical ammonia levels in well ventilated buildings is 50 ppm where manure and urine is deposited on solid floors. Levels can exceed 50 ppm with lower winter ventilation rates and reach 100 to 200 ppm in poorly ventilated buildings. At these levels ammonia by itself is not a significant health hazard for daily exposure. It is primarily an irritant. The effects of ammonia gas at these levels are:

Exposure Level	Effects on Humans
20 ppm and above	Eye irritant
100 ppm for one hour	Irritation to mucous surfaces
400 ppm for one hour	Irritation to eyes, nose and throat

Dust generated from feed, grain, forage and bedding material often contains a variety of particles that can cause significant adverse effects on a person's lungs. This type of dust is a complex mixture of organic material consisting of husk particles, cellulose hairs and spikes, and starch granules. The dust may also include pollens, grain smut and rusts, bacteria, fungi, aflatoxin, animal dander, insect and mite parts, rat hairs and silica.

Some of the common responses to breathing the type of dust described include chronic bronchitis. This is an inflammation of the airways and results in the coughing up of phlegm, mucus or sputum from the chest. This may be accompanied by wheezing. It may also induce or enhance asthmatic reactions. Some workers may develop grain fever. This is characterized by chills, fever and body aches that develop 4 to 8 hours after exposure to organic dust. Grain fever only occurs when a person is exposed to dust after not handling organic material for at least a week.

Breathing dust that contains mold spores can cause a serious reaction in the lungs of some people. Actually, only about six percent of us will develop a reaction to mold spores. The problem is that there is no means to determine who is susceptible and who is not. Initial exposure can result in symptoms similar to those of grain fever but the difference is that the body develops a hypersensitivity to the mold. Repeated exposures even a year after initial exposure can result in a serious allergic reaction. This can lead to several weeks of illness, hospital stays, permanent lung damage and, in very serious cases, death.

The first line of defense against exposure to dust is wearing an effective respirator. Many workers often wear what is called a dust mask consisting of a thin paper filter and held to the wearer's head by one strap. This type of mask will not be very effective in filtering out fine dust particles which travel deep into the lungs and are irritating and potentially damaging. One must wear a mechanical filter respirator that has been approved by the National Institute for Occupational Safety and Health (NIOSH). Any respirator selected for use should have a NIOSH approval number that starts with the letters "TC" on the package and mask. There are several types of respirators one can obtain:

- Disposable mechanical filter respirators
- Mechanical filter respirators
- Powered air-purifying respirators

A **disposable mechanical filter respirator** consists of a piece of filter material held to the person's face by two head straps that may or may not be adjustable. The filter becomes more efficient with use because the trapped particles cause it to become more dense. Breathing resistance will increase with use, and the respirator will be discarded when breathing becomes too difficult.

A **mechanical filter respirator** works similar to the disposable filter respirators. But, filters are replaceable and the face-pieces are made of flexible molded rubber, silicon rubber, vinyl, or plastic which will last longer. Filter life is usually longer than that of disposables. In addition, a dust cartridge can be obtained to be used with a chemical cartridge respirator which is commonly used when handling pesticides. This makes an excellent respirator because the face-piece tends to provide a more comfortable fit than the other type of mechanical filter respirators. Also, you would have a basic mask to which a chemical cartridge, mechanical dust filter, or both, may be added. All mechanical filter respirators can be purchased with an exhalation valve. This is an excellent feature because it allows exhaled air to be removed from the mask and substantially enhances the comfort of the wearer.

The most sophisticated dust respirators are called **powered air-purifying respirators.** With a rechargeable battery powered motor unit, they blow filtered air into a face-piece. Unlike all other dust respirators, there is no breathing resistance. Other advantages include a constant flow of air over the wearer's face and an easy fit. By blowing air down across the face, dust particles cannot enter the breathing zone, thus, it is an excellent respirator. Depending on the features obtained and durability of the material used, these respirators can range in price from $200 to $500.

Most cities have safety equipment supply dealers that sell types of respirators. A quick check of the yellow pages of the larger cities in your area under "safety products" or "safety equipment" should reveal a supplier. The important thing is to eliminate or significantly reduce exposure to breathing dust when working with zoo animals. Your good health just may depend on it!

ARTIFICIAL LIGHTS AS A SOURCE OF VITAMIN D

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INTRODUCTION

Animals that normally do not consume vitamin D-containing foods and that are not exposed to natural sunlight may develop a deficiency of vitamin D. Rickets and osteomalacia, classic signs of vitamin D deficiency, are common problems in certain reptiles, primates and birds housed indoors in zoological gardens. Artificial lights are commonly used by zoos in order to promote the health of animals housed indoors (Townsend and Cole, 1985). Aside from photoperiodic effects, a primary benefit of providing artificial light is to promote vitamin D synthesis, assuming the artificial light emits appropriate ultraviolet wavelengths. Dermal and epidermal conversion of 7-dehydrocholesterol to cholecalciferol requires irradiative exposure between 285-315 nm (Norman, 1980). The purpose of this experiment was to investigate whether the amount of ultraviolet light emitted by certain commercially available lights is sufficient to promote vitamin D_3 synthesis as indicated by weight gain and various measures of skeletal calcification.

METHODS AND MATERIALS

Seventy-four, day-old leghorn cockerel chicks were randomly assigned to six treatment groups representing three levels of dietary vitamin D_3 and four lighting regimes. All groups were fed the same basal diet which was formulated to satisfy all National Research Council (NRC, 1984) nutrient recommendations with the exception of vitamin D_3. The basal diet fed to Groups 1 and 2 was supplemented with 400 IU and 100 IU of vitamin D_3 per kg of diet, respectively. The basal diet fed to Groups 3, 4, 5, and 6 contained no vitamin D_3. All groups were housed indoors without natural light and were constantly exposed to cool white fluorescent lights at a distance of 2.3 meters. These lights are commonly used to illuminate indoor exhibits but emit little radiation below 400 nm. In addition, Group 4 was exposed to a Vita-Lite Power Twist by Duro-Test, a visible light source of low ultraviolet intensity for 12 hr per day, Group 5 was exposed to a Sylvania incandescent sun lamp, a light of high ultraviolet intensity for 15 min twice daily, and Group 6 was exposed to a Sylvania black light, a light of moderate ultraviolet intensity for 15 min twice daily. Each of the experimental lights was placed at a distance of 0.61 meters, and plywood light barriers were placed between treatment groups to prevent cross exposure.

At 6 weeks of age, all birds were killed by cervical dislocation. Each carcass was examined for general health and appearance. Beak flexibility scores were assigned with "1" indicating a rigid, healthy beak and "2" indicating a flexible, poorly calcified beak. Rib scores were also assigned, "1" indicating normal, healthy ribs and "2" indicating beaded ribs, determined by definite swellings distal to the costa-vertebral junction. The center toe of the left foot and the left tibia of each chick were disarticulated for analyses. Ash was determined according to modification of AOAC methods (Williams, 1984). Calcium content of the tibia ash was determined using atomic absorption spectophotometry, and phosphorus content was determined by a spectrophotometric ammonium molybdate procedure (Gomorri, 1942).

Differences in body weight, ash, calcium and phosphorus among treatments were analyzed with Dunnett's test to compare each experimental group with the control group (Gill, 1978). Beak and rib scores were analyzed using Chi-square and Bonferroni tests (Gill, 1978). It is worth noting that, since only one pen was used per treatment, variance between pens could bias the results, and therefore, only strongly significant differences may be trusted with confidence.

RESULTS AND DISCUSSION

Treatment effects on body weight, percent bone ash of both the tibia diaphyses and toes, beak score, and rib score followed similar trends. Groups 1,2 and 5 had the highest ($P < 0.01$) beak and rib scores, the highest final weight, and greatest percent bone ash in both toes and tibia diaphyses as compared with the control group (Table 1). Group 4, in contrast, had the poorest calcification of beaks and ribs, and the lowest percent ash in both toes and tibia diaphyses. Birds under the Vita-Lite had lower body weights after 6 weeks than the negative control birds ($P < 0.05$) (Table 1). The birds under the Vita-Lite had a poorer general appearance (unkempt, dirty feathers, and inadequate preening) than any other group of birds. It is interesting to note that, although not statistically significant, there was no mortality among birds under the Vita-lite.

The results of this study indicate that a limited duration of exposure to an artificial light of high ultraviolet intensity, (i.e., the sun lamp) can also result in adequate vitamin D synthesis in chicks housed indoors. It should be noted that precautions should be taken whenever artificial lights of high ultraviolet intensity are used because of the danger of harmful overexposure. Additional studies will need to be conducted to determine what exposure intervals can be safely tolerated by different species when sources of high ultraviolet intensity are used.

Based on the criteria used to evaluate vitamin D status, exposure to the black light did not appear to result in significant vitamin D synthesis. It may have been that the exposure interval used (i.e., 30 minutes per day) was simply too short to allow adequate time for provitamin D conversion or that the ultraviolet intensity (in the range of 285-315 nm) of the black light was insufficient to facilitate the conversion regardless of exposure duration. It should be noted that black lights can vary considerably in ultraviolet intensity and wavelength (Gehrmann, 1987), and the results obtained in this study may not apply to all makes and models.

The reason the chicks in Group 4 developed signs of rickets that appeared to be even more severe than those exhibited by the control group is not known and is worthy of further investigation. We believe the poor response exhibited by Group 4 lends little support to the use of this light source of low ultraviolet intensity in zoos in order to promote animal health. Due to the long duration of exposure (i.e., 12 hr per day), lack of adequate exposure cannot be considered a contributing factor to the poor vitamin D status of the chicks in Group 4. The manufacturer of the light of low ultraviolet intensity tested claims that the light will promote vitamin D synthesis and calcium absorption in humans and that there is no danger of overexposure. However, it has been demonstrated that very little ultraviolet light of the appropriate wavelength for vitamin D synthesis is produced by the Vita-Lite (Gehrmann, 1987).

This preliminary study supports previous findings that supplemental artificial lighting can affect vitamin D_3 synthesis as measured by weight gain and skeletal calcification. We believe that the results of this study indicate the following: (1) Artificial light sources of high ultraviolet intensity can satisfactorily promote vitamin D synthesis in chickens and presumably other species. Additional studies will be required to determine maximum safe exposure levels, however. (2) Artificial light sources of medium ultraviolet intensity, such as black lights, may or may not be capable of promoting adequate vitamin D synthesis. Further studies using longer exposure periods and various brands of lights will be required to determine the efficacy of light sources of medium ultraviolet intensity. (3) Artificial light sources of low ultraviolet intensity, such as the one tested, appear to have little value for supporting vitamin D synthesis in chicks and presumably other species. We recommend that lights similar to the one tested not be used for the purpose of promoting vitamin D synthesis in zoo animals.

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Table 1. Diets, light treatments and data summary.

Group #	1	2	3	4	5	6
Diet	400 D	100 D	0 D	0 D	0 D	0 D
Light treatment				Vita-Lite	Sun Lamp	Black Light
No. started	12	12	14	12	12	12
No. died	1	1	3	0	1	2
Initial wt (g)	34.4	36.1	34.7	33.9	34.1	33.3
± Std error	1.3	1.3	1.3	1.2	1.3	1.3
Final wt (g)	547.0*	540.5*	399.4	314.0	538.3*	403.9
± Std error	23.4	24.5	23.4	22.4	23.4	24.5
Beak score[a]	1.0*	1.0*	1.7	2.0	1.0*	1.9
Rib score[a]	1.0*	1.0*	1.6	1.8	1.0*	1.6
Ash (%)						
Toes[b]	15*	14*	12	10	15*	13
Tibias[c]	54*	53*	44	40*	54*	44

[a]1=normal, 2=abnormal; see text for description.
[b]As a percentage of dry matter.
[c]As a percentage of diaphyseal fat-free, dry matter.
*Means within a row differ significantly from negative control Group 3 ($P < 0.01$).

QUALITY EVALUATION AND TESTING OF HAY

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Introduction

Feeding captive herbivores under conditions often far different from their native environment dictates reliance on feedstuffs that may be different from those consumed in the wild. Exotic animal species, like domestic species, require nutrients rather than feedstuffs. Thus, nutritionists can develop rations based on an understanding of natural dietary habits and domestic animal models.

Hay often is the backbone of the herbivore ration. Hay provides: 1) needed nutrition, as well as 2) an occupation for the animal's time. Therefore, one must consider hay type and quality when purchasing hay and when designing a ration. Is it the type of hay best suited for the class of animals? Will this lot of hay provide the needed energy, crude protein, minerals, and vitamins? Will the animals be able to consume sufficient amounts of hay to obtain the needed nutrients? Will the hay provide the least cost source of the energy and protein? And, is the hay free from plants and materials that will be injurious to the animals? Examples are blister beetles, wire, plastic twine, weeds and bird droppings. If the answers are "no", a supplement will be needed to make up for deficiencies or a different hay should be purchased.

Three broad types of animals have different digestive systems and thus different needs for hays, Table 1.

Based on this classification, the following types of hay may be included in the feed supply of a zoo:, Table 2.

Purchasing, and nutritionist personnel then must be aware of quality factors and how to evaluate each when purchasing hay.

Forage Quality - What To Look For

Hay varies more in quality than any other harvested feed crop on North American farms. There is a wide difference in the quality of hay even within a single species grown in the same locality and under almost identical conditions. This variation is largely due to lack of understanding of the principles of good haymaking, to a tendency of many farmers to give less attention to their hay crop compared to other cash crops, and to the fact that cash hay is often an off-shoot of a dairy or other livestock operation. Hay buyers will frequently find both excellent and poor quality hays available at the same price. Substantial savings can often be made by feeding high quality hay at a proper price.

Nutritive value is a general term used in all feed evaluation to describe the over-all production potential of a feed. The animal also has a role in determining the productive potential. Nutritive value is the product of

Intake x Digestibility x Metabolic Efficiency of the animal. The greatest determinant is how much you can get the animal to eat making 50-60 percent of the value. Too much effort has been placed on digestibility which makes up 20-30 percent of the value. Metabolic efficiency makes up only 5 to 15 percent of nutritive value. Hay should be evaluated for characteristics that will affect its nutritive value. Quality in hay really means feed or nutritive value.

Several major factors known to influence hay quality and animal performance are:

- chemical composition
- species in the hay
- maturity
- leafiness
- color
- stem size and brittleness
- foreign material, and
- odor and condition

Chemical composition - Purchase first on chemical composition. Market hay grades based on chemical composition as influenced by stage of maturity and species are shown in Table 3. The terms used are defined with typical ranges in composition presented in Table 4.

Ruminants will consume 1.2 to 1.25 Kg NDF for each 100 Kg body weight, Table 3. NDF is the major chemical constituent to look for when evaluating forages.

Organoleptic estimates of forage quality are based on factors that influence quality and animal performance. These estimates will help to confirm the chemical analyses and/or will supplement those analyses to indicate harvest and storage management. Several factors are:

Species - generally choose a pure legume or a mixture high in legume. Legumes have more crude protein, pectins and lignins; less cellulose, and NDF than grasses; and both species are about equal in ADF at comparable stages of maturity. Legume hays have higher rates of intake and are more rapidly fermented than grasses at comparable stages of maturity. The animal obtains more nutrition from legumes because the microbes attack the fiber faster.

Stage of Maturity - Refers to the growth stage of a plant at the time that it is harvested. The stage of maturity if legumes and grasses can be easily identified before they are cut, but after the hay is cut and cured it is more difficult. The stage of maturity at which alfalfa was cut is determined by observing the amount of bloom as well as the texture and woodiness of the stems. Alfalfa cut in the bud stage can be recognized by the size of buds at the tips of the stems and by the absence of purple flower petals. Bud-stage alfalfa also is usually very leafy and the stems are relatively fine and pliable. Alfalfa cut in the early bloom stages has some purple flowers, petals and stems that are larger than in bud-stage alfalfa. Alfalfa hay that is cut after it has blossomed has many blossoms, distinctly larger, woody stems, fewer leaves, and a rather stemmy appearance. Alfalfa cut after the full-bloom stage is usually indicated by large stems, the presence of seed pods, and by a deficiency of leaves. First cut usually has larger stems than the aftermath cuttings.

Alfalfa blooms profusely under certain conditions and sparingly under others, making determination of the exact stage of maturity by the number of blossoms somewhat difficult by visual methods. Weathering or sun-bleaching of the hay or delay of the normal development of the flower parts of legumes because of weather conditions complicates the determination of stage of maturity even more. Cool cloudy weather will delay maturity. Legumes and grasses grown in areas of higher temperatures will usually have higher NDF concentrations.

The stage of maturity of clover can be determined by observing the color and condition of bloom and the maturity of the seeds, if any are present. Clover that was cut no later than the full bloom stage will have numerous heads that show the red or purplish-red blossoms of red clover, or the pinkish-white or white blossoms of white and subterranean clovers, provided the hay was not weathered while being cured. Clover cut in the full bloom stage will have no seeds or, at most, only a few shrunken ones. A stage between full bloom and full maturity is indicated by the brown color of all the clover heads and the presence of yellowish-brown seeds. Full maturity is indicated by the dark-brown color of the heads and the presence of plump, mature seeds. The first crop of clover often does not produce seed, which will account for the absence of seed in hay that has other appearances of being late-cut. Clovers should be cut at the one-fourth to one-half bloom stage for top quality hay.

The stage of maturity at which grasses were cut for hay can be determined easily by examining the heads. First-cutting orchardgrass, reed canary grass, and tall fescue should have been cut in the boot (head is emerging from the leaf roll) to early heading stage. First-cutting timothy, perennial rye-grass, and smooth bromegrass should have been cut in the early heading stage. If these grasses were cut before full bloom, no ripe seeds will be present and parts of the flower can be seen. Full maturity is shown by the plump brown seeds that shell out easily from the whitish dry glumes or chaff. The stage of maturity of grasses also is related to green color. Even if hot weather damaged, grasses with fully ripe seeds usually have yellowish-brown stems and heads and many brown leaves. Hay dealers often describe maturity in terms of hard hay and soft hay. Soft hay refers to hay with immature plants while hard hays have stems with seed heads.

Alfalfa-grass mixtures should be cut according to the maturity of the alfalfa; that is, when the alfalfa is in the late-bud to early bloom stage. Clover-grass mixtures should generally be cut according to the maturity of the grass. In both cases, higher quality is obtained with higher amounts of legume in the mixture.

Leafiness - The amount of leaves in relation to stems is a more critical factor with legumes than with grasses, because legumes lose their leaves more readily than grasses during curing and handling. Leafiness is extremely important since two thirds of the protein is found in the leaves.

Leafiness will depend upon the stage of plant maturity. As plants mature, the stems become larger, lower leaves fall from the plant, and the proportion of leaves decreases. Since leaves are high in protein and low in fiber, highest quality hay is that out in the late-bud to early-bloom stage when plants have a high proportion of leaves.

Leaf shatter during raking and baling is another major cause of reduced quality. This leaf loss is greater as maturity increases. The method of curing, the method of handling the hay from field to storage, and weather conditions during curing and baling also influence leafiness. It must be emphasized that hay must be cut early and carefully cured and handled in order to save leaves.

Leafiness in alfalfa hay may vary from 65 or 70 percent for very leafy hay, to only 10 or 15 percent for very stemmy hay. A bale of very leafy alfalfa hay has an appearance in which the leaves predominate and cling to the stems and the stems are soft and pliable. On the other hand, alfalfa hay which has a low percentage of leaves will appear very stemmy in the bale.

When leaves are off the stems and are loose in the bales, the hay is likely to lose feed value through waste when the bales are opened for feeding.

Color - this is another indication of hay feed value--usually it indicates how the hay was handled and stored. It should be remembered that most animals are color blind, thus only you are able to evaluate color. The most desirable color approaches the bright green of the immature crop in the field. This color usually indicates that the hay was cut at an early stage of maturity and will cured. The fresh aroma (odor), freedom from must or mold, and a relatively high carotene content add to its palatability and feed value.

The bright green color in hay may be lost by bleaching in the sun, rain during curing, fermentation in the bale, stack or mow, or because the plants were too mature when cut. Sun bleaching reduces the palatability of the hay while rain will leach a large portion of the plant nutrients from the plant.

The appearance of hay will tell much about the cutting and handling methods:

Sun bleached hay has a light golden yellow color and need not be discriminated against as seriously as hay which has been rained on or which has heated in the stack. Only material on the outside of the window or only the sides of the bale exposed to the direct sunlight will be bleached. The other material should be a bright green.

Hay which has been exposed to rain, heavy fog and dews has a characteristic dark brown or black discolored appearance. The stems of hay that have been bleached too long in the sun or that have been discolored by rain are usually harsh and brittle.

Brown colored hay indicates heating and fermentation caused by storage at too high moisture. This hay usually has a distinctively musty odor and the bale is often caked.

Yellowing, especially in grass hay, usually indicates that the plants were over-mature when cut. This can be distinguished from sun bleaching in that all plants will have the same yellowish color. Slight discolorations from sun bleach, dew, or moderate fermentation are not as serious as the loss of green color from maturity, rain damage, or excessive fermentation.

Foreign Materials can be divided into non-injurious and injurious. Non-injurious foreign material means those kinds of matter in hay that are commonly wasted in feeding operations, but are not harmful to livestock if eaten. This includes weeds, so-called wire grasses, overripe grain hay, grain straw, corn stalks, stubble, chaff, sticks, and any other objectionable matter. Some grasses, such as wild rye, most annual bromegrasses such as cheat and chess, pigeon grass (sometimes called foxtail or wild millet), broomsedge, and needlegrasses from which the needles have fallen, are considered as foreign material when mature.

Weeds are the most common non-injurious foreign material found in hay. They are usually not relished by the livestock and when eaten have little or no feed value. Hay containing weeds or other foreign material is discriminated against on the market because weeds represent waste and give the hay a bad appearance. Not all weeds reduce feed value. Dandelions may signify mold in hay because of their high moisture percent. Mustards and yellow rocket lower feed value while white cockle does not affect feed value. Weed seeds usually pass through the animal undigested; when the manure is spread on land, it becomes a source of weed infestation.

Material that is poisonous or will harm the animal when eaten is considered injurious foreign material. This includes sandburs, poisonous plants such as tansy ragwort, harsh or rough bearded grasses like mature foxtail, wild barley, 3-awn grass, or ripgut brome, and grasses that have a sharp point at the base of the seed such as matured needlegrasses with the needles attached. It also includes any other matter such as wire or nails. Hay containing injurious foreign material should not be purchased. In a judging contest, a sample containing injurious materials will be placed at the bottom of the class.

Hay growers are adopting the "Hay in a Day" concept to reduce the risk of damage. Most drying agents are calcium or sodium carbonate which are natural chemicals and will not affect animals. The most effective preservative for hay is propionic acid which is formed in the metabolic process of the animal. These compounds should not affect animal intake, but don't shift your animals onto these forages overnight. Start feeding gradually.

Farmers growing grasses for hay may treat mature hay with ammonia which will improve digestibility of the mature grasses. Do not feed high quality legumes that have been ammoniated as the hay may be extremely toxic.

Microbial or enzyme preservatives usually do not work in aerobic situations as in hay.

Odor and condition - The smell of new mown hay is the standard for comparisons. Mildew, mustiness or a putrefied (rotten) odor indicates lowered quality and are caused from storage at too high moisture or weather damage. Odor problems usually result in lower acceptability by livestock. This hay often has many white spores and a white, gray color.

Attention should also be given to the condition of the hay. It should be free from must and mold and from insect and disease damage. It also should not be dusty.

Stem size has been referred to several times. A guide to use for estimating stem size can be found in Figure 1 (Alfalfa Hay Description Form).

Storage - The manner in which you store the hay in the zoo will have a great influence on how the quality purchased is retained. Store hay in an area that is well ventilated and covered. Stack the hay on pallets if the area is moist or has water running through it.

Moisture - The moisture concentration in hay has a great influence on the potential for molding and/or heating. This may occur in transportation or storage. Purchase hay during the growing season that has less than 14 percent moisture unless a propionic acid preservative at recommended rates has been used. Hay out of storage in winter and spring will usually be in the range of 11 to 12 percent moisture.

Store hay on pallets and on edge to help prevent molding.

Herbicides in bedding - Check for herbicide use in bedding materials if the herbicides are toxic because animals won't know that they shouldn't eat those materials.

Summary

You may ask how I utilize this information when purchasing hay.

1. First, insist on a reliable forage analysis using the detergent system of analyses.

2. Select hays that are high in legume, leafy and cut early as a low cost source of feed nutrient.

3. Inventory your feed needs for each class of animals and purchase accordingly.

4. Color, odor and stem texture will indicate to you how the hay was handled.

5. Avoid harmful materials.

6. Materials in the Tables and Figures may be helpful to you in designing a descriptive statement on the hay you are purchasing. Insist that the hay be described as completely as possible.

7. Store properly.

Table 1. Three broad animal types and hay needs.

TYPE	DESCRIPTION
RUMINANT	Four compartment stomach; storage up-front; swallowed, unchewed and regurgitated and mixed with saliva; can use large amounts of forage
HORSES	Natural grass eaters; not ruminants; smaller digestive tract than most ruminants and cannot handle as much bulk - consume high quality, easily digested forage; not as efficient as a cow; cecum at end of digestive tract
MONOGASTRIC	Cannot effectively use forages

Table 2. Zoo animals need different hay quality.

1. Should receive top-quality leafy alfalfa:

Giraffe	Kudu	Sitatunga
Okapi	Reindeer	Dall Sheep
Pere David Deer		

2. Should receive good quality alfalfa:

Blackbuck	Rhinoceros	Ibex
Peccary	Hippopotamus	Tapir

3. Could receive timothy or grass hay:

Wisent	Oryx*
Yak	Camel

4. Should receive good quality timothy or grass hay:

Congo Buffalo	Addax*	Zebra
Banteng	Bison	Elephant

5. Receive alfalfa cubes in addition to regular forage:

Kudu	Bison

*Receive 50/50 Alfalfa/Timothy

Table 3. Proposed market hay grades for legumes, grasses, and legume-grass mixtures - AFGC Hay Marketing Task Force

Grade	Stage of Maturity International Term	Legume Hays[1/] Definition	Legume Hays[1/] Physical Description	Stage of Maturity International Term	Grass Hays[1/] Definition	Grass Hays[1/] Physical Description
Prime	Pre bloom	Bud to first flower; stage at which stems are beginning to elongate to just before blooming.	40 to 50% leaves[2/]; green; less than 5% foreign material, free of mold, musty ordor, dust, etc.		--------	---------
1	Early bloom	Early to mid bloom; stage between initiation of bloom and stage in which 1/2 of the plants are in bloom.	35 to 45% leaves[2/]; light green to green less than 10% foreign material; free of mold, musty odor, dust, etc.		--------	---------
2.	Mid bloom	Mid to full bloom; stage in which 1/2 or more of plants are in bloom.	25 to 40% leaves[2/]; yellow green to green; less than 15% foreign material; free of mold, musty ordor, dust, etc.	Pre Head	Late vegetative to early boot; stage at which stems are beginning to elongate to just before heading; 2 to 3 weeks' growth.[3/]	50% or more leaves[2/]; green; less than 5% foreign material; free of mold, musty odor, dust, etc.
3.	Full bloom	Full bloom and beyond.	Less than 30% leaves[2/]; brown to green; less than 20% foreign material; free of musty odor, etc.	Early Head	Boot to early head; stage between late boot where inflorescence is just emerging until the stage in which 1/2 inflorescences are in anthesis; 4 to 6 weeks' growth.[3/]	40% or more leaves[2/]; light green to green; less than 10% foreign material; free of mold, musty odor, dust, etc.
4.		--------	----------	Head	Head to milk; stage in which 1/2 or more of inflorescences are in anthesis and the stage in which seeds are well formed but soft and immature; 7 to 9 weeks' regrowth.[3/]	30% or more leaves[2/]; yellow green to green; less than 15% foreign material; free of mold, musty odor, dust, etc.
5.		--------	----------	Post head	Dough to seed; stage in which seeds are of dough-like consistency until stage when plants are normally harvested for seed; more than 10 weeks' growth.[3/]	20% or more leaves[2/]; brown to green; less than 20% foreign material; slightly musty ordor dust, etc.

6. Sample Grade[4/]
Hay which contains more than a trace of injurious foreign material (toxic or noxious weeds and hardware) or that definitely has objectionable odor or is under cured, head damaged, hot, wet, musty, moldy, caked, badly broken, badly weathered or stained, overripe, dusty, which is distinctly low quality, or contains more than 20% foreign material or more than 20% moisture.

[1/]Legume hay - 100 to 75 percent legume; Legume-grass hays - 74 to 25 percent legume; Grass hay - less than 24 percent legume. Suggested moisture levels are: Grade Prime, 1, 2 < 14%, Grade 3 < 18%, and Grades 4 and 5 <20%.

[2/]Proportion by weight.

[3/]For grasses that do not flower or for which flowering is indeterminant.

[4/]Slight evidence of any factor will lower a lot of hay by one grade, except Grade 6.

Table 4. Market Hay Grades for legumes, legume-grass mixtures, and grasses - AFGC Hay Marketing Task force[a]
"A continuum from legume pre bloom to grass headed and/or heavily weathered forage"

Grade	Description[b]	CP %	ADF %	NDF %	DDM %	DMI[c] gm/Wkg$^{0.75}$	DDMI	RFV %
Prime	Leg.-Pre.Bl	>19	<30	<39	>65.5	>143	>93.5	>143
1	Leg.-EBl., 20% grass-V.	17-19	31-35	40-46	62-65	134-143	82-93	126-143
2	Leg.-MBl., 30% Grass-EH	14-16	36-40	47-53	58-61	128-133	74-81	113-126
3	Leg.-FBl 40% grass-head	11-13	40-42	53-60	56-57	113-127	64-73[d]	97-113[d]
4	Leg.FBl 50% grass-head	8-10	43-45	61-65	53-55	106-112	55-63	86-97
Fair 6	Grass-Head, and/or Rain Damaged Sample	<8	>46	>65	<53	<105	<55	<86

[a]Description and DDM adopted by Nat. Alfalfa Hay Quality Committee
[b]Pre bloom, EBl=Early bloom, MBl=Mid bloom, FBl=Mid to full bloom, V=Vegetative, EH=Early Head
[c]DMI for sheep and goats = >82,76-81, 72-75, 63-71, 52-62, and <56 for grades Prime through Fair, respectively.
[d]Reference hay mid to full bloom alfalfa (Lema and Kawas and Jorgenson) DDM-54.2, DMI=120.2 gms/wk$^{0.75}$

Figure 1. Alfalfa Hay Description

Date ____________ Lot No. ____________ Producer ____________

Lot Tested; Yes ________ No ________ Address ____________

Lab Name: ____________ Address ____________

Report Attached: Yes _____ No _____; Producer Form Attached Yes _____ No _____

Lot Description:

Type Storage*[a/]: ____________ Quantity (Tons) ____________

*[a/] Haymow; open, enclosed or partial shed; outside stack covered/not covered; how covered; special stacking.

Artificial Dried: Yes ________ No ________; Air ________ Heat ________

Bale Size, Weight, No. Wires/Strings: ____________

Hay Description:

Maturity (see score card: ____________; Grass/Weed % ____________

Color: Dark Green _______, Lt. Green _______, Yellowish Green _______,
Light Bleach (5-10) _______, Streak Bleach _______, Hy. Bleach _______,
Hy. Windrow Bleach _______, Lt. Rain Damage**[b/] _______, Mod. Rain Damage _______,
Hy. Rain Damage _______, Lt. Brown _______, Dk. Brown _______, Black _______.

[b/] What stage in the drying did the rain appear?

Cure: No discoloration, no musty odor (fresh) _______, Sl. discoloration, sl. musty odor _______, few white mold _______, Hy white mold _______,
Light tobacco _______, Dark tobacco _______.

Stem Texture[c/]: (a) Fine _______, Med-Fine _______, Medium _______, Course _______;
(b) Soft[d/] _______, Med. Soft _______, Hard _______; (c) Flat Stem _______,
Hollow Stem _______, Woody Stem _______, Crushed _______.

[c/] Stem diameter: Fine = 1.9 mm, No. 12 wire size; Medium-fine = 2.3 mm, No. 11 wire size: Medium = 2.8 mm, No. 9/10 wire size; and Course 3.0-3.4, No. 7-8 wire size: Fine and Medium-fine stems are generally green and break apart easily while Medium and Course stems are generally light green to brown and are tough and brittle.

d/ To determine softness, take the palm of the hand and break over the cut edge of the bale. If the stems are hard and tough it will be painful to the palm of the hand.

Leafiness: (a) 50% or more _______, 40-49% _______, 30-39% _______,
20-29% _______, 15-20% _______, Less than 15% _______,
(b) Lt leaf shatter _______, Hy Leaf Shatter _______

Foreign Material: Grass Species _________, Maturity _________,
Percentage _________; Weed Species _________, Percentage _________; Other:
Straw _______, Cow Manure _______, Sheep Manure _______, Dead Rakings _______,
Other _______, Percent of Each _______, Wire _______, Twine _______

Other Distinquishing Characteristics or Features ______________________________

____

____

____

____

Described By: __________________________
Color Agency: __________________________

Figure 2.

PRODUCER QUESTIONNAIRE

LOT NUMBER ______________

FARM NAME ____________________ FIELD LOCATION ______________
(Field No. etc.)

ADDRESS ____
Box No. Road City State

1. Harvest Date ____________________; Date Stored ______________
Month Day Year

2. Type of Hay: Alfalfa
Alfalfa-Grass
Grass
Red Clover
Trefoil
Straw

3. Stage of Maturity: Pre-bud
Pre-bloom
10% bloom (first flower)
25% bloom
50% bloom
Full bloom

4. Cutting: First
Second
Third
Fourth

5. Number of bales in this lot: __________ (Estimated)

6. Drying Agent Used: Yes (Type: ____________________)
No

7. Preservative Used: Yes (Type: ____________________)
No

8. Weeds: Yes (Names(s) ____________________)
No

9. Estimated Percentage of Grass/Weeds in Stand: 0-20%
20-40%
Over 40%

10. Rain Damage: Yes
No

COMMENTS:

Signed: ______________________________ Date ______________

Figure 3.

HAY SCORE CARD

Wis. D.S.-W.-Rev. 8-64

Name: ______________________________ No. ____________________

The Crop: Check to indicate species - Use one or more checks (✓) to indicate approximate proportion of each. Alfalfa_____ Red Clover_____ Ladino______
Alsike______ Brome______ Timothy______ Other______________________

Field cured_____ Mow dried______ Crushed or Conditioned_____ Baled_____ Chopped______

I. Stage of Growth When Cut (40 Points) Cutting date____________________

(Check) (one)		1st Crop____	2nd____ 3rd____ 4th____
______	Initial bloom or earlier	40	38
______	1/10 bloom	38	37
______	1/4 bloom	35	36
______	1/2 bloom	32	34
______	3/4 bloom	28	32
______	Full bloom	24	29
______	Late bloom	15-20	22-26

See other side for alternate scoring for first crop.

II. Leafiness (%) (35 Points)

1.	50 or more	35	______
2.	45 - 49	34	______
3.	40 - 44	33	______
4.	35 - 39	31	______
5.	30 - 34	28	______
6.	25 - 29	25	______
7.	20 - 24	22	______
8.	15 - 19	19	______
9.	Below 15	15	______

III. Color and Condition (25 Points)

1.	Shade of green	21 - 25	______
2.	Yellowish	16 - 21	______
3.	Sl. Musty	18 - 21	______
4.	Sl. Brownish	18 - 20	______
5.	Med. Mold	14 - 17	______
6.	Med. Brown	14 - 17	______
7.	Pronounced Mold	8 - 13	______
8.	Dark Brown	0 - 13	______
9.	Extreme Mold (White)	0 - 7	______

SCORE

I. Stage of Growth ______________

II. Leafiness ______________

III. Color & Condition ______________

Total Points ______________

Deducted Points* ______________

Final Score

* Deduct 1 point for each estimated 1% of undesirable foreign material, such as coarse stemmy weeds, mature dry aftermath or stubble.

Estimated

Tot. Prot. T.D.N.

DIARRHEA IN SUCKLING CARNIVORES

Richard H. Evans, D.V.M., M.S.
Medical Director
Pacific Wildlife Project

Normal Intestinal Anatomy and Function

Villar absorptive epithelial cells (Figure 1) contain a brush border of microvilli, which contain enzymes for nutrient absorption. These cells are produced by the germinal epithelium found in the intestinal crypts, i.e., young, undifferentiated, primarily secretory crypt germinal epithelial cells. These cells migrate up the villus and differentiate into mature absorptive cells which replace senescent absorptive cells that have died and sloughed from the top of the villus. In addition to absorptive epithelium and undifferentiated crypt cells, the villi contain mucus secreting goblet cells interspersed among the absorptive cells.

Normally, nutrients, water and electrolytes are absorbed across the microvilli of the villar absorptive cells. Water, electrolytes and other substances are secreted into the intestinal lumen by the undifferentiated crypt secretory cells. These absorptive and secretory fluxes are balanced so as to maintain the proper body water, electrolyte and nutrient levels, i.e., homeostasis.

In the healthy animal, the intestines are colonized by various types and numbers of bacteria and other organisms. The acid environment of the stomach and proximal small bowel generally support only low numbers of gram positive aerobic (mostly staphylococcus and streptoccus) and anaerobic (mostly lactobacilli and clostridia) bacteria and gram negative aerobic bacteria (Enterobacteriaceae). The distal small bowel, caecum and colon contain large numbers of a wide variety of aerobic and anaerobic bacteria, with the latter being in highest numbers.

These bacterial populations are stabilized at 2-3 weeks of age as the individual's RESIDENT NON-PATHOGENIC INTESTINAL MICROFLORA and are kept in balance by a variety of defense mechanisms including local and systemic immunity and environmental intestinal factors. These bacteria prevent the colonization of the intestines by pathogenic bacteria by producing antibacterial substances, maintaining appropriate oxygen potentials and pH environment, and competing for available nutrients. Further, they serve as a method of metabolizing drugs, bile acids and other chemicals as well as producing volatile fatty acids and vitamins vital to the animal's nutrition.

Diarrhea

Diarrhea is defined as an increase in both the water content AND frequency of bowel movements. A single watery or loose stool is not diarrhea. Diarrhea results from an imbalance in the absorptive and secretory fluxes in the intestines as discussed previously, which produces a NET FLUID LOSS, i.e., decreased absorption, increased permeability and increased secretion. Examples of the major classes of conditions causing diarrhea are described below. Note that not all conditions are actually infectious diseases.

Causes of Diarrhea

1. Conditions effecting the epithelium
    A. Non-Invasive
        1) Bacteria (Vibrio, E. Coli, Staphylococcus, Clostridia, Klebsiella, Enterobacter, Salmonella, Camphylobacter, bacillus, Pseudomonas, Shigella)
        2) Drugs (Neomycin and other chemicals)
        3) Dietary (overfeeding, rapid dietary changes)

    B. Invasive
        1) Viruses (Rotaviruses, Coronaviruses, Reoviruses, Parvoviruses)
        2) Bacteria (E. Coli, Salmonella, Vibro, Shigella, Spirochetes)
        3) Parasites (Coccidia, Cryptosporidia, Giardia, Nematodes, Trematodes, Cestodes)

Figure 2 depicts the various ways in which the above organisms cause diarrhea. In the upper left-hand drawing labelled NON-INVASIVE ENTEROTOXIGENIC BACTERIA, it can be seen that these bacteria produce substances that interfere with the normal secretion of fluids by the crypt epithelial cells (the result of a mechanism called the cyclic AMP cycle), that is, they actually cause an increase in fluid secretion. The result is a NET FLUID LOSS. In the drawing to the right it can be seen that certain drugs, such as the antibiotic neomycin, actually cause damage to the microvilli which results in an increased secretion rate by the crypt cells and again a NET FLUID LOSS. The drawing below this shows the effects of parvovirus infection (Raccoon Parvovirus or Feline Panleukopenia), i.e., severe destruction of the crypt cells followed by loss of absorptive epithelium, resulting in decreased crypt cell secretions, decreased absorption and an increase in permeability which commonly causes fluid and blood loss, again the result is NET FLUID LOSS. The drawing to the left of this depicts how many kinds of viruses attack and destroy absorptive epithelium, resulting in increased secretion and decreased absorption for a NET FLUID LOSS.

Diet-induced diarrheas are, without a doubt, the most common enteric problems encountered in rearing orphaned wild carnivores. The vast majority are the result of too rapid a change from mother's milk to an artificial milk replacer and/or overfeeding; both of which cause imbalances in the intestinal microflora.

Young suckling carnivores have immature digestive enzyme systems on the microvilli, which are responsible for absorbing nutrients. Excessive caloric intakes of even 25-30% over normal may overload these digestive enzymes' system capabilities, resulting in poor digestion. Undigested and unabsorbed protein, fat and carbohydrates thus remain in the lumen of the bowel, acting as a giant osmotic sponge, causing fluid loss. Additionally this promotes bacterial overgrowth and endo- and exotoxin release, which serves to produce a NET FLUID AND ELECTROLYTE LOSS resulting in diarrhea.

At the outset of caloric overload, the feces, normally a golden-brown color and the consistency of peanut butter, turn a pale green owing to excessive bile secretion and the lack of bile reabsorption in the large bowel. As the digestive enzymes become depleted, the stool color changes to a grayish-green to grey. Complete enzyme depletion is marked by yellow to white stools, containing pieces (stringy white material) of sloughed mucosa (villi) and moderate amounts of admixed mucus. In addition, if there are large amounts of lactose in the diet, the stomach secretes excessive hydrochloric acid, which alters the pH of the small bowel, further decreasing the effectiveness of its digestive enzyme systems.

Treatment of Diarrhea

Treatment of diarrhea, regardless of the cause, includes resting the bowel by reducing food intake and rigorous rehydration by fluid therapy. Fluid therapy is probably the single most important treatment for diarrhea. For severe cases, intravenous balanced electrolyte solutions must be given to combat hypotension hypovolemic shock resulting from an abnormally low body fluid volume. Mild to moderately affected individuals can be very successfully treated by the administration of oral methods.

In the last few years it has been found that glucose and glycine absorption from the bowel is intimately related to sodium and water transport and that water absorption can be promoted (even in the face of severe digestive disease) if these ingredients are present in the replacement fluid. Further, the replacement fluid appears to be able to stop fluid loss if its make-up is similar to the fluid lost during diarrhea. Thus, an effective oral replacement fluid formula would consist of glucose, glycine, sodium, potassium, chloride, bicarbonate and water in proportions similar to that lost from diarrhea. Solutions containing glucose and/or sodium only are imbalanced and are not as effective in accomplishing rehydration and reversal of fluid losses from diarrhea. Similarly, lactated ringers, Gatorade^{R} and other similar solutions are only useful for oral fluid maintenance and do not reverse ongoing or replace existing fluid losses.

Fortunately, in the last few years, such a product as described above has been commercially marketed for dogs and cats (ENTEROLYTE^{R}, Beecham Laboratories, Bristol, TN 37620). This product has an added advantage in that it is isotonic rather then hypertonic (thus it is not likely to cause diarrhea itself), is rather palatable and comes as a powder that is mixed with tap water. The only disadvantage that has been found is the cost, which really should not deter any rehabilitator trying to provide the very best care for the animals.

It should be cautioned that oral fluid therapy is most effective in treating enterotoxigenic mediated diarrhea and may not be very effective when the intestinal mucosa is disrupted, as occurs in intestinal diseases caused by invasive organisms.

Rehydration with the above product is accomplished by administering 50-100ml/kg of body weight orally per day, by gavage or stomach tube if necessary. At the same time, milk feedings should be restricted or suspended. Feeding may be reinstituted 48 to 96 hours later in a diluted form. During these treatments, every effort should be made to maintain a normal body temperature.

There is little justification for the routine use of antibiotics for the treatment of diarrhea. They may further disrupt the bacterial populations that normally serve to inhibit the growth of pathogenic bacteria and worsen the diarrhea. In fact, antibiotics themselves may, and frequently do, cause diarrhea by bacterial flora disruption. Antibiotics are warranted in cases of systemic illness (fever, depression, shock, leukopenia or leukocytosis with a left shift) which indicates that bacteria or their toxins have entered the body, or in cases of diarrhea caused by protozoal organisms.

Antimotility drugs should also be avoided since they may result in markedly reduced intestinal transit time and thus promote bacterial toxin absorption and bacterial multiplication.

Fecal cytology is a very useful way of determining whether the bowel mucosa is intact, since infectious diseases that cause damage to the mucosa result in leukocytes and/or erythrocytes in the stool. Patterns and types of bacteria such as campylobacter (a spiral shaped organism) as well as many parasitic protozoa can be readily detected in examinations of fresh fecal material leading to a better understanding of the disease process.

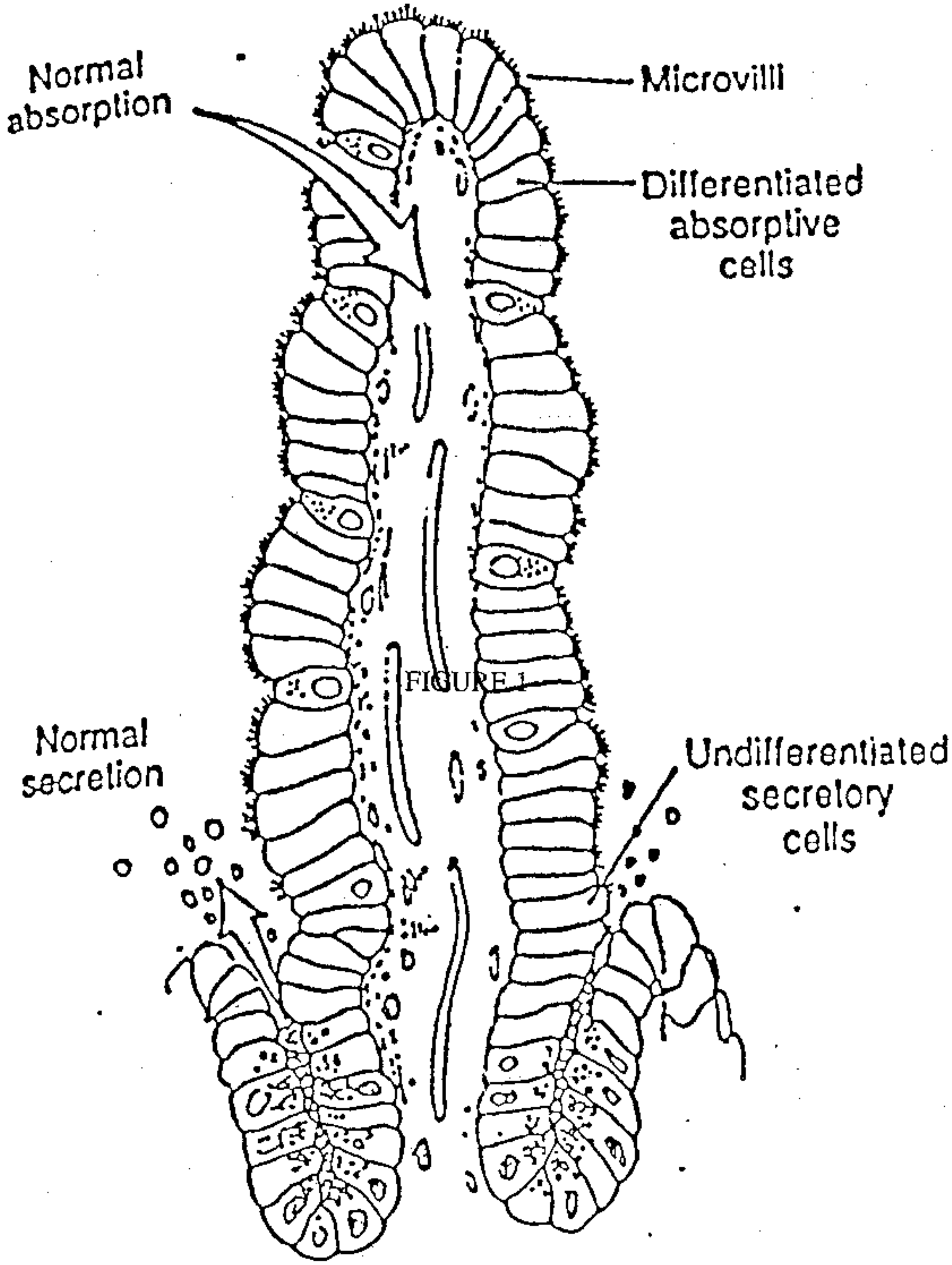
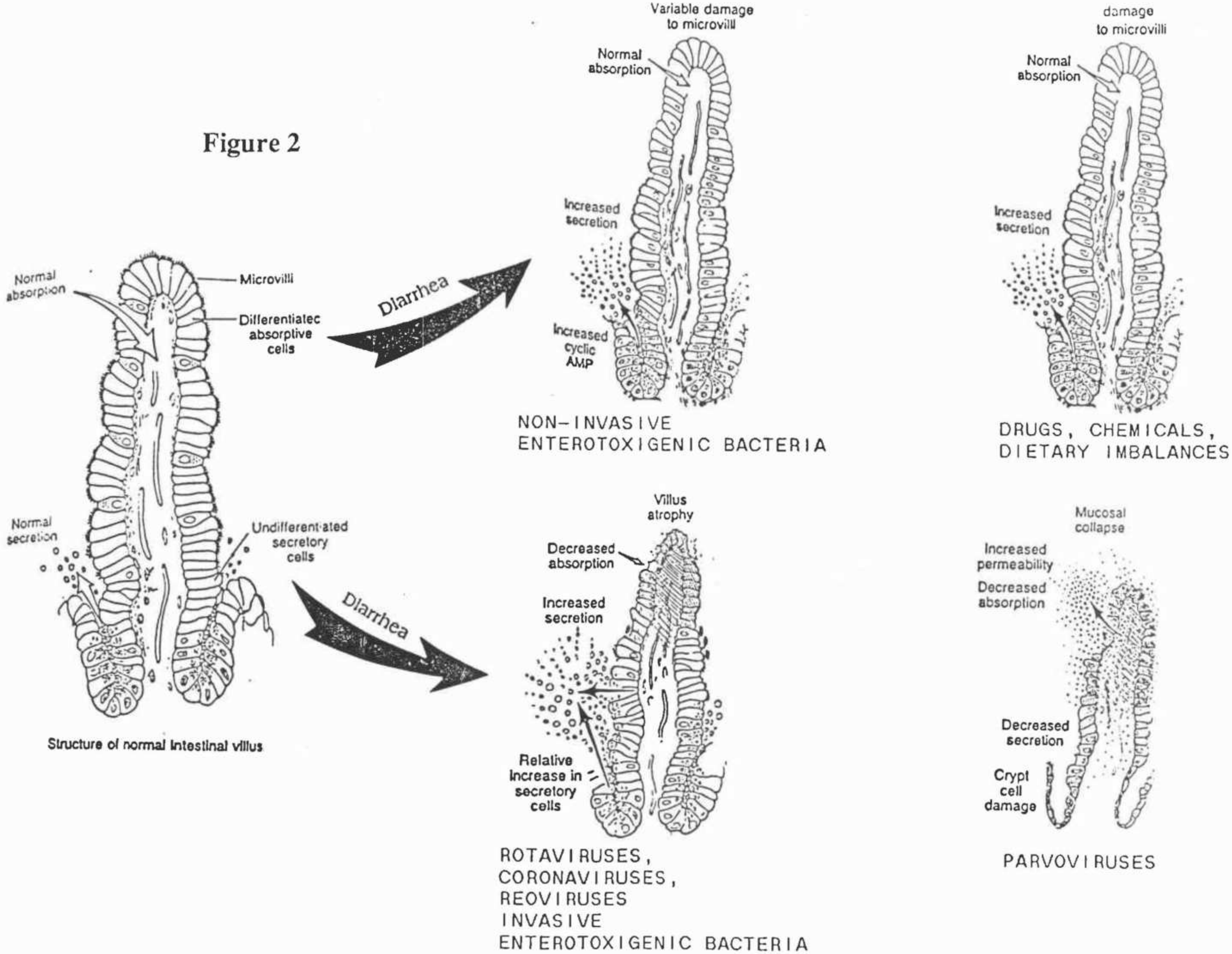

Normal absorption
Microvilli
Differentiated absorptive cells
FIGURE 1
Normal secretion
Undifferentiated secretory cells

FIGURE 1

Figure 2


Normal absorption
Microvilli
Differentiatec absorptive cells
Normal secretion
Undifferentiated secretory cells
Structure of normal intestinal villus
Diarrhea
Diarrhea
Variable damage to microvilli
Normal absorption
Increased secretion
Increased cyclic AMP
NON-INVASIVE ENTEROTOXIGENIC BACTERIA
damage to microvilli
Normal absorption
Increased secretion
DRUGS, CHEMICALS, DIETARY IMBALANCES
Villus atrophy
Decreased absorption
Increased secretion
Relative Increase in secretory cells
ROTAVIRUSES, CORONAVIRUSES, REOVIRUSES INVASIVE ENTEROTOXIGENIC BACTERIA
Mucosal collapse
Increased permeability
Decreased absorption
Decreased secretion
Crypt cell damage
PARVOVIRUSES

THE RESULTS OF MICROBIOLOGICAL CULTURE OF A COMMERCIAL FROZEN MEAT BASED ANIMAL FOOD AND WHOLE FROZEN CHICKEN THAWED BY VARIOUS METHODS

Joel Pond, C.V.T.
Lincoln Park Zoo

This study was originally undertaken in order to ascertain the cause of symptomatic and asymptomatic salmonellosis in several tamanduas. These tamanduas were being fed a diet which was principally composed of a commercial frozen meat based carnivore diet[a]. The commercial meat diet, the animal's actual slurry diet, and frozen whole chickens were cultured in an attempt to isolate the source of the *Salmonella* recovered from the tamanduas.

The commercial feline diet comes from the manufacturer frozen in five pound tubes. These tubes were broken open in the middle and a sterile swab was inserted into the middle of the meat mixture. A tube was cultured after being thawed 24 and 72 hours in a refrigerator, and 24 hours at room temperature. The whole chicken was cultured under identical circumstances. In addition, the tamandua slurry, prepared with the commercial meat diet, egg, milk, water, and a specially made multi-vitamin powder was cultured directly from the animal's feed bowls immediately after preparation and after the slurry remained at a temperature of approximately 27°C for 18 hours while it was available for ingestion by the anteaters.

All cultures were started on trypticase soy agar with 5% sheep blood (TSA), eosin methylene blue agar (EMB), and xylose lysine deoxycholate agar (XLD). In addition, a separate swab from the same area of the sample was placed in GN broth for 6 hours and then subcultured onto XLD media (1). The cultures were incubated at 35°C for

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a Nebraska Brand Feline Diet® Animal Spectrum, Inc., Lincoln, Nebraska.

18 to 24 hours. The plates were then examined for growth. The identification of gram negative organisms was made using a commercial identification system[b]. Gram positive organisms were differentiated according to their catalase reactions. Streptococci were then identified using a commercial identification system[c]. Staphylococci were not further differentiated. The overall numbers of organisms were evaluated quantitatively (2, 3).

The commercial feline diet which was thawed at room temperature for 24 hours yielded moderate to large numbers of all types of organisms. Most of these organisms were gram negative enteric organisms: *E. coli, Klebsiella pneumoniae, Citrobacter freundii.* Few gram positive organisms were recovered and these were streptococci. See Table 1.

Conversely, the commercial feline diet which was thawed 24 hours in a refrigerator yielded few to moderate numbers of organisms of any type. There were very few gram negatives. *E. coli* was the only enteric organism recovered from this sample. There were few to moderate numbers of Streptococci recovered.

The commercial feline diet which was thawed under refrigeration for 72 hours also yielded few to moderate numbers of organisms. *E. coli, Enterobacter cloacae,* and an unidentified beta hemolytic strep were recovered.

Another sample of the commercial feline diet was thawed in a refrigerator for 24 hours and then allowed to stand for about 6 hours at approximately 28°C. This sample, like the sample thawed for 24 hours at room temperature yielded moderate to large numbers of organisms. Gram positives were the predominant type recovered with moderate numbers of gram negatives. *E. coli, Proteus* spp., *Alcaligenes calco-aceticus,* beta hemolytic strep, and *Streptococcus faecium* were recovered from this sample.

The whole frozen chicken which was thawed at room temperature also yielded moderate to large numbers of bacteria. Of these, enteric organisms predominated with *Serratia odorifera* and *E. coli* being recovered. There were very few gram positive bacteria isolated from this sample.

The chicken which was thawed 24 hours at refrigerator temperatures was still partially frozen when the body cavity was opened. Consequently, only very low numbers of *E. coli* were isolated.

The freshly prepared tamandua slurry (at room temperature) yielded moderate to large numbers of organisms with gram positives

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[b] API 20E, Analytab Products
[c] API 20S, Analytab Products

predominating. *Streptococcus avium*, beta hemolytic strep, *E. coli*, *Klebsiella oxytoca*, and *Pseudomonas* spp. were recovered.

Similarly, the tamandua slurry which was cultured after remaining in the animal's cages overnight also yielded large numbers of bacteria as recovered from the freshly prepared diet.

It is obvious that any of the meat products tested had significantly lower bacterial numbers when thawed by correct and accepted food handling practices. Meats which have been thawed or maintained at room temperature for 6 hours or more appear to have bacterial numbers very similar to those recovered from fecal samples. The commercial feline diet is designed for feeding exotic felids. Yet this diet is also fed to animals which do not normally eat meat. Some zoos feed this diet in part to primates, rodents, and Psittacines. None of these animals could benefit from the bacterial shower they would receive after eating the feline diet. The presence of gram negative rods in the feces or cloacae of Psittacines is viewed as being pathogenic.

Meat thawing guidelines, as they apply to meats intended for human consumption are established by the United States Department of Agriculture. The U.S.D.A. recommends thawing any meat product at a temperature not to exceed 40°F. Thawing with hot water is not recommended. However, thawing in water which is less than 40°F is acceptable if rapid thawing is necessary (4).

From these results I am suggesting each zoo review their diets on an individual basis. I strongly urge the keepers who work with this feline diet to wash their hands with a disinfecting agent in the same manner as after handling fecal material. While no *Salmonella* spp. was isolated from any of the samples the large numbers of enteric organisms recovered still cannot rule out the possibility of the diet harboring the organism. Food poisoning occurs in humans, our pets, and, presumably in exotic animals.

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Seventh Annual Dr. Scholl Conference
on the Nutrition of Captive Wild Animals

FIBER UTILIZATION IN THE DIET OF THE RED PANDA

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INTRODUCTION

Bamboo is apparently a major component in the diet of the red panda in the wild (Roberts and Gittleman, 1984; Yonzon and Hunter, 1989). However, we know that in captivity these animals are not fed an all bamboo diet. In a recent red panda diet survey, 17 out of 20 North American zoos and 8 out of 10 zoos overseas fed bamboo as a portion of their diet. But an equal if not larger amount of the captive red panda diet consists of a 'gruel', with fruits and vegetables fed as well (Warnell 1987).

In North America, a typical gruel diet consists of ingredients from eight food groupings (Table 1). Those categories are as follows: water, cereals, milk products, fruits and vegetables, fiber sources and complete feeds, vitamin and mineral premixes, eggs, and miscellaneous items. Examples of cereal products include baby cereals, rice, corn flour and corn flakes. Apples, bananas and carrots appear to be the most commonly fed fruits and vegetables. Bamboo, alfalfa pellets, various monkey biscuits and dog food were categorized under fiber sources and complete feeds. Miscellaneous food items include applesauce, peanuts, sugar, salt and honey.

The survey confirms that the gruel portion of the red panda diet is consistent in the types of feeds offered, but the diets are in no way similar in nutrient composition. This is attributable to the differences in the amounts of various ingredients mixed in the gruel (Table 1). Specifically, the variation in vitamin and mineral premixes is a dramatic example of the diversity in gruel diets. Vitamin and mineral premixes ranged from .13% to 9.63% of the total gruel composition with an average of 2.44% (Table 1). From a management standpoint the addition of a vitamin/mineral premix as 10% of the gruel mixture is likely to produce serious health consequences. Excessive vitamin and mineral levels could lead to metabolic problems or toxicities. It is important to note that vitamin and mineral premixes can differ greatly in composition. It must also be remembered that bamboo may differ in nutrient composition depending on the season harvested, the growing conditions and the species, although there are limited data available (Dierenfeld 1981; Dierenfeld et al., 1982).

MATERIALS AND METHODS

So what would be an optimal red panda diet in captivity based on the availability of the feed, acceptability to the animals, oral health considerations and other management related questions? A study was undertaken in June of 1986 at the National Zoological Park in Washington D.C. to better understand how the red panda utilizes the components of the red panda diet fed there. This diet appeared to be 'typical' of other surveyed panda diets. Three subadults and two adults (4.1) were moved from the NZP's Conservation and Research Center to five corncrib style cages at the main zoo in Washington, D.C.

The move was initiated in part to control experimental conditions. The concrete flooring in all the cages made total fecal collections more accurate as it was easy to collect the feces without substrate contamination. Fine wire mesh ('chicken wire') was installed around each corncrib to ensure that vermin could not enter, and the red pandas had access only to food items offered. Temperature, barometric pressure and humidity were monitored daily in order to correlate feed intake with weather data.

RESULTS

Four of the diets fed will be discussed here, as preliminary data are available for these trials. They were as follows: an all bamboo diet, an all gruel diet, a diet consisting of gruel and bamboo offered separately, and a diet of gruel with dehydrated alfalfa meal added. Because the red panda is selective for only the leaf portion of the bamboo plant (Gittleman, 1989), and to avoid problems in intake measurement, only bamboo leaves were offered. Each of the digestion trials were from 5 to 7 days in length, with a period of adaptation prior to the trial of at least 7 days. Wheat kernels were chosen as the undigestible particle marker to determine digesta transit time (TT, time of first appearance of marker), and the total retention time (TRT, length of time food remained in the gut). When comparing all diets, there was a tendency for transit times to differ ($p \leq 0.10$, Table 2) (Siegel 1956). Although it appeared that on an all or partial bamboo diet the digesta passed through the gut faster, no statistically significant differences were found in the TRT among groups ($p \leq 0.125$, Table 3).

The apparent digestibilities of an all bamboo diet versus an all gruel diet were also investigated. The average dry matter digestibility was only 23.9% (n=4) on an all bamboo leaf diet, while for an all gruel diet the average DM digestibility was 68.2% (n=5). Differences in the digestibilities of the various diets may be explained, in part, by the tendency for bamboo to pass through the gut more quickly than gruel. Given the lower digestibility of bamboo it seems that the red panda has adapted to eating a large volume of bamboo, digesting what it can and passing it through rapidly to meet its energy needs. The NDF (neutral detergent fiber-plant cell wall fraction) (Van Soest, 1982) fiber digestibility was 24.7% and the crude protein digestibility was 50.4% for the four animals fed the all bamboo diet. These data suggest that the red panda does not digest fiber efficiently and only utilizes one fourth of the bamboo eaten.

Volatile fatty acids (VFA's) are the end products of fermentation in herbivores. They are often used as an indicator of fermentation activity which in turn is a function of substrate availability and retention time (Annison and Armstrong, 1970). VFA concentrations measured in fresh feces (collected ≤3 minutes after being voided) revealed significantly higher levels on an all gruel or mixed gruel diet, while an all bamboo diet produced the lowest fecal VFA concentrations. Microbiological tests conducted simultaneously on the feces also indicated higher VFA levels on a gruel diet. It was evident by measuring Lactobacilli (LBS), a microbe that grows favorably in the presence of VFAs, that the bamboo diet produced the smallest counts of LBS (0 to 0.68 X 10^4/gm) as compared to an all gruel diet (11.4 to 31,000 X 10^4/gm). Other microbiological tests using MacConkey's agar and a starch/cellulose broth showed similar trends but were less conclusive.

The bamboo fed contained 76.9% NDF with a average NDF digestibility of 24.7%, showing that a large portion of the diet is not readily available for digestion. Although we fed the animals a sufficient amount of bamboo to ensure some was left uneaten, the animals experienced an average weight loss of 0.69 kg during the 7 day trial. The preliminary data suggest that bamboo is poorly utilized by the red panda. From a practical standpoint bamboo is expensive and poses a management problem in its procurement. Based on transportation and labor expenses at the National Zoo in Washington, D.C., bamboo was found to be 13 times as expensive as a herbivore breeder pellet, even though the actual bamboo is free from peoples' yards! Because bamboo is not always available to zoos that would like to hold red pandas and bamboo is often subject to winter kill, a search for an alternate fiber source was undertaken. Dehydrated alfalfa meal was the one chosen, as it was relatively inexpensive, readily available and easily stored. In addition, 20% of the zoos surveyed used alfalfa in some form.

The total retention times for gruel and 10% alfalfa meal were similar to the all gruel diet although the dry matter digestibility values were somewhat reduced. The stools remained firm on the alfalfa meal/gruel diet (10% alfalfa in total gruel), while loose stools had been a problem on the all gruel diet. The acceptability of alfalfa meal was tested by giving the animals a simultaneous choice of 0%, 5%, and 10% alfalfa meal added to gruel. The locations of the bowls were rotated to avoid possible location preference. Four of the five animals preferred the lower levels of alfalfa meal while one consistently ate from the 5 and 10% bowls. It was thought that the animals might actually be selecting bowls based on the consistency of the gruel (more or less moist) since there were no corrections made for water absorbed by the alfalfa meal. A second study revealed the animals did prefer a food with a higher moisture content. At the end of the feeding trials the animals were given a pre-shipment medical exam. All of the animals appeared to be in good health but 3 of the 5 animals had developed elevated liver enzyme levels (SGOT, SGPT) and elevated serum cholesterol levels (Montali, et al., 1989). A follow-up study is being conducted to elucidate possible causative factors. Preliminary data from that study indicate that diet was not a predisposing factor for elevated enzyme levels.

DISCUSSION

With the preliminary data accumulated thus far, problems in typical red panda diets are apparent. We believe that gruel is not ideal for several reasons. Oral health is certainly not improved on a soft, mushy, high sugar diet. Plaque and calculus can accumulate and lead to various teeth and gum problems. Gruel diets usually consist of many ingredients and are therefore subject to problems in preparation, especially if several people measure and mix the diet. The nutrient composition is likely to differ even on a daily basis. Spoilage of this type of food is a consideration as well. Recommendations for future diets might include an extruded product thus eliminating the mixing, consistency and storage problems as well as providing a benefit to the animals' oral health. In the search for an optimal diet, more feeding trials should be conducted to ensure acceptability. As these baseline data accumulate, along with a continued and more detailed diet survey, we will be better equipped to make long term diet revisions for this endearing endangered species.

ACKNOWLEDGEMENTS

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TABLE 1. North American red panda 'gruel' diets (n=10).

Ingredients	-Percentage of ingredient used in gruel mixture- Min	Max	Average
Water	29.83%	50.79%	45.82%
Cereals	8.65%	53.04%	25.25%
Milk products	0.70%	41.56%	14.42%
Fruit/vegetables	9.00%	49.03%	26.21%
Fiber/complete	0.20%	19.84%	5.72%
Vitam./min.	0.13%	9.63%	2.44%
Eggs	2.23%	5.20%	3.71%
Other	1.23%	25.01%	8.60%

**Ingredients expressed as a % (by weight) of diet on an 'as fed' basis.

TABLE 2. Red panda transit times (time to first appearance of marker).

Diet	Mean Transit time (Min)	(Hrs)	Range (Min)	SD+/- (Min)
BAMBOO	323.75	5.40	180-405	73.92
B/G	225.63	3.76	160-310	51.02
GRUEL	566.25	9.44	250-965	334.12
G/10% ALF. MEAL	310.76	5.18	140-720	177.85

TABLE 3. Red panda total retention times (time for total passage of ingesta).

Diet	Mean Retention (Min)	Time (Hr)	Range (Min)	SD+/- (Min)
BAMBOO	351.88	5.86	255-410	36.36
B/GRUEL	338.13	5.64	230-530	93.66
GRUEL	573.88	9.56	300-965	324.56
G/10%ALF MEAL	577.35	9.62	360-700	96.69

THE NUTRITION OF ALTRICIAL BIRDS

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Though altriciality is not well defined with respect to homeothermy and condition of the chick at hatch, for nutritional purposes altricial birds are those which at hatch are unable to seek food on their own. This leaves the chick dependent on its parent or a surrogate for food and water. For the nutritionist this presents some interesting problems, because most avian nutrition research has been done in precocial birds. This is because precocial birds in general will consume nutritionally defined diets from hatch which involve only limited labor to provide. Since altricial birds must be fed each individual meal, research on their nutritional requirements demands considerably more labor. Thus, though most species of birds are altricial and many are desirable to keep and attempt to propagate in captivity because of their scarcity in the wild, little is known about their nutrition. From what little is known some unique nutritional problems in the propagation of altricial birds are discussed below.

Food and Water Intake

Being the recipients of only what food and water are brought to them, altricial chicks are not able to directly regulate their total food intake or the proportions of food and water in their diets. These must be regulated by the parent or a surrogate feeder to achieve maximum growth. Since requirements for body maintenance must be met before surplus food is available for growth, a comparatively small shortfall in total food intake comes directly from the food available for growth and results in a proportionally larger reduction in growth.

The proportions of food and water in the diet as well as total intake must also be regulated and relative amounts must change with the age of the bird. In work with cockatiels Grau and Roudybush (1988) found that during the first three days of life a high water diet (10% solids; 90% water) enhanced survival compared to diets containing 20% or 30% solids.

After five days requirements and tolerance for water changed. Diets containing 10% solids produced significantly poorer growth than diets containing 20% or 30% solids while 50% solids resulted in 100% mortality. These laboratory observations of the progressive reduction in the requirement and tolerance for water is supported by field observations of Stamps (1985, 1987) in budgerigars. Upon entry into the nest box parent budgerigars were observed feeding chicks in order from youngest to oldest. Since food settles in the crop-a blind sac off the esophagus- food near the top of the crop often contains more water and less solid food than food lower in the crop. The youngest chick which is fed first would then receive more water and less solid food as a proportion of the diet than subsequently fed older chicks.

Growth Curves

In the case of altricial birds kept in zoos the goals of feeding are to produce healthy animals which will reproduce and live long lives. While little is known about what diets and intake fed to growing altricial birds result in maximum reproduction and life span, some information is available on the growth and behavior of chicks fed by parent birds. Achieving growth in hand-fed chicks similar to that of parent-reared chicks does not necessarily mean that the birds will have long and reproductively active lives, but until better information is available it gives us a standard against which hand-rearing results can be compared.

A comparison of the growth curves of chicks fed by parent birds and growth curves from hand-fed chicks may help to focus attention on areas where differences exist. Thereafter assessments can be made as to whether these differences result in a significant effect on the bird.

Figure one shows the growth curves of cockatiel chicks fed by parents and chicks fed by hand. The earliest difference is the slower growth of hand-fed birds immediately after hatch compared to the growth of parent-fed chicks.

The poor growth of hand-fed chicks is due to less than adequate food intake. During the first three days after hatch the hand-fed chicks were fed a 7% solids diet every two hours from 6 am to 10 pm to meet their early high water requirements. The dilution of the diets coupled with infrequent feeding and the small crop size relative to body weight of hatchlings resulted in low total food intake and poor growth.

Following the initial three days of feeding the proportion of solid food in the diet of the hand-fed birds was increased from 7% to 30% and the feeding schedule changed to every four hours from 6 am to 10 pm. Because of the increased proportion of solids in the diet and increase of crop size of chicks food intake per unit of body weight was increased. This increase resulted in a growth rate parallel to that of parent-fed birds from three days to 24 days of age.

The body weights at 24 days of age in parent-fed birds peaked at 90 grams while hand-fed birds continued to grow to 120 grams. At about 24 days of age the crops of cockatiel chicks shrink resulting in a reduced capacity to accept food. In the hand-fed chicks however meal size was not decreased, because behaviors which would allow the chicks to avoid attempts of parent birds to feed were ineffective in inhibiting feeding by the hand-feeder. When food intake in the hand-fed chicks was finally reduced, chick weights fell to about 85 grams at five weeks of age-the same as parent-fed chicks.

Figure two shows growth curves of two groups of hand-fed cockatiel chicks. One group from figure one and another group which was feed restricted during hand-feeding. The feed restricted group shows poor growth from day eight to day 23 compared to chicks with higher food intake. By day 35 the two groups had achieved the same average body weight of 85 grams. The question this presents is whether the pattern of growth is important if both hand-fed groups and parent-fed chicks reach the same weight at five weeks of age. This will be considered in the section on weaning.

Feed Efficiency and Growth

Feed efficiency can be used as an index of the adequacy of total intake of a diet. Inadequate intake results in reduced growth compared to growth of birds fed adequately. Since feed efficiency is a measure of the amount of food required for a specific amount of weight gain, any reduction in gain results in a worsening of feed efficiency unless feed intake is reduced by a proportional amount. Reductions in gain are always disproportionately large compared to feed intake reductions, because in the partitioning of food to meet the requirements of maintenance and growth the requirements for maintenance are met before food is used for growth. For example, if an animal uses 70% of its food for maintenance and 30% of its food for growth on an adequate intake, a reduction of 15% in total food intake results in a 50% reduction in the amount of food available for growth. In this case feed efficiency worsens dramatically. The bird now needs 170 grams of feed to achieve the same growth it obtained from 100 grams of feed at an adequate intake. Since food intake is low, the chick will require a much longer time to consume the 170 grams of food it needs to achieve the growth it could have shown had it been fed adequately.

To use feed efficiency as a measure of adequacy of food intake, food intake (dry weight basis) must be measured over a significant period of time. In a rapidly growing bird such as a cockatiel this can be as short as one 24 hour feeding period. Over the same period weight gain must be measured. It is important to weigh the bird at a time when the crop is empty, because the crop contents can be a significant portion of the body weight and can interfere with measuring daily weight gain. During the next period increase the amount of food as a proportion of body weight which is fed. Calculate feed efficiency again. If feed efficiency improves the bird was initially underfed.

Failure to Gain Weight

In early growth of cockatiels the failure to gain weight is an indicator of a problem comparable to sustained weight loss in precocial birds. Roudybush and Grau (unpublished results) fed a protein-free diet to cockatiel chicks beginning at one week of age. After an initial small weight loss chicks maintained their body weights for a week and died. This indicates that chicks of this age were unable to mobilize body stores to prolong their lives. This inability to lose weight may mask problems which would result in weight loss in precocial birds. Altricial chicks should gain weight daily and should be weighed at least once a day to confirm this weight gain. Cockatiel chicks normally develop the ability to lose weight sometime between one and two weeks of age.

Meal Size

The maximum size of meals fed to altricial birds is determined mainly by the presence or absence of a crop. In cockatiels meals as large as 25% of the chick's body weight can be fed. In birds such as blackbirds which lack crops gain and improved feed efficiency from increased food intake can be used as indexes of adequate feeding.

Night Feeding

Night feeding or feeding more than 16 hours a day is not required in cockatiels to achieve growth rates comparable to chicks fed by their parents. Feed efficiency and growth rate are again good indexes of adequate intake.

Diet Viscosity

Diet viscosity is often erroneously used as a measure of the amount of water in a mixture of solid food and water. Viscosity by itself is a poor measure of the relative proportions of food and water in a mix. Diets can be formulated to be more or less viscous based on the amounts of water absorbing ingredients they contain or can be made more or less viscous by regulating the time and temperature of cooking in the case of cooked diets. The amounts of food and water in a mix should be measured and viscosity adjusted either by proper formulation of the dry mix or by closely regulated cooking. The viscosity of hand-feeding diets is however important to achieve uniform crop emptying and to maintain a clear airway in hand-fed chicks. In birds with crops the diets must be viscous enough to avoid settling and separation of food from water in the crop. If settling occurs mostly water is removed from the crop leaving a desiccated lump of food behind which does not pass into the gut. This mass of food can mechanically limit the capacity of the crop leading to underfeeding from reduced meal size or may provide a substrate which persists in the crop long enough to allow infections of bacteria of molds to become established. In addition diets of low viscosity often travel up the esophagus when a chick leans on a full crop. This causes the chick to repeatedly swallow this food and occasionally aspirate small drops. This aspirated food may not be enough to cause suffocation but can lead to infections and eventual death from pneumonia.

If a diet is too viscous the chick may experience difficulty swallowing and aspirate food. This usually leads to a quick death by suffocation.

Weaning

The weaning process has been characterized in cockatiels to a limited extent by Roudybush (1986). Weaning is the process in which an altricial bird changes from being fed to feeding itself. More specifically the process involves a behavioral change in response to hunger. Preweaning chicks which consume a significant portion of their total food intake by seeking and ingesting food voluntarily will beg to the exclusion of voluntary food intake when hand-feeding is limited. Post weaning birds may still beg but consume enough food voluntarily to maintain their body weights.

Weaning or self-feeding appears to be a response to a physiological process related to early development and is not a learned behavior. Chicks of weaning age weaned between zero and three days after being offered food for voluntary intake even though they had had no previous experience with free food. Figure three shows that chicks which had experienced slower growth rates between eight and 23 days of age weaned later than chicks which had grown maximally during this period. This occurred even though the mean weights of all chicks were the same at 35 days of age and earliest weaning did not occur until 44 days of age. Early growth and development were significant affecters of weaning age.

Behavior and Food Intake

Earlier it was stated that altricial birds are wholly dependent on parents or surrogate feeders for regulation of their food and water intakes. The questions arise, however, of how the parent is able to regulate the chick's intake; how this intake is monitored by the parent; and how the parent responds to any monitoring which occurs. We have already seen how in budgerigars parental behavior of feeding youngest chicks first can result in higher water intakes in young chicks compared to older chicks. Other parameters of food intake may be regulated by behaviors in the chicks which stimulate behavioral changes in the parents. Chicks which received low protein diets begged more vigorously than chicks which received an adequate level of protein. Chicks which were fed excessive levels of water begged more vigorously than chicks given less water and eventually began to scream and run back and forth in front of the feeder. Chicks fed excessive levels of protein regurgitated and blocked feeding by biting and screaming when touched. Chicks fed an adequate diet in adequate amounts were docile and accepted feeding with little or no begging. The varied and consistent responses among chicks from groups of birds fed various diets suggest that different dietary deficiencies of major nutrients may result in behaviors which stimulate parents to respond by correcting this deficiency. The part of this equation which remains to be tested is the parental response to characteristic chick behaviors. If the behaviors in both parents and chicks can be discovered, these behaviors may become useful as indicators of diet adequacy.

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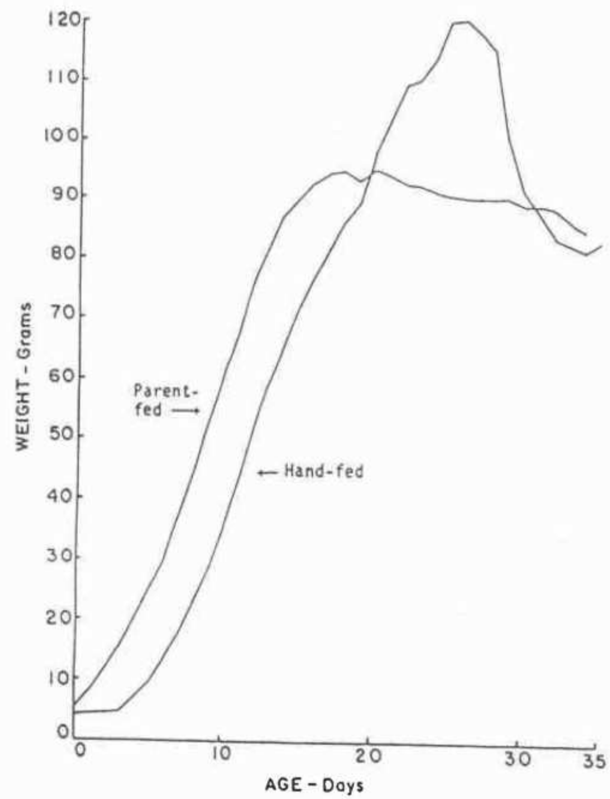

Fig. 1 A comparison of growth of parent-fed (n=27) and hand-fed (Trial 1) (n=14) cockatiel chicks from hatch to 35 days of age.

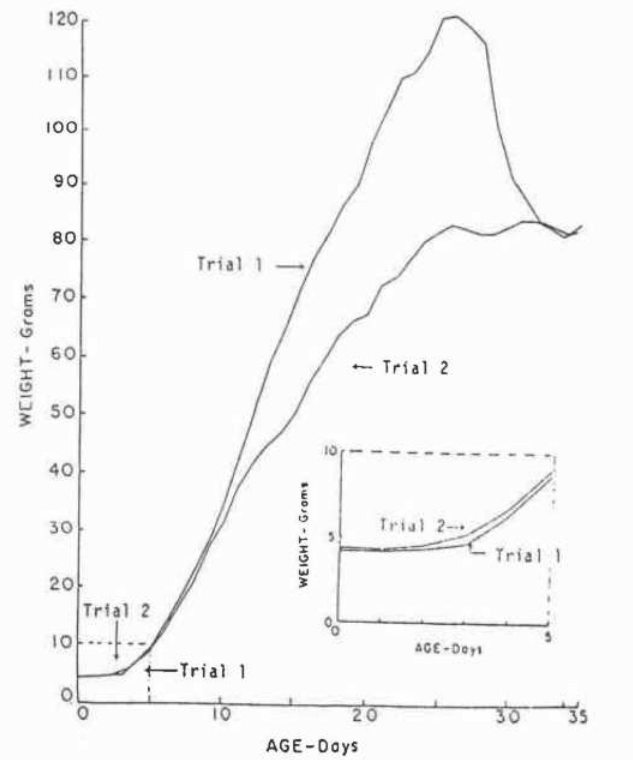

Fig. 2 A comparison of growth of Trial 1 and Trial 2 hand-fed chicks from hatch to 34 days of age. The inset shows an enlarged portion of days 0-5 (n=14/trial).

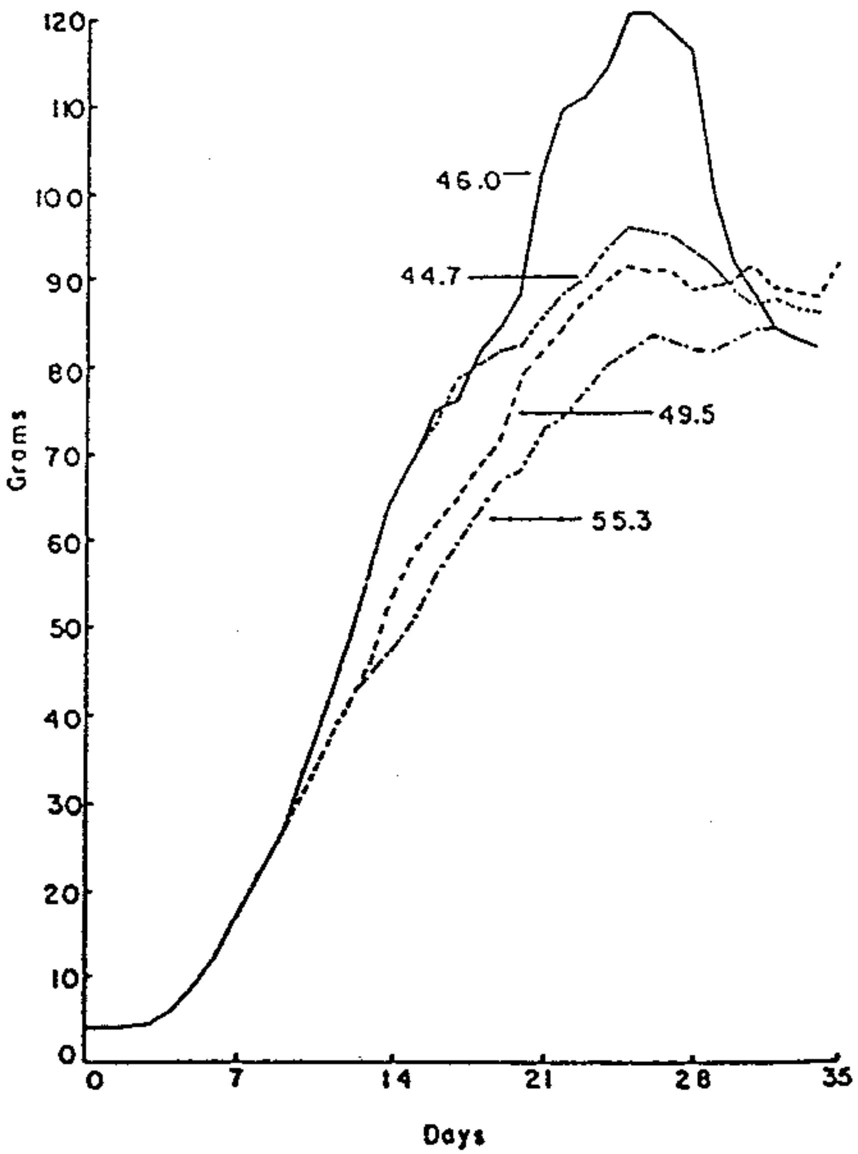

Fig. 3. Growth of cockatiel chicks hand-fed different amounts of food. All chicks were fed the same diet. Numbers indicated on each curve are the mean ages of weaning for that group.

IF THE DIET IS DEFICIENT WILL THE ANIMAL LET US KNOW?

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When animals appear ill, don't grow properly or fail to reproduce, it is reasonable to include defects in the diet among those factors that may be responsible. A veterinarian may perform a physical examination in a search for the cause of the problem. Broken bones are usually obvious, but other deviations from normal can be subtle and difficult to detect. Homeostatic mechanisms can obscure incipient nutrient deficiencies which even modern clinical chemistry techniques may not detect. For example, plasma calcium concentrations usually fall within the normal range even when calcium balance is decidedly negative for extended periods. This is possible because of the reservoir of calcium provided by the skeleton and the effectiveness of the mechanisms for regulation of soft tissue calcium concentration.

Indeed, it is important to have specific knowledge of the metabolism of individual nutrients if one must diagnose deficiencies on the basis of animal examination alone. Some nutrients, such as selenium, exhibit different half-lives in different tissues. If one wishes to distinguish between the long-term and short-term status of a subject relative to this element one could determine the selenium-dependent glutathione peroxidase concentration in erythrocytes as compared to the selenium concentration in plasma. Since the selenium-dependent glutathione peroxidase in erythrocytes is incorporated during synthesis of these cells, levels of this enzyme will change gradually, proportional to erythrocyte half-life as well as to the need for and supply of selenium. In contrast, plasma selenium concentrations tend to be a more immediate reflection of selenium supply and demand.

It is apparent, then, that if we expect the animal to inform us if its diet is deficient, that information is highly dependent upon the questions we ask. Almost always our confidence in the answer can be strengthened by examining the diet itself. Few quantitative nutrient requirements have been experimentally determined for wild animals, but extrapolations of the information base for domestic species have been used successfully for many years. Studies of dietary habits in the wild, and investigations of gastrointestinal morphology and function, help assure that success. Nutrient data are available for many feedstuffs. When these data are strengthened by analyses of feeds actually being used and are accessed with computer software such as the Animal Nutritionist[R] (N-Squared, Durango, CO), the nutrient profile of a particular diet can be predicted. Comparisons with known or probable nutrient requirements provide insights that can be compared with observations on the animal itself. With this combined approach, when the animal can't speak or if its message is garbled, a correct identification of the problem is much more likely.

COMPARISON OF CALCIUM AND PHOSPHORUS LEVELS IN CRICKETS FED A HIGH CALCIUM DIET VERSUS THOSE DUSTED WITH SUPPLEMENT

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INTRODUCTION

Many birds, reptiles, and mammals are insectivorous; that is, insects are part of their diet. Some animals in zoos receive insects as treats and obtain the majority of their nutrients from a complete feed or zoo diet. Consequently, zoos need not rely on insects alone to meet the nutrient requirements of these animals. However, some animals are very insectivorous and may eat only insects. In this case, the insects they are fed must supply the nutrients they need to live and reproduce normally. In the wild such animals have access to a wide variety of insects and they may also augment their diet with other small invertabrae and dirt. Unfortunately, zoos cannot provide the same variety. Choices may be limited to items such as crickets, mealworms, waxworms, and earthworms.

Crickets are inadequate as a complete source of Ca and may be lacking in other nutrients. Allen and Oftedal (1982) reports values of .10% Ca and .73% P with an imbalance in the Ca:P ratio (.13:1) of crickets on a dry matter basis. Ray Pawley, Curator of Reptiles, Brookfield Zoo, Brookfield, Illinois, in a study determined the Ca content of crickets, on a dry matter basis to be .25% and .69% P with a .36:1 Ca:P ratio. Such ratios are far from the desired 1:1 to 2:1. Consequently there is a need to supplement crickets used in insectivore diets.

Methods of supplementing crickets include feeding them a high Ca diet or dusting them with a high Ca powder. According to the work of Allen and Oftedal (1982) it would take a diet with a Ca content of at least 10% to achieve Ca levels approaching 1% in the cricket. Those crickets should be on the high Ca diet with an available water source two days prior to feeding out.

The purposes of this study were: to validate Brookfield Zoo's feeding/dusting regime and the use of a new commercial diet, examine possible differences between water or fruit as a moisture source, and compare these methods with those utilized by other zoos.

MATERIALS AND METHODS

To achieve maximum gut fill a commercial diet was fed for 48 hr, the time recommended by the manufacturer and past studies (Allen and Oftedal, 1982). Crickets were fed in cylindrical plastic containers, with a diameter of approximately 7 in. and a height of 5 in. with gravel in the bottom and water in a sponge or fruit (apple and orange) as a moisture source. Five replicates were conducted with 20 crickets (approximately 10 g) for both moisture sources. The commercial diet was 8.0% Ca and .86% P. This arrangement was repeated twice for a total of 10 replicates of each treatment.

Crickets were also dusted with a compound used in one of Brookfield Zoo's departments and compared with crickets fed the commercial diet. The dust was 11% Ca and 3.2% P. A group of 100 crickets were dusted with 1/8 tsp of powder and housed in a plastic bin approximately 22 in. x 7 in. with gravel similar to a cage in the zoo's reptile house. Ten gram samples of crickets were collected over time at the following intervals: 0-5 min., 3 hr., and 22 hr. This procedure was repeated twice. All samples were frozen and analyzed for dry matter, and Ca and P content by the Department of Animal Sciences, Michigan State University, East Lansing, Michigan 48824-1225.

RESULTS

Although the Ca:P ratio was improved, it was still far from the desired 1:1 to 2:1 ratio (Table 1). The Ca:P for unsupplemented crickets was .13:1 (Allen and Oftedal, 1982). Possible reasons for the low levels are: the crickets may not have begun to consume the diet immediately and may have effectively been on feed for less than 48 hr. due to stress from shipment; or the crickets may have been in their last weeks of life when they may not eat as readily. There were no apparent differences between fruit and water as moisture sources (Table 1).

The Ca:P ratio of dusted crickets decreased as time after dusting increased (Table 2). If the dusted crickets were ingested immediately, compared to those crickets that were on the commercial diet for probably less than 48 hr, fed crickets still had three times the Ca content of dusted crickets.

A survey was conducted to determine how other zoos supplement their crickets for reptiles. Thirteen zoos across the country were questioned. Included were six small zoos (600 total specimens or less) and seven large zoos (1800 total specimens or more). Ten of the thirteen zoos supplemented their reptiles either by dusting with a high Ca or vitamin powder, or by feeding a complete diet with normal to high Ca levels or some combination of these methods (Table 3). The types of dusts varied greatly.

They ranged from commercially available vitamin powders to homemade preparations that included: powdered cuttle bone, powdered limestone, bonemeal, Ca gluconate, Ca lactate, or a mixture of the above. Most small zoos used a commercial dust while most large zoos used their own mix or both methods (Table 3). Types of diets offered also varied greatly, from a commercially prepared complete feed high in Ca and manufactured specifically for supplementing crickets to more general commercial feeds such as chows, chick starters, poultry mashes and game-bird feeds to unsupplemented or maintenance diets of fruits and vegetables alone. Of the small zoos that supplemented crickets by feeding a diet, all fed a general commercial feed. Large zoos mostly fed a specific commercial feed and a few used a general commercial feed (Table 3). Approximately equal numbers of zoos used water as opposed to fruit and/or vegetables as a moisture source with the supplemental diets (Table 4).

DISCUSSION

Feeding was better than dusting with the compound used at Brookfield Zoo. Even those crickets on a commercial diet for only 24 hr. had higher Ca levels than dusted crickets which could have been ingested immediately. If crickets were dusted with pure Ca carbonate they would have higher Ca levels than those fed a diet if eaten immediately. When feeding a supplemental diet to crickets this study suggested that crickets should not be in their last weeks of life when they may eat less readily and that it may take more than 48 hr. to achieve maximum gut fill due to possible shipping stress. The authors were concerned that having fruit available as a moisture source would encourage the crickets to eat it instead of the high Ca diet since the fruit may be more palatable; however, this study shows there seems to be little difference in the Ca and P content of crickets with either moisture source. The survey indicated that there was generally no standardization among zoos as to how they treat their insects before feeding them.

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Table 1. The Ca and P content of crickets fed the commercial diet.

Moisture Source Offered With Diet	Ca %	P %	Ca:P
Water in a sponge	.45	.92	.49:1
Apple and orange	.38	.99	.38:1

Table 2. The Ca and P content of dusted cricket.

Time after dusting	Ca %	P %	Ca:P
0-5 min.	.12	.67	.18:1
3 hr.	.12	.83	.15:1
22 hr.	.08	.62	.12:1

Table 3. Types of supplement, dust, diet and moisture source in surveyed zoos.

	Small zoos <600 total specimens	Large zoos >1800 total specimens
Numbers that supplemented	4	6
Types of supplementation		
dust	2	1*
feed		1*
both	2	5
Types of dusts		
"commercial"	3	1
own mix		3
both	1	2
Types of diets		
"commercial" specific	0	4
"commercial" general	2	2
Moisture source available with experimental diets		
water	3	
fruit and/or vegetables	4	

*Brookfield Zoo - some departments feed and some dust.

AN INTRODUCTION TO THE AMERICAN ASSOCIATION OF ZOO KEEPERS DIET NOTEBOOK

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The American Association of Zoo Keepers (AAZK) is collecting exotic animal diets from zoos throughout North America. Diets compiled to date have been organized and will be published in the AAZK Diet Notebook. A brief history of the notebook will be reviewed using example response forms and completed diets. Finally, long term goals for the notebook will be addressed.

Since the beginning of recorded time, man has been fascinated with animals, often keeping them in captivity. For some species little knowledge of their needs was available. Often these species survived only short periods of time in captivity, requiring their replacement with wild-caught animals. Other species survived but did not reproduce well, again requiring their replacement with wild caught animals. Still others thrived and reproduced no matter what they were fed or how they were housed. Today's zoological institutions try to provide nutritionally balanced diets and proper housing for all the animals they maintain. Many wildlife biologists are working to identify and describe the natural histories of even the most obscure species, and this information is being applied to captive animal management.

Understanding the need for nutritionally balanced diets of animals in their collections, modern zoos now discourage visitors from throwing popcorn, peanuts, marshmallows, or other inappropriate foods to their animals. In areas where the public is allowed to feed the animals, the proper food is dispensed by coin-operated machines, to the benefit of the animal, the public, and the zoo's budget. The AAZK is proud to contribute to the expanding wealth of knowledge of nutritional and dietary information with the Diet Notebook.

The Diet Notebook was initiated at the 1982 National AAZK Conference, held at the Metro Toronto Zoo, with the intent of helping fulfill the need for dietary information. Diets in zoos around the world vary considerably, as does our success in maintaining certain species. It was decided that a collection of diets currently in use could assist institutions when formulating diets for new or difficult to manage species.

The South Florida AAZK Chapter completed the initial stages of the diet notebook, designating the response form, selecting coordinators for each taxonomic class, and collection of diets. In October 1986 I became the project head, with the task of assimilating and compiling the submitted diets.

The Diet Notebook is divided into four sections; 1)

Mammals, 2) Birds, 3) Reptiles, Amphibians, Fish and Invertebrates, and 4) Appendix. The appendix is to include company product sheets, nutritional values, and a list of reference material. The loose-leaf format of the notebook is designed to allow the addition of new and revised diets. All diets have been arranged in and grouped by taxonomic order; and individual species are then identified by scientific name, with some zoos identifying their animals to subspecific level.

Each species and subspecies has been assigned its International Species Inventory System (ISIS) number. This sixteen digit numerical system will aid in the location of animals and in the addition of diets. The ISIS number is actually a taxonomic code, e.g.: Barbary Lion Panthera leo leo ISIS # 1412007002001002

Class	14 Mammalia
Order	12 Carnivora
Family	007 Felidae
Genus	002 Panthera
Species	001 leo
Subspecies	002 leo

The original response form was developed for all the taxa, but as the forms were put to use it became apparent that a separate form was needed for the fish and invertebrates. The form varies only in two areas due to the special needs of some of these animals; this will be discussed later.

On all forms, the common name, scientific name, order and ISIS number are specified. The contributor, institution where the diet is fed, and when the diet was submitted are also listed. In the event of questions concerning a diet the contributing institution should be contacted. Often publications can not keep up with the rate of change, therefore some of the information may need to be updated. Because of this, the notebook is intended to serve as a starting point in the search for information.

Several qualifying questions are asked on the response form. How long has the diet been in use? Have the animals bred while on the diet? How many animals are fed the diet? These questions were designed to provide information about the diet and its success. For example, the number of animals fed from a diet may vary; hoofstock are commonly fed together, while many carnivores are fed separately.

Diets are listed in a variety of ways: some are given per individual animal, some are for male and female, as in large cats where the males may get more food than the females; some are listed per day of the week. Individual zoos seem to display a preference for certain food items used in many of their diets. This preference is probably due to local availability, history of success with the food item, and cost. After looking through the mammal diets, it was noted that many hoofstock diet items were similar in that they consist of pelleted feeds and hay, while primate and small mammal diets were often dissimilar. The greatest variations are seen in those which use fresh produce as the main ingredient.

Instructions for "preparation" of the diets could range from something as simple as feeding one food item or as complex as mixing and grinding several ingredients, such as fish burgers at the Shedd Aquarium. Instructions for food preparation may also be important to the acceptance of the diet; for example, the diet may need to be pureed for the tamandua, since large pieces of fruit may not be readily accepted by this animal.

The section for "Notes and Remarks" gives the respondent the opportunity to explain the feeding schedule and food preparation. How the food is presented could be an important part of how well the food is accepted; for example, some tree vipers feed willingly on dead prey but others must be induced to strike and feed by "slap" feeding. It should be noted that some diets may not be readily accepted when first introduced to the animal, but after several days of being fed the new diet, the animal may begin to accept it. On the "Fish and Invertebrate Response" forms, frequency of feeding, daily feeding rates or optimum food density or other related information should be included. Any note that the contributor regards as important can be included in this section.

"Special Considerations" is the section where changes occurring in a species' diet are indicated. For example, changes in the diet may be appropriate seasonally; for pregnant or lactating females, birds with chicks, or overweight animals. Occasionally medication is given in the diet; this should be stated. Diets for various life stages of fish and invertebrates may be included here, as can live diets which require special instructions regarding maintenance or culture. Such information tends to vary greatly from institution to institution.

Although many zoos are beginning to employ nutritionists, many zoos do not have large enough animal collections or budgets to warrant a nutritionist on the staff. In some cases, food items may be sent to commercial laboratories for analysis. Diet composition can be evaluated through the use of computer programs. Unless a nutritionist is involved at this level, information on food or diet composition is usually unavailable or limited. Because of the lack of information on the nutrient concentrations of some zoo diet items, a complete nutritional profile may not be included in the response form. An initial list of the products and companies' names and addresses have been listed in the introduction of the mammal notebook. A comprehensive list will be included in the appendix. If a nutritional analysis of a feed is not given, the company can be asked to provide this information, although many manufacturers consider such information proprietary.

The AAZK Diet Notebook Mammal Diets Volume I comprises 235 diets representing 213 species and subspecies from 14 zoos. More mammal diets are being compiled for volume II. The number of diets per species varies from one to eight. Many "high profile" animals such as tigers, elephants, and hippopotamuses are well represented. Surprisingly few diets are available for others, such as the chimpanzee. There is a great variety of animals being exhibited in zoos in North America, and many of these species are currently represented by one diet. It is hoped that other zoo staff will be encouraged to complete the diet response form now that the first section of the notebook is nearing publication.

The appendix is the final section of the diet notebook. It will contain the compilation of nutritional analysis for quick reference of individual dietary products and produce, e.g., vegetables, fruit, hay. A complete list of manufacturers, their addresses, and their products will also be included. A list of reference material (books, published papers, and articles) is being created. (Anyone with reference material they believe should be included in the appendix please write the information on the response form or send it directly to me.)

The purpose of the Diet Notebook is to supply zookeepers and zoological institutions with a starting point when formulating diets for new or difficult to maintain species. The notebook is strictly a collection of diets; none of the diets has been analyzed for accuracy or completeness. AAZK is not endorsing the validity of any of the diets given in the notebook. We are compiling these diets with the hope that many may benefit from this source of information.

The Diet Notebook can be a useful reference; however, its limitations should be recognized. Since many animals do not consume all offered foods, the nutrient composition of the ingested diet may differ from that of the offered diet. In addition, forage, including browse, may vary widely in nutrient composition, depending on regional differences in soil nutrients. Factors such as these should be taken into account, and generalizations about diet accuracy must be made with caution.

A project such as the Diet Notebook cannot be completed without the help of many people. This book is the culmination of hundreds of hours of work by AAZK members who began and continue to work on the project, keepers who sent the diets, coordinators collecting the diets, the volunteers who entered the data into the computer, and staff at National AAZK Headquarters. Everyone should be proud of his/her contributions to the Diet Notebook.

ZOO NUTRITION: A SCIENCE COMING OF AGE

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INTRODUCTION

Zoos are no longer institutions of public animal display for the primary purpose of recreation, but rather encompass much broader goals of education, conservation and research (Conway, 1969). As zoos are becoming the major, indeed the final, refuge for many species, it is imperative that we develop scientifically sound husbandry practices for not only day-to-day maintenance, but also captive breeding programs. Species survival plans (SSPs) have currently been established for about 40 species. It has been estimated, however, that detailed SSPs will be required for about 2000 species of terrestrial vertebrates (Read and Harvey, 1986) in the near future to save them from extinction.

The field of zoo animal nutrition is one of many specialities which must be applied in order to successfully meet the future challenges. The existence of a specialty conference such as the Dr. Scholl Conference on the Nutrition of Captive Wild Animals, and zoo staff nutritionist positions are evidence of the recognized need for zoo nutrition specialists. These particular examples, however, have been established for 15 years or less in North American zoos (Rapley and Oyarzun, 1980). Although much information has been obtained and exchanged within that time period, zoo nutrition as a specialty science still requires definition and development. It is imperative that zoos consider nutrition not only on a day-to-day management basis, but also as a major research thrust.

The intent of this paper is to outline and discuss: 1) the need for a zoo nutrition program, 2) various personnel involved in zoo nutrition programs, 3) the basic process of diet development and 4) current research and future needs. This approach is not intended to categorize and limit individual contributions, but rather to emphasize individual strengths which should be integrated to best satisfy established priorities and direction.

THE ZOO NUTRITION PROGRAM

I. Why a nutrition program?

When we bring animals into captivity for any reason, we assume ultimate responsibility for their health and well-being. This charge is not, and has not historically been, taken lightly yet now, more than ever before, we realize that we cannot afford the trials and errors of the past in developing proper animal diets. Now, asking the right questions and disseminating the answers is essential as time becomes the critical factor in species survival. Due to shortages of time and animal resources, and with increasing emphasis on SSPs, the need for detailed knowledge and management protocols, including dietary information, is imperative.

Thus we have a moral obligation to provide optimal diets for species in captivity, meeting both the physiological needs of health and reproduction as well as psychological needs in terms of feeding habits, behaviors and palatability factors. Examining any one of these areas in detail requires research scientists, but integration of the various factions is best accomplished within a comprehensive nutrition program.

For not as altruistic reasons, there are also financial considerations for development of nutrition programs. Unpalatable as it may seem, conservation of money is essential for sustained long-term care of captive animals. Minimizing costs of feeding zoo animals frees a greater proportion of very limited budgets for other important aspects. Economic considerations to be addressed within a zoo nutrition program include those related to diet ingredients (quality, seasonal and/or regional availability) as well as labor costs (commissary and keeper time in diet preparation, cleanup).

II. Personnel - who's involved? And what are their contributions?

Many staff personnel are involved in developing a comprehensive zoo animal nutrition program, which, at a minimum should include: curator(s), veterinarian(s), commissary manager(s), keeper(s) and nutritionist(s). Responsibilities vary considerably depending upon institution size, administration and general operation, and roles overlap. Nonetheless, each contributes uniquely to the overall operation of the program, and the program operates most effectively with interaction among the various entities.

Historically, zoo diets have been established by animal curators and/or veterinarians. Over time, to greater or lesser degrees, diets have often been altered by commissary managers due to ingredient availability or costs, or by keepers in recognition of individual animal preferences and/or perceived or known needs. Each of these contributions should be utilized, but integrated into an optimal nutrition program.

Curators are responsible for collection composition, acquistion/disposition, exhibition, and animal as well as personnel management. They possess a wealth of knowledge concerning natural history, ecology, husbandry, behavior, and physiology of species under their care. Although many animal curators have no specific training in animal nutrition, they are familiar with feeding regimes for numerous species in their (and other) collections. Curators are key personnel in identifying species with current dietary management problems, and will provide the strongest voice in establishing future zoo conservation priorities.

Zoo veterinarians oversee health programs, of which proper nutrition is a major component. The expertise of the veterinary staff should be fully utilized in parenteral or crisis feeding of sick animals. Clinical and pathology evaluations for identification of potential nutritional problems are an essential contribution of the zoo veterinarian to the overall nutrition program. Medical and animal care experience of the veterinarians, in cooperation with other staff members, are the basis of preventive medicine provided by zoo nutrition programs. However, rarely do veterinarians have extensive nutritional training. Less than 50% of veterinary schools in North America require any undergraduate coursework in animal nutrition (AVMA, 1984), although most teach at least one course in general or clinical nutrition as a regular part of the vet school cirriculum.

Commissary managers coordinate feed acquisition and distribution to animal keepers. In this capacity, commissary managers provide the direct link between managerial and keeper staff. Responsibilities can include purchasing, quality control, and some or most feed preparation. They should be aware of various commercial products, and associated costs of feeding including economic considerations of dietary ingredients as well as labor. Commissary managers with basic training in nutrition can, and should, be encouraged to evaluate product suitability (cost, nutritive value, and storage characteristics).

Keepers are the pivots of the entire feeding program. They are in daily contact with their animals, know individual animal variations, management situations and/or limitations, and have direct influence on the diets the animals receive. The breath of knowledge and animal experience within the keeper staff parallels that of the curatorial staff. Keeper training and ongoing education courses should incorporate information on nutritional principles underlying the diets fed, as well as emphasize that animal husbandry is both an art and a science. The science of feeding zoo animals can be learned, but the ability to identify and effectively manage biological variability must be acquired by experience.

Nutritionists have specific training in the nutritional sciences, but often limited or no experience with the species or management situation of concern. Either the staff or consulting nutritionist must rely heavily on input, cooperation and collaboration with other zoo staff members as outlined above for successful program implementation. Zoo nutritionists should be expected to evaluate diets currently fed for nutritional value, identify appropriate animal models for comparison of nutrient requirements, and suggest changes in diets based on nutritive value and/or costs. On-staff nutritionists should be encouraged to develop a research program, supervise feeding protocol development, gather feed intake data, publish and present scientific papers, and function as an interface with academic as well as industry nutrition representatives.

Field biologists, academic and industry scientists provide endless data for use by the zoo nutritionist. Useful information is scattered throughout the scientific literature among at least a dozen topic areas from animal science to zoology. One future priority might be to concentrate the number of publications used by the comparative animal nutritionist in order to provide the greatest access to compiled information.

III. How are diets chosen?

In many repects, zoo diets are developed by nutritionists in the same ways they have been historically. Limitations of past methods, however, need to be recognized and corrected. Three major inputs in diet development are addressed below:

1) Examine the wild diet

2) Review zoo records

3) Select an appropriate domestic model

Wild dietary observations can, and do give a general idea of appropriate substitute diets. However, this method presumes that diets have been well documented for the species of interest, including seasonal and/or regional variation that may occur. In reality, field studies are extremely limited, or simply do not exist for many species. Often taxonomic lists of feeds (plants or prey items) eaten are reported, with no accompanying data on nutritional value. We cannot mimic wild diets in most zoo commissaries -- we attempt to mimic nutrients. This becomes a difficult task if no nutritional guidelines are reported. Even the necessary use of available domestic cultivars as feedstuffs (which have been genetically altered to fulfill needs for human consumption) provides a significantly different nutritional base from wild populations, i.e. a fruit is not a fruit. It is important to realize that nutrients, rather than ingredients per se, are the key elements in using dietary information from free-ranging species. Much more analytical work needs to be conducted by both field and laboratory scientists to correct this deficiency.

Zoo feeding and animal health records are some of the most valuable resources available for determining success of a particular diet. Unfortunately, no standardized systems of recording such data have been adopted within the zoo community. Thus a critical first element remains simply recording current diets, evaluating them nutritionally, and comparing success (reproduction/health/growth) or failure within and among institutions. Cluster analysis as described by Roberts (1987) appears the most promising statistical method of comparing numerous variables (including diets) among zoos, research facilities and private owners. Although recording diet ingredients (see Bunn, this volume) is a first step in diet evaluation, it is only a first step. As Allen (1980) points out, comparing diets actually consumed versus those offered often reveals substantial differences in nutritional content, as does assessing the diet recorded on paper analysis compared to that actually fed the animal. Once again, nutrients, rather than ingredients, should be stessed in recording dietary information. At an **absolute minimum**, diet records should include quantity fed, and nutrient evaluation including calories, crude protein, crude fat, neutral and acid detergent fiber (herbivores), total ash, Ca, P, and vitamins A, D and E content. Standardized forms need to be developed at not only the individual zoo, but also at a national organization (AAZPA, AAZK) level.

Selecting an appropriate domestic animal model upon which to base nutrient requirements is relatively simple for many species. For instance, zebras closely resemble horses anatomically and probably physiologically, thus nutrient needs can be extrapolated between species. This is obviously not the case for numerous zoo animals, where entire orders or even classes (Reptilia) have no domestic counterparts. Nutritional guidelines have been established for feeding fewer than two dozen livestock, pet, laboratory and fur ranch mammalian species through the National Research Council (NRC) of the Acadamy of Sciences. Even fewer models exist for birds, domestic poultry species encompassing only the orders Galliformes and Anseriformes.

A suitable domestic model may exist for a particular species from an anatomical and/or physiological basis, yet behavioral differences could be distinct; all three aspects must be fully integrated within the field of comparative nutrition. Furthermore, it is certainly possible that nutrient requirements established for domestic animals are not totally suitable for zoo animals: high feed efficiency and extremely rapid growth or reproduction are not primary production goals in the zoo. Zoo animals are often longer-lived than either wild or domestic counterparts, thus geriatric nutrition can be of major importance. Due to controlled environments provided within the zoo, species can often lead much more sedentary lives than even grazing livestock or the family dog, resulting in over-nutrition, obesity and/or other health problems.

Thus the NRC nutrient requirement guidelines are only guidelines: limitations must be recognized. On the more positive side, the relatively recent emphasis on captive breeding programs within zoos (rather than simply maintenance) should most certainly benefit from the information compiled with domestic models. As zoo production goals more nearly approach those of the models, nutrient requirements may be found to be even more similar.

ZOOTRITION - CURRENT RESEARCH AND FUTURE NEEDS

Apart from an overall organization plan for the growing field of zootrition, specialized areas of investigation are apparent.

Requirement Information

The nutrient needs of any species, at any given physiological state, and under various management regimes, can be continually reviewed and refined. Yet before any refinement should be attempted, baseline information is required. Again, this underscores the necessity of recording dietary nutrient content and intake in a systematic manner. Measurement of progress is difficult or impossible if the starting point is unknown. Established nutrient requirements of similar domestic models provide a logical starting point upon which to identify similarities or differences for any given species.

Field Data

Coordination with field biologists should be encouraged whenever possible. Zoo personnel can identify specific questions as well as entire species for which natural history data are lacking. Successful conservation efforts (within zoos) for many of these species will depend upon properly addressing these questions within time and animal resource allocations. Patterns of thought must be directed PROactively, rather than REactively.

Both field and zoo studies of nutritional ecology should include analytical measurement of the diet, as well as some physiological assessment of animal response. Zoo nutrition programs can provide a mutually beneficial support service, working with field personnel in coordinating sample collection and assays as well as interpreting data.

Palatability

Feeding behaviors need to be examined in a scientific manner; unpalatability of nutritionally balanced diets remains a problem for many species. Factors including feed size, shape, color, texture, odor, taste and temperature should be addressed.

Product Development

Finally, the integration of all three areas above can lead to the production of a diet which meets both the physiological and psychological needs of the zoo animal. This, of course, was stated as an original goal of developing a comprehensive zoo nutrition program.

From here, Where to?

Numerous research projects with direct or indirect impact upon zoo animal nutrition have been, are, and will continue to be conducted by scientists at all levels within the zoo, university, field biology, private and government communities. The most pressing current need appears to be that of information exchange among various factions. Priority needs of zoos must be identified and established by qualified personnel on a national (or worldwide) scale in order to maximize limited funding and animal resources, as well as to minimize redundancy.

There is no reason, save lack of inertia, not to establish a nationally sponsored (AAZPA/AAZK) nutrition program for use by all zoological institutions. This might include (but is not limited to): 1) a network of analytical laboratories for providing feed and physiological parameter assays of nutritional value at minimal cost, 2) a computerized bulletin board of recommended standardized diets for various species based on currently recognized nutrient requirements and/or 3) regional coordination of feed supplies to maximize nutritional value and minimize costs. This overall concept has already been initiated on a small scale within individual SSP programs; much wider application is expected once the benefits of collaboration and cooperation are realized.

SUMMARY

The field of zoo animal nutrition is becoming firmly established as a science. The need for cooperation, education, and organization are recognized as the keys for future progress.

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WELL-BALANCED NUTRITION: CONSULTANTS AND THE ZOO NUTRITIONIST

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A professional nutritionist is a rare convenience in today's modern zoo, a luxury supported primarily in larger, well-funded institutions. Only five zoos in North America have staffed this important position. The situation will change, however, as more and more emphasis is placed on the propagation of endangered species. Zoos are beginning to discover that a professional nutritionist is as vital as the veterinarian for the well-being of the animal collection.

Most zoos in the U.S. have adopted one of three basic approaches to nutrition. The first of these is simply doing nothing. This approach is by far the easiest and least expensive, however, it is also the least beneficial for the collection.

A second approach to managing nutrition needs is hiring a nutrition consulting firm. The firm will sample and analyze all diets in the zoo over a given period of time in order to make recommendations to improve diet quality and reduce feed costs. Unfortunately, recommendations may be adopted or imposed with little explanation to the staff about why such changes are necessary and beneficial. Further, some zoos may consider all diet work to be complete once the firm's contract expires. As a result the zoo may be no better off nutritionally than it was before the firm was hired.

The third approach is to make a professional nutritionist a full-time staff member of the zoo. An in-house nutritionist can accomplish the goals of the consultants without the potential for alienation and drift inherent in dealing with an external firm. The zoo's nutritionist has three basic goals to acheive: (1) to analyze all diets to ensure that each animal in the collection is adequately nourished; (2) to reduce feed costs wherever possible; and (3) to conduct a program of research designed to expand the body of knowledge in zoo nutrition. Meeting these three goals may often be a difficult if not impossible task.

The field of animal nutrition is new and unfamiliar to most zoo professionals, colleagues who frequently do not appreciate the value of diet analyses. Most staff nutritionists in the U.S. are the first persons to fill the newly created position in their respective zoos. They are the 'new kids on the block.' Because the position of nutritionist is relatively new to the zoo world, their exact function and extent of responsibilities varies greatly from institution to institution. For example, several nutritionists have the added responsibility of running the commissary and can be found chopping fruit when shorthanded. These nutritionists must balance schedules as well as diets. Some institutions consider research and publication as the primary task of their nutritionist, which leaves little time for sampling and analyzing diets.

A fourth approach to zoo nutrition involves two professionals, one on staff and one on a consulting basis. The San Antonio Zoo has adopted this approach with very positive results. The staff nutritionist samples diets and creates a computerized database based on results of diet analyses. The consultant provides additional support data from a variety of sources which may not be available to the zoo staff at a single site or may not be contained in the National Research Council's guidelines. For example, the consultant may provide alternate feed sources unknown to the staff nutritionist. The consultant will not have the staff nutritionist's in-depth knowledge of the zoo's animal collection, staff, and feeding traditions; therefore, the two meet periodically to combine their evaluations and present a unified set of recommendations.

Having two nutritionists may appear excessive to some when so few zoos have only one or none. However, one of the most valuble facets of the consulting nutritionist is his/her ability to persuade animal departments to approve and institute diet changes. The consultant's experience and the 'mystique' of an outside opinion lend credibility to the nutritionists' proposals and will often lessen some of the apprehension the staff may feel towards change.

The role of the nutrition consultant must be tailored to each zoo in order to be effective. The consultant's strengths should balance the weaknesses of the existing program. For example, Dr. Duane Ullrey (Professor of Animal Nutrition at Michigan State University) suggests that a zoo with a research staff may wish to hire a consultant to "assemble a rationally organized data base", thus affording the staff more time for research (personal communication). Alternatively, a zoo may seek a consultant who can help establish a research project.

Of course, the potential for problems exists in any situation, but these can be prevented with a little foresight. It is important that the goals of the zoo be documented from the outset. The staff's expectations regarding diet and the performance of both the staff and consulting nutritionist should be ascertained, preferably in writing, before any work is begun. Determining goals in advance clarifies which tasks must be accomplished first. It is also important that the two nutritionists work together effectively and harmoniously; if they cannot, the zoo's money is wasted.

The field of zoo nutrition is in its infancy. According to Dr. Ellen Dierenfeld, nutritionist of the Bronx Zoo, "There is never a lack of work for nutritionists. So many developments have occurred in human nutrition in the past few years; just imagine the possibilities for a field with so many species to work with!" (personal communication).

The trend towards using an external consultant is expanding in North American zoos because the benefits of their work with staff nutritionists far outweighs the expense of their contracts. As the importance of correct and adequate nutrition is realized, the hiring of zoo nutritionists may "follow the trend seen in zoo veterinarians in that some zoos have budgets set aside for consultants" (Mary Allen, Allen and Baer Assoc., personal communication). A plan for nutrition management that combines the skills of a staff nutritionist with those of an external nutrition consultant will result in a program of balanced nutrition that will meet the needs of the zoos for many years to come.

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THE ROLE OF A KEEPER IN A DIET EVALUATION PROGRAM

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In 1987 the Los Angeles Zoo undertook a program to evaluate the diets of a number of species in its mammal, reptile and avian collections.

From the initial evaluation of diets fed, through the implementation and ongoing revision of modified or restricted menus, input from the animal keepers was encouraged. How this was accomplished and the structure that has subsequently been established out of this recognition of the importance of the keeper's involvement is the subject of this paper.

Once the zoo administration has committed its resources to the evaluation of the collection's diets, it is important for management to inform the animal care staff of the reasons for study and the importance of individuals most involved in the daily feeding and monitoring of the collection in assisting with this work.

Keeping the animal maintenance staff informed of the goals of the diet evaluation program is good communication and sound management, for from this expectation that the keepers have an important contribution to make, comes the information and cooperation nutritionists require to accurately assess a diet.

There may be members of the keeper staff who feel uneasy that the zoo is bringing in outside professionals to evaluate the diets they feed to "their" animals, who are, in the keeper's opinion, "doing just fine, without changing things all around."

It is important for supervisors and management to be aware of this attitude, if it exists, and to listen to and discuss with a keeper his concerns, for it may affect the input that individual gives the investigator, and probably the manner in which diet revisions are implemented and followed through by that individual keeper.

If the keepers know that their input is added to the factoring of the diet analysis and dietary recommendations, they are much more willing to work towards implementing changes, should they occur.

A general meeting with all of the zoo staff who will be involved with the diet evaluation--commissary personnel, veterinary staff, animal keepers, supervisors and curators should be scheduled at the beginning of the study. This gives zoo management the opportunity to reiterate the goals of the program and an opportunity to review how it will be carried out with the nutritionists present to answer any questions.

Once the nutritionists are on grounds, it is important for keepers to know what their role is to be and to determine how much time will be needed for their assistance. If additional time is required by the keeper to complete his routine assignment, as well as provide information for the diet evaluators, management should see that help is provided. This reinforces the organization's commitment to the program and clearly demonstrates to the keeper that his input is important to the success of the project.

At the Los Angeles Zoo the keepers prepared the diets for each group of animals to be evaluated and each portion of the diet was weighed by the nutrition staff. Keepers provided information on why dietary supplements had been added to the diet, or to those of specific individuals. Lists of the varieties of browse fed to primates and hoofstock over the course of a year were included in the diet presentation. If feedstuffs were added during winter months, or periods of moult, or for pregnant, lactating or laying females, it was the keeper who would report this information. Any rotation of diet items, such as vegetables alternated through the week in primate diets, or whole prey fed once a week to carnivores, also needed to be included with the presentation of the total diet for the group. Keepers often provided input as to feed preferences, consumption patterns and animal health histories which might be impacted by diet, such as obesity and lumpy jaw.

Generally food items were weighed as they were prepared for feeding one day, and the remains weighed back the following day. For hoofed animals this generally entailed raking up left-over hay, and for animals with more variety in their diets, this necessitated the sorting of individual items.

It was in the individual sessions with the nutritionists that the keepers had the opportunity to ask questions and discuss dietary concerns about the animals in their care. This ability to discuss with the nutritionists problems that the animal keepers saw with their animals, or other more general inquiries, gave the keepers information which may not have been addressed in the final report.

In the introduction of the revised diets, the animal keeper is again of great importance in the success of the program. Understanding on his part as to why the changes are occurring, and a discussion as to how to best implement them, will go far in seeing that the modifications are tried and more fairly evaluated. It is the keeper who will note how the diet is being accepted, if the amounts offered are adequate, and if there are changes in the animals' stools, coat condition or weight. The records that will be kept while animals are converted from one diet to another will be maintained by the animal keeper. His observations will be important in deciding if the adjustments are successful or not.

If the zoo has not established a liaison person to coordinate the diet evaluation program from the beginning, it is particularly critical that there be one when the revised diets are ready for implementation.

This individual should schedule regular meetings with keepers and their supervisors to present the revised diets, discuss implementation and solicit feedback on progress or problems with format. This liaison should be the contact person for the zoo staff and the nutritionists. He should relay information or inquiries from keepers that require the input of nutritionists through the keepers' supervisors, so that as many people as feasible are kept current on problems and revision. This individual should make the breakdowns of the original diets, along with the revised diet, be available to the keeper and work with the keeper so he knows why and how the diets are to be altered and can report easily on progress.

If new items not currently stocked by the zoo will be required to implement the revised diets, the liaison person should be actively involved in the acquisition process. After consulting the nutritionists, he should inform the keeper and his supervisor how to implement the diets without particular items on hand. He should also have a good idea as to how long it will take to get the new items in stock, and apprise the keeper of the anticipated transition time in converting totally to the new diet.

Records should be maintained on the diets of all animals in the collection. These records should be centralized so information is not lost as keepers change areas of responsibility. As diets change in response to economics, group dynamics or medical concerns, these changes should be recorded in a master file.

The bottom line in determining the level of success in completing a diet evaluation and revision program, like the one conducted at the Los Angeles Zoo, is communication from the beginning of the project. Keepers provide the basic information that makes the assessment of the diets possible. They also provide the leads to other departments--the animal management, curatorial and veterinary staffs, whose input provides an overview of how a particular species has fared historically in the collection.

Keepers are the individuals who will carry out the implementation of any diet revisions, and inform management of concerns and problems. Management's acknowledgment of the importance of the keeper to this project should be well known and supported by that facility's management and supervisory staffs.

A diet analysis of a zoo collection is no small undertaking, and its implementation succeeds in the long term because of a commitment to sound nutrition as an important aspect of a collection management in which all levels of the animal care staff are involved and actively participating.

FOOD HANDLING AND COMMISSARY PROCEDURES

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The goal of zoo commissary operations is to assure that animals receive good quality foods and feeds that help maintain health and reproduction. Areas of food safety as well as nutrient stability of food products are of particular concern to the operations. The purpose of this paper is to highlight threats to the safety and stability of food used in zoos, the cause of problems, and good operating procedures which will help prevent problems.

SAFETY:

Safety may be challenged by biological, chemical and physical factors. Biological concerns include bacteria and molds such as staphylococci, salmonella, clostridium and aflatoxin. Depending on the species and physiological condition of an animal, the severity of these food-borne illnesses may be devastating. Food is not sterile. However, we must strive to minimize the almost inevitable microbial growth with proper and sanitary handling procedures. In general, bacteria multiply rapidly in a temperature range of 45° to 140°F (7.2° to 60°C). Even at freezing temperatures, some microorganisms may not grow but they will not be killed. Bacteria can eventually multiply when frozen food is thawed. Meat products provide the perfect medium to support microbial growth (Frazier, 1967). Holding meats at the temperature "danger zone" for an extended length of time can be hazardous.

The causes of microbial contamination include improper processing and storage procedures, and pest infestation (AFSS, 1985). Each step in processing should be considered a risk for biological contamination whether it is at the processing plant, the commissary, or in the animal enclosure. Carriers of bacteria can be improperly cleaned equipment and tools, such as band saws, tables, or knives. Pests also can carry bacteria and spread contamination.

Food products can be contaminated physically which will pose a threat to animal safety. Examples of physical threats are: wire in baled hay, metal fragments from plumber solder in a meat mix or glass shards from a broken light bulb in chopped fruit. Each of these items are accidental and/or coincidental in nature but can cause health risks and are preventable. The basic cause of physical threats is improper management and maintenance of physical facilities.

Foods may contain or be contaminated with chemicals such as pesticide residue, heavy metal contamination or residues left from cleaners and sanitizers. These problems may be caused from receiving adulterated food items, but can appear anywhere in processing and storage of a variety of food items. Other causes include: improper storage such as leaving acid food items in open cans; improper cleaning, i.e., splashes and inadequate rinsing; and improper labelling leading to confusion as to the identity of a toxic or potentially toxic product.

Many of these safety problems may be manifested in acute animal health problems which may be readily identified. For instance, if an animal cuts its mouth on a glass shard in its food, the laceration may be identified and the enclosure/food inspected for the presence of sharp objects. However, identification alone does not minimize the potential problem. It is much easier to prevent food safety problems than it is to remedy them once the damage has occurred.

NUTRIENT STABILITY:

A threat which may be much less easily identifiable is the loss of nutrients in foods. Many nutrients are relatively unstable and thus degrade or are destroyed over time or on exposure to certain elements. Animal health will be adversely affected, but the problems may be manifested in a general failure to thrive or reproduce. In critical situations where the animal may be borderline in its nutritional status, stresses may pose greater health risks.

Factors which affect nutrient stability include temperature, oxidation, enzymes, light and pH. Nutrient losses begin as soon as the plant is harvested or the animal is slaughtered. Losses continue through processing when products are exposed to heat, steam or pressure, acid or alkaline conditions, canning, drying or freezing (Bender, 1978; Clydesdale, 1979; Griswold, 1962; Harris and Karmas, 1975).

Lipid oxidation (rancidity) reduces the content of essential fatty acids, carotenes and vitamins A, E and C in foods. Lipid oxidation also is antagonistic to amino acids, thiamin and vitamins

C and B_6. Nutrients in food also may be decreased through liquid waste which occurs during thawing, cooking and canning. Of special interest are the losses of water soluble vitamins and minerals when fish is thawed in water. Table 1 shows vitamin destruction in cooking. In general, vitamins which are considered highly unstable are vitamin C (ascorbic acid) and thiamin. Folic acid, B_6, riboflavin, pantothenic acid, B_{12}, A, E, and D are considered somewhat unstable. Considered as generally stable are niacin and vitamin K (Harris and Karmas, 1975).

PREVENTION:

It is evident that there are many factors that can render a food unsuitable for feeding. This highlights the importance of proper and strict guidelines and procedures for handling every food item. Measures taken to prevent unsuitable food from ever being offered to our animals are designed to exclude contamination vectors and decrease nutrient losses. Commissary operations are the key in protecting the zoo animals.

Most importantly, food products should be purchased from a reputable supplier. Good quality is essential. Nutrient quality and presence of contaminants can be assessed by sampling and analysis.

Products should be inspected upon receipt. Thus, it is important to schedule deliveries during business hours, at times which would allow for inspection. Inspection includes identifying damaged cans and bags as well as for pest (insects/rodents) infestation. Foods in transit should be stored at proper temperatures and arrive at proper temperatures. For example: frozen fish should arrive frozen and the shipment should be examined for evidence of thawing in transit or thawing/refreezing. Delivery trucks should also be inspected and, if applicable, local warehouses. It is of primary importance to reject unsuitable items or shipments at this time, before they are accepted into the Commissary.

In order to decrease the likelihood of contamination of food at the commissary, it is necessary to assure the physical building is in good repair. Ceilings, walls and floors should be nonporous with no cracks or holes. Grouting should be secure and clean. The floor/wall junctions should be curved if possible. Windows should have screens, if opened, and strip plastic should be used over all open doors. Exposed lights should have covers to reduce breakage and prevent those that break from falling into products.

Since equipment can harbor pathogens, it must be properly maintained, thoroughly cleaned and kept in good condition. The design of equipment should be such that it allows for easy breakdown and cleaning. Cutting boards should not have cuts and cracks. Separate cutting boards should be used for meat only.

The commissary should have an effective pest control program. The basic rule with pest control is to deny pests access to food, water or shelter. Use pesticides carefully to avoid contamination.

Products should be stored correctly after acceptance for delivery. To facilitate cleaning, store products in containers off the floor, on pallets and away from walls. Keep packages sealed or in closed containers. All items must be labelled appropriately. To assure freshness and nutrient stability, stock should be rotated so that items which were received first are the first issued. This is termed first in/first out (FIFO). Ideally, the manufacturer of the product dates the product so the user can determine date of manufacture. If the manufacturer uses date codes, the coding system should be obtained. In addition, commissary staff can monitor the use, as well as freshness, of items when they are date stamped upon receipt into the commissary.

Freezers and coolers should be kept at appropriate temperatures. These temperatures should be monitored. Overloading these areas with products may cause temperatures to decrease. It is possible that items in the center of a shipment may not cool properly if added to a cooler/freezer at once. Optimum freezer temperature is less than 0° F. Optimum cooler (refrigerator) temperature is less than 40°F. Note that the proper method of thawing frozen products is essential in decreasing the incidence of microbial contaminants (Frazier, 1967). Frozen foods should be thawed at refrigerator temperature. Thawing in water may increase nutrient loss and increase the possibility of microbial contamination. Another option is microwave thawing which may decrease nutrient losses and help control microbial growth because thawing time is reduced.

Manufactured products must be formulated to contain adequate nutrients in order to meet the animal's estimated or established requirements. The manufacturer must provide a margin of safety which accounts for nutrient losses incurred during the manufacturing process as well as a recommended shelf life. The only method to assure that nutrients are being supplied is chemical analysis. In addition to verifying that the specified nutrients are contained in the product when it is received, proper product storage and use will help maintain a nutritionally complete feed at the time the product is consumed by the animal.

In conclusion, it can be said that the zoo commissary plays an integral role in assuring that captive exotic animals receive safe and nutritionally complete diets. This is accomplished by adhering to strict guidelines for product acceptance, processing, storage and issue. The job isn't finished, however, when the product leaves the commissary. In general, these guidelines should be in effect until the time the animal actually consumes the food.

TABLE 1: VITAMIN LOSSES IN COOKING

VITAMIN	SENSITIVE TO	COOKING LOSSES	PRIMARY FACTORS
Vitamin C	oxygen heat alkaline pH water	0-100%	1. leaching into water, esp. from cut surfaces 2. oxidation 3. heat destruction
Thiamin (B1)	water heat alkaline pH	30-70% veg.'s 0-80% meat 0-50% baking	1. leaching 2. heat destruction
Riboflavin (B2)	water alkaline pH	9-39% animal 10-30% plant	1. leaching 2. exposure to light
Niacin	water	3-27%*	1. leaching
Pantothenic Acid	heat water alkaline pH acidic pH	7-56%*	1. leaching 2. heat destruction
Pyridoxine (B6)	water	30-82%	1. leaching
Folic Acid	heat oxygen alkaline pH acidic pH	46-95% fish/pork 29-70% egg yolk, liver, chicken 0-50% vegetables	1. heat destruction
Vitamin B12	alkaline pH oxygen heat	0-20%	1. leaching (meat drippings)
Biotin	oxygen	0-50%	
Vitamin A[(a)]	oxygen heat light	0-60%	1. exposure to light (sunlight <u>or</u> artificial)
Vitamin E	oxygen light	0-60%	1. oxidation
Vitamin K	light oxygen	insufficient data	1. exposure to light 2. oxidation

*generally good recovery in cooking liquids
(a) present as beta carotene and other provitamin A carotenoids in vegetables
Source: Cooperative Extension Service, University of Maryland HE-85-NFH-003

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