WILLIAM A. RAPLEY, D.V.M. QUESTIONS AND COMMENTS

QUESTION: What proportion of organ meat and muscle are used in your carnivore diets?

RESPONSE: In the plain and the feline diet it is muscle meat and horsemeat. In the beef by-products, which is the bear diet, there is a wide variety of organ material used, e.g., spleen, lung, liver, kidney, etc. Now Sergio, our Nutritionist, is looking at more beef by-products in our other carnivore mixes. There is good economic sense here because including labor the beef products and the plain horsemeat products cost about $0.50/pound (Canadian dollars) before you 20% discount and the bear diet is less than $0.40/pound including labor.

QUESTION: It looks like the system works exceedingly well going down through the system, but for the keeper who is feeding the animals it looks as though there might be difficulties for them to get the feeling that they were really involved and committed in making suggestions to modify the diet. How do you overcome that problem?

RESPONSE: Well it is a problem and it is a very good point. We try to convince the keepers that what we are doing is working by observing the improvements we have made in any of the animals over the years such as the Reindeer, Black-tailed Deer and so on. We try to sell them on this idea and we

try to get them to become involved with the studies; the weighing controls, the weighing of amounts offered, the weighing of remains, the weighing of the animals on a routine basis, etc. I think that's a pretty good stimulus in that area.

QUESTION: How do you control the feeding of the beef heads since I understand they sometimes can produce an undesirable odor?

RESPONSE: They are only fed in the holdings and they are only fed overnight, whatever is left over is removed the next day. We have only used the ox tails a little bit because they are fairly expensive. We would like to look into this more especially horse tails as they are available to us. I think the fact that they are not fed in front of the public controls that particular aspect.

COMMENT: At the Metro Toronto Zoo in the case of the cubs though the half shank bones are left in and the public does not seem to object at all.

RESPONSE: Oh, yes. The half shank bones for tiger cubs were put out and it was announced to the public when they were put out. We did not have any complaints in that area.

FEEDING PROGRAMS AND NUTRITIONAL RESEARCH AT THE WORLD FAMOUS TOPEKA ZOO

Gary K. Clarke, Director, World Famous Topeka Zoo
George G. Doering, D.V.M., M.S., Research Nutritionist, Theracon Labs, Topeka, KS

Gary K. Clarke, Zoo Director:

I mentioned to Mary Allen that I really did not want much of an introduction, and I must say -- that wasn't much of an introduction.

I personally am delighted that the Lincoln Park Zoological Gardens and the Chicago Zoological Park have joined together to sponsor this conference on the Nutrition of Captive Wild Animals. It is an important area of Zoo management that deserves to be addressed in its own right.

I recall starting my Zoo career in the middle 1950's as a young Keeper at the Kansas City Zoological Gardens. I was interested in all aspects of Zoo operation and animal management, and made careful notes and observations on anything and everything -- including diets. I was surprised at how many peanut butter and jelly sandwiches were fed to the collection -- from gorillas to elephants. I later learned that the Director of the Zoo at that time was particularly fond of peanut butter and jelly sandwiches. I do think the state of Zoo nutrition has advanced somewhat since those days.

As my career continued I became an Animal Department Supervisor at the Fort Worth Zoological Park, primarily in the Bird Department. Like all Zoos, we were extremely conscientious of budget limitations and we always were on the lookout for a bargain. One day the city market contacted us and advised that they had a surplus of beets. We stored several tons of beets in every nook and cranny of the Zoo and fed them primarily to the bird collection in the Tropical Bird House. Most of the exhibits were "jewel box" displays in habitat settings with rocks, branches, and green plants. The effect of the beets in the birds' diet resulted in the birds passing a bright red stool, which was deposited on the rocks, branches, and green plants. This, in turn, alarmed the Zoo visitors who made a continuous path to the diet kitchen service door and yelled at the Keepers saying "Hey, your birds are bleeding out here." Quickly, we changed the diet.

When I arrived in Topeka as a brand new Zoo Director we had no budget line item for animal food. Everyday one of the Keepers would make the rounds of the grocery stores and pick up boxes of discarded lettuce leaves and overripe produce. Unfortunately, the grocery store employees usually considered these boxes as simply trash and garbage, and we ended up with old cigarette butts, pieces of wire, and other undesirable foreign material.

The Zoo did not buy meat for its big cats -- it depended upon the Highway Patrol to advise them of road kills and cattle truck accidents on the Kansas turnpike or neighboring highways, and someone from the Zoo would go out and pick up the carcasses. These would then be butchered and hung in the delapidated walk-in cooler and fed sporadically to the cats. Since cleaning procedures were rather lax at that time, many bones had been washed down the drain over the years and one of the first tasks I faced was having the entire sewer line along the cat row dug up and replaced.

We had no central commissary system and the small kitchen facility would be filled with all the Keepers in the Zoo at the same time -- both of them. There was no rhyme nor reason as to what and why certain items were fed, and no records were maintained on anything. There were lots of problems and some of them were certainly nutritional in origin.

At this point in time I thought regularly of the Philadelphia Zoological Gardens and the fact that they had, right on the Zoo grounds, the Penrose Research Laboratory with a full time qualified staff to assist the Zoo in nutritional problems. Obviously, this was beyond the means of a modest Zoo like Topeka, which was extremely limited in size, staff, and budget. However, I felt very strongly that the Zoo should participate in scientific activities, and could do so on a cooperative basis with qualified individuals in the community. Thus, a cooperative nutritional research program was developed that continues to have positive and lasting benefits for the Zoo.

From the local researchers' point of view, our Zoo is a unique resource for scientific investigation. It provides a collection of exotic animals under captive conditions that are rather typical of most other Zoo situations. It provides a staff that works on a daily basis with the collection. From the Zoo's point of view, the cooperative program offers the professional expertise of specialists in a given field, and the opportunity to improve and develop new procedures. The researchers are available for consultation and advice on a variety of other matters and it is like having additional staff without additional payroll.

In the mid-1960's I contacted Mark Morris, Jr., D.V.M., Ph.D., with reference to some of the nutritional problems we were experiencing at the Zoo. Dr. Morris and his staff responded as much for community service to the Zoo as anything else, and this working relationship evolved into an on-going nutritional research program over the last 15 years. The most dramatic result of this program is in the area of prepared diets. Much of our collection is now being fed prepared diets and we feel there are many benefits including: 1) quality control and standardization of the food, 2) easier preparation which saves labor,

3) improved reproduction in the animal collection, 4) greater longevities in the animal collection, and 5) an excellent system of daily record keeping on what is fed, what is consumed, stool quality, and haircoat conditions.

Another very important facet of the program is the involvement of Keepers and Commissary Workers in the research program. George Doering, D.V.M., of Theracon Labs works on a close personal basis at the Zoo with the Zoo staff in the mechanics of actually introducing new diets or improved forumulations to the various species.

I have presented our cooperative research program from the Zoo administrator's point of view and would now turn the program over to Dr. Doering to give you a perspective from the researcher's point of view.

George Doering, D.V.M., M.S.:

You have been informed of the history and mechanics of our nutritional research program in Topeka. I would like to impart some of the knowledge we have gained. This information has not only benefited animals at the World Famous Topeka Zoo, but captive and research animals all over the world.

I. BASIC NUTRITIONAL PRINCIPLES

Initially nutritional principles derived from domestic animals and man were applied to captive animals.

A. All Mammals Require Six Essential Nutrients to be Supplied Daily for Optimum Performance. These Nutrients Include:

1. Water, the most important nutrient, is 70% of the adult weight, and 95% of the weight of newborn animals. Water aids in palatability, digestion, circulation and excretion via urine, stool and sweat.

2. Protein, made of 22-26 nitrogen containing amino acids, is an important part of all tissues, including muscle, tendons, bone, blood, milk, skin, hair, nails and hooves. Protein can also be used for energy but is more expensive than fat and carbohydrates.

3. Fat, lipids or ether extract is necessary for energy, palatability and glossy haircoats.

4. Carbohydrates, or nitrogen free extract (NFE), are broken down to glycogen and glucose and used for energy by all cells. Cellulose is degraded in ruminants to assimilable acids and used for energy.

5. Vitamins are essential for numerous metabolic chemical reactions and transfer of energy.

6. Minerals, or ash, are 21-26 elements required for structure of bones, hemoglobin, hormones, and catalysts in enzymatic reactions.

B. It is Essential That the Nutrients be Available in Adequate but Balanced Ratios to Each Other. Excessive vitamin-mineral supplementation can be detrimental. The diet must contain enough energy so that poor eaters still recieve a balanced diet in the small amount that they eat.

C. Daily Record Keeping is of Extreme Importance. The diet fed, the amount fed, amount consumed, stool quality and amount, and general condition of the animal are essential data for nutritional studies and ongoing information concerning the well being of the animal.

D. Overfeeding or Underfeeding is not Practiced. Rather than be offered a set amount of food each day, animals who ate less food and yet maintained their weight were offered less food. Animals who consistently consumed all of their ration were offered increasing amounts, provided excessive weight gain or diarrhea did not occur. The detrimental effects of obesity are well documented. Obese captive animals do not live as long, have poor reproductive histories, are poor surgical risks, and cannot tolerate excessive hot weather. In addition, it costs more to feed an obese animal. In contrast, thin animals lack resistance to combat disease or parasitism, and do not adapt to extremely cold weather.

E. Fast Day for Mature Felidae is Observed on Sunday. This seemed like a natural phenomenon, and no adverse effects have been noted in over 15 years of practice. Fasting also saves on food costs and labor.

II. DEVELOPMENT OF DIETS FOR VARIOUS ANIMAL GROUPS

A. Exotic Felidae Diet - Prior to 1966, the World Famous Topeka Zoo was having difficulty raising cubs of the large felidae. Problems presented in the young cubs were collapsed chests and pathologic limb fractures. Gary Clarke consulted with Dr. Mark L. Morris, Jr. about feeding large cats. The major

food offered to the cats was horsemeat and road kills. Diagnoses of cubs which had died were classic examples of nutritional secondary hyperparathyroidism.

This condition results when meat alone is fed to young growing animals. Rapid bone growth requires extra dietary calcium and phosphorus in contrast to maintenance mineral requirements for adult cats.

Meats have a severely inverted calcium;phosphorus ratio (See Table I). In order for the body to balance and excrete the absorbed phosphorus from the meat with calcium, the young cub's bones are demineralized as a source of calcium. The results of a prolonged dietary Ca:P imbalance (normal should be 1.2-2:1) are folding and pathologic fractures of leg bones and collapsed chests because of fractured ribs.

Dr. Morris developed a balanced diet by combining horsemeat, chicken, animal fat, cereal grain, fiber, vitamins and minerals. Ground grain and fiber were added to approximate the vegetation consumed when cats eat the intestinal contents of naturally killed prey. The diet was canned and feeding trials conducted. Acceptance of the canned diet was excellent. Reproductive performance was significantly improved. A feline diet was also developed in frozen blocks to decrease the labor costs of opening cans. In 1978 a water reconstituted exotic feline diet was developed. Meat meals, animal fat, fiber, vitamins and minerals were combined with a jelling agent into a dry meal. When water is stirred into the dry mixture and time allowed for jelling, a ready-to-eat diet with the texture of cooked meat loaf results. This diet can be cut and handled as chunks. The reconstituted feline diet has maintained jaguars, bobcats, African lions, Bengal and Siberian tigers and American lions. For finicky eaters, reconstituted diet and water can be blended with a percentage of more expensive frozen or canned diet, further reducing the overall cost of feeding collections of large felidae.

B. Bird of Prey Diet - A bonded pair of golden eagles maintained at the World Famous Topeka Zoo were observed mating. Since no captive golden eagle pairs had successfully hatched chicks, consultation concerning their nutritional requirements was requested. The diet of the eagles had been chunk horsemeat, beef hearts and an occasional rat or rabbit. Since the natural prey of golden eagles is rats and mice, whole carcass nutritional analyses of laboratory animals were conducted. Research was then conducted to develop a frozen meat base diet with an analysis similar to that of a whole rodent's body. Another objective in the development of this diet was for it to have

the fibrous texture or consistency of meat. This is necessary so the bird of prey can grasp a chunk of the diet in its talons and fly from a feeding stump to a perch or nest where the food is consumed.

In 1971 the first successful captive hatching and raising of a chick was accomplished by the golden eagle pair. As a result, the Topeka Zoo received the Bean Award for the first captive reproduction in the species. The pair was fed only the bird of prey diet. Housing consisted of two joined baseball backstops, perches, stumps and nesting materials. The birds did not mate while in flight, as we have been led to believe.

C. Ratite Diet - Ratites are the large flightless birds, including ostriches, cassowaries, emus and rheas. This diet is pelleted and based upon the nutrient requirements of the rapidly growing domestic turkey. Special nutritive requirements for ratites include increased amounts of minerals for egg shell development and for bone development of the chicks. Manganese and selenium are also present at above normal amounts.

Growing ratites can develop a condition called "straddled leg syndrome" and the exact etiology is unknown. The amount of energy in a ratite diet is restricted by adding dietary fiber. This slows development and seems to aid in prevention of the straddled leg syndrome.

Two dietary management problems were encountered and solved in developing the ratite diet. Incubator hatched chicks did not have the instinct to eat, which is acquired in the wild from the male parent. Placing a chicken with the newly hatched chicks solved that problem as the ostrich chicks imitated the pecking of the chickens. Crop impactions were a common occurrence in growing rhea chicks. They would ingest, to their detriment, twigs, leaves and rocks, and anything else they could swallow, in addition to their prepared diet. Raising the chicks on artificial turf instead of dirt solved the impaction problem.

D. Primate Diet - Dry primate diets developed for research centers have been available for over 20 years. It has been documented that new world primates require vitamin D_3 in their diet. If only vitamin D_2 is supplied, nutritional secondary hyperparathyroidism will develop. This is very similar to the syndrome in felidae. Folding fractures, large fibrous jaws, loose teeth and death result. This syndrome was known as "cage paralysis" until pathologists documented the condition.

Smaller primates and pro-simians did not relish dry or moistened primate biscuits. A complete balanced canned primate diet was developed from cereal, eggs, milk, sugar, vitamins and minerals. This moist canned form was very acceptable to the smaller primates. Improved reproduction and elimination of bone disease resulted from the use of this diet. Management improvements included less labor preparing diets of fruits, vegetables and supplements. The costs of procurement, preparation and storage of the natural diets were far in excess of the canned diet. Because vitamin C is required for primates and is degraded by the manufacturing process, it is essential that natural sources of vitamin C (oranges) be offered daily.

In many Zoos primates are given alfalfa hay, carrots, potatoes, bananas, oranges and other fruits and vegetables, in addition to their primate ration. Much time is consumed (behavioral modification) while eating high moisture roughage foods and pulling leaves off the hay stems. Sometimes it is found the vegetable or "zoo salad" part that is fed consists of over 60% of the diet by weight. Such a diet is deficient in protein and energy.

E. Marmoset Diet- Cooperative marmoset dietary research was performed by Theracon Laboratories, Topeka, Kansas, and the Texas Dental School, Houston, Texas. It was determined that marmosets and tamarins require four times the level of vitamin D_3 required by other new world primates. Therefore, the canned marmoset diet contains this excessive level of vitamin D_3. This amount is toxic for non-marmosets.

Marmosets are involved in research projects as animal models for colon cancer and dental problems. A palatable balanced canned ration simplifies the feeding of large colonies of marmosets. As with other primates, a natural source of vitamin C (orange slices) is necessary.

F. Polar Bear Diet - Polar bears are known to eat fish and seals in the wild. Thus, at zoos it was accepted that captive polar bears had to have fish for survival. The procurement, storage and nutritional quality of frozen fish leaves much to be desired. Some fish contain an enzyme, thiaminase, which breaks down the B vitamin, thiamin. Frozen fish under long storage conditions contain deficient levels of vitamin E and may contribute to an inflamatory disease condition of the bear's fat, known as steatitis.

It was originally thought that polar bears do not eat mammals or fish with intestinal contents containing vegetation, therefore, the assumption was made that polar bears probably cannot digest carbohydrates.

Two young easily-handled polar bear cubs were available at the Topeka Zoo to conduct digestion studies. These cubs were fed diets containing carbohydrates, and their feces collected and analyzed. It was determined that they did indeed digest carbohydrates just as other bears. Later research conducted along Hudson's Bay determined that stomach contents of polar bears in the summer contained vegetation and small vegetation consuming mammals.

A dry expanded biscuit-type diet was then developed for polar bears similar to the omnivore diet available for other bears. Fish meals, meat meal, cereals, fat, fibers, vitamins and minerals were balanced into this palatable diet that adequately maintains polar bears. No supplementation of fish is necessary.

III. FUTURE OF CAPTIVE ANIMAL NUTRITIONAL RESEARCH

Since 1966 numerous commercial captive animal diets have been developed and marketed for felidae, canidae, birds of prey, ratites, omnivores, carnivores, reptiles and soft-billed birds. Because of the limited market and small sales volume, some of the diets are no longer commercially available. The future will likely see the use of more dry and/or water reconstituted products to save the severe labor intensive inflationary costs of shipping, freezing and canning. Water is an essential nutrient and aids the texture and palatability of a food. Water is inexpensive but when the cost of shipping the weight of added water is added on, the cost of frozen and canned diets is increased.

The interest in nutrition that has developed at zoological parks in the United States and Canada in the past five years is enlightening. At least three zoos in the United States and Canada currently have full time nutritionists. Several other zoos utilize local nutritionists on a part time basis, or have a consulting nutritionist available. These nutritionists are able to evaluate the nutritive value of certain diets and make proper adjustments or recommendations. It is the goal of a nutritionist to maximize the genetic potential, reproduction and life span of specific species by feeding them a diet most suited to meet these goals. It is our hope that our continued efforts will aid the health and longevity of numerous species and especially the endangered ones. As inflation and space encroachment increase in the decades to come, nutritionists will have the task of developing balanced diets using ingredients that are then available and reasonable in price. We envision our future as challenging and dynamic.

TABLE I

CALCIUM:PHOSPHORUS RATIOS
VARIOUS MEATS AND FELINE DIETS

Chicken Necks, including Bones	2:1
Whole Chicken	1.4:1
Chicken Meat, no Bones	1:18
Hamburger and Chunk Beef, no Bones	1:16
Horsemeat	1:30
Beef Heart	1:38
Beef Liver	1:44
Feline Diets	1.3-2:1

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GARY K. CLARKE AND GEORGE G. DOERING, D.V.M., M.S.
QUESTIONS AND COMMENTS

COMMENT: You really have not definitely established what the nutrient requirements of the marmoset are.

RESPONSE: Yes, I know. This is something that we did not do. There has been some work done in this area in Texas.

COMMENT: There is evidence that at least some prosimians have the ability to synthesize Vitamin C but I am not saying that we should not provide Vitamin C.

RESPONSE: It is a situation of behavior modification too. In our case, we do not put any Vitamin C in the products so what is there has survived processing. It is up to your discretion to add any extra.

A PRELIMINARY REPORT ON THE USE OF GELATIN-BASED DIETS FOR ZOO ANIMALS

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The Metro Toronto Zoo has been exploring the use of gelatin-bound diets for several animal species since 1975. This type of foodstuff was not originally intended to be used as the sole ration for the animals, but rather to be included as a portion of the daily ration. In this way the gels have served more like "carriers" for providing additional protein, vitamins and minerals in a "package" form. This eliminates much of the traditional practice of "sprinkling" supplement powders on the diets of those species where no suitable commercial feeds are available.

Gelatin-bound purified diets for Rainbow trout (WOLF, 1951) and Chinook salmon (HALVER, 1957a) have been used to investigate the nutrient requirements of these two species of fish. Both authors found that the use of gelatin as a binding agent proved to be a most useful tool in basic research.

A synthetic inert binder, carboxymethylcellulose, has also been used for the same purpose in studies with purified diets for Chinook salmon (HALVER, 1957b; DeLONG et al, 1958). Binding substances are commonly used by feed manufacturers in the production of pelleted rations. As an example, lignosol is used as a binding agent to give the necessary firmness in pelleted feeds for livestock.

Gelatin-bound diets for aquarium fishes have been previously described by REICHELT & JOYNER (1965) and PETERSON et al (1966). Based on this idea, the Metro Toronto Zoo first introduced a gelatin diet in the feeding of the aquarium fish collection in early 1975. This diet was a modification of the gelatin diet developed in 1964 at the National Aquarium in Washington, D.C. as reported by PETERSON et al (1966).

More recently the use of gelatin apparently has been extended to the development of new commercial zoo feeds. The Zu/Preem Feline Instant diet developed by Hill's Division, Riviana Foods, and the Flamingo-Fare diet from Reliable Protein Products, appear to be gelatin-based diets (however gelatin is not listed as an ingredient component in these diets).

Since 1975, many other gelatin-based diets have been developed at the Metro Toronto Zoo. These were developed to solve immediate practical feeding and/or nutritional problems. As an example, the

Primate gelatin diet was first designed for use as a medium for supplementing a fresh source of vitamin C plus other nutrients such as protein, minerals and the rest of the vitamins to the daily ration for the great apes whose diet consisted mainly of fresh fruits and vegetables.

The seven gel-diets presently in use include the turtle gelatin, lizard gelatin, fish gelatin, soft-billed bird gelatin, primate gelatin, fruit bat gelatin, and hornbill gelatin. As their versatility and acceptability have become more and more obvious, they are now under review to further improve their nutrient composition with the purpose of developing formulas that could be fed either as the sole ration or to be included as a large percentage in the daily ration for these animal species.

The gelatin powder, basically 91% protein in its composition, is not used as a source of protein. Gelatin completely lacks one of the essential amino acids(Tryptophan) and with the exception of Arginine is also deficient in most essential amino acids. It also contain excesses of some non-essential amino acids (Glycine). Gelatin has a very poor Biological Value (12-16) as compared to meat proteins (B.V. = 72-79), cereal proteins (B.V. = 50-65), or whole egg protein (B.V. = 100).

Gelatin as the sole source of protein can not satisfy the needs for amino acids of an immature animal and will not permit normal growth, thus, in preparing a gel-diet a combination of proteins from different sources must be included in order to ensure a good amino acid balance in the final product.

The use of gelatin in diet formulation provides several advantages derived mainly from its physical properties. Gelatin powder, when dissolved in hot water and mixed with the rest of the diet components, congeals upon cooling, forming a network of cross-bonds which binds all the ingredients together into a homogeneous mass. The gel formed can be flexible and rubberlike or fudgelike depending on the amount of gelatin powder added and the nature of the ingredients dispersed in the mixture.

One of the biggest advantages of the gel-diets is the ease of preparation. Large or small amounts can be prepared as needed. It can be done by hand-mixing all the ingredients in a bowl, or by using a blender, food processor machine, or a commercial-type mixer such as the Hobart vertical cutter-mixer model VCM-25 for preparing larger quantities.

For gels which will be used in an area with air temperatures above 80-90^{o}F, a larger percentage of gelatin powder must be included

in the formula to avoid melting. Gels with high density also require higher percentages of gelatin powder as a high concentration of dry ingredients can interfere with bonding of the gelatin molecules.

The ease of storage is another definite advantage in the use of gel-diets. It keeps well under refrigeration and frozen gels, when thawed, retain good consistency and can be chopped or torn into any desirable particle size or shape as required by any particular animal species.

Animal acceptance of all the gel-diets presently in use at the Metro Toronto Zoo is very high, with excellent palatability. Gorillas will accept the Primate gelatin diet as readily as fresh fruit, while Orang-utans have proved to be more reluctant to accept this type of foodstuff. Fish-gel is very well accepted by all the Barbs and Tinfoils, the Rasboras, Distichodus, Black sharks, and the Moonlight gouramis. The turtles and clawed frogs generally eat the Turtle-gel readily. For those species not accepting it outright, slivers of gel are offered inserted in pieces of fish or other diet components.

As a food for animals in an aquatic environment, the gel-diets are especially useful. The gel does not disintegrate in water (maintaining both form and texture) thus conserving the integrity of the dietary components and producing less tank turbidity than traditional foods such as beef heart.

Extensive control of ingredients and processing methods is possible with on-site production of the gels. Modifications and adjustments of formulas are also easily carried out.

One gel-diet currently undergoing evaluation at MTZ is the Turtle gelatin diet. The ingredient and nutrient composition of this diet is shown in Table I. A long term study was designed to test the adequacy of this diet against a commercial herptile diet (Zu/Preem Herp Diet) and a control group receiving the normal MTZ turtle ration. The results will be evaluated based on growth and development of Red-eared turtle hatchlings (Chrysemys scripta elegans) and on subsequent reproduction once these animals reach maturity.

In Figure I the preliminary results on growth for one of the two groups under study are shown. These animals, from birth to 5 months of age, were fed on the normal MTZ turtle ration (T2) and then distributed to the different diet treatments by taking into consideration age, body weight, etc., in order to obtain comparable groups of 5 specimens, each with an average initial body weight of 15 grams. The growth curves shown in Figure I represent average body weights for the 5 individuals in each group, from age 5 to 12

months. The animals on 100% Turtle gelatin diet (T1) are so far achieving the best growth rate, as compared to those on the normal MTZ turtle ration (T2) and the Zu/Preem Herp diet (T3). The results on growth for the turtles in the second study group are not as conclusive and require further evaluation.

Another factor that leads one to assume that the Turtle gelatin diet may be a suitable food for these animals derives from the fact that reproduction of the Red-eared and Blanding's turtles in the collection has increased considerably since the introduction of this diet. This diet was first introduced in 1976 and since then its percentage in the daily ration for these animals has been increased consistently. In Table II the number of viable hatchlings produced since 1977 is shown. For 1980, figures shown include hatchlings produced to the end of July of that year.

The Fruit bat gelatin diet (Table III) is an example of a gel-diet developed to solve an immediate nutritional problem that arose in 1977 in our Indian flying foxes (Pteropus giganteus). These animals, up to November 1977, were fed on a "traditional" diet of mixed, chopped fruits supplemented with a protein-vitamin-mineral powder.

In September 1977 we had a total of 17 bats in the collection. During the period from September to November of that year 4 animals died and six of the remaining individuals developed a condition characterized by general weakness, poor appetite, loss of body weight, and inability to fly. In addition, some of them also showed soft, bony swelling formations along the wing bones. Their diet was evaluated and found to be highly deficient in several nutrients. Protein, calcium, phosphorus and vitamin D were especially low. A gelatin-type diet was formulated as a medium for supplementing these nutrients and at the same time they were treated with injections of Calphosan (0.1 cc) and Aqua-ADE (0.1 cc). These animals were put on diet C as shown in Table IV. In general, the health of these animals improved considerably, the ones that presented swellings in their wings completely recovered and the swellings disappeared, and two animals even recovered their ability to fly.

To a group of 3 Indian flying foxes that remained in the Health Unit, the Fruit bat gel diet was increased to a level of 75% of their total daily ration for an extended period of time (Table IV - diet B) with good results as measured by body condition of the animals and no adverse effects. Since late 1977 the gel diet was also introduced to the ration for the Egyptian fruit bats (Rousettus aegyptiacus) as shown in Table IV.

Since this gel diet was introduced, there have been no detrimental effects on the animals' reproduction. It may also have contributed to the improved reproduction as shown in Table V. Since 1978, when only two adult female Indian flying foxes were left in the group, each one has produced a young every year.

CONCLUSIONS

All the gelatin-based diets were originally formulated to solve specific feeding and/or nutritional problems, but since then some of the formulas have been adjusted and improved and have become a more significant portion of the animals' diets.

The formulas are easy to modify and allow complete control of diet composition providing an excellent medium for supplementing specific nutrients and for administering special additives (Carophyll red) or medications (antibiotics or other drugs). They are relatively inexpensive, easily prepared on-site in either small or large quantities as needed and have a good storage life when frozen.

All the gel-diets currently in use at the Metro Toronto Zoo have proved to be highly palatable to the animals, with very good acceptability.

We are still working to improve the nutrient composition of these gel-diets in order to make possible their use as complete, balanced rations.

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TABLE I. MTZ GELATIN DIET FOR TURTLES

Ingredient composition	%
Water	39.89
Ground horse meat	15.89
Purina trout chow # 1	8.55
Unflavoured gelatin powder (175 bloom)	8.55
Ground smelt	5.98
Whole eggs	4.99
Corn oil	4.27
Cyphos-21	4.27
Hykro Mynah food	2.85
Carnivore supplement powder	4.05
Rogar/STB SA-37 Pet supplement	0.71

Calculated nutrient composition (as fed basis)

Moisture	%	60.68
Dry matter	%	39.32
Crude protein	%	17.58
Crude fat	%	8.07
Crude fibre	%	0.33
Gross energy	Kcal/g.	1.74
Calcium	%	1.61
Phosphorus	%	1.40
Magnesium	%	0.04
Potassium	%	0.20
Manganese	ppm	46.23
Copper	ppm	4.95
Zinc	ppm	99.06
Sulphur	ppm	0.49
Iron	ppm	17.95
Iodine	ppm	3.34
Cobalt	ppm	1.16
Selenium	ppm	0.0041
Vitamin A	IU/Kg.	10,080.00
Vitamin D3	IU/Kg.	915.35
Vitamin E	IU/Kg.	47.39
Vitamin K	mg/Kg.	25.31
Vitamin C	mg/Kg.	42.60
Vitamin B12	mg/Kg.	0.04
Riboflavin	mg/Kg.	2.87
Pantothenic acid	mg/Kg.	15.77
Niacin	mg/Kg.	11.15
Biotin	mg/Kg.	0.14
Pyridoxine	mg/Kg.	1.97
Thiamine	mg/Kg.	2.73
Folic acid	mg/Kg.	0.90
Choline	mg/Kg.	894.20

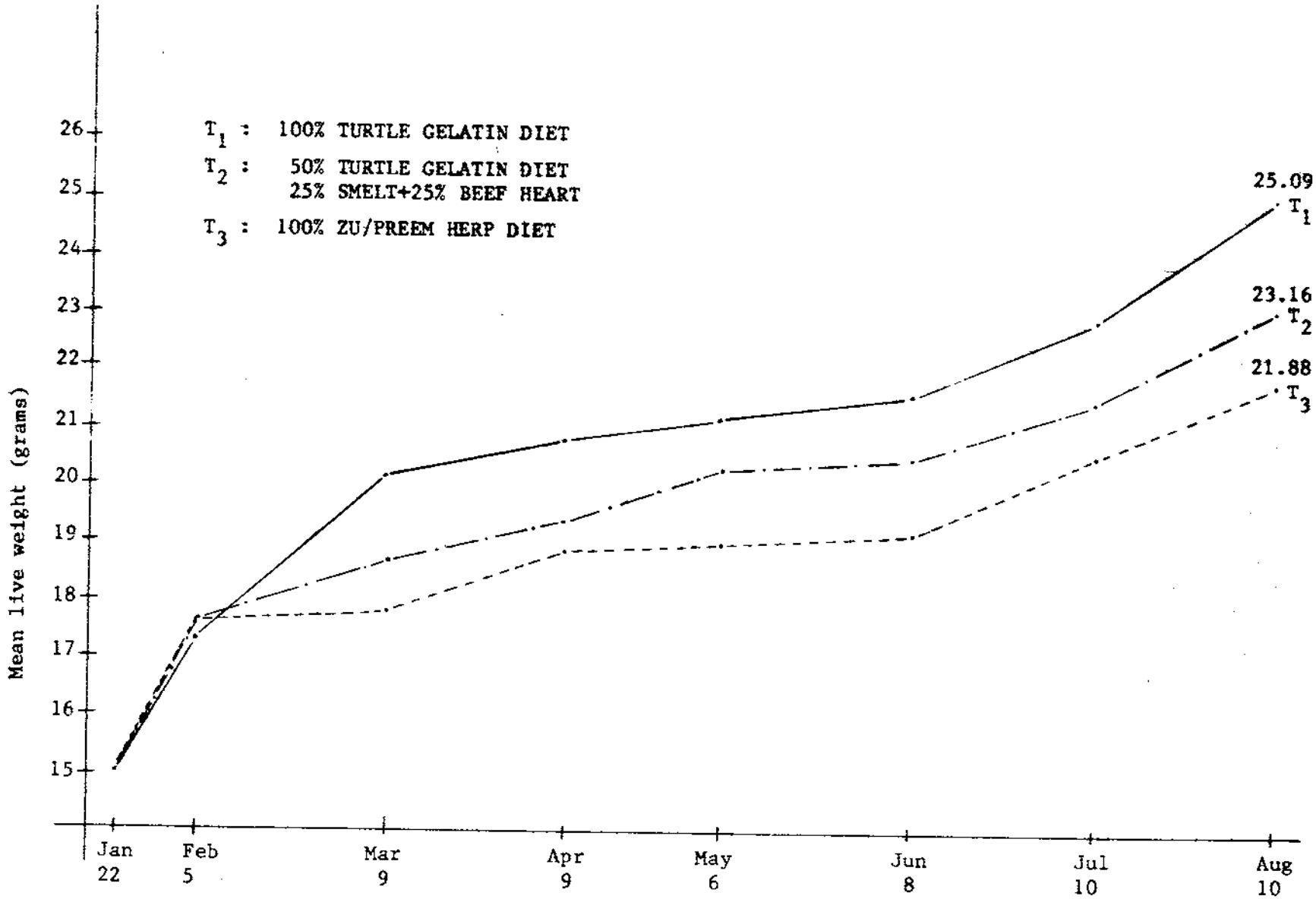

Fig I. Preliminary results of the effect of dietary treatment on growth of Red-eared turtles (Chrysemys scripta elegans) from 5 to 12 months of age.

TABLE II. RED-EARED AND BLANDING'S TURTLES HATCHED AT THE METROPOLITAN TORONTO ZOO (1977-1980).

Year	Chrysemys scripta elegans	Emydoidea blandingi
1977	8	-
1978	16	1
1979	60	5
1980	30	12

TABLE III. MTZ GELATIN DIET FOR FRUIT BATS.

Ingredient composition	%
Water	39.84
Banana	31.87
Jelly powder-strawberry flavour	6.77
Unflavoured gelatin powder (175 bloom)	3.19
Sugar	2.39
Pulverized limestone	0.80
Cyphos-21	1.59
Rogar/STB SA-37 Pet supplement	1.59
Vitamin E supplement powder	0.40
Ascorbic acid	0.40
Skim milk powder	3.98
Corn oil	2.40
Beef heart	4.78

Lab. Analysis (dry matter basis)		
Dry matter	%	100.00
Crude protein	%	21.55
Crude fat	%	2.98
Crude fibre	%	0.69
Ash	%	8.54
Gross energy	Kcal/g.	4.06
Calcium	%	2.37
Phosphorus	%	1.15
Magnesium	%	0.12
Potassium	%	0.66
Manganese	ppm	29.00
Copper	ppm	17.00
Zinc	ppm	27.00

TABLE IV. DIETS FOR FRUIT BATS AT THE METRO TORONTO ZOO.

Ingredients		*Rousettus aegyptiacus* DIET A	*Pteropus giganteus* DIET B	DIET C
Fruit bat gel diet	%	18.88	75.58	36.44
Bananas	%	40.45	8.72	28.34
Grapes	%	9.44	5.81	16.19
Figs	%	9.44	2.91	6.07
Oranges	%	10.78	2.91	4.05
Apples	%	-	2.91	4.05
Vitamin-mineral suppl.	%	-	1.16	4.86
MTZ Carnivore mix	%	6.74	-	-
Shrimp meal	%	1.80	-	-
Pulverized limestone	%	1.35	-	-
Rogar/STB Sa-37 Pet suppl.	%	1.12	-	-
Total	%	100.00	100.00	100.00

TABLE V. FRUIT BAT BIRTHS AT THE METRO TORONTO ZOO (1973-1980).

Year	*Pteropus giganteus*	*Rousettus aegyptiacus*
1973	-	1
1974	-	5
1975	1	6
1976	1	9
1977	5	11
1978	2	14
1979	2	13
1980	2	14

CARLA SANTOR QUESTIONS AND COMMENTS

QUESTION: In the slide where you were comparing the three turtles on different diets, I wanted to ask how many turtles in each group and were they related?

RESPONSE: They were related. The controls were set up randomly and there were five turtles in each group. Four animals in each group were siblings. They were from the same hatchings. One animal in each group was from a different hatching.

QUESTION: I do not understand. Do you have split litters?

RESPONSE: Yes, there are four from each litter in each group.

AVIAN DIETS AT THE NATIONAL ZOO

Olav T. Oftedal, National Zoological Park, Washington, D. C. 20008

Nutritional problems undoubtedly limit the potential success of many avian breeding programs. Traditional feeding practice involves the offering of a large array of food items with the hope that the birds have sufficient nutritional wisdom to self-select a balanced diet. In the large multi-species exhibits that are favored by the public, several feed pans may be put out, but with little concrete knowledge as to which birds are eating what. The nutritionist attempting to evaluate such diets rapidly realizes the impossibility of the task: quantitative information on diet intakes of individual birds simply cannot be obtained.

The National Zoological Park (NZP) is like other zoos in the use of complex, multi-item feed pans in the large exhibit and flight cages. We do not, however, have confidence in the nutritional adequacy of these diets. Innate and/or learned feeding behavior may indeed lead wild birds to self-select balanced diets if environmental constraints permit, but the captive animal is confronted with an array of foods that differs in composition, in quantity, and in spatial and temporal distribution from that of the wild. Feeding behavior that is adaptive in the wild may be maladaptive in captivity. For example, I think of the strong preference of some birds for fruits that are deficient in protein, calcium, and other nutrients. In the very least, feed pans should be comprised of relatively high-quality, nutrient-rich food items. At the National Zoo, we have been simplifying diets in an effort to minimize self-selection and thereby ensure that nutritionally balanced diets are consumed. Many of these efforts involve pelleted feeds developed in cooperation with Zeigler Bros., Inc. of Gardners, Pa. Such diets are tested in the more controlled set-up of holding and small exhibit cages so that acceptance can be monitored.

The art of aviculture has a large role to play in the revision of bird diets, and the nutritionist cannot afford to forget this. The diversity of feeding behaviors among birds requires the use of diets of various physical forms. The factors that influence diet palatability are poorly understood, but probably include texture, color, taste, and physical location; smell appears to be less important for most birds than it is for mammals. Successful introduction of a diet requires patience, careful observation, and sometimes a bit of "trickery" to induce a bird to sample a novel and strange item. Incorporation of live insects in a feed pan may lead to accidental ingestion of neighboring food pellets, for example.

The formulation of bird diets is an exercise in comparative nutrition: nutrient requirements of most zoo species must be extrapolated from domestic poultry (Scott, Nesheim and Young, 1976; National Research Council, 1977). Unfortunately, detailed nutritional research has been limited to a few species of galliformes and anseriforms; little is known about peculiarities in the nutritional physiology and biochemistry of frugivorous, insectivorous, fish-eating, or meat-eating birds. The fact that the bulbuls (Pycanotus) and some other passerines appear to require Vitamin C while domestic fowl do not is a case in point (Chaudhuri and Chatterjee, 1969). A substantial margin of safety should be added to the nutrient levels in feeds to allow for interspecific variation in requirements as well as possible nutrient losses associated with the manufacture and storage of processed feeds. The extra cost of added nutrients is small relative to the risks of omission.

To facilitate diet planning, the more than 180 species of birds at the National Zoo have been divided into diet categories according to feeding behavior and ecology (Table 1). I will briefly mention some of the problems associated with birds in these various categories. It is our intention that similar diets be used for species within each category; of course some flexibility with regard to inter-species and inter-bird differences must be retained.

CARNIVORES

The carnivorous birds that prey on small terrestrial vertebrates are relatively easy to feed if they can be trained to take killed rats, mice, or mouse pups. These items constitute balanced diets if fed fresh or after proper frozen storage. Economic considerations dictate the use of commercial bird-of-prey rations (meat-based, frozen products) where possible. NZP has written nutrient standards for bird of prey ration (table 2) as a consequence of which several major manufacturers have increased their levels of vitamin and/or trace mineral supplementation. These higher levels provide a margin of safety. Muscle meat per se is avoided in bird feeding due to deficiencies of calcium, vitamins A and D_3, iodine, and perhaps other nutrients. Yet when a bald eagle chick hatched in 1979, the diet recommended to us by another institution that had had prior success with bald eagle chicks was based on the use of chicken breast muscle. Appropriate levels of vitamin and mineral supplementation were calculated, but quantitative addition of supplements was difficult given the small amounts of diet prepared for daily use. Hence the chick was converted to bird of prey, whole mouse pups, and

other items as soon as possible. Similar constraints were found in the successful rearing of 2 young spoonbills in 1980; in this case, supplemental carotenoids (canthaxanthin) were also added to promote feather pigmentation.

Some types of fish are known to contain thiamine-destroying factors (thiaminases) and to contribute to the induction of Vitamin E deficiency. In 1977, NZP lost 3 brown pelicans that had been fed on unsupplemented fish; cause of death was diagnosed as nutritional muscular dystrophy (Vitamin E deficiency). Large fish may be supplemented with vitamins in tablet form; 50 IU of Vitamin E and 30 mg of thiamine per kg of fish (fresh weight basis) are probably more than adequate although higher levels of thiamine have been recommended (Geraci, 1978). Birds that feed on cut-up fish are more of a problem in that a means must be found to make the supplements adhere in the proper quantities. The concept of a commercial substitute for fish remains attractive as supplementation could be easily controlled during manufacture. Fish used for feeding should be carefully inspected for signs of spoilage: discoloration, disintegration of flesh, loss of red color in gills, bad odor, etc.

Flamingoes were previously fed a soaked trout feed supplemented with shrimp meal and various sources of carotenoid pigments. Since trout appear to have lower requirements for calcium and trace minerals (some of which fish can absorb directly from water), and do not need Vitamin D, commercial trout diets may not contain adequate levels of all nutrients for birds. Specially formulated flamingo pellets containing both shrimp meal and carotenoids are now used; these are soaked in sufficient water to make a slurry. It is important that the water used for soaking is also consumed by the birds or the water-soluble vitamins will be lost.

Obligate insectivores are often difficult to feed successfully; swallows, for example, must be hand-reared and trained to feed on items other than flying insects. Available data on the composition of such commonly used insects as mealworms and crickets indicate very low levels of calcium, vitamin A, and vitamin D. These deficiencies can be explained in terms of the anatomy and physiology of the insects. NZP has recently developed a "cricket diet" for feeding insects. This diet contains very high levels of calcium, trace minerals, vitamin A and vitamin D in an effort to increase the levels of these nutrients in the gut contents of the insects being used in reptile, bird, and mammal diets.

OMNIVORES

Some omnivorous birds adjust easily to a pelleted diet. Various duck and game bird pelleted diets are widely used in the feeding of waterfowl and pheasants, for example. At NZP dry feeds are purchased via a contract awarded to the lowest bidder. To ensure quality, consistency, and control over nutrient levels, open-formula rations have been developed with the assistance of Dr. Milton Scott of Cornell University and Dr. John Chah of Zeigler Bros. Most commercial rations are closed-formula, i.e., the exact ingredient and nutrient compositions are closely guarded trade secrets. In an open-formula ration, both ingredients and nutrient additives are specified in precise amounts; the customer, rather than the manufacturer, controls the composition of the diet.

An open-formula Avian Breeder Diet is used for both waterfowl and pheasants during the breeding season (Tables 3,4); at other times of the year an open formula Avian Maintenance diet is fed (Table 5). The nutrient levels included are rather generous, and include a substantial margin of safety, especially in the breeder diet. Niacin levels are elevated in recognition of the increased niacin requirements of domestic ducks, while high levels of vitamin E and selenium serve as prophylactic measures against nutritional muscular dystrophy that was diagnosed in the waterfowl collection in the early 1970's. High levels of calcium are included in the breeder diet to permit the laying of large numbers of eggs which are usually removed for artificial incubation. Fish-eating ducks such as mergansers and goldeneyes are fed an expanded cat food that floats. This feed replaces the trout feed diet that was previously used; the feeding of smelt has been largely discontinued in view of potential nutritional problems (see above). Successful rearing of ruddy ducks in 1979 was accomplished by providing floating duckweed onto which live crickets and other food items could be tossed. The duckweed helped stimulate feeding; the quantitative nutritional contribution of the duckweed was not known, however.

Seed-eating birds are traditionally offered diets of mixed seeds that may be deficient in protein, calcium, vitamin A, Vitamin D_3 and certain trace minerals if not properly supplemented. At NZP small seed-eaters such as red bishops have been easily converted to small (3/32"), hard pellets of balanced composition; these pellets are fed in conjunction with shredded kale which provides a supplemental source of vitamin C and other labile vitamins that may deteriorate in pelleted feeds. The extent to which vitamin C is synthesized by most omnivorous species of birds is not known; hence a dietary source is recommended in most cases. Various parrot species have been converted to large pellets (3/8") which are offered along with small quantities of various treats that may also help to alleviate boredom on a restricted diet.

Soft-billed birds pose a particular challenge. A traditional soft-billed feed pan might contain a great variety of cut-up fruits, greens, soaked trout pellets, hard-boiled egg, bird-of-prey ration, mealworms, etc. Under the controlled conditions of small holding cages, several versions of semi-moist, soft pellets have been tested. Superb starlings and Bali mynahs have been converted to soft pellets under these conditions, but it has not been possible to keep them converted when they are reintroduced into large mixed-species exhibits. After several unsuccessful attempts to introduce toucans and hornbills to soft pellets, a gelatin-based diet was devised that had a firm consistency after preparation in a pan, overnight refrigeration, and cutting into cubes. Some fruit is included in the mix to improve palatability; this diet is now readily accepted. The amino acid composition of such a diet must be carefully formulated due to the peculiar amino acid content of gelatin protein.

Cranes are fed pelleted rations developed by Dr. John Serafin at the Endangered Species Program of the Fish and Wildlife Service. The use of diets deficient in sulfur-containing amino acids as a means of restricting growth rates is a novel approach to the serious problem of leg abnormalities in rapidly growing young cranes.

HERBIVORES

Leg problems are also problematic among young ratites. An open formula ratite diet containing high levels of dietary fiber, and hence low levels of gross energy, was developed in an attempt to restrict energy intakes and growth rates among young birds (Tables 6,7). This diet is also fed to adult ratites; free-choice oystershell is made available to laying birds as a supplemental source of calcium.

Geese consume the same open-formula avian diets fed to other waterfowl but they also graze some grass in the exhibit areas. Although NZP does not keep grouse, pelleted diets developed in Scotland and Norway are worthy of note (Moss and Hansen, 1980).

SUMMARY

A variety of new manufactured diets are being tested at the National Zoological Park in an attempt to improve the nutrient intakes of various types of birds (Table 8). In some cases pelleted diets were already well established, but the formulation of these diets has been changed (e.g., diets 1-6 in Table 8). In

other cases birds formerly on complex, mixed diets of questionable nutritional composition have been converted to simplified diets in dry pellet (diets 7-8), semi-moist (diet 9), or gel (diet 10) form. Improved nutrient standards have been established for bird-of-prey rations, and supplementation of fish is recommended. Efforts are underway to improve the nutritional composition of insects used for feeding purposes. Most of these new diets are still in the experimental stage: even if successfully incorporated into feeding regimens, the long-term effects on health and reproduction have yet to be determined. The present report should be considered preliminary only. It will be many years before the outcome of changes currently being made can be fully evaluated.

ACKNOWLEDGEMENTS

Many of the experimental diets described herein represent the joint effort of Dr. Milton Scott of Cornell University, Dr. John Chah of Zeigler Bros., Inc., and the author. Most diet testing was conducted by Suzanne Frank, keeper in the NZP bird house, who also has kept and organized records of our efforts. I am indebted to Charles Pickett, Ornithologist and supervisor of the keeper staff, for his support and cooperation. An earlier version of this paper was presented at the 1980 annual meeting of the American Association of Zoo Veterinarians in Arlington, Va.

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Table 1. Classification of NZP Birds by Diet

	Example
a. Carnivores	
A. Terrestrial-vertebrate prey	Owls
B. Carrion feeders	Vultures
C. Fish-eaters	Pelicans
D. Fish/scavengers	Gulls
E. Aquatic probers/Surface feeders	Ibis
F. Filter-feeders	Flamingoes
G. Specialized insectivores	Swallows
H. Other	Kiwi
b. Omnivores	
A. Ground foragers	Pheasants
B. Fruit, berry, and insect eaters	Starlings
C. Nectar feeders	Lorikeets
D. Seed-eaters	Finches
E. Omnivorous scavengers	Crows
F. Waterfowl	
-- Dabbling ducks	Wood ducks
-- Diving ducks	Scaups
-- Fish-eaters/divers	Mergansers
G. Other	Cranes
c. Herbivores	
A. Terrestrial	Ostrich
B. Aquatic	Geese

Table 2. Bird of Prey Ration: Nutrient Standards

Moisture	62.0%		Maximum
Crude protein	45.0%		Minimum
Crude fat	12.5%		Minimum
Crude fiber	3.8%		Maximum
Ash	10.0%		Maximum
Calcium	1.2%		Minimum
Calcium	2.5%		Maximum
Phosphorus	1.0%		Minimum
Magnesium	0.07%		
Sodium	.20%		
Potassium	0.5%		
Iron	80	ppm	
Copper	8	ppm	
Zinc	90	ppm	
Manganese	70	ppm	
Iodine	0.5	ppm	
Vitamin A	8,000	IU/kg	
Vitamin D_3	1,800	ICU/kg	
Alphatocopherol	50	IU/kg	
Vitamin K	2	ppm	
Thiamine	5	ppm	
Riboflavin	8	ppm	
Niacin	80	ppm	
Pantothenic acid	32	ppm	
Folic acid	20	ppm	
Pyridoxine	9	ppm	
Biotin	0.3	ppm	
Vitamin B_{12}	.02	ppm	
Choline	1,500	ppm	

Nutrient standards are on a dry matter basis.

Table 3. Avian Breeder Diet (Open Formula): Ingredients

Ingredient	Percentage by Weight
Corn, yellow, No. 2, ground	55.7
Barley	12.5
Soybean meal, 44% protein	12.0
Fish meal, 65% protein	2.5
Fish solubles, dried	0.5
Meat and bone meal, 50% protein	5.0
Corn fermentation solubles	2.5
Whey, dried	1.0
Alfalfa meal, 17% protein	3.0
Limestone, ground	4.5
Salt	0.25
Dl-methionine	0.055
Vitamin and mineral premixes	0.50

Table 4. Avian Breeder Diet (Open Formula): Nutrient Standards

Crude protein	18.0%		Minimum
Crude fat	3.0%		"
Crude fiber	6.0%		Maximum
Lysine	0.85%		Minimum
Arginine	1.0%		"
Methionine	0.36%		"
Tryptophan	0.18%		"
Calcium	2.3%		"
Phosphorus	0.6%		"
Magnesium	.06%		"
Sodium chloride	0.4%		"
Potassium	0.6%		"
Iron	100	ppm	"
Copper	10	ppm	"
Zinc	100	ppm	"
Manganese	130	ppm	"
Iodine	.4	ppm	"
Selenium	.2	ppm	"
Vitamin A	10,000	IU/kg	"
Vitamin D_3	1,500	ICU/kg	"
Vitamin E	120	IU/kg	"
Vitamin K	1.5	ppm	"
Thiamine	3	ppm	"
Riboflavin	5	ppm	"
Niacin	90	ppm	"
Pyridoxine	6	ppm	"
Panthothenic acid	24	ppm	"
Folic acid	4.0	ppm	"
Biotin	0.25	ppm	"
Vitamin B_{12}	.015	ppm	"
Choline	1,500	ppm	"
Linoleic acid	1.2%		"

Nutrient standards are on an as fed (net weight) basis.

Table 5. Avian Maintenance Diet (Open Formula): Nutrient Standards

Crude protein	12.5%		Minimum
Crude fat	12.0%		"
Lysine	0.63%		"
Arginine	0.6%		"
Methionine	0.25%		"
Tryptophan	0.13%		"
Calcium	0.8%		"
Phosphorus	0.6%		"
Magnesium	0.06%		"
Sodium chloride	0.4%		"
Potassium	0.6%		"
Iron	40	ppm	"
Copper	4	ppm	"
Zinc	25	ppm	"
Manganese	25	ppm	"
Iodine	0.4	ppm	"
Selenium	0.2	ppm	"
Vitamin A	6,000	IU/kg	"
Vitamin D_3	500	ICU/kg	"
Vitamin E	120	IU/kg	"
Vitamin K	1.0	ppm	"
Thiamine	3	ppm	"
Riboflavin	4	ppm	"
Niacin	60	ppm	"
Pyridoxine	5	ppm	"
Panthothenic acid	20	ppm	"
Folic acid	1.5	ppm	"
Biotin	0.25	ppm	"
Vitamin B_{12}	.015	ppm	"
Choline	1,000	ppm	"
Linoleic Acid	1.2%		

Nutrient standards are on an as fed (net weight) basis.

Table 6. Ratite Diet (Open Formula): Ingredients

Ingredient	Percentage by Weight
Oats, heavy, pulverized	30.0
Alfalfa meal, 17% protein	30.0
Soybean meal, 44% protein	10.0
Fish meal, menhaden	5.0
Meat and bone meal, 50% protein	2.5
Brewers died yeast	2.5
Soybean oil	2.0
Oat hulls, pulverized	16.5
Dl-methionine	0.05
Salt	0.5
Dicalcium phosphate	0.5
Vitamin and mineral premixes	0.5

Table 7. Ratite Diet (Open Formula): Nutrient Standards

Crude protein	18.0%		Minimum
Crude fat	3.0%		"
Crude fiber	17.0%		"
Lysine	0.85%		"
Arginine	1.0%		"
Methionine	0.36%		"
Tryptophan	0.18%		"
Calcium	1.05%		"
Phosphorus (available)	.5%		"
Magnesium	.05		"
Sodium chloride	0.4%		"
Potassium	0.6%		"
Iron	100	ppm	"
Copper	10	ppm	"
Zinc	100	ppm	"
Manganese	130	ppm	"
Iodine	.4	ppm	"
Selenium	.2	ppm	"
Vitamin A	10,000	IU/kg	"
Vitamin D_3	1,500	ICU/kg	"
Vitamin E	120	IU/kg	"
Vitamin K	1.5	ppm	"
Thiamine	3	ppm	"
Riboflavin	5	ppm	"
Niacin	90	ppm	"
Pyridoxine	6	ppm	"
Pantothenic acid	24	ppm	"
Folic acid	4.0	ppm	"
Biotin	0.25	ppm	"
Vitamin B_{12}	.015	ppm	"
Choline	1,500	ppm	"
Linoleic acid	1.2%		"

Nutrient standards are on an as fed (net weight) basis.

Table 8: Summary of Manufactured Feeds Used for NZP Bird Collection

		Pellet Type	Pellet Size
1.	*Avian Maintenance	Dry	5/32"
2.	*Avian Breeder	Dry	5/32"
3.	*Ratite	Dry	5/32"
4.	Crane Maintenance	Dry	5/32"
5.	Crane Breeder	Dry	5/32"
6.	Flamingo	Dry (Soaked)	5/32"
7.	Parrot	Dry	3/8"
8.	Finch	Dry	3/32"
9.	Soft-billed bird	Semi-moist	5/32"
10.	Frugivore	(Gel)	Meal
11.	"Cricket"	Crumble	----
12.	"Feline"	Extruded	----

* Diets marked with asterisk are Open Formula.

-- All diets except No. 12 manufactured by Ziegler Bros. Inc., Gardners, Pennsylvania

-- Diet No. 12 manufactured by Hills', Division of Riviera Foods, Topeka, Kansas

QUESTION: The situation with the Ruddy Ducks at National Zoo points out one very important consideration, they did have some success there even in the absence of detailed nutritional studies and I think that points out the importance of behavior modification and behavioral management in any nutritional program as well, especially when you can couple it with detailed nutritional analysis.

RESPONSE: I think a nutritionist, in particular, comes into a zoo and is faced with an array of species he/she has never had to deal with before. The keepers and the Curators are the ones who know the birds and birds, as you are all aware, are not as flexible in their behavior as are mammals and there are all sorts of tricks of the trade to use in dealing with birds. I had a very enlightening discussion with Bill Conway of the Bronx Zoo when I first started and he gave me a paper that he had done on all of these various tricks of the trade to try to get birds to feed. It is important to recognize that there are birds that have never been successfully maintained in captivity because they do not feed. So I think the first step in dealing with a problem like this is to contact and communicate with the person that is working daily with

the animals. I can make a balanced diet but if the bird will not eat it, it will not do a bit of good.

QUESTION: Why does the Ratite diet have a high fiber content?

RESPONSE: The Ratites are herbivores unlike most birds and they do consume a relatively high level of plant fiber in the wild. In particular, our goals are to try and reduce the energy content of the feed so that the animals have to consume more to get the same amount of energy. We are trying to keep them from consuming too much, too quickly, too soon and therefore hopefully try to restrict growth. John Serafin of Patuxent Wildlife Research Center had some data on cranes where they had tried changing the energy levels of the diet fed to the cranes. They were not very successful because the birds would, in fact, eat more and therefore their growth rates were not reduced. But I think he did succeed in his procedure when he reduced the sulfur amino acid content of the diet. He showed that you get a reduction in the growth rate only during the very early period and these animals did catch up in their growth later on. When you are talking about growth restriction, there are lots of ways to do it and they are not all equivalent. Any nutritional deficiency will stunt the growth of an animal and I am not sure that John Serafin's way is the best way. He is not sure that his way is the best way,

however, it is one way. There is a lot of work to be done in this field.

QUESTION: Are the Ratites at National Zoo fed free choice or on a fixed schedule?

RESPONSE: The adults are fed free choice. The young are not. The young ones in fact are very carefully monitored and they are given a lot of greens, a lot of kale along with it to provide bulk. They are definitely not fed free choice when they are young and just out of the egg shell.

QUESTION: Can you provide extra calcium for these birds offering it free choice?

RESPONSE: This is an alternate approach and I noticed that Toronto follows it. Dr. Milton Scott of Cornell has done some studies with poultry where they have tried offering free choice to show that birds would self-regulate the calcium intake at least to some extent. I would like to see more data on this. I think that it would be very useful if birds could do this. Of course, what nutritionists are scared of is that animals do not have nutritional wisdom except with regard to certain nutrients such as salt and perhaps water and energy. But perhaps we will be convinced that the free choice provision would be a viable way to go. It may be working very well in a lot of places.

COMMENT: When working with heavy breed chickens, they are generally handled this way.

RESPONSE: We are actually doing this with our Ratites. You notice our Ratites did not have excessive calcium levels. We are using free choice calcium in that case and some of these birds are quite heavy layers. Some of our formulas for our breeder diets, such as finch breeder diet, do not have a very high calcium level because we do not have that level of egg production in the Passerines, at least the Passerines that we are working with, and of course that is what finally determines the amount of egg shell the animal has to put out.

QUESTION: Do you use Thiamin and Vitamin E in a fish eating bird diet?

RESPONSE: We are using 120 IU/kg of feed in our pelleted diet. When considering a diet specifically of fish, where you are talking about a 60% moisture diet, you must account for that and also the fact that you do have unstable fatty acids in that type of feed. You might want to go to an even higher level of Vitamin E because we know that fatty acids will increase the Vitamin E requirements of animals, at least of mammals and chickens. My problem with a commercial product available which we have been using, Sea Tabs, and with which you might be familiar is that although they have

a very high level of Thiamin, their level of Vitamin E is not very high at all. I do not feel that I would be using the Sea Tab product but we are presently. I just have not found the time to get around to modifying the supplement to our fish eating birds. I really do believe we should be going to higher levels of Vitamin E with animals that are fed exclusively on fish. By the way, I would love to see an artificial fish.

COMMENT: I would like to point out that your evaluations and formulations of soft-billed bird diets are as subjective as those of the old-time aviculturists.

RESPONSE: Nutritionists have a basic conviction that there is a uniformity in the requirements and the data are available on really a wide variety of species but I would say that there is some degree of subjectivity especially when you deal with birds for which there is no satisfactory model available. For example, I had a discussion with George Doering about this in regard to level of manganese which should be used in a bird diet, specifically for carnivorous birds. Perhaps the levels they were using were perfectly adequate. We did not see any problem but we opted for a higher level of manganese because that was what the requirement for poultry indicated, however, we really do not know whether the requirement for a bird of

prey is more like a chicken or more like a cat. And the same is true in the case of Vitamin A requirements, we just do not know but I would not agree that it is as subjective. I would say that there is an element of subjectivity.

QUESTION: What form of free choice calcium do you offer your Ratites?

RESPONSE: We use oyster shell large hen size.

OPTIMIZING THE USE OF VITAMIN AND MINERAL SUPPLEMENTS

Richard Patton, Zoo Nutrition Service, Los Angeles

A wide variety of supplemental products are used in zoos to augment the nutrition of captured wild animals. These products are frequently used in a random application because it is felt that little is known about the exact requirements of exotic animals, and a "just in case" approach is preferred to none at all. In actuality, certain generalizations may be quite safe, even though the exact vitamin needs of zoo animals are unknown. Table 1 campares the known needs of several species for most of the vitamins and several micro minerals. These values are from NCR publications and are expressed per kg of dry matter for the animals food. The NCR committies are conservative and cautious, but these values do represent the consensus of respected professionals. Their values may not stand the test of time, but at least they have the courage to give us values to change from. Table 1 shows that the vitamin A requirements are fairly similar regardless of species, with the value of about 5000 IU/kg of feed meeting the needs of creatures as divers as the catfish and the turkey.

There is no vitamin D requirement listed for mink, but inasmuch as 1000 IU/kg is listed as meeting needs of the cat, dog, pig, mouse, catfish and several others, one should feel confident that 1000 IU of D/kg of feed would meet a minks normal needs, yet run little danger of toxicity. Similar trends are evident for most micro nutrients listed in Table 1. Pigs require 80 mg/kg iron and dogs a similar 60. The coefficient of variation is small and lends credibility to the premise that the mean requirement of all domestic animals is probably clsoe to that of all exotic animals and further, that there are few, if any situations where a given animal needs a specific vitamin at a level greater than one order of magnitude from the mean. Indeed, one is tempted to devise a formula similar to Brody's equation for energy requirements, wherein exact needs can be predicted given metabolic weight. On a metabolic weight basis, it may be possible to predict maintenance level vitamin needs of all warm blooded animals.

Table 2 lists five selected products used in zoos. A sixth, Clovite, is used widely in zoos but was not listed because it claims to provide only vitamins A, D & B_{12}. As such, it was not included in this comparison of more wide range micro nutrient supplements. This discussion is not an indorsement of any product, but rather an attempt to point out that different products make different claims, have different strong points and differ in value depending on their intended use. For example: Clearly Chaparrel should not be rated

as a mineral supplement, it makes no claim for minerals. The manufacturer of 707 does not intend the product for zoos but it is widely used by zoos. No effort was made to include all products used by zoos, but rather to contrast the wide range available.

From Table 2 it is seen that the highest potency product (SNS) is not the least expensive on a per lb. basis. The cheapest (Chaparral) is not the most economic when considered in terms of potency per dollar spent. The first question to ask when evaluating a supplement product is "how much bioabailable vitamin (or mineral) does a dollar buy?" When ranked on the merits of I.U.'s or mg's delivered per dollar, alarming differences become evident. Considering vitamin A, SNS is 50 times a better buy than Vionate-Pet. Considering iron, the ZuPreem product was not only 20 times a better buy than 707, it was also a superior molecular form (iron sulfate is absorbed better than iron carbonate).

Few supplements are designed to parallel the needs of any particular species. Administering the recommended dose invariably overdoses but at widely varying levels for different micro nutrients. For example, Table 3 points out the levels of micro nutrients delivered in 2 oz. (the recommended daily dose) of 707. A 400 kg mature horse needs 10,000 IU of vitamin A per day, but the daily dose of 707 is five times this level. The same is true for vitamin D. The daily dose of 707 mixed into a kg of feed also provide 18 times the B_{12} required by the cat but only one fifth of the cats choline needs or one-third of its zine requirement.

The ideal supplement would appear to be one where the recommended dose provides 100% of all the requirements. The customer could adjust this up for overkill or down for economy and know exactly what he is doing. But because exact requirements are rarely known, and manufacturers seem to ignore them where they are known, it may be awhile before the ideal product is available. In the meantime, certain points can be made by way of conclusion: Generalizations are possible, we can often extroplate from known species vitamin requirements to unknown; there is a great variation in cost effectiveness among products available for micro supplementation; most supplements are poorly designed to meet animal requirements.

TABLE 1. SELECTED MICRO NUTRIENT REQUIREMENTS OF SEVERAL SPECIES (AMOUNTS PER KG OF FEED, D.M., BASIS)

	PIG	DOG	MINK	CAT	CHICK	TURKEY	MONKEY	MOUSE	COW	HORSE	SHEEP	RABBIT	TROUT	CAT FISH
Vit A, IU	4,100	5,000	3,500	10,000	1,500	4,000	10,000	500	3,200	2,500	1,500	580	2,000	5,500
D, IU	275	500	-	1,000	200	900	1,600	150	300	-	300	-	-	1,000
E, mg	11	50	25	80	10	10	-	-	-	-	-	40	30	50
Thia, mg	1.5	1.0	1.2	5	1.8	2.0	1.9	2.8	-	-	-	-	10	20
Ribo, mg	4.0	2.2	1.5	5	3.6	3.6	1.9	4.0	-	-	-	-	20	20
Pyr, mg	-[1]	1.0	1.1	4	3.0	4	3.2	1.0	-	-	-	39	10	20
Niacin, mg	22	11.4	20	45	27	70	127	10	-	-	-	180	150	100
Folic, mg	-	.18	.5	1.0	.5	.9	2.6	-	-	-	-	-	5	5
Panto, mg	16.5	10	6	10	10	11	-	8.5	-	-	-	-	40	50
Biotin, mg	-	.10	-	.05	.09	.3	.63	-	-	-	-	-	1.1	.1
B_{12}, mcg	15	22	-	20	9	3	4.4	5	-	-	-	-	20	20
Mn (mg)	20	5	-	10	55	55	-	20	40	-	30	8.5	-	-
Fe, mg	80	60	-	100	80	60	-	-	50	40	40	-	-	-
Cu, mg	6	7.3	-	5	4	6	-	-	10	6	5	3	-	-
Zn, mg	50	50	-	30	50	70	-	50	40	-	45	-	-	-
I, mg	.2	1.54	-	1	.35	-	-	-	.5	.1	.1	.2	-	-
Co, mg	-	-	-	-	-	-	-	-	.1	-	.1	-	-	-
Se, mg	.1	.11	-	.1	.1	.2	-	-	.1	.5	.1	-	-	-

[1] A blank indicated requirement is unknown

TABLE 2. COMPARISON OF SUPPLEMENTAL PRODUCTS FOR COST[1] EFFECTIVENESS
(ALL UNITS MG EXCEPT A&D WHICH ARE IU x1000)

	707		CHAPARRAL		SNS		ZU/PREEM		VIONATE-PET	
	LB.	$1.00	LB.	$1.00	LB.	$1.00	LB.	$1.00	LB.	$1.00
A ($x10^3$)	400	200	262	477	454	605	120	272	100	12
D ($x10^3$)	70	35	175	320	45	60	40	91	10	1
E	320	160	260	475	454	605	300	681	54	6
Thia	120	60	31	57	295	393	15	34	18	2
Ribo	320	160	81	148	295	393	12	27	36	4
Pyr	60	30	16	30	295	393	7	16	5	.5
Niacin	2000	1000	525	954	4536	6050	60	136	125	15
Folic	20	10	6	11	227	300	1	3	1	.1
Panto	240	120	62	114	454	605	55	125	50	6
Biotin	6	3	-	-	4	5	.4	.8	-	-
B_{12}	3	1.5	1	2	.2	.3	.1	.3	.1	.01
Choline	3200	1600	875	1590	-	-	1200	2727	2600	305
Mg	2000	1000	-	-	-	-	1362	3095	192	23
Mn	2000	1000	-	-	80	106	1225	2784	34	4
Fe	1640	820	-	-	397	529	8172	18,572	250	30
Cu	110	55	-	-	159	211	817	1856	25	3
Zn	80	40	-	-	238	316	2724	6190	-	-
I	40	20	-	-	16	21	9	22	10	1
Co	30	15	-	-	80	106	23	52	2	.3
Se	-	-	-	-	.7	1	9	21	-	-

[1] Dec 1980 retail price, f.o.b. supplier: 707 $2.00/lb, La Salle, Colorado; Chaparrel $.55/lb, Albuquerque, N.M.; SNS (Morne's) $.75/lb, Upland, CA; ZuPreem $.44/lb, Topeka, Kansas (discontinued 1980); Vionate-Pet $8.50/lb, Squibb.

TABLE 3. 2 OZ. 707 PROVIDES

MICRO NUTRIENT	I.U. or MG	OVERAGE*
A	50,000 IU	5X
D	8,750 IU	5X
E	40 MG	.5
B_1	15	3X
B_2	40	10X
B_6	7.5	1.9X
Niacin	250	1.4X
Folic	2.5	1X
Panto	30	1.8X
Biotin	.75	1.2X
B_{12}	.375	18.0X
Choline	400	.2
Mn	250	4.5X
Fe	205	2X
Cu	13.75	2X
Zn	10	.2X
I	5	3.2X
Co	3.75	37X

*Compared to highest listed requirement of several animals

RICHARD S. PATTON, Ph.D. QUESTIONS AND COMMENTS

QUESTION: Would you comment on the danger of toxicity?

RESPONSE: Obviously this is possible. I think that you can see where someone could get carried away and overuse some of these products. The SNS, for example, at 450,000 IU of Vitamin A/pound, you could give an elephant a couple of pounds of that and perhaps be overdoing it on a long term basis. The 707, for example, has 2,000 mg of Niacin compared to 60 for the ZuPreem product. Yes, I think toxicity is a possibility in some cases but by and large many health food advocates are walking proof that it is very hard to reach a toxicity on many of these micro-nutrients. So I am not really that preoccupied with the toxicity as much as I am with the waste of money and the problem of not providing adequate levels of the micro-nutrients.

QUESTION: If you over use calcium and phosphorus are you courting disaster?

RESPONSE: Too much of anything is not good for you. Let me assume that you mean that the calcium and phosphorus levels are in balance but are in excess. A couple of things happen. First of all, the more minerals you have in the diet of one given type, calcium/phosphorus for example, the more you suppress the absorption of other minerals. It is on

a kind of percentage basis so you can get into a deficiency. You can supress the absorption of these other minerals by having high calcium/phosphorus. The other problem is the calcium/phosphorus if available can combine and you can get a insoluble salt that simply passes through. You will sometimes see chalky feces in such a case. An excess calcium/phosphorus intake would just mean a high ash diet and that is precisely what we are doing in some of the commercial pet foods these days, for example, dry cat food that has a 9-10% ash on dry matter basis. Animals can tolerate a pretty high ash intake. I am not concerned with being overly cautious in this area.

QUESTION: I would like to reiterate and agree with you that some of these supplements are not very well designed for the animals for which they are intended. I have had a problem with fish supplementation in that to try to get the Vitamin E levels up to where I want them I am pushing Vitamin A levels into a potential toxicity range. We do not really know what toxic levels are for a fish eating animal that gets a high intake of Vitamin A in the wild.

RESPONSE: Let me point out that there are a number of people around the country who will manufacture a vitamin supplement exactly to your specification for a very nominal fee and

they will ship it to you. SNS is one of them. $0.75/lb. will get you exactly what you want and in the exact forms that you want it. There are a couple of others and if anyone is interested I would be happy to refer you to them.

FEED MANUFACTURING AND QUALITY CONTROL

Joel E. Drews, Ph.D., Continental Grain Company
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Animal feed manufacturing is a business that usually involves very large volumes of material. Continental Grain Co. has 28 feed plants scattered across mostly the Eastern 2/3 of the United States, making over 2,000,000 tons of feed annually. How do we go about making up the feed that goes into the one bag that is going to be fed to my animal or to your animal?

If we look at a typical plant, feed starts with ingredients. The major ingredients will be delivered in hopper cars or in trucks. Bagged ingredients also are used. Bagged ingredients are usually vitamins and minerals. A Quality Assurance (QA) man and an unloading man will inspect these vehicles and samples will be taken. These samples will be taken into the laboratory for further testing.

Materials that are being unloaded into the storage bins pass over magnets which remove tramp metal from the ingredients. Sifting mechanisms are also used to help remove foreign material. There are some extraneous materials that come in with raw ingredients and every effort is made to remove these items before they end up in feeds.

All of these different ingredients are sampled by a QA man, taken into the lab and examined to make sure that corn is corn or that wheat midds are wheat midds and not wheat bran. There are some chemical tests made. One test is a Urease test on soybean meal to make sure the soybean meal is properly cooked so that it does not contain some of the anti-nutritional factors that are in the raw bean. These anti-nutritional factors are destroyed by heating and the Urease test is one method of determining that proper heating took place during the cooking procedure. Many chemical tests are made on the different ingredients. For example, ether extract is used to measure fat and atomic absorption methods are used to measure trace minerals. The purpose of the sampling and testing is to make sure that all of the ingredients that come into this plant meet the specifications that were set up by our research group and passed on through our purchasing group. Before the ingredients go into storage bins for use in final feeds, we are sure they do meet the specifications and can be used to make the kind of feeds that we are attempting to formulate.

In the actual plant environment, there will be a man scheduling the various feeds that they are going to make at the plant that day.

The scheduling is needed to make sure that feeds are made in the proper order so that incompatible types of products do not follow each other. For example, high calcium layer feeds are not followed immediately by a chick broiler ration where possible carryover of the calcium supplementation would not be too advantageous.

In our case, formulas come from the Research and Development Center where the Researcher and the formulation people put together the actual formula that will go to the plant over a computer and teletype network. The plant receives a printed formula from which to make the feed with the particular ingredients that they have.

At the plant, the production formula will be used to set individual ingredient feeders for each ingredient per formula. These feeders will deliver a given amount of ingredient per unit time. At the same time, there will be a microingredients premix weighed out so the ingredients to go into the premix will be put there exactly as specified in the formulation. After all the feeders are set, the control panel will be started up and the line will begin to mix feed. As the individual ingredients are metered out, they go down the line to a high speed blender. The feed grains go through a hammermill so that the material is ground to a uniform consistency (uniform particle size) before being mixed.

After mixing, the feed goes over sifters that separate large particles from proper sized particles. The large particles are primarily foreign material that was not removed earlier. The large particles are discarded.

From this point, after the sifting, if feed is going to be a meal or mash-type feed, it would go directly to a packaging line or to a load-out bin. If it is a pelleted feed, it would move on to a pelleting mill. Here the feed is mixed with steam and water and conditioned in a conditioning chamber above the pellet mill. It is then forced through the die and pushed out as pellets.

At the pellet mill is another check point in the system. The formation of the pellets can be checked at this point to make sure that the pellet is of correct consistency, that there is not either too much or too little moisture added resulting in soft pellets. Because of the heat generated by the pelleting, the pellets go into a cooler to cool them back down to ambient temperature and again remove the moisture from them so that we end up with a product about where we started at 10, 12, or 14% moisture.

At this point, samples of the feed are taken and examined again. The QA man will take a portion of this sample to determine how hard the pellets are. Is the pellet hard enough to hold together during

the shipping procedure? Will it fall apart, or is it too hard for animals to eat? If either extreme is found, the feed is not to be sold but is to be sent back for a reworking type of operation.

From the pellet mill the feed can either go into bulk load-out bins or into a sacking bin to produce feed in a sack. In an effort to manage inventory control and keep fresh feed in your facility and in our facility, there is a coding system which can differentiate production lots. There should be some kind of coding system on sacks so that orderly stock rotation can be managed. Coding can be done either by a wheel on the sacking machine which will imprint some type of code date on the tape that is sewn on to close the sack. Another method of coding sacked feed is by printing a code on the feed tag.

After the feed is sacked and coded it comes down a chute and is loaded on pallets. The pallets can go into storage and then can be loaded out to the customer.

A review of the quality control through the whole procedure, from the time the ingredients entered the plant until the finished product was ready to load out at the plant, shows that QA people and the production people were looking at appearance, texture, color, and aroma of all the ingredients and the finished products. This was done to make sure that the ingredients were the correct ingredients in the first place, that they were combined in the correct amounts to make the correct feed and that the finished feed met specifications. Chemical, bacteriological and palatability tests can all be made as further quality control program insurance procedures.

Vitamins are important in feed because they are labile ingredients or labile chemicals. They have to be reactive in order to perform their functions in metabolism. What causes destruction of the more labile vitamins in a feed? Vitamin A, thiamine, pantothenic acid, and vitamin K are either destroyed by heat or their destruction is accelerated by heat even through the actual mechanism may be oxidation.

Storage conditions then become important. Feed shouldn't be stored next to steam pipes and feed shouldn't be stacked on top of radiators. This does not mean that feed has to be kept in a freezer or in a cooler, but feed is a biological material just like the animals we are feeding and it needs to be treated with some amount of respect.

Vitamin C provides an example of what happens during storage. If we start with 100% of the vitamin C in a diet, no matter what that level is, at about 3 months - 90 days - you are going to be

down to about ½ of the vitamin C that you put into the bag in the first place. There is not much that the vitamin manufacturer can do to slow this process down and retain biological availability of the vitamin C. The feed manufacturer can take care of some of it by over supplementation initially but that becomes costly.

The data suggests that diets containing vitamin C should be fed before they are 90 days old. That is exactly the recommendation that we make. The 50% level of vitamin C will still be 2 to 3 times the animal's requirement, but there is no way we can stop the destruction.

Vitamin A under good storage conditions of relatively cool, dry conditions, could lose up to 30% of the initial vitamin A activity after 6 months of storage. Under poor storage conditions of high heat and high moisture, you could lose as much as 80% of that vitamin A in a 6 month period.

Storage conditions of the feed are important. The vitamins, because they are reactive chemicals, are going to be somewhat slowly destroyed. However, under dry, cool storage conditions, properly formulated and manufactured feed will maintain adequate levels of all the vitamins, with the exception of vitamin C, for long periods of time.

Proper care during manufacturing, quality control, and proper care during storage will result in high quality feeds to meet the nutrient requirements of captive wild animals.

JOEL E. DREWS, Ph.D. QUESTIONS AND COMMENTS

QUESTION: How do we balance out the vitamin destruction caused by the heat in pelleting?

RESPONSE: That is taken care of primarily at the time of formulation, to over-formulate for the known amount of destruction that is going to take place during the manufacturing process. Again, there is a bit of over-formulation that goes into the product based on the expected destruction during storage. We don't just keep adding and adding so that if you get some fresh material that did not go through a pellet mill you would be at toxic levels, but we try to balance out the known sources of destruction with supplementation. Again, many of these vitamins are available in some type of a stabilized form in a gelatin beadlet type of thing which has less destruction than the actual vitamin molecule itself would have.

QUESTION: What are the relative costs of stabilized forms of vitamins? In other words, what decisions are made as to whether to use them or not use them?

RESPONSE: In general, there is no unstabilized Vitamin A available in the market place. The cost of the stabilized vitamin is so low that the manufacturers do not offer the raw chemical as it is just not to their advantage. There is no need for it. For Vitamin C, the stabilized form is maybe half

of penny per gram difference which by the time you get it into a finished feed becomes practically nothing. So generally the stabilized Vitamin C is used. There is work being done with better methods to stabilize Vitamin C and it can be made very stable. In general, the stabilized forms of vitamins are being used as the costs are not much different from the raw chemicals themselves.

QUESTION: Suppose a zoo is getting special order medicated feed. To have it manufactured, the zoo must be prepared to receive a rather relatively large lot which is not used up very quickly. What would you recommend for storage conditions if you knew you would have to be storing and using this feed over a period of nine months to a year?

RESPONSE: If a medicated feed or custom-mixed type of arrangement is made that would have to be fed over a long period of time, the storage conditions that I would recommend would be to put them in a freezer type of situation. If your freezer has some kind of humidity control so that you do not get a build up of frost under the polyliner in a bag that would be the best arrangement. If you do not have the humidity control, you could end up on the day you take the feed out of the freezer with a situation where the moisture has condensed and you might begin to get mold growth at that point. Total moisture in the product is

going to be 12% but at the point where that water dripped off the inside of the bag you are going to have all of that 12% right there on the feed, you can get mold growth easily. My recommendation for medicating animals is to go a water route if at all possible. I recommend this because of the problem of the amount of feed that might have to be made up at once and the problem that you can get into with storage. Of course, additionally some of these drugs are not particularly stable and unless you know for a fact what the stability of the drug is you may be getting into some trouble in storing long term.

QUESTION: So then, if you are getting frost inside of a liner of a bag or moisture in a feed, the beads of frost producing the moisture are originating from within the feed. If that's the case, then is there no way to control the frost inside the bag?

RESPONSE: If you have a polyethylene or polypropylene liner in the bag, the frost on the inside of the bag came from the feed. If it is a paper liner, it could have come from inside or outside the bag. As it is thawing you can keep flipping it over the bag of feed so that you do not get the dripping or that build up of frost in one spot.

QUESTION: What kind of damage is there to the protein content during pelleting and do you take that into account?

RESPONSE: It is small because the analysis that is done on the feed at the end comes out very close to what was calculated to be from the raw ingredients. Of course, on the other hand, we use chemical methods so it would come out to be the same. Performance characteristics of the animal would indicate that the pelleting process itself is not a severe heat treatment like you would see in studies of damaged protein where feeds are subjected to autoclave conditions in an attempt to deliberately produce nutrient destruction. In feed pelleting we use a temperature of approximately 200-250° but the ingredients are only subjected to that heat for a very short time.

QUESTION: Are there not constraints that exist when manufacturing an extruded feed vs. a pelleted feed, specifically in terms of the maximum fiber level that is tolerated in the extrusion process?

RESPONSE: I did not cover extrusion in this talk but what occurs during extrusion is a cooking and gelatinizing of the starch content of the diet. It is a higher temperature procedure; typically the product is forced out of the die and at this high temperature will then puff, cook, and expand and will be cut off with a knife. We are limited in the type of ingredients that we can include in that type of a diet because of the nature of the equipment used,

specifically what effect this cooking process has on fibers and fats. Typically pet food products are of the extruded type, most other diets for large animals or birds are generally pelleted diets.

COMMENT: The reason I am bringing this up is that I would be interested in trying to develop some type of a higher fiber diet for primates because we have leaf eating monkeys that are in the wild are consuming a high fiber diet. They have advanced development of the forestomach as a fermentation chamber and there are known cases of problems when you feed them a regular primate chow. We would like to have something with a higher fiber level and yet the expanded biscuit seems to be more palatable, the texture being more acceptable to a primate than a pellet would be. I have thought of a baked product but then you would have problems with quality control.

RESPONSE: There is an open formula baked primate diet with a higher fiber level in it. I am sure you have talked to Joe Knapka of NIH. We have been in the process of talking on the phone for the last two or three years but we have never tried to extrude any form yet. I think it can be done in the extrusion process but I have not run any through fiber plant yet. At the levels you indicate, we are talking a 7-10% fiber level. I do not think that high

fiber diets, like ruminant diets, would work very well in an extruder.

ENVIRONMENTAL CONDITIONS AND FEEDING BEHAVIOR IN CAPTIVE SNAKES

Edward Almandarz, Curator of Reptiles
Lincoln Park Zoological Gardens, Chicago, Illinois

INTRODUCTION

The Lincoln Park Zoo has been fortunate over the years in having good success in reptile reproduction and longevity. In a five year span we recorded 750 reptile births and hatches, averaging 150 births per year. A number of specimens set longevity records, naming a few such as a King Cobra that spent 18 years in our zoo, an Asiatic Cobra going on 28 years, and the oldest zoo resident is an African Dwarf Crocodile, who has been in our collection 41 years. I can't help but feel that these accomplishments are due to the environmental conditions we've provided our reptiles over the years, their excellent feeding behavior, and most important the excellent husbandry by the keepers.

Establishing a successful feeding program for captive reptiles depends on meeting a combination of their needs. I have found in my years working with reptiles that the greater percentage will acclimate to the conditions we set up for them, and for most parts accept food almost immediately after they are introduced to their new environmet. But there are exceptions; when we are faced with those who are reluctant to settle in, therefore requiring special attention, which may or may not always be rewarding.

The example that I will be focusing on is primarily snakes. The same methods apply to lizards; but I have found that most lizards are more tolerable to some of the drastic temperature changes in comparison to snakes. Therefore, lizards have not required as much special attention. There are some exceptions, and with those we use the same special methods as we do with snakes.

The first consideration in our feeding program is setting up appropiate habitat conditions for the reptile.

SIMULATED HABITAT

One of the special needs to successful feeding habits is the habitat we design for the reptile. By dressing up the enclosure with treelimbs, artificial plants, rocks, logs, and a suitable substrate, we have created an environment as close as possible to the reptiles natural surroundings. Within this simulated habitat we assure the reptile security and comfort; food is digested in leisure, they have the various cage props to rub against when shedding, they have different levels to climb where temperatures may vary, and finally they have hiding places for security and comfort.

TEMPERATURE RANGE

The most important requirement which has an influence on feeding behavior is the temperature range maintained. Where for example cold conditions will often reduce vigor and loss of appetite, and extreme warmth will cause stresses and food regurgation. A drastic sway of the temperature is almost certain to affect the snake and cause it to go off feed.

Here at Lincoln Park, we maintain a temperature range between 75-85 degrees for most parts of the year, but during the summer months when the outside temperature soars and remains steady, it affects the building and the snakes within their enclosures. With the building temperature rising in the low 100 degrees and holding steady for several days, we encounter high mortality and feeding problems. Under such conditions, we will do everything possible to alleviate the stresses. The cage lights are turned off to reduce some of the heat, portable fans are utilized to circulate the air, and in extreme cases, we will move some of the snakes to a cooler area of the building. Aside from this isolated problem, our collection will function on a normal basis for most parts of the year.

MOISTURE

Although temperature is an essential factor in the snakes feeding behavior, we also consider moisture an important part of their needs. Insufficient use of moisture can result in poor shedding, eventually leading

continue

to serious physical problems, where activity in the snake is reduced along with loss of appetite. To assure the snake a normal shedding, we spray the enclosures daily with light mists of tepid water. Spraying is controlled so that drying will take place within several hours, avoiding a build up of moisture and constant dampness. Spraying also enables the snakes to drink beads of water on the different cage props, in addition to their drinking bowl.

ARTIFICIAL SUNLIGHT

The final consideration for the reptile's needs, we provide each cage with an ultraviolet incandescent sun lamp. The lamps are left on for parts of day, allowing the animals to bask when ever they desire. Basking is stimulating for the reptiles and helps maintain normal feeding behavior.

DIETS

The food selection for captive snakes is limited in comparison to their wild, but what we have available for feeding appears sufficient enough for the snakes needs. The diet chart (p. 6) illustrates the different foods we feed our snakes.

No supplements are added to any foods with the exception for our King Cobra, who feeds mainly on dead Yellow Ratsnakes, stuffed with 15 to 20 freshly killed adult mice. The ratsnakes averaging between 4-6 feet, are purchased through reptile dealers and frozen soon after arrival at our zoo. Each time the King Cobra is fed, one ratsnake is thawed and inserted with mice. The King is fed every other week, allowing it to fast between feedings to stimulate its appetite.

With the exception for the large boidaes who are generally fed live food, most of our specimens have learned to feed on dead food. Feeding takes place one day a week, with each specimen receiving approximately 3 to 4 mice per feeding. The juvenile specimens feed mainly on pinkies or common anoles, but if these foods are rejected we will try crickets and mealworms to induce feeding.

RELUCTANT FEEDERS

There can be many reasons for a snake to stop eating. The temperature in the cage may be too hot or too cold. Sometimes, if the temperature remains constant, this lack of fluctuation inself will cause the snake to go off feed. An obese snake will often put itself on a diet. Some snakes will habitually refuse food during certain months of the year, especially in the winter. And if a snake is encountering physical problems and run down, it will not eat.

The last resort and our only hopes in restoring normal feeding habits is force-feeding. But before this drastic measure is carried out, we will explore every possible avenue to learn why the snake is refusing food. If the specimen is new in the collection, we examine past feeding records with its species; where we may find certain patterns of fasting during the year. We may change the normal temperature range to stimulate eating. In some cases we intentionally stress the snake by raising the humidity, creating an aggressive behavior that often results in the snake grabbing at anything that goes into its cage. And the last step is breaking down the habitat design and resetting the props in a different order, where a fresh look often arouses the snakes curiosity, stimulating much activity that will result in feeding. If all these condition changes fail, we are compelled to force-feed.

FORCE-FEEDING

Force-feeding is a drastic procedure. Often, the process of force-feeding puts the snake under so much stress that it dies.

There are basically two methods in which force-feeding can be administered; the use of a caulking gun with a trigger device that pumps ground food through a rubber hose, or one can force-feed whole foods with a long blunt forceps. The choice of methods will depend on the person and their success.

I have force-fed whole foods for many years and with farily good luck. In the early years our zoo used the caulking gun method but had very little luck. There was great stress on the reptiles and often they would

continue

regurgate moments afterwards. This was a quick method if numbers of specimens needed force-feeding.

Force-feeding whole foods appears less stressful on the snake, but the only caution one must take is not to injure the snakes mouth. But after a number of feedings, you acquire that certain knack that enables force-feeding without hurting the snake.

Prior to the actual force-feeding, we will place the food in the snakes mouth, allowing an opportunity to bite, taste and swallow on its own. If the food is rejected, we will proceed to force-feed. The food may consist of adult or baby mice, depending on the snakes size. Only one or two mice are force-fed to ease the digesting process and possible regurgation. As a lubricant, we will coat the mice with egg fluids, making it less stressful on the snake when the food is massaged down. Force-feeding is administered only several times a month with regular feeding in between, with hopes the snake will begin eating.

Force-feeding may last for weeks or many months before the snake begins feeding on its own. I can recall a Ball Python who required force-feeding for several years when suddenly one day it began to eat. If the snake happens to specialize in its feeding habits, such as a Hognose who feeds on frogs and toads. We will try and induce a change in its diet, by rubbing the scent of a frog on a mouse. This procedure is done in the winter when frog food is scarce and we are unable to sacrifice exotic specimens. This method has proven successful, where eventually the hognose feeds on mice without exposing it to the frog.

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A. FOOD SIZE IS DETERMINED BY SIZE OF SNAKE
B. FOOD SIZE INCREASES WITH THE SNAKE GROWTH
C. QUANTITY OF FOOD INCREASES WITH GROWTH

Species Size	Species	Main Diet	Alternates
10 ft. and Over (Heavy Body Girth)	Anacondas/Pythons	Chickens Ducks Rabbits	Rats Guinea Pigs Pigeons
6 ft. to 10 ft. (Medium Body Girth)	Boidae Members Bushmasters Rattlesnakes Cobras Mangrove Snakes Indigo Snakes	Mice Rats Guinea Pigs Chicks	Pigeons
3 ft. to 6 ft.	Boidae Members Rattlesnakes Moccasins/Copperheads Cobras Vipers Racers Ratsnakes Kingsnakes Watersnakes	Mice Rats (small) Hampsters Chicks Fish (smelt)	
3 ft. and Under Adult species and Juveniles	All species	Mice (Pinkies) Anoles (common) Crickets Earthworms Mealworms Minnows	

PROGRESS AND PROBLEMS IN REPTILE FEEDING PROGRAMS

Ray Pawley, Curator of Reptiles
Brookfield Zoo, Illinois

As we have already heard from Ed Almandarz, it is vital to any reptile nutritional program to adjust the environment such as temperature, humidity, furniture, etc. to suit the individual needs of each animal. It must be kept in mind that until their external needs are properly met, the intake of food will be minimal or not at all.

Starting with the slides, a snake with such bizarre feeding habits as the egg-eating snake is unique in its ability to consume food items several times the diameter of its head! The more normal body to food particle-size is represented by the sand boa or the rhinocerous viper consuming a mouse that is about the size of the snake's head, or the tortoise engulfing bite-sized vegetation.

It is important to stress the adage "Make haste slowly." More reptiles have been inadvertently killed by the over-anxious keeper or curator by making repeated, hasty changes in the reptile's environment during its "settling in" period than by those who plan a more comprehensive feeding strategy in advance where the animal can be monitored with relatively little disturbance.

Many snakes, for example, will accept their first meal in their new home almost as soon as they arrive. Others, like this Mangrove snake, required several months of patient coaxing with different humidity levels and food types before it fed. The Fer-de-lance seen here did not accept food for 16 months, an extraordinarily long period. Because its body weight seemed to be holding fairly well, and because this is a particularly delicate (although highly venomous) snake, it was never force-fed.

Food particle size can be crucial to the reptile's ability to ingest food. A reptile may choke to death attempting to take in overly large food since many species do not have the appropriate teeth or claws for tearing and reducing food size. On the other hand, it is almost impossible for a large boa or python to swallow a baby mouse due to its elaborate jaw structure modified for swallowing its comparatively large prey whole.

Preparation of mixed fruit and vegetable diets are accomplished at Brookfield Zoo by first determining what is available on a year-round basis. Next we evaluate digestibility, palatability, and try to arrive at proportions that provide a reasonable nutritional balance.

While some dietary variety may be desirable, one should be aware that by feeding some seasonably-available foods such as strawberries, papayas or kiwi-fruit, there is a risk of certain individual reptiles becoming addicted to such items and, in the end, refusing to feed at all when their seasonal favorite becomes unavailable.

Bananas, apples, sweet potatoes and lettuce or other greens such as spinach, kale and/or hydroponic grass are given in roughly equal parts by weight. From this gross nutritional base we add supplements to more appropriately round out areas of deficiency. Since absorption of all (or even any) of the offered vitamins and minerals is still largely unmeasured, we cannot be sure of how much of any one nutritional constituent to offer. Since digestive efficiency is linked to temperature levels, the picture becomes all the more complex. The regime we use has been the result of trial and error over many years with some educated guesswork.

Foods are inspected by the keeper before processing by sight, smell and texture. For example, bananas are normally in an unripened state upon arrival in the Reptile House. The bananas are rotated by allowing them to further ripen a few days to improve their digestibility.

Ingredients used to supplement the vegetative mixture include a carrot derivative (super carrodee) for vitamin A, mink chow which is high in fish protein, calcium in various compounds, brewer's yeast, mineral salt, and oil vitamins. For reptiles that have undergone chronic or acute stress due to parturition, oviposition or harrassment from a cage-mate, electrolytes and simple sugars may be given as or when needed. The oyster-shell chips are mixed into the food of the tortoises of all sizes on a regular basis.

I believe we could greatly improve our feeding program if we had more information about observations of many reptiles in the wilds as to foraging, methods of food ingestion, nutritional composition of their food, food habit changes related to age, reproduction, and maintenance, and fecal composition and analysis.

The keeper begins preparation of food by reducing the raw items to proper particle size following which these ingredients are carefully blended or "tossed" -- not stirred -- so they are as evenly distributed as possible. Because all of our reptilian herbivores have simple stomachs capable of digesting at least some animal protein, most of the tortoises and iguanas receive some chopped whole smelt (minus heads and tails) on their food plate. Still others get hard-boiled egg yolk as a supplement. The tortoises get chopped alfalfa added to their diets to give bulk. The tortoises frequently attempt to select out the most tasty fruits and vegetables, so thorough distribution of these ingredients is necessary to thwart this effort. Finally, the food is placed so that it is readily available and, in group exhibits, competition is minimized.

Providing grit to our tortoises is, in my opinion, essential to their well-being. The resulting feces will contain a few particles of grit that move through the intestine and it is quite likely that the grinding action

of these particles contributes to more homogenious fecal consistency (except for alfalfa and grass fibers). We add oyster-shell chips and smooth-pebbled pea-gravel to accomplish this. An assortment of pebble-sizes is appropriate, but the ingested grit should be approximately the size of the eye of the reptile. Large, or sharp-edged grit items can be injurious to the mouth and throat while sand-sized particles, in large quantities, may cause impaction. As is the case with gallinaceous and seed-eating birds, grit availability and grit size is, I believe, essential to their continued well-being. The use of some calcium carbonate (oyster-shell) as a grit medium is likely to be nutritionally advantageous.

We have frequently been asked about our mealworm supplement regime.

Rather than raising these insects on the premises due to cost and time factors, we purchase these on a monthly basis. The mealworms are kept refrigerated to retard pupation. A week prior to feeding, a day's supply of mealworms is placed in a container with a powdered mixture of 7 parts mink chow, 2 parts calcium gluconate and 1 part dicalcium phosphate. After 7 days these "enriched" insects are fed out to the collection. Incidentally, a similar procedure involving the "dusting" of our crickets is also utilized. It is likely that the basic calcium level of the individual mealworm is only slightly affected. However, it is likely that the unusually high levels of calcium in the gut makes up the deficit in this otherwise deficient prey species.

According to an analysis of our mealworms, the treated larvae contain a nearly 3 to 1 calcium/phosphorous ratio. On the presumption that this may be a more than adequate level of calcium, and presuming that other dietary items may be relatively high in phosphorous, the final ratio should be not too far off from 2 to 1. The calcium content of the treated mealworms, by weight, is about 1/3 the amount of calcium in cow's milk! Whether this amount is excessive we do not know at this point.

There is some apparent difference between the treated and untreated worms; the treated mealworms appearing to be more robust after 7 days of wallowing in their highly nutritious medium!

It is important to offer only a few insects at a time to the reptile predator because a dish full of seething, swarming mealworms in a mass is more apt to confuse than attract.

During the past two years during which time we have been using this "enrichment" procedure, there has been a significant improvement in lowered mortality and increased "well-being" among many of the lizard and turtle species. Apparently the induced abnormally-high calcium levels in the meal-worms are meeting various nutritional needs of many of our insect-eating reptiles.

There are other aspects involving calcium metabolism that must be kept in mind as well. We use ultra-violet radiation from sun lamps and fluorescent vita-lights to accomplish this. Over exposure, especially involving snakes and amphibians, can be injurious through "burning" or over-accelerated calcium metabolism. These light sources, especially the sun lamps, should be used with due caution.

Several of our terrapins and tortoises have been reared totally within an artificial environment and have had no access to natural sunlight or a wild diet. Most have developed strong, apparently normal shells (carapace and plastron) indicating we are probably not too far off in our procedure for raising these deformity-prone animals.

There is much to be done in determining the nutritional needs and parameters of reptiles. Many theories and procedures now in practice need to be validated through carefully monitored investigations involving the use of reptile controls. Clearly, this is a costly proposition. I am suggesting that with limited funds and an inter-zoo strategy outline, progress can be made in delineating our needs and accomplishing these with as little duplication as possible. The end result may have a significant impact on improving reproductive programs, longevities, and even the economics of maintaining a zoological reptile collection.

EDWARD ALMANDARZ AND RAY PAWLEY
QUESTIONS AND COMMENTS

QUESTION: In exhibits where you have several specimens you said you did not separate them at feeding time. Do you over-feed and assume that they will get what they need?

RESPONSE: First of all, in group exhibits we try to let reptiles sort out the available food resource, that is partition this adequately which does not always work out. There are some enclosures where we have to provide small amounts of the food in a widely distributed fashion because an inhibited reptile that is off in the southwest corner of the cage is not going to walk across the cage to get its meal. We have to make sure the food is placed near it. We watch these group exhibits very closely and we take into account how the food is presented and where it is presented. Sometimes we will take an individual out of the cage and put it in another smaller enclosure for feeding. We have two flat-headed terrapins that at feeding swim right to the dip net to be lifted out to be put into their little bucket where the food is located. Perhaps Ed Almandarz might have a few comments.

(Almandarz) Well, what I was trying to refer to earlier is that the cannibalism in snakes primarily is in juveniles. If you have three or four cobras in one cage, you will find

some aggressiveness in the feeding behavior but it is nothing serious. As Ray had said the food is scattered out and the animals have their own stations to which they will go to feed.

QUESTION: In newborn animals, do you just rely on instinct to eventually take over and allow this instinct to instruct the animal in feeding?

RESPONSE: (Almandarz) Well, I think each individual has his or her own methods for handling the juvenile. I personally believe even though the juvenile has sufficient nourishment from the egg I do like to begin offering food within the first week after the snake has finished shedding its skin. I give it a certain period of time before I decide I want to try some other sources of food from say a pinkie or an anole to some type of insect which could be a cricket or whatever. I just keep manipulating the temperature and food variety to encourage feeding.

(Pawley) Regarding that question relative to the feeding strategies of baby reptiles. We follow much the same procedure that Ed has mentioned. Our situation is that we have relatively few cages in which to keep a clutch of baby reptiles. Using snakes as an example, at feeding time we will take those baby snakes, put them all in individual containers and attempt to feed them and then

the following morning we will put them all back together. This is a very poor way to do this as ideally the babies should be kept individually housed but under crowded conditions, we sometimes have to resort to this. It is better than trying to put six food items in with six baby snakes because the next morning you might wind up with one big baby snake.

QUESTION: You mentioned the use of grit, do you use granite grit or oyster shell?

RESPONSE: (Pawley) In talking about the grit we use for the tortoises that we feed, we use an oyster shell grit but that is not the exclusive grit. I would say that 90% of the grit consists of pea gravel. I am certainly glad that you brought that up because people perhaps would have gone away with the wrong idea. The pea gravel granite type grit is perhaps as neutral a grit as one can get but we do use the reptile's tendency to take in grit by also adding to this some calcium carbonate in the form of that oyster shell. Otherwise if we give them all oyster shell grit he might wind up with a stomach full of concrete.

QUESTION: Do you adjust the photo period at all and does this have an impact on the feeding behavior of the reptiles?

RESPONSE: (Almandarz) We had a roach problem in our collection and this holds true with a lot of other institutions. I have to rely on the lighting in order for the snake to get a full share of its food without the roaches getting in and gutting out the innards of the mouse. Reptiles do learn to adapt their feeding behavior even under light conditions. On occasions where you do not have the roach problems such as the second floor where cages are sealed and roaches cannot get in, we turn off the lighting and allow them to eat in a nocturnal environment.

(Pawley) Based on our experience at Brookfield, I found that the lizards generally tend to be more phototrophic than the snakes. The lizards and the turtles seem to be more susceptible to light period, particularly ultra-violet, than the snakes and we use the light and the darkness as the tool in aiding us in feeding the reptiles as Ed has mentioned.

QUESTION: Do you have any feelings about mealworms vs. other insects in reptile diets?

RESPONSE: (Almandarz) In my collection we feed mealworms until we encounter a bad experience with the animal, that is, if the animal has trouble digesting the mealworms then we switch to crickets and no longer feed mealworms to that particular species. With some lizards that are of fairly

large size yet are small enough to feed on crickets, we will also substitute pinkies occasionally not just feeding them insects.

(Pawley) We have found that here again temperature is so critical. We have found that lizards consuming mealworms which have this chitinized exoskeletan may not digest as efficiently at different temperatures. It may not digest that mealworm as efficiently at a temperature of 90° as it will if it can bask at 100° for a brief period. I found that there seems to be a correlation between digestive efficiency and temperature levels that are available for that lizard. We use the mealworm as a nutritional vehicle just due to the convenience and its availability. We do use crickets as well as mealworms. There are some advantages and disadvantages to both. The minutes crickets are dropped into the cage they are gone. You have to have a fast lizard to run a cricket down to make use of it. Mealworms tend to stay where they are at. However, mealworms are not all that appealing to some of the lizards that seem to prefer a more active insect, such as the Blood-sucker Lizard, the Colodes, the Basilisk, and that sort of thing. There seems to be a preference for something that moves around faster than something like a mealworm.

QUESTION: In many of the European zoos, they breed flies, locusts, and all sorts of different live foods which would introduce more diversity. We do not really know much about the nutritional values of most of these things. I think its an interesting concept to get beyond just mealworms or just crickets.

RESPONSE: (Pawley) Based on your initial question which had to do with the use of the mealworm, yes, I am sure if we had the availability of other species of insect items that we would very much like to go to those.

DIET CONSISTENCY AND PERIODONTAL DISEASE IN EXOTIC CARNIVORES

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During the thirties, in London, a scientist named Sir Frank Colyer wrote an exhaustive 700 page book about dental disease in animals. While addressing the subject of progressive destruction of the masticatory apparatus, he said, "In my opinion there is abundant evidence to show that, in animals, parodontal (sic) disease is attributable to injury of the gums caused by food." Colyer then proceeded to analyze the problem at length in domestic animals, in wild animals in captivity, and in wild animals in their natural habitat. He observed that the relocation of the wild animal from its natural habitat into a captive environment brought about a radical change in the environment of its oral cavity, and this change resulted in the development of oral pathology. After examining thousands upon thousands of individual cases of oral pathology in exotic animals, he came to the following conclusions:

1. "The disease starts as an injury to the gum margins caused by food. This injury may be of a traumatic or of a chemical nature; when traumatic, the food in the process of mastication penetrates the soft tissues; when chemical, the products of stagnant food injure the epithelial surface and thus expose the deeper tissues to infection."

2. "The bone lesion is a progressive, rarefying osteitis commencing at the margin of the bone."

3. "The disease is caused by an alteration in the character of the diet of the animal of either a physical or of a chemical nature--in other words, by a departure from natural diet and conditions."

During the 50 years since Colyer's exhaustive study, there have been untold millions of dollars and man hours spent investigating the etiology, pathogenesis, treatment, and prevention of oral pathology in mammals. The American Dental Association tells us that oral pathology is the single most common pathologic problem in humans. They estimate that 99% of the population have oral pathology in one form or another. Analysis of the mechanisms of periodontal disease, one of the most common and destructive types of oral pathology, suggests that it is

predominantly a bacterial problem and that the bacteria in the oral cavity affect the periodontium in four ways: 1) by invading the tissues directly, 2) by releasing harmful toxins, 3) by producing destructive enzymes, and 4) by initiating antigen/antibody reactions." The bacteria accomplish this by forming amorphous colonial microbial masses known as dental plaque. Since the pathogenesis of oral pathology has been described in detail elsewhere, I won't discuss it here.

Much is known about the relationship between dental plaque, nutrition, diet, and oral pathology. What is well known but not well accepted is that:

1. The consistency or texture of food has an affect upon the composition and the rate of dental plaque formation.

2. Soft diets tend to produce more bacterial plaque than firm diets.

3. Excessively course, granular diets can produce periodontal disease through overuse and by direct injury of the supporting tissues.

4. Foods of firm consistency will increase the number, distribution, and tone of the capillaries in the gingival tissue; which in turn, improves the metabolism and vitality of all of the supporting and surrounding structures.

5. The degree of keratinization of the stratified squamous epithelium which affords protection against trauma and other injurious agents is affected by the frictional qualities of the diet.

6. Chewing, by its mechanical action produces a compression and expansion of the periodontal ligament space around the teeth which, in turn, promotes formation of a dense fibrous suspensory structure by increasing both circulation and fibroblastic activity.

7. The width of the periodontal ligament, a measure of its health, is directly related to the intensity of the mastication function.

8. Regarding the maintenance of the alveolar bone itself, the proper balance between bone resorption and new bone formation is materially aided by hard foods and that inadequate masticatory function induced by soft foods

will produce atropic changes and lower the threshold of bone activity.

9. And, finally, although there is poor evidence that oral pathology can be initiated by diet consistancy and/or texture alone, texture is a major secondary contributor or modifier of the disease process.

In short, diet consistancy and texture more than likely play a regulatory role in the etiology of oral pathology.

It is clearly difficult, and in fact, quite often misleading to extrapolate the data developed in human medicine directly to a similar problem in animals. This is particularly true with exotic animals. But, it is equally true that such results cannot be completely ignored. Nothing short of actual clinical trials to determine the relationship between diet, texture and oral pathology will be able to document the issue as it relates to a specific species. However, the test that will meet with universal approval has not yet been devised. Moreover our problems are urgent, and solutions are needed now. The weight of the evidence of the observations made in my clinical practice with exotic animals is overwhelming. There is sufficient evidence at this point to declare that oral pathology is a major problem, particularly in carnivores. I have treated numerous cases from the Order Carnivora: Dingo, Dhole, Cape Hunting Dog, South American Maned Wolf; Hyenas; Wolverine, Binturong; Bears; Serval; Caracal; Cheetah, Leopard, Jaguar, Lion, Tiger; Otters; Lesser Panda, and on and on. The etiology is diet related, and there are sufficient data to cause alarm among concerned clinicians.

In man, the incidence of spontaneous bacteremia appears to be directly related to the severity of existing oral pathology, as well as to the amount of tissue trauma during mastication. It is well known that transient bacteremias occur spontaneously in normal, healthy persons in day-to-day living. For example, 24% of 305 persons while brushing their teeth and 17% of 225 persons chewing hard candy produced bacteremia. Procedures such as gastrointestinal tract endoscopy, percutaneous liver biopsy, and urethral catheterization also cause significant transient bacteremias in man. Numerous studies have shown that almost all dental procedures produce bacteremia, and that the very common oral streptococcus viridans group of organisms are responsible for over 50% of the infective endocarditis reported in the literature. Of the two factors responsible, trauma and infection, one study described infection as the more important, and noted that bacteremia occurred in 86% of the patients with marked gingivitis with such slight trauma as moving of the tooth or biting on a tooth. Therefore, it is probably true that exotic

animals with oral pathology--particularly periodontal disease, experience transient bacteremias during their daily routine as well. Although there is not good evidence in animals, there is sufficient data from analysis of a variety of zoo-maintained mammalian species, to show that periodontal disease is plaque related, and from the bacterial analysis of the plaque of zoo animals, it has been shown that diet does influence the diversity of the bacterial content and the composition of the plaque.

I want to make it clear that I am not proposing that diet is the sole cause of periodontal disease, or of all oral pathology. What I am proposing, is that from my perspective of 10 years of investigative analysis and treatment of oral pathology in a wide variety of exotic animals, I see a direct relationship between the texture of the diet, oral problems, and systemic health. I also see a cause and effect relationship which is a relatively easily controllable factor in the maintenance of our animals.

Diet related oral pathology affects the body of an animal in one of three ways:

1. Through immediate contact from adjacent tissues, the infection spreads from one local area to another, i.e. cellulitis to local osteomyelitis.

2. Via natural pathways, it spreads through the trachea, into the lungs; through the esophagus into the stomach; through the eustachian tubes to the inner ear; etc.

3. Through the lymphatic and circulatory system it spreads to the entire body by continuous passage of bacteria, toxins, and harmful and metabolic byproducts.

I have repeatedly treated severe oral pathology in association with arthritic problems, acute renal failure, pancreatic, and hepatic infections, etc.

I believe our task as medical personnel caring for exotic animals can be defined as maintaining a healthy, active, and reproducing group of animals. That is no small task, and there are enormous voids in our knowledge. As a consequence, I propose we do more to eliminate those variables that we know something about. The etiological relationship between diet, oral pathology and systemic health is well known and understood.

The veterinary medical staff caring for any group of captive exotic animals must of necessity examine diet from a variety of viewpoints, including:

1) the reported food preferences in the wild,

2) known nutritional requirements of related domestic species,

3) occupational therapy value of food items not necessarily related to nutritional value,

4) practical considerations relating to the foodstuff's availability, perishability, and/or economy.

In reality, zoo diets tend to remain rather variable to accommodate changes in foodstuff availability, additions or deletions to the collection, and newly available nutritional information. Of course the diet should provide suitable nutrients for growth, maintenance, reproduction, lactation, and the changing needs of the individual animal or group.

From my perspective, the major emphasis appears to be on the nutritional composition of the diet, and the economy of acquisition, storage, and transport. But captive animals need wear and tear on the dentition. The masticatory apparatus of carnivores was designed to be used, and used aggressively and ferociously. If the animals don't use their dentition and mastigatory apparatus, they are going to lose it, and the systemic health of any individual animal will not be adequately maintained with the loss of the primary entry mechanism to the digestive system. Moreover, as the average age of our captive breeding groups increases, which it certainly should as our reproduction research programs prove successful - we will be faced with the oral pathology problems of the geriatric individual, which can be considerably more complex.

Oral pathology should be recognized as a serious problem in the care and maintenance of exotic animals. Human dental technology has sufficient solutions to manage the problem. But, the application of those solutions to animals represents a time consuming, and expensive effort. I propose that a great deal can be done to eliminate oral pathology as a consideration in exotic animal medicine by the means of <u>prevention</u>. It is possible to do something immediately and significantly to minimize oral problems in captive exotic carnivores. That "something" is to reevaluate their diet. Animals need more "hassle factor" per mouthful of nutrients. The best kept secret of the last fifty years is that we must eliminate the preprocessed, the over-cooked, the smashed, the blended and the pureed foods, and feed our animals a more appropriate diet duplicating the feeding habits of feral conditions. The literature contains hundreds of references to the food habits of feral carnivores and, therefore, the appropriate

menu is readily available. Convenient prepared diets, those without sufficient "hassle factor," are ruining the mouths and compromising the health of our animals.

Carnivores, in their natural habitat, eat rabbits, mice, rodents, birds, etc., in toto: i.e., toenails, eyeballs, and intestines. This is the diet we must reproduce, not predigested TV dinners. I have attempted, with this presentation to outline a health problem from a clinical perspective. My primary purpose has been to stimulate more discussion to better define the problem, and then to encourage group effort to resolve the matter by establishing norms for more appropriate diets.

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DAVID H. FAGAN, D.D.S. QUESTIONS AND COMMENTS

QUESTION: Has there been much work done with the dog since you should find dogs that are being fed different types of diets?

RESPONSE: The truth is that there has been an enormous amount of work done with domestic small animals. Ralston Purina has a number of diets they can use to generate periodontal disease in a domestic dog in 30 days. There are scientists at work on a cure for this. Other pet food manufacturers are considering hard crunchy foods, like that material that the BONZ products is made from. Some are even planning to put a mouthwash of some sort in it so that it gives the dog better breath; this is stretching it a little bit. But there is certainly a whole body of information that is yet to be applied.

I am a strong advocate and user of computer literature searches. The big feed manufacturers have much data that, I believe, has application to this particular problem. Soft diets have a tendency to create tremendous problems. Chronic viral stomatitis in domestic cats is a feed-related problem without a known solution. I would recommend the dry feeds as opposed to the soft moist materials. I think you need to have a little skin, bite

through a leg, eat an eyeball, have more of a challenge in carnivore rations.

QUESTION: You mentioned hassle factor, how important is the micro environment within the mouth, the pH, etc., beyond the hassle factor?

RESPONSE: I think the problem is not a simple one nor are there simple solutions. I think there is clearly a genetic resistance to oral disease. For instance in groups of lemurs in San Diego (red, black and white, and ring-tailed), one group has no oral disease whatsoever, another has a predisposition for the accumulation of tartar and calculus. In yet another, there is a tendency for periodontal infection, but only around the dental comb which causes a kind of an irritation. Dental disease in animals tends to itch, abrading the comb and in very short order (a matter of six months to a year) the comb is eliminated. All of these animals are housed in the same location, in the same identical circumstances, and fed the same way so I am quite convinced that there is a genetic factor here. There is a genetic resistance to periodontal or dental disease.

There are two aspects to the environmental problem - one is the gross environment. I have treated a number of

animals in a very large kennel in North Hollywood that provides most of the animals for the television commercial business. They have, I believe, an epidemic of micro-organisms in that kennel. There are several hundred animals there in a fairly small space. There are mixed breeds, pure-breds, males, females, old ones, young ones, and brand new ones and, in a matter of a month, anybody that shows up there gets their teeth buried in calculus. I believe it is related to the gross environment of the facility.

I also think there is a very considerable influence of the local micro environment of the oral cavity. For instance, you can have periodontal disease locally because of traumatic incidents. I did some work at the Primate Research Center at Davis some years ago. They had wooden hutches for the primates which the animals would bite and chew, getting slivers from the wood causing a local oral infection around one tooth that would act as a focus of infection. This allows the spread through the rest of the mouth. You see this very often in humans. When you never get rid of that deep periodontal pocket, it is a constant source for reinfection and influences the local micro environment. It is a multi-faceted problem.

QUESTION: What is currently being fed to bears in various zoos? I am interested in finding something that they can chew on, resembling a brick, that the starlings cannot carry away. The dry dog food we feed currently is in the small nugget form.

RESPONSE: I am always asked to recommend diets and I am reluctant to do that. I travel sufficiently so that I have seen a variety of diets that are extraordinarily effective. I have seen a variety where the same species, under different dietary circumstances, are reproducing well. So I do not feel comfortable making specific suggestions.

QUESTION: Do you know if there is a larger brick form available? The explanation I have been given is that since the dog food is extruded it cannot be made any larger.

RESPONSE: I do not know if there is a brick-type form produced anywhere. It may be the case that extruded forms cannot be made larger. But I do think you need a dry form of feed. It needs to have more hassle factor, it needs not to get carried away by birds or washed away by rain. It needs to have a high degree of desirability and it needs to be able to get carried around and stored and not go bad on you. It needs to be inexpensive. It needs all kinds of things and I am working on it! I do not have a good solution yet but I would suggest you try to get back to feral equivalents as much as possible.

COMMENT: Concerning Felidae, in the zoo animals in Topeka we just do not seem to have the oral problems you are describing here today.

RESPONSE: I am not surprised by that and I do not see that as necessarily an argument that it does not exist. I have seen, in the last ten years, more than enough oral disease in all manner of carnivores from one end of the spectrum to the other. For instance, last year I was looking at the cheetah at the Wild Animal Park near San Diego. They did not have much in the way of oral disease either. And yet not very far away we had some serious problems in other animals. I suspect that one of the recommendations, or one of the solutions to this problem, would be for me to come to Topeka and see what is going on there with respect to what my experience has been in other facilities. Perhaps you have the secret that just has not been shared yet.

COMMENT: The secret is no hides and no bones!

RESPONSE: Well, that is part of the dilemma. I do not see that as an argument that the problem does not exist. I see that as a statement that it is a bizarre problem.

COMMENT: I am wondering about the age influence. I would have to discuss this with some of the people from Topeka since I have not been there that long and do not know the ages

of some of the cats. However, everytime one is anesthetized, especially females for implants, they are examined and there does not seem to be this problem.

RESPONSE: This could be genetic. Healthy cats do not have oral disease and I believe there is very much a genetic influence in this. It is quite conceivable that the genetic composition, your genotypes, is better and resists the problem. Perhaps the thing to do is to share those genes.

COMMENT: I want to reinforce what Ray Pawley has said earlier. Although not expected, oral disease problems are rather common in reptiles. The earlier recommendations of soft diets for turtles, for example, can lead to a lot of trouble. Many of these animals get alveolar ridges on the surface of the palate and beak and snakes frequently do not shed their teeth properly.

RESPONSE: I have treated a number of infections and an assortment of problems in reptiles and actually as bizarre as it seems, there are a number of oral problems in birds, broken beaks and malformed beaks primarily. I see oral pathology from many points of view: developmental, genetic, environmental, dietary, traumatic, infective and see it in avian, reptilian, and mammalian species and a good deal in herbivores and a whole lot in carnivores.

QUESTION: Do you agree that there is a high incidence of stress modification in periodontal disease in zoo animals as is found in human populations?

RESPONSE: Yes, there are some 50 different forms, groups, or subdivisions of oral disease described in humans. In a paper I presented at an AAZPA meeting, I re-organized the subdivisions as a matter of convenience, into four basic groups. One of the groups, the biggest, is periodontal disease because it is kind of a catch-all. In that paper I described a general adaptation syndrome which essentially can result in nervous displacement activity. When a human is subjected to a lot of stress (hair pulling, husband/wife beating, etc.) psychiatric care is available. Animals are subjected to a considerable amount of stress by virtue of their captivity with no really good way to alleviate that stress. They do not have psychiatrists to consult and because of this they can exhibit a great deal of nervous displacement activity in the form of biting and gnashing. As an example, I saw evidence of this problem a few years ago in the Primate Research Center in Davis. There was a baboon that was involved in a drug study. He was being given an analgesic chemical and his behavior was described as abnormal. And as coincidence would have it, I was looking at some other animals at

the facility at the time and happened upon this baboon for a totally unrelated reason. He had an extraordinarily severe oral infection, both of his upper canine teeth were fractured and there was a very extensive osteomyelitis. He really had a serious problem - this fellow had Excedrin headache #360. I suppose the only time his headache went away was when he got the analgesic. He did a lot of biting, gnashing, and self-mutilation. As another example, at the AAZV meeting someone was talking about a margay or a South American bird-eating cat that plucks the bird before eating it. When he was fed a prepared diet, there was nothing to pluck. Unfortunately Zu/Preem does not come with feathers - not much to pluck, so as a consequence this cat was plucking himself and his cagemate. It is an awful lot of trouble to fix a fractured mandible or to eliminate an osteomyelitis or take somebody out of his behavioral hierarchy and treat him for three weeks or a month and reintroduce him having taken away his canine teeth so he does not have his dominance or protection. So I think the difficulty with not addressing the problem is very expensive and will cause failures. It is a problem that can and should be addressed. I think it is one that needs attention and I relish and appreciate having the opportunity to make some comments about it.

This is clearly the format to address these sorts of subjects. The problem will not get solved if nobody thinks about it or says anything about it so I do not propose the problem to create disorder but rather to introduce it into your thinking process. Certainly in this room there is all of the where-with-all to start to find solutions.

QUESTION: Do you consider your hassle factor necessary at every feed or as a certain percentage of weekly feedings?

RESPONSE: It will vary with the species. It is a trial and error situation.

COMMENT: We feed our wolves a straight carnivore mix but have tried to give them a hassle food one day a week, a half of an ox head and a knuckle bone another day during the week. But until the advent of the new complete type of diet the wolves were notorious for developing rickets and suffered from a lower reproductive rate.

RESPONSE: I do not think there is any question about the fact that the nutritional composition of the prepared diet is much better.

QUESTION: What do you feel about oxtails?

RESPONSE: I have mixed feelings about oxtails. They seem to have a whole lot of occupational value over and above the cleansing value. I think there is certainly as much good

as harm, probably more good. Feeding an oxtail once a month is probably not going to have a significant effect, feeding it everyday is probably too much - two or three times a week is reasonable. I know a person in San Francisco that has a bachelor herd of male lions that I have worked with. He feeds them cervical vertebra with the musculature still on it. He has been successful in terms of maintaining good oral health in these cats. I have been treating them regularly for about four years so I can deduce from this marvelous statistical sample of one facility and eight cats that neck meat is a good thing, that the cervical vertebra idea is good. It might be an alternative to oxtails.

QUESTION: Is the low level of calcium a problem in periodontal disease?

RESPONSE: Yes it is, but I do not think it is a primary factor. I think it is a secondary, or contributing, factor.

QUESTION: Are you seeing in any of your cases a problem related to imbalanced calcium/phosphorus levels as a result of the animals receiving a diet of muscle meat?

RESPONSE: No, none of the cases I have shown here have been on muscle meat. Most of them have been on Zu/Preem, including the cheetah. Previously it had been fed in a thawed state but it is now fed partially frozen. From the time it

came out of the commissary in its pre-thawed state, until it got to the cheetah, an hour had passed - it would sit in the truck and would become discolored. A decision was made not to pre-thaw it. It was assumed that it would thaw on the way to where it was going. Perhaps one solution to the oral pathology problem is frozen Zu/Preem! The cheetah, about a dozen, seem to be in pretty good shape. One of the things I forgot to warn you about - you ask me what time it is and I will tell you how to build a watch - I could go on forever!

NUTRITION AND SUCCESSFUL PROPAGATION OF CRANES

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INTRODUCTION

Cranes are omnivorous birds which consume both plant and animal matter. A crane's diet may change with season as well with the bird's location. In general, these birds consume crustaceans, insects, small rodents, fish, amphibians, grasses, grains, seeds and sedge tubers. Observations in the wild have proven that Sandhill cranes (Grus canadensis) ate wheat, roots, tubers, seeds, berries, leaves, as well as a variety of animals: grasshoppers, beetles, snails, frogs, lizards, snakes, birds' eggs, and small mammals (Serafin and Archibald, in press). Sandhill cranes in Wisconsin were observed by Hammerstrom (1938) to eat berries, buckwheat and beetles. The different subspecies of Sandhills tend to adapt to their surroundings and make use of the particular vegetable and animal material readily available to them. As there is a total of fifteen different species of cranes which exist worldwide, this fact should also apply to them. They feed primarily in marshland or fields using their long beaks to probe for insects and tubers. Variation in diet is a function of seasonal changes (including such factors as migratory patterns) as well as general regional differences. Very important also is the reproductive and growth stage of the bird. The endangered Whooping Crane (Grus americana) studied by Allen (1952) consumed a large amount of aquatic life in the breeding season. Animal matter makes up more of the diet in the breeding season than in the non-breeding season (Serafin and Archibald, in press). Plant material ingested consisted of onion, prairie lily, sprouting corn, acorns, grasses, wheat sorghum and oats (Allen, 1952). The animal constituents are worms, slugs, insects, fish, frogs, small rodents and crustacea such as crabs.

DIETS FOR CRANES

In a captive breeding program for wild animals, nutrition plays a very important role. In successful propagation of cranes, proper nutriton is essential for growth as well as for the proper functioning of reproductive processes. It is difficult to formulate a standard diet for captive cranes which will provide optimum nutrient levels for all species since each species differs in its background, ranging from the Sandhill Cranes occurring in the Indiana, Illinois, Wisconsin region to the Brolga Crane from Australia to the arctic-nesting Siberian Crane. However, we can use information obtained from studies in the wild to

formulate a general diet which contains all of the necessary nutrients required for their propagation. General knowledge can be applied from other Gruiformes in order to create a diet sufficient for all species of cranes as all birds require somewhat similar nutrient intakes (Serafin and Archibald, in press). Principal nutrient requirements among similar species do not differ significantly.

Several diets have been used over the years for cranes; however, most zoos and research facilities are using basically the same diets with a few modifications, depending upon the geographical location and the availability of funds and resources.

Ollson (1975), a private bird breeder, provided his adult cranes with game bird crumbles, grains, such as milo, hard boiled eggs and mealworms. He increased the mealworm content just prior to and during the breeding season. He makes greens available to the cranes and insects are also abundant. Chicks are started on a simple diet of hard-boiled eggs and mealworms, which are both high in protein. Feed is offered at 12 to 24 hours. At one week of age, Ollson mixes "Vionate" (a brand name for a multiple vitamin and mineral powder) into the diet. At two weeks of age, the crane chicks receive a diet of 20% poultry pellets saturated with "Vionate", along with egg and mealworms.

In Walsrode, Germany, Walsrode Vogelpark feeds a basic diet of corn meal, soy groats, zein, corn germ, tapioca meal, lucerne and wheat bran (Serafin and Archibald, in press). The same diet was fed to birds of all ages; however, protein levels were slightly higher for breeding birds (Table 1).

The St. Louis Zoological Park (Wylie, 1980) feeds different diets for various ages of birds consisting mainly of a pelleted diet of 50% Purina Game Bird Maintenance and 50% Game Bird Layena (Ralston Purina Company, St. Louis, Missouri) in the fall and winter. In the spring, 75% Purina Game Bird Chow and 25% Purina Trout Chow are fed, supplemented with Zu/Preem bird-of-prey diet (Hill's Division, Riviana Foods, Inc., P.O. Box 148, Topeka, Kansas) along with greens such as lettuce.

Crane chicks are fed Purina starter-grower, which is mixed and ground with egg, chopped greens, Zu/Preem, mealworms and Theralim (vitamin). After 4 weeks, the same diet is fed, although the egg and oyster shell are deleted.

Patuxent Wildlife Research Center in Laurel, Maryland (Serafin and Archibald, in press) has been raising cranes for 10 years with a basic diet of corn meal, wheat middlings, soybean oil meal, ground oats, fish meal, alfalfa meal and meat and bone meal. The Maintainer diet, which is given to sub-adult and adult non-breeding cranes in the form of a 3/16" diameter pellet, consists of these ingredients containing 20% protein whereas the Crane Breeder diet which is supplied to breeding birds con-

tains 22% protein and a higher level of calcium (Table 1). Young cranes are fed this diet in the form of a mash containing 24% protein.

The International Crane Foundation (ICF) in Baraboo, Wisconsin feeds a pelleted diet which contains similar nutrients to those in the Patuxent diet (Sunde, 1980). In the past, a diet was fed consisting of a 36% protein which Serafin (Archibald, 1974) from the Patuxent Wildlife Refuge in Maryland suggested may place an excretory stress on the cranes. Although no data has demonstrated this problem, the protein level in the new diet has been decreased (Table 1).

In the consideration of nutrition and successful propagation of cranes, there is the ongoing fear that domestication of these wild birds as well as any wild animals may occur as a result of taking them away from their natural habitat and raising them in the artificial settings of zoos and parks. These animals are subjected to artificial environments, unnatural breeding situations such as artificial insemination and now the concern of monotony in the diets has been raised by several people (Hediger, 1965). In the wild, there is great variety in habitat as well as food habits whereas Hediger (1965) states that there is a monotony in the complete diet. At the ICF, an attempt is made to avoid this monotony by supplying corn, which encourages the birds to probe in the ground as is done in the wild. The birds eagerly capture and consume most of the insects, rodents, and nesting birds entering the outdoor pens.

There are many different feelings concerning these issues, and the correct way to feed and successfully propagate animals in captivity is not yet known. Changes are constantly being made and we may eventually develop the correct methods for successful propagation.

FEEDING PROGRAM AT THE INTERNATIONAL CRANE FOUNDATION

The current feeding program at the ICF is based on four different diets; maintenance, breeder, starter and grower. Each one is used in conjunction with the changing seasons as well as aging of the birds themselves (LaRue, in press, b).

The shape, size and form of the food presented to the bird is important (NRC, 1977b). Pelleted diets are being used at the ICF as they prevent the birds from picking over the feed and choosing certain particles while leaving others which may contain important nutrients (Sunde, 1980). Feed waste is minimized and there appears to be improved palatability of a number of feedstuffs. Salmonella organisms are also destroyed by heat during the pelleting process; however, feed costs are higher for pelleting feeds and some nutrients may also be destroyed by heat (Church, 1977). Formulation must take this into account.

Feed is stored in 50 lb paper bags in a cool dry room for not more than 4 weeks. After this time, the feed loses its key nutrients and freshness. The cranes do not eat older feed as well. Feeds not kept in

airtight bags in a freezer should be used within 4 weeks after mixing. The feed must also be isolated from rodents.

Walkinshaw (1949) observed that Sandhill Cranes began their feeding ritual in early morning at about sunrise, fed until mid-morning with a final feeding period in mid-afternoon lasting until sunset. At the ICF, feeding is performed daily at eight o'clock in the morning. They ensure that the feed is clean, fresh, free from contaminates, palatable and nutritionally adequate. Feed quantity and quality is checked daily and any moldy feed, resulting from water dripping from the bird's beak or simply moisture accumulation in the feed, is removed. The feeder (plastic bucket) is filled one-half to two-thirds full depending upon the individual bird's habits or the number of birds present in the pen. Too little feed does not allow for the full requirements to be met; too much increases exposure time to the air which in turn increases the probability of moisture build-up and disease and decreases palatability of the pellets. Frequent presentation of feed tends to stimulate general feeding activity. The feeder is hung approximately 30 centimeters above the pen floor. These buckets are preferably hung in a corner providing better leverage for the birds to fulfill their poking and probing behavior. These plastic buckets are an improvement over previously used wooden feeders which sat on the ground, and allowed for increased moisture accumulation in the feed and greater access to rodents which serve as disease vectors. The plastic buckets appear to be adequate for singly-housed birds or pairs of birds that share feed.

Water requirements of birds are related to ambient temperature, humidity and food composition. Water should be available at all times (NRC, 1977a). The Crane Foundation provides the birds with fresh clean water daily in rubber buckets (scrubbed daily) which are usually placed on the pen floors. The birds tend to dig in the mud, then probe and splash in the buckets causing mud to build up if the daily change is not made. In the winter, heaters attached to bricks are placed in the buckets to prevent the water from freezing.

Weighing the birds periodically can aid in determination of adequate feed intake. Feed intake can then be measured and average daily consumption thus calculated. ICF researcher Halibey (1979) monitored feed consumption in several species of cranes over a period of three months (March-May). Although feed consumption wanes according to the time of year, daily intake (Halibey, 1979) for six species of cranes averaged 4.8% of their body weight as a result of feeding a diet of 2,533 ME/kg (Table 2). Intake varies also with energy content of the diet and feed intake will generally increase if there is a reduction in energy of a diet. Feed consumption (Halibey, 1979) for egg-laying females is greater than that for males or non-laying females (Figure 1). Feed consumption for the egg-laying females, as occurs in the chicken, peaks 24 hours prior to oviposition and declines on days when eggs are laid (LaRue, in

press, a) (Figure 2).

Halibey (1979) also performed a study to determine patterns of daily feed consumption. Feed was weighed at 2 hour intervals from sunrise to sunset. The greatest percentage of feeding was at midday with early morning being the second most active feeding time. Unlike in the wild these birds are not required to leave their feeding site at night and are thus not restricted to feeding during the day (Figures 3 and 4).

The diet currently used at the ICF was formulated by M. L. Sunde (1980) at the University of Wisconsin. The main constitutent of the diets (Table 3) is ground yellow corn, which is high in starches that are are readily digested by poultry. Soybean oil meal, a very important protein source for poultry today is present in the diet. Soybean oil meal is a good protein source in that it is a good source of lysine, an essential amino acid. Wheat, oats, fish meal and meat and bone meal are additional sources of protein. Ground limestone provides calcium and phosphorus in the form of dicalcium phosphate. Unidentified growth factors which improve growth rate are brewers dried yeast, corn distiller soluble, and dried whey. Iodized salt is added to fulfill the sodium and iodine requirements. Manganese, zinc and selenium are trace minerals (which are required in small amounts). Zinc is needed for proper bone formation and feather development. Manganese is also important for growth and its deficiency leads to perosis and results in poor hatachability and embryo deformations in females. Selenium has been recently added to the diet as it usually is found in the soil; however, its concentration varies throughout the soils of the United States and can be a problem in areas where soil levels are low. Its deficiency causes degeneration of the gizzard and pancreas. Vitamins A, D_3, B_{12}, riboflavin, niacin, calcium pantothenate and choline make up the vitamin premix.

The maintenance diet which is presented to mature birds in a 3/16 inch (4.68 mm) pellet is fed to the cranes in the fall and winter. It is also fed year-round to immature birds until three years of age. It contains a 19.4% protein level, with 1% calcium and .85% phosphorus (Table 4). During the winter months, this ration is supplemented with whole corn (a handful is thrown out into the pen) in order to provide additional carbohydrates needed for thermoregulation (LaRue, in press,a). Grit for the gizzards is also supplied to the birds during the winter when snow prevents them from acquiring natural grit from the soil.

One month prior to the onset of egg laying (February), the breeder diet is fed to all birds that are three years old and older that are to participate in the breeding program and is continued until after the postnuptial molt (LaRue, in press, a). (Both natural copulation and artificial insemination are employed at the ICF). This diet contains 20.5% protein with 2.45% calcium and .89% phosphorus presented as a 3/16 inch pellet. The calcium-phosphorus ratio is greater than twice that

in other diets. It is at this stage that adequate blood calcium levels are extremely important to the egg-laying female (Table 4). Most of the calcium in the diet of a growing bird is used for bone formation whereas most of the calcium in the mature laying bird diet is used in eggshell formation. In a laying hen, for example, blood calcium levels are more than twice as high as those in non-breeding hens and cocks (Taylor, 1970). The total amount of blood calcium which is circulating in the hens' bloodstream is approximately 25 milligrams. According to Taylor (1970), every 12 minutes during the main period of shell formation there is a changeover of the calcium in the blood stream. This calcium comes ultimately from the feed. According to Comar and Diggers in 1949 (Halibey, 1979), 70% of the calcium in one eggshell comes from the diet and 30% from bone. As a result, a calcium-deficient diet results in the hen drawing upon skeletal reserves for calcium to make the eggshells. During a period of no or low eggshell deposition, bone calcium is replaced. A chicken hen will mobilize two grams of skeletal calcium in 15 to 16 hours, which is 8 to 10 percent of the total amount of calcium in her bones (Taylor, 1970). This has been observed in other birds as well and as a result, precautions are taken against this phenomenon in making up the crane diets. This calcium requirement is met not only by supplying it in the form of ground limestone in the diet, but a dish of oyster shell is also supplied - free choice - in the pen. Both of these are primarily calcium carbonate; however, the oyster shell flakes remain in the gizzard long enough to provide a continuous supply of calcium that is nutritionally available throughout the long period of shell formation and in hens, this is significant since the calcium can be continually released, even at night during non-feeding times (Nesheim et al., 1979). Halibey (1979) observed that oyster shell consumption peaks about 48 hours prior to oviposition twenty-four hours prior to laying, a hard-shelled egg can usually be felt in the oviduct (Figure 2). This evidence is not conclusive as some females did not consume oyster shell until the latter part of the breeding season. Presumably, at this time blood calcium levels were decreased.

Another point concerning the calcium-phosphorus ratio is that the phosphorus level does not increase proportionally with the calcium levels in the diet. Phosphorus is very important; however, at this stage, calcium requirements increase much more than do those for phosphorus. The phosphorus content of an egg is rather low.

Although evidence is not conclusive as to the benefit of this new breeder diet, some females that had not laid eggs previous to this time did so the first year on this diet. However, this diet has not been used for a sufficient amount of time to judge its long-term benefits.

Towards the end of the breeding season the birds, mainly the females, may become weak and physical condition may decline as a result of stress. Vitamins and electrolytes may be frequently added to the drinking water for several days (Table 5).

Newly hatched crane chicks usually remain in the artificial hatcher for 24 hours or until the down is dry. The chick is then placed in a brooder box. Controversy exists as to whether the chicks should then be immediately offered food or whether the yolk sac absorption will provide sufficient nutrients and energy sources for the next one to two days. Ollson (1975) claims that he finds it best to offer feed at 12 to 24 hours following hatching, and that a healthy chick will not eat when as young as 18 to 24 hours old. He feeds mealworms by hand which the chicks eat quite readily. At the ICF, the chicks are usually offered water from a red spoon almost immediately in order to avoid any problems with dehydration. (Dehydration can be detected by observing the chicks' legs). Red is a stimulatory color and is apparent on most adult crane heads. The drinking water supplemented with vitamins and electrolytes (Table 5) is supplied in a red plastic bowl weighted down with glass marbles. These colored marbles stimulate the chick to drink from the bowl while using the red spoon to gradually lure the bird over to the dish. The chick is checked and offered water every few hours. The following day, a pelleted starter diet is placed before the chick. It consists of 23% protein and 2554 ME/kg of diet (containing the highest protein and energy content of all the diets) in a 1/8 inch (3.12 mm) pellet. This appears to be a good size (Table 4). Individual pellets can be offered on the same red spoon used for drinking water using the same principle of eventually luring the bird to the feed dish. Again, red appears to serve as a mode of stimulation. Sometimes tapping the spoon on the edge of the dish aids in stimulating the bird to eat. If problems arise, such as difficulty in ingesting pellets, a mash can be made by mixing water with pellets to soften them. Gradually, as the chick begins to eat, pellets can be substituted for the mash.

Chicks normally lose weight the first few days of life but will begin to gain weight again within four days. Weight gain must then be carefully monitored so as to prevent any possible slipped tendons (perosis) or other leg problems as a result of becoming overweight. In order to prevent this, an exercise program is stressed. The birds are taken outside daily, allowed to run and swim (in a plastic pool). This also provides access to insects, which the chicks avidly consume.

Another difference besides protein content and metabolizable energy content of the diet is that it is the only diet containing added biotin and folic acid. Biotin deficiency in poultry chicks results in dermatitis and the bottoms of the birds' feet become calloused and cracked. This cracking may spread to the area around the beak as well (NRC, 1977b). At this time in the development of the crane chick, the feet are tender and may be more subject to these maladies. Folic acid is necessary for growth and its deficiency results in retarded growth, poor feathering and perosis (NRC, 1977b).

At 10-14 days, the chicks gain approximately 20% of their body weight daily (Figure 5) and they are then switched from the Starter diet

to the Grower diet. This diet contains 19.4% protein which is a lower protein percentage than in the Starter diet as protein is not required in as high a concentration at this point (Table 4). In similar starter diets for chickens, recent results have shown that the high level of protein was required to provide sufficient levels of the essential amino acids lysine and methionine (Scott et al., 1976). However, at two weeks of age, the protein requirement is decreased in order to slow the growth and allow the chicks' legs to strengthen, accomodating slowly to the weight gain.

At six weeks of age the chick can be placed on the Maintenance diet, which is provided in the larger pellet. Continued exercise programs allow for proper growth and additional access to insects.

CONCLUSION

The successful captive propagation of a wild animal entails a complicated program which ensures its spatial, psychological and nutritional needs. Field studies on wild cranes, experimentation, and knowledge acquired from other wild and domesticated birds will lead to the successful propagation of these endangered birds.

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We would like to thank Dr. Milton Sunde of the Poultry Science Department at the University of Wisconsin, Madison for his time and patience in developing the ICF Crane Diets. These diets are custom-manufactured by Mayrs and Keinast Company, Beaver Dam, Wisconsin.

TABLE 1

Composition of Several Crane Diets

Diets	Nutrients			Principal Ingredients
	Protein	Calcium	Phosphorus	
Old ICF Breeder Diet	36%	5.0%	1.4%	soybean meal animal fat meat and bone meal alfalfa meal
Walsrode Vogelpark Breeder Diet	20%	3.0%	1.0%	corn meal soy groats zein corn germ tapioca meal lucerne wheat bran
Patuxent Wildlife Research Center Breeder Diet	22%	3.0%	.75%	corn meal soybean meal wheat middlings fish meal ground oats alfalfa meal meat and bone meal
Current ICF Breeder Diet	20.5%	2.45%	.89%	ground corn soybean meal wheat middlings fish meal ground oats alfalfa meal meat and bone meal

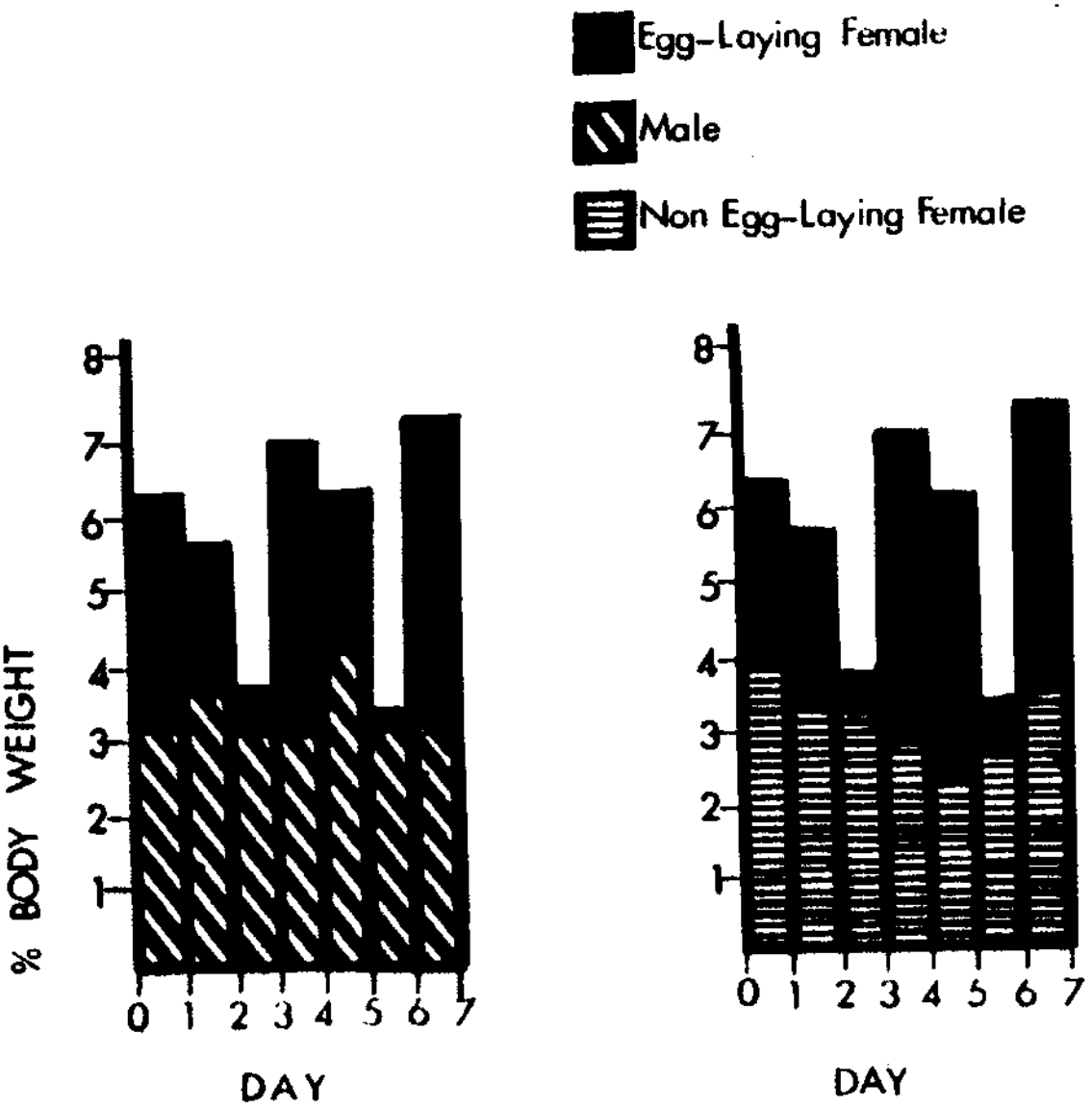
TABLE 2

Average Daily Feed Consumption in Six Species of Cranes

Species	% of Body Weight	Body Weight (lbs)
Grus japonensis	4.3	16.5
Anthropoides paradisea	5.0	11.2
Grus antigone antigone	4.8	21.5
Grus vipio	4.5	11.9
Grus leucogeranus	4.5	14.0
Bugeranus carunculatus	5.4	15.0
	Average 4.8%	

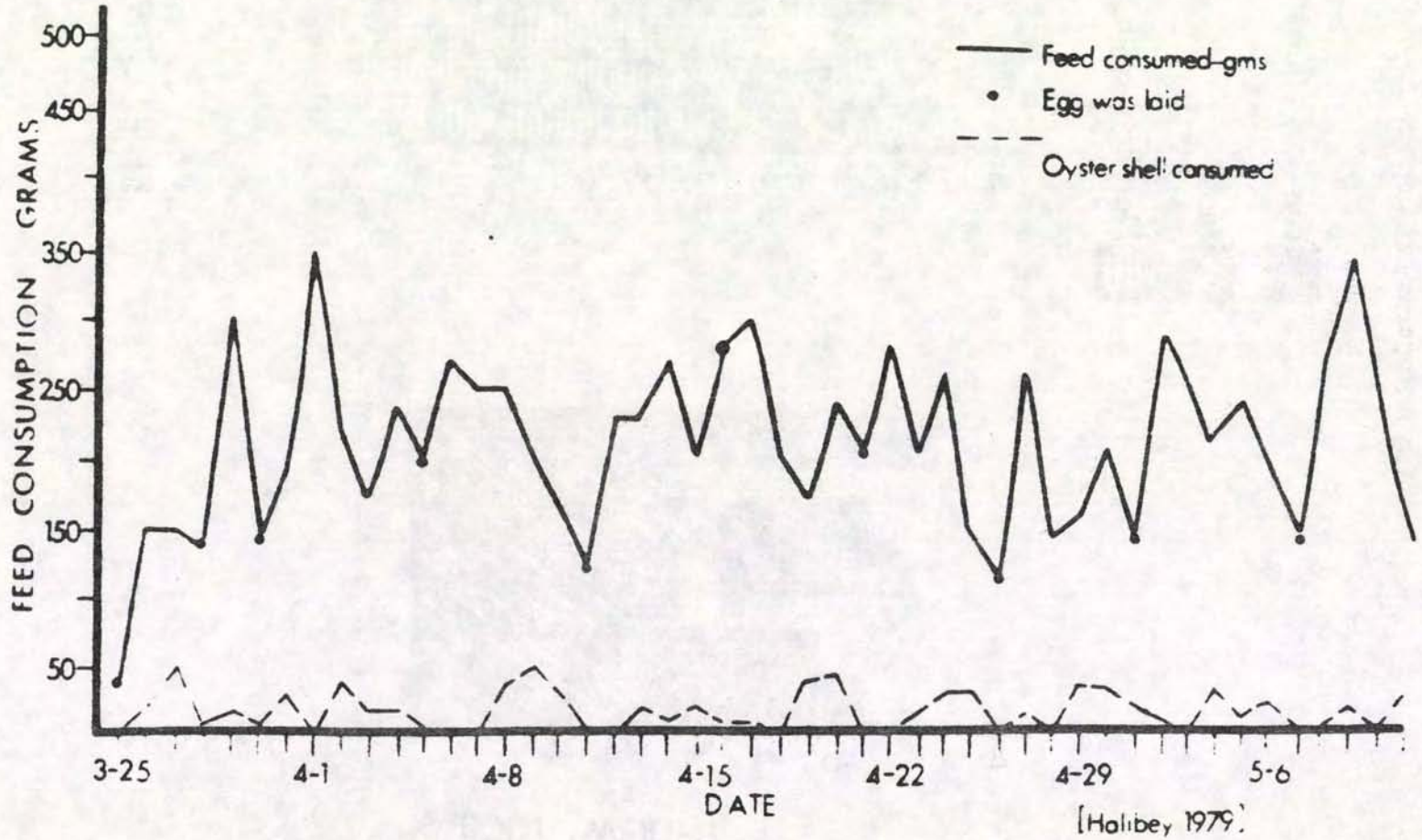
(Halibey, 1979)

FIGURE 1. Comparison of Feed Consumption in Cranes at the ICF



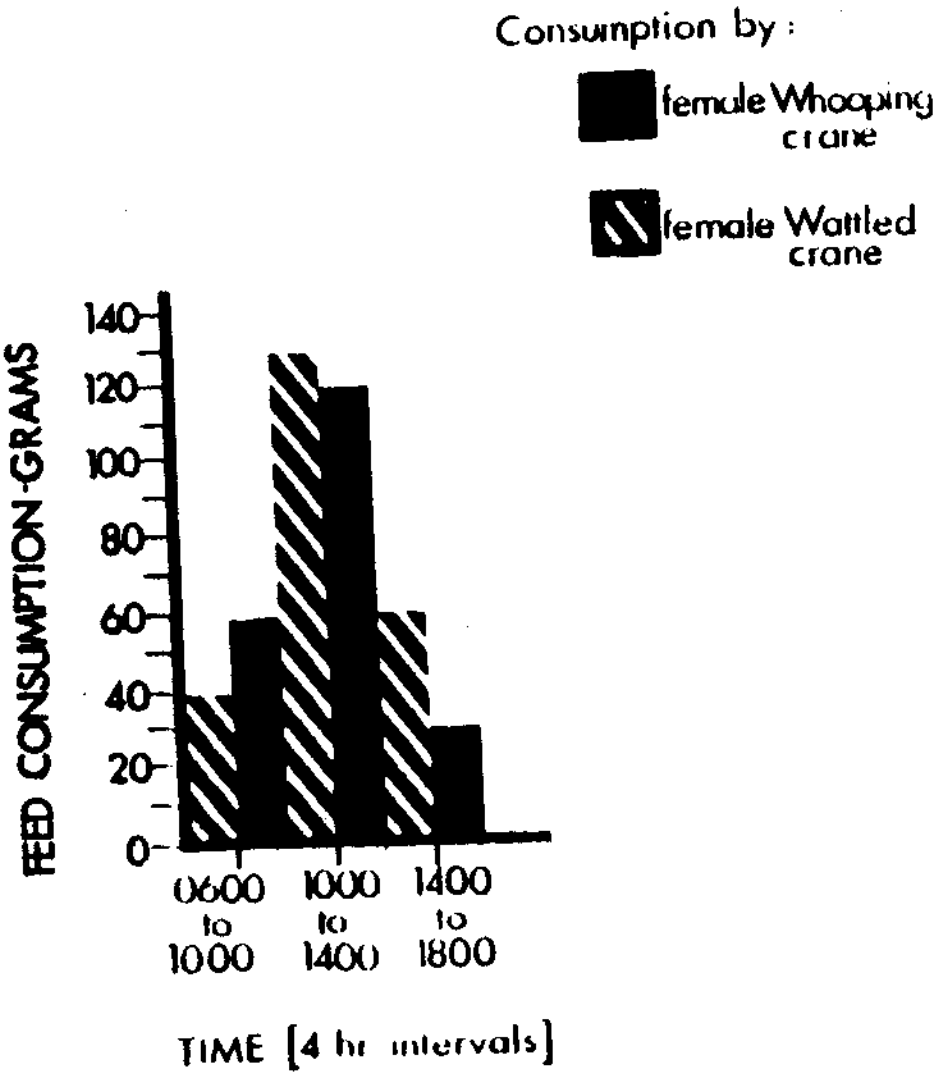
[Halibey, 1979]

FIGURE 2 -Feed Consumption and oyster shell consumption in a female crane



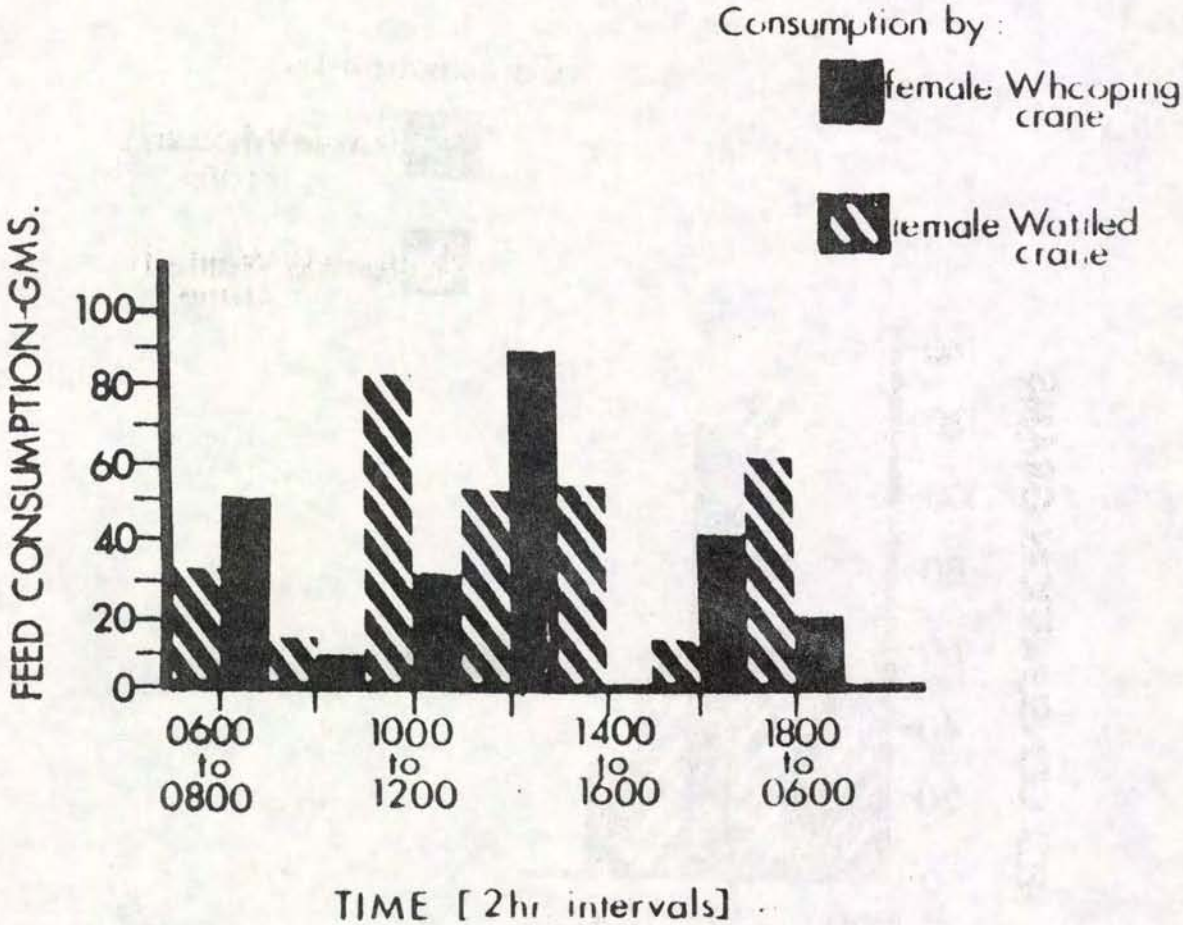
[Halibey 1979]

FIGURE 3. 12 Hr. Feed Consumption Study in 4 Hr. Intervals



[Halibey, 1979]

FIGURE 4. 12 Hr. Feed Consumption Study in 2 Hr. Intervals



[Hallbey, 1979]

TABLE 3

International Crane Foundation - Crane Diet Formulas

Ingredients	lb/ton	lb/ton	lb/ton	lb/ton
Ground yellow corn	825	695	740	740
Soybean oil meal, 44%	300	380	250	250
Wheat middlings	200	240	240	240
Wheat bran	-	-	100	100
Fish meal	100	120	75	75
Ground oats	150	230	300	300
Gound limestone, 38% Ca	70	-	10	10
Meat and bone meal or meat meal, 50% protein	80	100	100	100
Alfalfa meal, 17% protein	100	100	100	100
Brewers dried yeast	40	50	-	-
Corn distiller soluble	30	-	-	-
Dried whey	70	60	60	60
Dicalcium phosphate	20	10	10	10
Iodized salt	10	10	10	10
DL methionine	1.5	1	1	1
Vitamin premix	4	4	4	4
	g/ton	g/ton	g/ton	g/ton
Manganese oxide	150	200	200	200
Zinc oxide or carbonate	150	100	100	100

.02ppm. Selenium is added to all diets.

(Sunde, 1980)

TABLE 3

International Crane Foundation - Crane Diet Formulas

(Con't.)

Ingredients				
Vitamin A, I.U.	8,000,000	8,000,000	8,000,000	8,000,000
Vitamin D_3, I.U.	2,000,000	2,000,000	2,000,000	2,000,000
Riboflavin, gm	3	3	3	3
Vitamin E, I.U.	50,000	50,000	50,000	50,000
Vitamin B_{12}, mg	10	10	10	10
Niacin, gm	75	75	75	75
Calcium pantothenate, gm	20	20	20	20
Choline, gm	1,000	1,000	1,000	1,000
Biotin, mg	-	200	-	-
Folic acid, mg	-	500	-	-

(Sunde, 1980)

TABLE 4

International Crane Foundation-Diet Information

	Maintenance	Breeder	Starter	Grower
% Protein	19.4	20.5	23	19.4
ME/kg diet	2,530	2,533	2,554	2,530
% Calcium	1.00	2.45	1.15	1.00
% Phosphorus	.86	.89	.93	.86
Pellet size, diameter	3/16" (4.68mm)	3/16" (4.68mm)	1/8" (3.12mm)	1/8" (3.12mm)

(LaRue, in press,a).

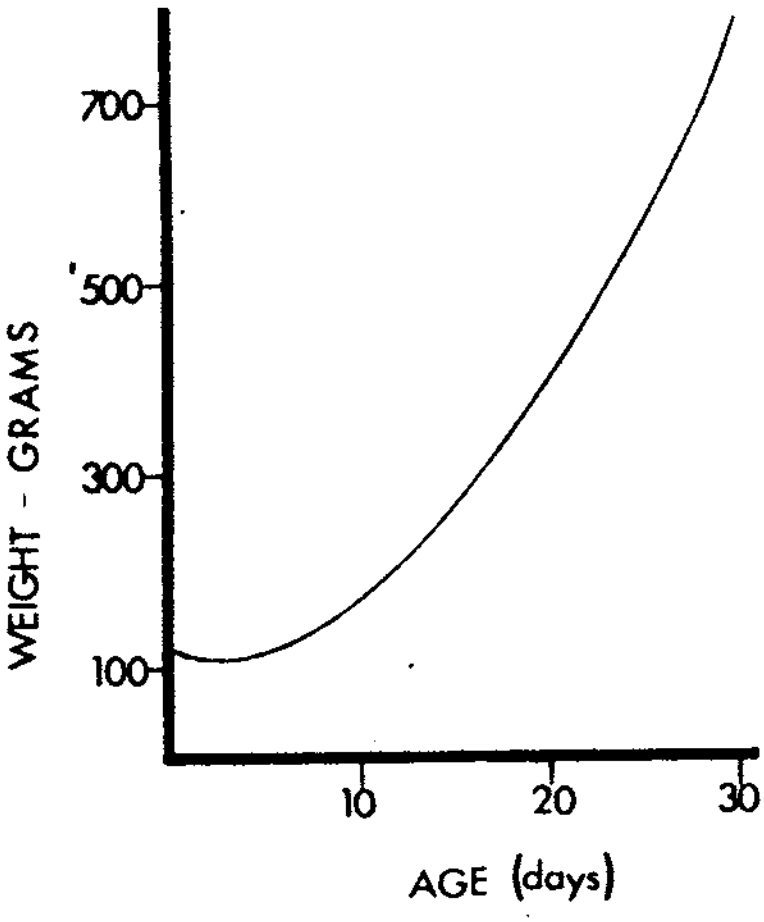
TABLE 5

Soluble Vitamins and Electrolytes for Poultry

Ingredients per pound	
Vitamin A (as palmitate)	5,000,000 I.U.
Vitamin D_3	750,000 I.U.
Vitamin E (dl-α-tocopherylacetate)	2,500 I.U.
Riboflavin	500 mg
d-Pantothenic Acid	4,000 mg
Menadione Sodium Bisulfite complex	2,000 mg
Folic acid	125 mg
Thiamine Mononitrate	250 mg
Potassium and Sodium (as chloride salts)	
With solubilizing and flavoring agents	

Salisbury Laboratories
Charles City, Iowa 50616
ICF formula: mix 1 teaspoon/2 gallon bucket of water

FIGURE 5. Growth curve for chicks raised at the ICF



[LaRue, in press,a]

SHIRLEY E. RUSSMAN, B.S. QUESTIONS AND COMMENTS

QUESTION: Were all the intake data on a percent dry matter basis or as-fed?

RESPONSE: The data were presented on an as-fed basis.

QUESTION: Who formulates the diets for you?

RESPONSE: Dr. Milton Sunde from the University of Wisconsin at Madison.

FORAGE QUALITY AS RELATED TO ANIMAL NEEDS AND FORAGE EVALUATION

Dr. Dwayne A. Rohweder[1]

It is a pleasure to discuss the topic with you as there is considerable misunderstanding worldwide on how to describe forage and feed quality, how to communicate quality and how to relate that quality to animals—domestic and wild. It also is appropriate that we discuss the subject at this time because we are making major changes in U.S. hay standards and your input as to forage needs of exotic animals will help make those standards more meaningful. Both exotic and domestic animals are major consumers for U.S. hay.

If you read the present U.S. hay grades developed in 1946, you will find that there are at least 155 grades of hay listed. Those grades, as described, are based primarily on organoleptic characteristics and have little relation to feed value (e.g., I have samples of U.S. No. 1 extra-leafy alfalfa hay and U.S. No. 3 alfalfa hay and both show seed pods. This factor will have significance as we proceed through this discussion). The present grades also do a very poor job of communicating quality between producer-dealer and consumer. Consequently, less than one percent of the hay sold is graded, and that is for governmental agencies such as the one you represent.

When you consider the nutrient needs for wild animals in the zoo and attempt to obtain hays to meet those needs, there are several factors that should be considered: 1) The diet in captivity is probably different from that in the wild for many animals; 2) Each animal has a need for several nutrients in specific amounts; 3) Those nutrients must be in an acceptable form for the animal to use; 4) What is the "life cycle" of the animals—when they breed and when they give birth to young and subsequently give nourishment to that offspring?; 5) What is the growth pattern of the forages prior to these stages in the animal's life cycle in their native habitat?; 6) What is the type of animal for which you are attempting to determine a ration?; and 7) The hay also may have an "occupational" value giving the animal something to do. However, this latter value should not overshadow the real value for hay—that of feed.

There are few research studies dealing with the nutrient needs of wild animals in captivity. However, two studies by Ullrey (3, 4) provide some data relative to forage needs of these animals. The findings by Ullrey et al. coincide very well with findings on like types of domestic animals. These data will be integrated into the recommendations for hay needs.

[1]Professor of Agronomy-Extension, University of Wisconsin, Extension and College of Agricultural and Life Sciences, UW-Madison. Presented at conference on Nutrition of Captive Wild Animals, December 5-6, 1980, Lincoln Park Zoological Gardens, Chicago, IL.

HERBIVORES IN THE ZOO

Several zoo animals are listed in Table 1[2]. They are classified as to mono-gastric, "horse-like", or ruminant animals. An estimated weight and estimated daily needs for net energy (NE) in mega calories (M. cals) are listed.

I have used NE rather than metabolizable energy or total digestible nutrients because animal nutritionists have found the NE system to be satisfactory for animals ranging in size from the mouse to the elephant. NE is the energy that reaches the cell with the daily need based on weight. The values listed will provide a starting point for developing a maintenance ration. The value should be increased by about 50% prior to birth of young and lactation. The value should be increased by about the same amount prior to breeding.

CHARACTERISTICS OF ANIMAL TYPE

Ruminants have a four compartment stomach with storage up front. The forage is swallowed unchewed, regurgitated, and mixed with saliva as chewed. Through this process, the ruminant can use large amounts of forage. That forage may also be of somewhat lower quality for maintenance as long as the animal can consume sufficient forage to obtain the required nutrient needs. During breeding and lactation, higher quality may be needed. High quality is needed for weight gain.

Ruminants grazing in the wild and browsers generally select the young, highly digestible parts of forages before they consume the less digestible portions of the plant. Smaller ruminants generally cannot handle low quality forages as well as larger ruminants.

Horse-like animals and horses are natural grass eaters but they have smaller digestive tracts (cecum) than most ruminants and thus cannot handle as much bulk. They can consume large amounts of high quality, easily digested forage. These animals resemble mono-gastric animals in assimilation of nitrogen.

Mono-gastric animals generally cannot use forages very effectively. However, immature, high quality, leafy legumes can be consumed and digested by these animals.

[2]The author is indebted to Ms. Mary E. Allen, Nutritionist, Brookfield Zoo, Chicago Zoological Park, Brookfield, Illinois for assistance in the preparation of this table.

HAYS FOR HERBIVORES

Feeding captive herbivores under conditions often far different from their native environment dictates reliance on feedstuffs that may be different from those eaten in the wild. Exotic animal species, like domestic species, require nutrients rather than feed stuffs. 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. The hay provides needed nutrition as well as an occupation for the animal's time. Therefore, consider hay quality 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? And, will the animal be able to consume sufficient amounts to obtain the needed nutrients? If the answers are "no", a supplement will be needed to make up for deficiencies.

Today most hays are evaluated by visual estimation based on plant type (legume, grass or mixture); maturity; leafiness; amount of weathering; damage from mold, heating, dust; and contamination from weeds and trash. However, visual estimation is difficult, lacks precision and makes it difficult to describe and communicate quality between producers, dealers and consumers. Therefore, I encourage you to adopt a testing program.

The present feed testing technique is the proximate analysis system developed in 1850 and emphasizes crude protein and crude fiber. Crude protein (CP) is excellent for evaluating legume hays because digestibility of crude protein increases as concentration of crude protein increases. However, it is much less precise with legume-grass mixtures and with grasses. Most hays purchased in the midwest contain some grass. Crude fiber also is misleading because it over-estimates the value of some feeds, under-estimates the value of other feeds, and fails to indicate how the indigestible portion functions in digestion. Crude fiber is determined by treating a feed first with a weak acid and then a strong alkali. Consequently, the amount of crude fiber obtained will depend on the forage. For example, a mature oat straw can be treated and obtain a higher estimate of digestible energy than from an analysis of early-cut, high quality alfalfa. The animal will not agree with this analysis.

Three basic and more precise methods of estimating in vivo digestibility are in use today: a) the digestion trial, b) the in vitro rumen fermentation technique, and c) newer chemical methods which more adequately characterize the constituents in feeds. The digestion trial is lengthy and costly, although accurate. The in vitro technique most closely approximates energy availability in forages, but it is doubtful the technique will be widely adopted for routine use. Many scientists have indicated that the acid detergent fiber (ADF) and neutral detergent fiber (NDF) analyses propsed by Van Soest (1) are the chemical assays of choice to estimate in vivo dry matter digestibility (DDM) and dry matter intake (DMI), respectively.

This analytical system divides the organic matter of plants into cell walls and cell contents through the use of detergents, Table 2. The nutritional availability of cell contents is almost complete, averaging 98 percent, and

digestive enzymes for these substances exist in the digestive tract of all animals. Cell walls include substances that are digested to a significant extent only in animal species possessing important gastrointestinal fermentation capabilities. The cell wall portion of a forage affects the volume a feed will occupy in the digestive tract, a principle factor limiting consumption by animals.

A major difference between forage species is related to the concentration of NDF and hemicellulose. Legumes have less NDF than grasses. Temperate or cool season grasses such as bromegrass, orchardgrass or timothy have less hemicelulose than sub-tropical or tropical grasses such as 'Pangola' digitgrass, bahiagrass, and bermudagrass. And, the NDF concentration varies considerably between varieties of bermudagrass. DMI decreases from legumes to temperate grasses to sub-tropical grasses. This characteristic is an important consideration in feeding herbivores, particularly those resembling the horse or non-ruminants.

Through numerous animal digestion trials, it has been determined that ADF concentration is inversely related to in vivo digestible dry matter, and NDF concentration is inversely related to dry matter intake. Studies have shown a high correlation between both relationships and that ADF and NDF are effective in predicting DDM and DMI, respectively.

Ullrey, Robinson, and Whetter (4) compared several forages as to efficiency with which wild ruminants and monogastric herbivores obtained needed nutritional needs. Alfalfa hay estimated to be at early bloom maturity (Grade 1) was fed to several ruminants, Table 3. The addax (small desert browser) and the giraffe appeared to be more efficient in digesting gross energy and CP than the other ruminants, particularly the banteng. The dorcas gazelle was highly selective and consumed mostly leaves. While digestibility of the leaves was not greatly different from the entire plant by the other ruminant, the greater concentration of CP in leaves provides a greater potential for greater digestible protein intake per unit metabolic body size.

Alfalfa at an estimated mid-bloom maturity (Grade 2) and oat hay at heading maturity (Grade 5) were fed to the Przewalski's horse, onager, fringe-eared oryx, and Arabian oryx, Table 4. Because the horse and onager consumed soil, digestibility of the carbohydrate fractions were not obtained. However, the ruminants appeared slightly more efficient than the equine species in digestibility of CP and energy. The digestibility of CP and energy was considerably lower for the oat hay than the alfalfa even though the alfalfa was quite mature. The late alfalfa maturity accounts for the lack of difference in digestibility of oat and alfalfa hay.

Sudangrass hays of estimated heading maturity (Grade 4) were fed to the Caucasian tur, plains bison, Asian, and African elephant, and the black and the white rhinoceros, Table 5. The horse-like and mono-gastric animals were much less efficient in digesting the grass hays. Note also that the more immature sudangrass (2) had higher digestibilities than that harvested with higher ADF and NDF (1).

There also appears to be a trend toward lower digestibiliy of energy and CP by the animals as hays were shifted from early cut alfalfa, more mature alfalfa, and grass hays. These data also appear to indicate, as with domestic animals, that while digestibility of legumes and grasses at comparable stages of maturity are nearly the same, the intakes are not. It, therefore, is not wise to feed grass hays to horses and monogastric animals.

EVALUATING HAYS

Organoleptic characteristics influencing the feed value of hays are: 1) amount of legume, 2) maturity, 3) leafiness, 4) color, and 5) foreign matter. Legumes have higher intake and are usually higher in crude protein than grasses. Immature forages, legumes and grasses, have higher crude protein, higher digestibility, and higher intake than more mature forages. Thus, the earlier reference to green seed pods in the different hay grades indicates that digestibility will not be greatly different. Immature legumes, before first flower, first cutting in June will have a higher energy concentration than second, third, or later cuttings, but also drop faster after first flower. This factor may not be a major consideration in hay purchases. Leafiness also reflects maturity, but more importantly reflects how the hay was handled and the amount of weathering. Color, a factor rated high by dealers because it makes an attractive package, also reflects the amount of weathering as well as field exposure, disease infection, and insect infestation. Color also indicates presence of mildew, mold, and heat damage. These later characteristics definitely limit the feed value and desirability of hay for all animals. Foreign material indicates the presence of weeds, trash, dirt, etc. that lower digestibility.

The organoleptic characteristics, primarily maturity, help characterize the AFGC hay grades, Tables 6 and 7, but are not used in the final evaluation for quality (2). Grades change with advancing maturity. Percent leaves and some color change parallel the change in maturity. The concentration of CP decreases with advancing maturity and change in grade. The percent CP in grasses can be changed with level of fertilization but generally follows the same trends as in legumes. The concentrations of ADF and NDF increase with maturity. Note that the ADF concentration is nearly equal for legumes and grasses at comparable stages of maturity; however, the concentration of NDF is higher for grasses than for legumes. Consequently, the top grade for grass hay is equal to the third grade for legumes. Digestibility and intake data in Table 8 reflect these differences. Digestible dry matter intake (DDMI) values confirm placing immature grass equal to mid-bloom legumes. These values are an estimate of digestible energy intake.

The relative feed values can be used to price hays. If mid- to full-bloom alfalfa grass hays (Grade 3) are selling for an average of $50 per ton, then prime hay can have a value of $68.50 while full head grass hays can be worth only $41.50. Actual values may vary.

The information in Tables 6, 7, and 8 also can be used in designing rations for both domestic and wild animals. Average concentration of TDN, CP,

calcium and phosphorus for selected alfalfa and timothy hays are shown in Table 9. Calcium and CP concentrations are higher for alfalfa than for timothy or grass hays. Phosphorus concentration in immature timothy is nearly double that at full head. Nutrient needs for selected domestic animals are shown in Table 10. For example, pre-bloom alfalfa will supply the maintenance energy, CP, calcium and phosphorus requirements for an 800 kg dairy cow; full-bloom alfalfa will supply only needed CP and calcium; immature timothy, well fertilized, will almost satisfy maintenance energy, CP, and phosphorus while; mature timothy will supply none of the requirements. By knowing the nutrient requirements for wild animals in captivity and the composition of hays, the nutritionist can be more selective in purchasing hays; can be more precise in determining supplement needs and can reduce costs.

Recent research indicates that equine species prefer high quality legumes over grasses. However, equines often exhibit a white residue in the urine when fed early cut, pure alfalfa hays. This problem can be alleviated or reduced by feeding an alfalfa-grass mixture containing not over 25 percent grass or by gradually changing from the present feed to the higher quality alfalfa rather than making an abrupt switch.

Hay may serve to occupy the time of some animals. If so, you may purchase a small amount of additional hay for this purpose. But, with present prices for grain and supplements, it generally is to your advantage to purchase high quality hay that will supply as many of the nutritional requirements of the animals as possible.

The College of Agricultural and Life Sciences at the University of Wisconsin-Madison recently modified their hay purchase program to purchase only Grade 1 alfalfa hay, let bids quarterly, let the market determine bid price, sample on delivery, and pay a premium or levi a discount when the chemical composition was above or below the bid specifications, respectively. After 18 months of activity, about 40 percent of the lots have been on the CP percentage or above. About two-thirds are below the specifications. Even though the record does not appear outstanding, it has improved the overall quality of hay purchased. In retrospect, about one-fourth of the lots should have been rejected.

Zoo personnel also can improve the quality of hay reaching the animal. Proprionic acid is the preservative that seems to work best in preserving hay and silage, however farmers presently have problems achieving consistency of results when using preservatives to improve keeping quality of hay. Some farmers are using lesser amounts than recommended plus drying to improve hay quality. Hays treated with proprionic acid can be used for ruminants, but equine species do not readily accept these hays. The large round bale permits fast removal of hay from the field, but is not very satisfactory for maintaining top quality hay unless dried properly. If the hay is baled wet enough to hold leaves, the large bales have a tendancy to heat and thus lower protein digestibility. If baled dry enough to keep, leaf loss appears higher than with conventional bales. Conventional square bales are much easier to handle and transport. Hay should be stored on edge rather than on the flat side if moisture is or can be a problem. This allows for more air movement around the bale.

SUMMARY

It is extremely difficult to purchase hay on sight and achieve a specific nutrient composition. Present grades do not express feed value, by the proposed AFGC hay grades based on the ADF and NDF fiber analyses offer new opportunities to provide more precise estimates of feed value. Data obtained when feeding hays to wild animals appears to parallel that obtained with domestic animals. Therefore, the domestic model adjusted for nutrient needs of each wild animal appears to offer the nutrionist in the zoo an opportunity to improve hay purchase practices and save money.

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Table 1. Selected herbivores found in the zoo with approximate adult weight and classified by type with an estimated daily requirement of net energy in mega calories.

Ruminants	M. Cal N.E.
Blackbuck (40 lbs.)	0.7
Sitatunga (90 lbs.)	1.2
Dall Sheep (100-120 lbs.)	1.4
Addax (120 lbs.) Desert	1.5
Ibex (150 lbs.)	1.8
Pere David Deer (400 lbs.)	3.9
Reindeer (300 lbs.)	3.1
Kudu (Antelope) (600 lbs.)	5.2
Oryx (Antelope) (300-400 lbs.)	3.2
Okapi (500 lbs.)	4.6
Camel (1000-1200 lbs.)	8.0
Yak (Wild Ox) (700 lbs.)	6.0
Bison (1200 lbs.)	9.0
Wisent (European Bison) (1800 lbs.)	11.8
Banteng (Buffalo) (1800 lbs.)	11.8
Congo Buffalo (1800 lbs.)	11.8
Giraffe (2000 lbs.)	12.7
Mono-Gastric (Horse-like)	
Zebra (700 lbs.)	5.8
Tapir (800 lbs.)	6.4
Rhino (5000-7000 lbs.)	24-32
Elephant (5000-12,000 lbs.)	25-48
Hippo (8000 lbs.)	36.0
Mono-Gastric (Pig-like)	
Peccary (100 lbs.)	1.4

Table 2. Division of forage organic matter by the system of analysis using detergents[1]

Fraction	Components	Nutritional availability	
		Ruminant	Non-ruminant
A. Cell contents (Soluble in neutral-detergent)	Lipids	Virtually complete	Highly available
	Sugars	Virtually complete	Highly available
	Organic acids & water	Virtually complete	Highly available
	Soluble matter	Virtually complete	Highly available
	Starch	Virtually complete	Highly available
	Non-protein nitrogen	Virtually complete	Highly available
	Soluble protein	Virtually complete	Highly available
	Pectin	Virtually complete	Highly available
B. Cell walls (Fiber insoluble in neutral-detergent-NDF)			
(1) Soluble in acid-detergent	Hemicellulose	Partial	Very low
(2) Insoluble in acid-detergent (Acid-Detergent Fiber-ADF)	Cellulose	Partial	Very low
	Lignin	Indigestible	Indigestible
	Lignified N compounds	Indigestible	Indigestible
	Heat damaged protein	Indigestible	Indigestible
	Keratin	Indigestible	Indigestible
	Silica	Indigestible	Indigestible

[1] Jorgensen, 1971.

Table 3. Composition and apparent digestibility of alfalfa hay fed to wild ruminants--percent.

Animal	Gross Energy	CP	ADF	NDF	Starch/ Sugar
Alfalfa Comp.	4.4 k cal/g	17	36	42	26
Digestibility--%					
Addax	70	79	42	57	96
Giraffe	64	71	55	54	84
Bongo	56	68	42	42	83
Gaur	56	67	41	38	89
Banteng	54	63	33	29	90
Alfalfa Leaf Comp.	4.5 k cal/g	25	21	27	33
Dorcas gazelle					
Digestibility--%	62	72	39	40	86

Ullrey et al., 1979

Table 4. Composition and apparent digestibility of alfalfa and oat hay fed to wild ruminants and monogastric herbivores--%.

Animal	Gross Energy	CP	ADF	NDF	Starch/ Sugar
Alfalfa Comp.	4.3 k cal/g	16	37	45	25
Oat Comp.	4.0 k cal/g	6	41	67	8
Digestibility--%					
P. Horse* (H)	51	66	--	--	--
Onager* (H)	51	64	--	--	--
Oryx (R)	54	60	19	41	82
Arabian Oryx (R)	55	74	39	33	96
Arabian Oryx (R)(Oat)	47	27	44	49	88

*Consumed soil

Ullrey et al., 1979

Table 5. Composition and apparent digestibility of sudangrass hay fed to wild ruminants and monogastric herbivores--percent.

Animal	Gross Energy	CP	ADF	NDF	Starch/ Sugar
Sudan Comp. (1)	4.2 k cal/g	8	44	66	13
Sudan Comp. (2)*	4.4 k cal/g	7	35	62	23
Digestibility--%					
C. Tur (1)	50	63	47	42	78
Bison (1)	50	52	--	--	--
Elephant (1)	35	43	20	31	100
B. rhino. (1)	34	30	22	33	85
W. rhino. (2)	69	44	54	67	100

*Less mature

Ullrey et al., 1979

Table 6. Proposed market hay grades for legumes, grasses, and legume-grass mixtures - AFGC Hay Marketing Task Force

Grade	Legume Hays[1]			Grass Hays[1]		
	Stage of Maturity International Term	Definition	Physical Description	Stage of Maturity International Term	Definition	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 7. Typical chemical composition for proposed market hay grades[1/] - AFGC Hay Marketing Task Force

Grade	Legume hays			Grass hays			Relative Feed Value
	CP %	ADF %	NDF %	CP[2/] %	ADF %	NDF[3/] %	%
Prime	>19	<31	<40	---	---	---	
1.	17-19	31-35	40-46	---	---	---	
2.	13-16	36-41	47-51	>18	<33	<55	
3.	<13	>41	>51	13-18	33-38	55-60	
4.	---	---	---	8-12	39-41	61-65	
5.				<8	>41	>65	

[1/] Chemical analyses expressed on dry matter basis. Chemical concentrations based on research data from NC and NE States and Florida. Dry Matter (moisture) Concentration can affect market quality. Suggested moisture levels are: Grades Prime, 1 and 2 < 14%, Grade 3 < 18%, and Grades 4 and 5 < 20%.

[2/] Fertilization with nitrogen may increase CP concentration in each grade by up to 40 percent.

[3/] Tropical grasses may have higher NDF concentrations than indicated in this table.

CP = Crude Protein; ADF = Acid Detergent Fiber; NDF = Neutral Detergent Fiber; Relative Feed Value is based on Digestible Dry Matter Intake. See Table .

Table 8. Typical digestible dry matter (DDM), dry matter intake (DMI), and digestible dry matter intake (DDMI) values for proposed market hay grades described in Tables 6 and 7.[a/]

Grade	DDM *in vivo* %	Dry Matter Intake gm/W $kg^{0.75}$		Digestible Dry Matter Intake - gm/W $kg^{0.75}$		Relative Feed value[b/] %
		Legume	Grass	Legume	Grass	
Prime (Leg. Preflower)	>68	>142	---	>97	---	>137
1	66-68	134-141	---	87-96	---	122-136
2	63-65	238-133	>122	72-86	>78	109-121
3	60-62	<127	114-122	<71	68-77	95-108
4	57-59	---	106-113	---	60-67	84-94
5 (Grass-Post head)	<57	---	<105	---	<59	<83
6	---		---		---	---

a/ Formulas used to calculate relative feed value: DDM = 59.0 - 2.26 ADF% + $14.2\sqrt{ADF\%}$; DMI = 84.7 - 3.69 NDF% + $32.37\sqrt{NDF\%}$; DDMI = DDM x DMI/100; Relative Feed value = DDMI x 1.4085 where DDM = *In vivo* digestible dry matter; DMI = Dry matter intake; DDMI = digestible dry matter intake.

b/ Relative feed value is an estimate of overall forage quality. It is calculated from intake and digestibility of dry matter when forages of known composition were fed to cattle. The values are relative; however, they are equally appropriate for all classes of livestock. Relative feed value estimates the intake of digestible energy when the forage is the only source of dietary energy and protein.

Table 9. Average Composition of Alfalfa and Timothy Hays

Crop-Maturity	Net Energy Maint. M. Cal/Kg	Net Energy Gain M. Cal/Kg	TDN %	CP %	Ca %	P %
Alfalfa						
Pre-Bloom	1.36	.76	63	19.4	1.25	.23
Full-Bloom	1.22	.55	57	15.9	1.28	.20
Timothy						
Pre-head	1.34	.73	62	12.3	.66	.34
Full-head	1.24	.59	58	8.3	.38	.18

Table 10. Nutrient needs for selected animals.

Animal	B.W. kg	Daily Nutrient Needs						
		Feed kg	CP g	NE(M)* M Cal	ME(M)** M Cal	Ca g	P g	Car. mg
Mature cow	350	5.0	468	6.9	10.1	14	11	37
Dairy	500	6.5	638	9.0	13.4	20	15	53
	800	9.5	915	12.8	19.1	27	21	85
Bull	800	12.0	915	13.9	24.2	27	21	85
Dry Cow	350	5.8	340	--	10.3	9	9	35
Beef	500	7.6	440	--	13.6	12	12	46
Horse	400	6.3	540	--	13.9*	18	11	--
	600	8.5	730	--	18.8*	27	17	--

* For Dairy/Forage NEm = 60% ME

** DE in M. Cal.

TE - Feces = DE - Urine & gas = ME - heat & energy in dig = NE(M,G, L)
DE = TDN & DDM.

DWAYNE A. ROHWEDER, Ph.D. QUESTIONS AND COMMENTS

QUESTION: Is there a preference for storing baled hay on the flat side or on the edge?

RESPONSE: If it is very dry, it would not make much difference but if there is a slight chance that it was baled while still a little too moist, I would store it on edge. You will allow more air to circulate around it to help to dissipate the moisture and heat and by doing this you will not allow it to mat. Most farmers do not do this because it is very hard to walk on top of bales stacked this way!

QUESTION: Is sodium proprionate effective in retarding spoilage?

RESPONSE: Sodium proprionate or proprionic acid is the only additive that works very well in preserving silage or hay. However there are problems with this. We can use proprionic acid on silage and hay up to about 2% with ruminants without seeing any problems but we have quite a time getting horses to eat the treated hay. One also needs to realize that there is difficulties in getting consistent application of proprionic acid. The consistency with the retarding of molds, heat, and spoilage depends on the degree to which we have the proprionic acid applied evenly across all the hay. Now keep in mind, this is a fairly strong acid, it is an irritant, and it is very hard to work with. People do not like to work with it. They really

do not get back into the hay when it is being applied and because of the irritant problem they really do not monitor it very closely. If I can use the experience of a couple of dairymen; they have a production of 19,000 lbs. of milk in their dairy herd which is very high. They make a lot of silage but they also make some hay. They have finally settled on the application of one half percent of proprionic acid to the hay and will bale it at about 25-30% moisture, which is dry enough to keep. So they will put on proprionic acid at about one half percent vs. about two percent that would be needed if you applied it the whole way. That is enough proprionic acid to stop the fermentation and mold action, until they get it into the barn. They have built in a common air dryer in their barn which cost about $3,000. They put in the hay, turn the fan on and leave it on. This takes care of the remaining moisture. As a result they have some very beautiful hay, and they can command a price twice what the normal hay is sold for around there. So this is one way to do it.

There is a fellow down in southern Illinois who is involved in another interesting operation. He bales his hay at 30% moisture in a big round baler and takes it into a barn that he has had custom built. The south side of the building has solar panels and the solar heated air is forced up

through the bales and dries the hay. Because of this artificial drying method, he can harvest hay with a higher moisture level in the big bale. If any of you are in the northern part of the United States or buying hay from someone who is not using an artificial drying system, I would encourage you not to buy the big round bales because you are bound to get heating and molding in those kinds of situations. We just cannot dry them that well in this area.

QUESTION: Is the twelfth cutting in California any different than the first or second cutting?

RESPONSE: The alfalfa in the first cutting is growing during a time when it is cool and moist. Early in the season, it is going to have a higher energy level than it will later in the season. When you get the second and third cuttings that grow during July and August in the higher temperatures, the energy is not going to be as high but it does not go down as fast. Now let me tell you some of the things we ran into when we started to look at the feeding and chemical analysis data. We did get some trials out of Utah which did not fit the mold. I began to ask for reasons for this and I did not really get good answers to my questions from the scientists in Utah as to why this was happening. The alfalfa breeder

in our department is a Utah boy, born and raised on a farm, and I told him what the problem was and he said, "Oh, that's simple, I know the reason for that. My dad never did feed second or third cutting alfalfa to our livestock out there, only first cuttings. He knew that when it grew during the hot part of the season the energy level was lower and you did not get the production out of it." I can show you data on timothy, oats, alfalfa where we can take these plants into a growth chamber, control the climate, and can change the digestibility, energy content, and protein content of those plants, all at the same stage of maturity.

QUESTION: When we feed good leafy alfalfa or early cut alfalfa to the rhino and zebra or any of the horse-type animals, they get a white residue in the urine.

RESPONSE: This white residue in the urine comes from the very high amounts of crude protein found in that kind of hay. One solution is to feed an alfalfa/grass mixed hay, aiming for a ration of about 75%:25%. That will usually take care of the problem. Also if you feed a lower quality hay and then switch to a higher quality alfalfa, you will sometimes get this white residue in the urine or will get loose stool. Equine nutritionists will recommend making such a switch gradually to allow the animals to adjust

slowly. The research we have to date with the horse shows that they can use, and they do a better job with the very high quality alfalfa hay than they do on old, mature timothy. We have had some interesting times working with the hay dealers in the Chicago area. Approximately 10 years ago Arlington Park Racetrack wanted to buy timothy hay. "Timothy is the only thing we should feed horses" is an old-time adage. Now, gradually, we have gotten the horse folks to change to buying alfalfa/grass hay.

QUESTION: What has happened when you open up what looks like a good bale of alfalfa and the leaves drop at your feet?

RESPONSE: The hay was raked when it was too dry. It was in the row in the field and then went into the baler. The physical compression knocked all the leaves off. You will find, upon opening the bale, one slice with all the stems and then between the next slice are all the leaves. This is the reason why you should take a sample of the hay by going from the end of the bale all the way through with the 18-inch long forage sampling probe. This manner of sampling, going through the stems, leaves, stems, leaves, etc., gives you a more even sampling of the hay. People will take a slice of a bale and send it in for analysis. This results in erroneous data. If the hay is dried to 20%

moisture in the row and then raked when the dew is still on it, the leaf loss will be minimized. This is where the use of proprionic acid the gentlemen asked about earlier is beneficial. The proprionic acid would enable the hay to be baled at 25% moisture and fewer leaves would be lost.

QUESTION: Could you comment on cubed alfalfa hay?

RESPONSE: We have just completed some work on the effect of cubing. A company in the Midwest gave us a piece of cubing equipment they said could cube anything. We tried this on 50% alfalfa/grass and full grass but found you need 100% alfalfa and it has to be very dry to make it work. It has to be down to about 12% moisture and you put just a smattering of water on it when you cube it which enables the cube to hold together. You could bale the hay, put it in the barn, and then as you take it out, put it through the cubing operation. But that certainly adds another cost doing it this way. If you are going to buy good alfalfa cubes, they have got to be made in an area of the country where there is good alfalfa. Our research in Wisconsin shows that we would be better off to bale the hay normally and then use a hydraulic baler which squeezes two bales together forming one 80-100 lb. bale rather than the two 50 lb. bales we presently have.

A problem with this is that if these bales are unloaded anywhere there are labor unions, you will have to use two men to handle an 80-100 lb. bale. We have a regulation on campus that states that one person cannot lift over 50 lbs. which precludes the use of these bales. The positive aspect of squeezed bales is that when you increase the pressure and increase the density to 25 lbs. per cubic foot, as you have with squeezed or cubed hay, you could increase the intake of the same quality of hay. Our data in Wisconsin with the more dense bales, whether it be alfalfa, red clover, or birdsfoot trefoil, all showed the same thing. We had a 15-30% increase in intake with a ruminant animal by having that type of product. We are not quite sure why except that the compression changes the quality or the configuration of the stem enabling the animal to increase his intake. We do have some people who are pelleting hay. Pelleting is another way you can increase the density but you have to be careful when you buy pelleted hay because once it is in that 1/8 to 3/16 inch pellet, you will never find out what went into it. In fact, I know some of it that has been sold out of Wisconsin and shipped to Florida with a guarantee of 13% protein, which is not hard to do. But I also know some of the stuff that goes into it

so I think you do have to be careful. I do not want to scare you at all, but I want to tell you what you might be running into.

COMMENT: In some situations in zoos,hay is used primarily for its occupational value and perhaps to provide some additional fiber rather than to provide an increased level of digestible energy or protein. Therefore, some of your comments may be a little less crucial for using hay in that situation. Moldiness and adequacy of curing may be more of a problem than the maturity of the hay.

RESPONSE: I do realize that consuming hay is an occupation that keeps them busy and is an important one to consider. But I would respond to your comment by asking: with the price of grain, soy bean meal, and the protein feeds that you use, can you not save on your food budget by buying quality hay and adjusting the amount of grain or pelleted feeds and supplements that you feed? You see, this is what the farmer is doing today when the price of corn goes up to $3.80 a bushel and soy bean to $8.50 a bushel. I would begin to look at the quality that I could get out of the hay and say, "I can have my occupation in here but I can also get some of my energy and protein from it. Perhaps I had better do that to cut my budget."

QUESTION: With present equipment and knowledge, is it possible to bale fresh alfalfa and freeze it?

RESPONSE: I would have to say right now it would be an impossibility to do it on a fresh basis because you will never get it out of the bale chamber, it would compact and be virtually impossible to remove. We would like to bale it at 50% if it would keep. I have talked to agricultural engineers from some of the major companies. I do believe there is a possibility of baling hay at 50% moisture with a regular bale, if we can get it to come out of the bale case. We could spray it with a gelatinous material that is digestible by the animal and keep it sealed, as you would have in a silo situation. At the present time that has not been a very practical way of doing it because as you start to shift it around, you may knock a hole in the gelatinous material allowing air to get in. Another way is being attempted by a company in Germany that developed a silo sort of thing we call the sausage maker. If you drive around the country in the summer time, you will begin to see some of these long white sausages made from a plastic material. Alfalfa hay is pushed in from one end, just like we did making meat sausage back on the farm in the thirties. Of course, most of you are not old enough to remember this! It works very well until you get the cats,

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A Conference on the Nutrition of Captive Wild Animals

December 5 and 6, 1980

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The Dr. Scholl Nutrition Conference is sponsored by
the Chicago Park District and The Lincoln Park Zoological Society
through a grant from the Dr. Scholl Foundation.

dogs, and rats in it because they like to chew the plastic. We are presently exploring the possibilities of setting up a haymarket. Hopefully we can get a system established so that we could provide you with the kind of hays that you need.

The item that I think does have some possibility of doing what we want to do and gets completely away from the weather damage is a system that we are working on. The equipment is now in the hands of a commercial machinery company. We will go into an alfalfa field, even on a day when it is cloudy or drizzly like today, cut the alfalfa, chop it, bring it in and squeeze it. You squeeze it to get it down to about 65% moisture. By doing that you take out protein but if you cut this prior to bloom you will end up with a residue that is about 15-16% protein. The protein that is squeezed out will be put in a vat and have a coagulant added to it. The coagulated protein that we remove has a crude protein content of about 45-55%. It has an amino acid balance between milk and meat, which the FAO states is the best balanced plant protein anywhere in the world. The water that comes out contains potash so that it can be put back on the land. We can get just as much production out of the product as we can by feeding the complete alfalfa as we have always done. The benefits

of this system are: 1) you eliminate the consideration of weather damage, 2) you end up with a protein supplement, and 3) you have a product that is of very high quality. We just have to figure out how to get it down to an acceptable dry matter level. But I think that this plan offers more possibilities than does freezing.

QUESTION: Is it not the practice to run hay through a crusher or crimper just after it is cut and before it is baled?

RESPONSE: 95% of the farmers in the State of Wisconsin do that to accelerate the drying. It takes you roughly 30 sunshine hours to dry hay. Now, those of you who live in the Midwest know that the odds of getting three days without rain in June are not very good, about 1 in 4, and so what we found by using the crimper is that we can cut this down from three days to two. We also found that cracking the stem (the legume stem is a hollow stem) we get the moisture out faster and also save more of the leaves. In the end, we do get higher quality hay and we do it mainly because of the fact that we reduce the amount of weather damage that can occur.

GENERAL DISCUSSION

QUESTION: What would be an appropriate diet for a North American porcupine?

RESPONSE: At our zoo we have used alfalfa based rabbit pellets, lab chow, and assorted vegetables and are satisfied with this diet.

RESPONSE: At the National Zoo we have tried going to a pellet a little higher in fiber than what a traditional diet would provide. It was acceptable but we really do not know what level is most appropriate since we have not done any digestion trials.

QUESTION: Is there any information on the best diet for moose? We have contacted Chuck Schwartz in Alaska who has developed a high fiber made from, in part, Aspen sawdust. Barley and other grains are also used in the pellet. He is or has been conducting feeding trials with it.

RESPONSE: At the Metro Toronto Zoo we are presently using a pelleted ruminant ration, 15% protein and 13% fiber. Free choice cattle mineral supplement which provides calcium, phosphorus, and other minerals with Vitamins A and D added, and trace mineral salt blocks are also offered. We have found that alfalfa hay consumption is consistently low, however, the moose do consume hydroponically grown barley and sunflower in addition to their pelleted ration. In the past, we have

manipulated the protein and energy levels; the protein had gone as high as 20% with the use of a concentrate and we had tried increasing the energy level by using barley. We also used to feed browse but discontinued its use about three years ago. We feel that on the present diet the moose can grow and reproduce well.

COMMENT: I would like any information about the best way to hand-raise Bactrian camel.

RESPONSE: We have been successful by using Carnation milk diluted 1:1 with water, or 2:1 dilution.

RESPONSE: At our zoo, we have used Pet milk diluted 1:1 with water for hand-raising our Bactrian camels.

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