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TABLE OF CONTENTS

INTRODUCTION BY LESTER E. FISHER, D.V.M.

I want to extend my thanks and appreciation to all of you for making time to come and participate here in this nutrition conference today on relatively short notice. I think first notes went out during the AAZPA meeting here in Chicago in September. I have felt very strongly that such a gathering would be a good thing to try. I had absolutely no idea especially because of timing if we would end up with ten people or 100. I am happy to report that it looks like we will certainly exceed 100 in total attendance today and that is truly very gratifying to me.

I do not want to do too much historical perspective because some of our speakers may do that, but I do recall my early years at Lincoln Park Zoo. There were times in the past at this zoo and, I am generalizing, at many zoos, when we fed the carnivores only meat, and we fed the bears three day old bread and surprisingly some of the animals did fairly well. Perhaps some of our speakers today will explain why.

We have come a long, long way in a realtively few short years. My personal hope for this meeting today is that not only are we going to hear the assembly of the fine speakers who have agreed to come and talk and share in the program today but that the audience participation is something that I personally hope will develop. In arranging the program and talking to our speakers, we tried to impress upon them that the presentation is part of their time and the other part is to welcome discussion. When we get down to the specifics about nutrition those of you coming here will have some definite questions about perhaps very specific species or individual animals that you have in your care. I would hope that you will have answers to your questions because then I feel your time in coming will have been more worthwhile.

I should like to thank the two committee members who really put in a lot of time: Mary Allen from Brookfield Zoo and Erich Maschgan from Lincoln Park Zoo. They have really spent the hours in contacting speakers, putting together the prgram, and in just getting this in the state it is today. If at the conclusion of this conference it is the consensus that a nutritional gathering such as this does make sense, maybe this would be the first annual and we, at Lincoln Park, would be happy to look forward to hosting another such meeting.

The Dr. Scholl Foundation certainly should be recognized. They are the ones who gave me the basic support money to allow the conference to be held and allowed us to print the preceedings which we hope to share with colleagues throughout the country and throughout the world.

NUTRITIONAL CATARACTS IN TIMBER WOLVES

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Nutritional deficiencies and their association with the development of cataract has been reported in several animals[1-12]. Diets deficient in the amino acid tryptophan have caused cataracts in rats[1-3], guinea pigs[4], and pigs[5]. Diets deficient in phenylalanine and histadine as well as tryptophan can cause lens opacities in rats. This last report claims that a deficiency of any of the essential amino acids except arginine can result in lenticular opacities in rats. Deficiencies of methionine have produced cataracts in rats[7] and in trout[8]. A diet deficient in riboflavin can also produce lens opacities in trout[8] as well as predispose rats to galactose cataracts[9]. Vitamin E deficiency results in cataracts in young rats[11]. Turkey chicks also develop cataracts when the hen's diet is deficient in vitamin E[12]. Our findings suggest that diets deficient in the amino acid arginine can result in cataract formation in young timber wolves.

This study was started five years ago when we were asked to assist a wolf breeder who noted that his pups were blinded by cataracts when they were raised on a commercially prepared canine milk replacement diet[a]. The sire, Ceasar, and the dam, Cleo, which the breeder had purchased as pups, had been raised on this formula and had cataracts. The sire, now 10 years old, had unilateral cataract surgery at six months of age; the dam's cataracts had spontaneously resorbed during her second year. Five pups produced by Ceasar and Cleo prior to this study all had cataracts after being raised on the milk replacement diet. They were started on the diet at nine days of age and kept on the diet for over 30 days. Three of the pups with cataracts were humanely euthanized and sold to a local museum. Their eyes were enucleated and three were fixed in buffered formulin and three in 2.7% glutaraldehyde in phosphate buffer for histologic examination. The cataracts of the two remaining pups had partly cleared by one year of age. These two pups, Germaine and Ivan, were the parents of pups also studied during the fourth and fifth year of this study.

Wolves breed only in the late winter, and the pups are born 63 days later in early spring. Usually four to six pups are born in a litter.

Wolf pups, to be sold as pets or used in exhibits, must be removed from the dam at an early age before the wild instinct is imprinted. It is generally felt that separation must be done before two weeks of age or earlier. Most of the pups in this study were taken from the dam at nine or 10 days, however, one was taken as early as seven days and a few as late as 12 days. The pups were forceweaned, then raised on a commercially prepared milk replacement diet or a diet formulated by the breeder.

FIRST-YEAR STUDY (1974)

Six pups (3M, 3F) were born in the spring of 1974. Three pups (2M, 1F) were left with the mother and three pups were placed on the commercial diet. Those given the commercial formula were weaned at nine days of age and bottle-fed every four hours. When examined at 17 days of age, the pups raised by the bitch had normal, clear lenses (Fig. 1). The three pups given the artificial diet were developing posterior subcapsular opacities. These early changes appeared clinically as tiny vacuoles along the posterior Y sutures (Fig. 2). In two pups the vacuoles around the Y sutures had increased to a butterfly type appearance (Fig. 3). A few days later the anterior subcapsular area was also becoming opaque (Fig. 4A, B). When examined at four weeks of age (2-1/2 weeks on diet), the opacities in the bottle-fed pups were very extensive (Fig. 5) and there was an obvious lack of movement when these pups were placed with their litter mates. We were unable to examine the retinas because of the extensive opacities involving the anterior and posterior subcapsular cortex. The pups were very healthy otherwise and were similar in weight to the litter mates who remained with the dam. The wolves raised with the dam still had clear lenses, however, the pups were more difficult to handle and more nervous than the bottle-fed group. This latter behavior is typical of wolves imprinted with the wild instinct.

The commercial formula was discontinued in two pups (four weeks old) that were then fed a commercial dry dog food[b] diet fortified with animal grade ground beef. This resulted in a remission of their cataracts over the next four weeks. At that time only a mild muclear opacity was observed (Fig. 6). One month later (12 weeks of age) there was only slight evidence of any previous lens opacities in the pups. In one pup this was seen as a zone of increased density in the nucleus (Fig. 7). The cataract persisted in the pup that stayed on the commercial diet; he was humanely euthanized to be used in a museum exhibit. The eyes were removed; one was fixed in glutaraldehyde and one was fixed in buffered formalin for histologic study by light and electron microscopy.

SECOND YEAR STUDY (1975)

Six pups were born in the spring of 1975. This study also included a coyote pup that was fed the commercial diet. All diets were again started when the wolf and coyote pups were nine days old. Three pups were fed the commercial diet, one was fed the commercial diet plus lard, and one received the commercial diet plus vitamin C. The remaining pup was nursed by a lactating German Shepherd dog. Milk samples from the wolf bitch and the German Shephard bitch were collected after both had been lactating for at least one week. These were sent along with a sample of the commercial formula to two private laboratories for biochemical analysis. Blood samples from all pups were sent to the Department of Public Health Laboratory for evidence of galactosemia. All tests were within normal limits. The vitamin C and lard additives were suggested by a representative from the manufacturer of the commercial diet. The lard was used to produce a more normal type of fatty acid in the diet. The commercial formula used a vegetable oil for its fatty acid source. Vitamin C was added, as most animal milk contains higher levels of vitamin C than is contained in the formula. Both these additives were used for lack of any specific direction at this stage.

All pups were examined after being on the diets for one week except for the coyote, which had been on the diet for 10 days. The pups on the commercial diet with and without vitamin C and lard had similar lens opacities involving the anterior and posterior subcapsular areas. These were seen as vacuoles along the posterior Y sutures and in the anterior subcapsular area (Fig. 8). The pup raised by the German Shepherd and the coyote pup had no lens changes. When examined one week later, the opacities in the other pups had progressed to involve much of the anterior and posterior cortices. The coyote and the pup nursing on the German Shephard bitch were still free of lens opacities. The pups were then taken off the commercial diet and were fed dog food mixed with ground beef, as in the first year study. After three weeks, only a mild opacity of the nucleus was noted in the affected pups.

The milk samples were analyzed by two laboratories. One laboratory analyzed the three samples in their wet form (Table 1). The second laboratory compared only the wolf milk and the commercial samples in the dry form (Table II). The main disparity appeared to be in the protein content of the two diets. The wet samples showed less than half the amount of protein in the commercial formula as in wolf milk (5.1:12.6%). Evaluation of the dry samples revealed one third less protein in the commercial formula as in the wolf milk. There was slightly more carbohydrate and fat in the commercial formula than in wolf milk.

THIRD-YEAR STUDY (1976)

Six pups (3M, 3F) were born. This experiment was designed to have three pups on the commercial formula and three pups on the formula plus lactalbumin, a protein supplement high in amino acids. The pups were started on the formula at 12 days of age. When examined at 19 days, all had very mild posterior subcapsular opacities, not unlike those seen previously but not as advanced. It was suggested by the breeder that the formula with the protein supplement be analyzed because it was difficult to keep the protein additive in suspension. Analysis of the two diets (wet) revealed 5% protein in the commercial formula compared to 6% protein in the formula with the protein additive. The lactalbumin had apparently settled to the bottom of the nursing bottle and was not being incorporated into the diets. The lactalbumin was also very unpalatable as compared to the commercial diet alone. Four pups were started on regular diets at 3-1/2 weeks of age, and they experienced total regression of the cataracts. Two pups were given the commercial diet for an additional two weeks. No additional cataracts occurred, and the existing opacities in these two pups moved more centrally. The pups werethen euthanized to be used in a museum project, and their eyes were removed and fixed in glutaraldehyde for electron microscopic study.

FOURTH-YEAR STUDY (1977)

Four pups resulted from a mating between Ceasar and Cleo and one pup from a mating between two of their previous pups, Germaine and Ivan.

Germaine's pup was started on the commercial formula at seven days of age, as her lactation was inadequate. The other four pups were started on various diets at 10 days of age: (1) commercial diet plus corn oil (25% dry weight) and casein (10% dry weight), designed to reduce the amount of lactose by 40%; (2) commercial diet plus 15 gm lactose designed to double the lactose; (3) commercial diet plus 10 gm of casein and one gm of arginine; and (4) commercial diet plus 10 gm of casein and one gm of methionine. Arginine and methionine were used at this time because of their low levels in casein and because there was a considerable disparity between these animo acids in wolf milk and the commercial formula.

When Germaine's pup was examined at 17 days of age (10 days of diet), he had developed prominent lens opacities that were more severe than those normally seen by that stage. He was immediately taken taken off the commercial diet and fed the regular diet previously described. The lenses of the pup received the diet with lactose supplement and those of the pup receiving supplemented arginine were clear. However, the pups on the diet with added corn oil and casein and those on the diet with methionine additive were developing posterior subcapsular cataracts. The diets were continued for an additional two weeks. The lenses of the two pups with clear lenses remained clear, while the lens opacities of the other two progressed slightly. At this stage, all four pups were transferred to commercial dog food with a beef supplement, and remission of the opacities occurred as in previous years. Germaine's pup, which had extensive opacities at 17 days of age, still had significant opacities when examined at six months of age (Fig. 9).

FIFTH-YEAR STUDY (1978)

Nine pups were born in the spring of 1978, five from Cleo and Ceasar and four from Germaine and Ivan. Special diets were given Cleo's pups at nine days and Germaine's pups at 10 days of age. Six different diets were used: (1) commercial diet, old formula manufactured prior to 1976 (one pup); (2) commercial diet, slightly improved formula (one pup); (3) commercial diet plus 10 gm of casein (one pup); (4) commercial diet plus one gm of arginine (two pups); (5) commercial diet plus one gm of tryptophan (two pups); and (6) commercial diet plus 15 gm of lactose (one pup). A diet that was specially prepared to contain all amino acids excpet arginine was lost in the mail when sent to the breeder. That pup was put on diet No. 5 with the tryptophan additive. Biochemical analysis of diet No. 2 revealed a slight increase in the perdentage of lactose from the formula manufactured before 1977.

All pups except the two with arginine and the one pup with lactose supplements developed the typical posterior subcapsular opacities adjacent to the Y sutures when examined seven days after starting the special diets. The diets were continued for seven more days at which time the cataracts were more advanced. The lenses of the three pups that were previously clear remained clear. At this point, the pups were transferred to the regular diet. All lens opacities regressed except in one of the pups that had been given tryptophan supplement. His lenses have stayed opaque at five months of age (Fig. 10), and cataract extraction will be performed in the near future if no evidence of resorption or regression is noted.

PATHOLOGY

Several eyes underwent histopathologic examination at various stages of cataract development.

The initial six eyes that underwent pathological examination were from the wolves uethanized prior to the first year study. These eyes had the most severe cataracts.

Grossly the eyes were normal except for marked pigmentation of the iris and the lens opacification. Microscopically the entire lens showed cataractous changes (Fig. 11). The lens capsule was intact with marked corrigation anteriorly with cystic epithelium beneath the hillocks of the capsule (Fig. 12A). Other areas show duplication of the capsule (Fig. 12B). The cortical stroma contained areas of liquefaction and globule formation (morgagnian globules) with complete loss of normal lens architecture (Fig. 13). The iris and ciliary body from these eyes contained many foci of chronic inflamatory cells. This is probably associated phakolytic uveitis.

The eyes from the pup in the first year study were not quite as severely affected as those described above. Numerous vacuoles were seen in the lens epithelium as well as in cortical fibers (Figs. 14A&B).

In the eyes from the wolves from the third year study only mild changes were noted in cortical fibers. These were seen as intracellar vacuoles (Fig.15).

DISCUSSION

Wolf pups started on the milk replacement diet at an earlier age developed more severe lens opacities than pups started several days later. This was evident in the fourth-year study, when one pup was started on the formula at seven days of age and had advanced opacities compared to pups started at nine or 10 days. The pups started at 12 days had very minimal lesions. This suggests that during the development of the lens there is a critical time at which the lens is more susceptible to nutritional stresses. Another wolf breeder, who weans his pups between 14 and 21 days of age and feeds them the same commercial formula, has not observed cataracts. It is possible that the cataracts were very mild and not notices. In the third-year study, in which the diet was continued for an additional two weeks, no further lens opacities occurred in two pups, which also suggests that the lens fibers at this age were not susceptible to the protein deficiency. In a cooperative study in California (Lipton)[13], pups were taken from the bitch at five days of age. Those fed the commercial diet had dense cataracts when examined at approximately three weeks of age. Four pups in that study raised on goat milk also had dense opacities, while one nursed by a German Shepherd remained free of cataracts.

The type of opacity that begins at the posterior suture lines is typical of the protein deficiency cataract described in other animals. It begins as an intracellular vacuole within the lens fiber, suggesting some nutritional disturbance within the lens fiber. The only amino acid deficiency cataract not shown to begin at the Y sutures resulted from methionine deficiency in rats[7]. The galactose type cataracts described in animals begins at the equator of the lens and is seen as extracellular vacuoles histologically.

The pups raised on commercial diet and lactose did not develop lens opacities. The commercial diet already contains more lactose than wolf milk. It has been theorized that perhaps the lactose acts as a catalyst, assisting in the absorption of arginine. This area needs further investigation. One also might question whether the addition of arginine acts solely in preventing the development of opacities or if its ration to other amino acids is correct so that the improved ratio of certain amino acids is beneficial (example: lysine to arginine). This latter hypothesis has been suggested[14]. Other amino acids, as noted in Tables I and II, are also deficient in the commercial formula, however, it was felt that the addition of casein should have compensated for the lack.

When fed to orphan puppies, the milk replacement formula is not generally meant to be the complete diet beyond two or three weeks of age. Usually at this time a semi-solid diet is prepared so that pups can start lapping on their own. Thus, for the majority of canines, artificial milk replacement is seldom used beyond two or three weeks of age. If the wolf puppies also receive supplement at two weeks of age, chances are the opacities would be minimal.

We have seen sporadic litters of dogs that have been raised on the commercial formula which have had lens opacities similar to those seen in the wolf puppies. We have seen similar opacities in several collie pups raised exclusively on the formula. It is certainly possible that the nutrition in these litters might have been deficient. In a study conducted on Beagle hound puppies raised on the formula from day one to six weeks of age, no lens opacities were seen[14]. However, another study using several litters of newborn puppies, separated half the puppies and left them with the dams while the other half was fed the commercial formula. When examined at weaning age, 60% of the pups fed the commercial diet had some form of a lens opacity whereas those left with the dams were normal[20].

There are many other causes for cataracts in pups such as inheritance, viruses, toxins, drug toxicity, metabolism, and these must be eliminated before nutritional disturbances can be blamed.

Inherited cataracts that are either congenital or that develop early have been reported in several breeds[14-17]. We have seen several litters of pups with congenital cataracts that have been presumed to be from viral infections in utero; however, toxoplasmosis has been confirmed in two of the litters. It has long been known that rats fed high levels of galactose will develop cataracts[10]. Many chemical toxins causing cataracts have been reported, although mostly in association with human drug studies. Disophenol, used for worming young puppies, has been shown to cause transient cataracts[18]. Many cases of congenital cataract can be traced to obvious illness during early pregnancy.

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The authors wish to express their gratitude to Mr. James Reider, owner and operator of Timber Wolf Farm, Incorporated, for his help and cooperation in raising and feeding the wolves used in these experiments. The time and financial commitment he has spent in this study have been extensive. We are also grateful to Dr. James Corbin, University of Illinois, and Dr. Robert Mitzenberg, University of Wisconsin, for their assistance in formulating diets, conducting biochemical tests and consultation. The commercial formula for the experiments was donated by Bordon Co.

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REFERENCES - PRODUCTS

a. Esbilac, Borden Co.

b. Wayne Dog Food

LEGEND OF PHOTOGRAPHS

Fig. 1	Normal lens from 17 day olf wolf. Note remnants of Tunica vasculosa lentus.
Fig. 2	Opacity along the lens posterior Y sutures in 17 day old wolf.
Fig. 3	Vacuoles adjacent to lens posterior Y sutures in 17 day old wolf.
Fig. 4A	Anterior subcapsular opacity of lens in 23 day old wolf.
Fig. 4B	Biomicroscopic photograph of anterior subcapsular opacity (arrow) of wolf lens in Fig. 4A.
Fig. 5	Extensive opacification of lens in four week old wolf.
Fig. 6	Nuclear opacity of lens of eight week old wolf.
Fig. 7	Zone of increased density of nucleus of lens (arrow) in 12 week old wolf.
Fig. 8	Vacuoles in anterior subcapsular area and along posterior Y sutures in 16 day old wolf.
Fig. 9	Opacity of lens nucleus and inner cortex in six month old wolf. Note outer cortex is clear.
Fig. 10	Five month old wolf with bilateral cataracts.
Fig. 11	Histopathology of lens showing severe cataratous changes in six month old wolf pup (x 40).
Fig. 12A	Histopathology of correlations of anterior lens capsule with cystic epithelium below hillocks of capsule. Same lens as Fig. 11 (x 100).
Fig. 12B	Histopathology showing duplication of anterior lenses capsule with cystic epithelium. Same lens as Fig. 11 (x 200).
Fig. 13	Ultrastructure of lens fiber showing numerous vacuoles (morgagnian globule) (x 14,530).
Fig. 14A	Ultrastructure of anterior lens. Note vacuoles in lens epithelium (x 10,000).

Fig. 14B Ultrastructure of lens fibers in posterior subcapsular area. Note large vacuoles in lens fibers (x 10,000).

Fig. 15 Ultrastructure of intracellular vacuoles in lens fibers from mildly affected lens (x 10,800).

TABLE I

ANALYSIS OF MILK SAMPLES (WET)

	Esbilac	Wolf	Canine
Galactose	0.300	0.120	0.210
Lactose	2.600	1.800	2.460
Glucose	0.010	ND	ND
Ash	0.830	1.650	1.200
Phosphorus	0.110	0.276	0.190
Potassium	0.148	0.178	0.109
Sodium	0.071	0.062	0.088
Calcium	0.149	0.418	0.278
Manganese	0.010	0.018	0.010

	Esbilac	Wolf	Canine
Protein	5.100	12.600	10.700
Amino Acid Analyzer (mg/g as is)			
Lysine	2.810	5.490	4.320
Histidine	0.937	3.550	3.080
Ammonia	0.694	2.560	2.030
Arginine	1.240	7.340	5.510
Aspartic	3.040	11.200	7.860
Threonine	1.820	4.840	4.080
Serine	2.210	5.500	4.390
Glutamic	8.940	27.300	21.900
Proline	4.150	13.600	11.400
Glycine	0.696	0.922	0.795
Alanine	1.380	4.920	4.010
Cystine	NC	NC	NC
Valine	2.890	7.030	5.360
Methionine	0.316	2.650	2.500
Isoluecine	1.950	5.790	4.810
Leucine	3.920	17.100	14.000
Tyrosine	2.020	4.560	3.750
Phenylalanine	1.890	5.640	4.470
Tryptophan	0.969	2.010	2.400

ND - None detected
NC - Non calculable

TABLE II

ANALYSIS OF WOLF'S MILK AND ESBILAC POWDER

	Wolf's Milk			Esbilac Powder	
	As is Liquid	As is Dried	% of Protein	As is Powder	% of Protein
Solids	24.360	100.0000	-	98.700	-
Protein, %	12.540	51.5000	-	36.300	-
Fat, %	7.090	29.1000	-	43.160	-
Ash, %	1.610	6.6000	-	5.250	-
Carbohydrates, % (Calculated by difference)	3.120	12.8000	-	15.300	-

ANALYSIS OF WOLF'S MILK AND ESBILAC POWDER

	Wolf's Milk			Esbilac Powder	
	As is Liquid	As is Dried	% of Protein	As is Powder	% of Protein
Amonia, %	0.129	0.5310	1.03	0.288	0.79
Lysine, %	0.509	2.0900	4.06	2.480	6.83
Histidine, %	0.390	1.6000	3.11	0.920	2.53
Arginine, %	0.624	2.5600	4.97	1.150	3.17
Aspartic, %	0.965	3.9600	7.69	2.450	6.75
Threnonine, %	0.429	1.7600	3.42	1.400	3.86
Serine, %	0.460	1.8900	3.67	1.710	4.71
Glutamic, %	2.326	9.5500	18.54	7.080	19.50
Proline, %	1.208	4.9600	9.63	3.380	9.31
Glycine, %	0.086	0.3540	0.69	0.579	1.60
Alanine, %	0.451	1.8500	3.59	1.090	3.00
Cystine, %	NC	NC	NC	NC	NC
Valine, %	0.643	2.6400	5.13	2.070	5.70
Methionine, %	0.285	1.1700	2.27	0.850	2.34
Methionine, %	0.283	1.1600	2.25	1.010	2.78
Isoleucine, %	0.541	2.2200	4.31	1.580	4.35
Leucine, %	1.620	6.6500	12.91	3.360	9.26
Tyrosine, %	0.384	1.5800	3.07	1.530	4.21
Phenylalanine, %	0.565	2.3200	4.50	1.740	4.79
Tryptophan, %	0.130	0.5320	1.03	0.497	1.37
Taurine, %	0.018	0.0738	0.14	NC	NC

NC - Non calculable

SAMUEL J. VAINISI, D.V.M. QUESTIONS AND COMMENTS

QUESTION: Could you tell us when you got those samples, at what stage of lactation were they taken?

RESPONSE: They were taken at about seven days.

QUESTION: In both the wolf and the dog?

RESPONSE: Yes, in both the wolf and the dog. It was not colostrum that was taken.

QUESTION: Certainly the amino acid composition would be very much affected by stage of lactation in terms of the relative proportion of protein in the milk?

RESPONSE: Referring to Table II, it is shown that the protein level was 51% as a dry weight compared to 35% as a powder. Everything else is basically identical.

QUESTION: What is the fat level?

RESPONSE: In a year that I did not include, we did add lard to the diet because it was suggested by Dr. Monson that lard would be a more typical animal-type fat. We added that as bulk and it did not seem to make a difference. We also added Vitamin C. The first year we added a couple of things. For just lack of direction, we added a few things that might have made a difference. The fat content in the wolves' milk was 29% and the Esbilac was 43%, that's based on dry weight.

QUESTION: How large were your samples?

RESPONSE: We had quite a bit - almost two ounces.

COMMENT: My impression from viewing the canid milks, is that I do not think there is much difference in composition from one milk to another. I would suggest that at least some of the differences you are seeing are sampling problems. There really are not any good data on wolves' milk, but what I have seen suggests to me that there really is not much difference. I would really question whether you got representative samples. I would like to see more data on the composition of wolves' milk to show that there is, in fact, a consistent difference.

RESPONSE: Referring to Table I, there is really not that much difference between the wolf and the canid.

COMMENT: Refer to the next Table where you show amino acid levels.

RESPONSE: There is really not much there.

COMMENT: Look at the arginine, in the wolf it is 7.3 and in the dog it is 5.5.

RESPONSE: That is not really a big difference.

COMMENT: Other reports that I have seen on dog's milk suggests that arginine levels are higher than that, closer to the values for the wolf and I cannot understand that the Esbilac is different in its protein level.

RESPONSE: If you ask the gentlemen right behind you, he'll confirm that it is, indeed, only 5%.

Dr. Monson: Yes, that is correct on a wet weight basis. It is 15% of solids. It analyzes right around 5% as you have indicated - 5.1% protein. And one of the things that we have talked about is the fact that any formula is based on the protein in cow's milk and we are talking about nonruminant milk which is something else again and something we really have not addressed ourselves to. There is a difference. If you look at the composition of ruminant vs. nonruminant milk, particularly in regard to arginine and lysine, ruminant milk generally has almost a two to one ratio of excess lysine over arginine. Whereas in nonruminant milk generally they are closer to one to one.

RESPONSE: When Borden manufactures this product they do not advertise it for use in other than canine animals since there are a lot of problems in that area (canine).

COMMENT: But this is 5% on a wet weight basis out of 15% total solids. You are running around 35% protein which is the same thing you see in dog's milk on a dry weight basis.

RESPONSE: Is that correct? I'm not sure.

COMMENT: My data suggest this.

RESPONSE: I cannot dispute that since it is out of my area.

COMMENT: The other thing that is interesting here is that I have data on the protein consumption of suckling puppies and what is peculiar is that when estimates are calculated of what the puppies are thought to need in terms of protein, these figures are much lower than what the actual consumption data revealed. In other words, the puppies are consuming a rather high level of amino acids relative to what we would expect their requirements to be. Now of course the nutrient requirements of the puppy have not been studied in any great depth particularly with regard to amino acid requirements. Amino acid requirements, even of something like the cat, have not been well studied, so you are dealing then with an area that is really open to further investigation.

RESPONSE: I would like to just make an open plea with regard to tigers that we have raised on Esbilac and the orphan product KMR, we see cataracts developing in Siberian Tigers and also in Bengal Tigers and the odd thing about that particular cataract is that it is often unilateral not a bilateral problem. You would expect it to be bilateral. I would like to ask anyone who has a big cat if some milk could be taken and sent to me. I would be most happy to have it here. I would also like to study that cataract because there is a possibility that there is a nutritional component involved here.

QUESTION: It has been many years now but I think Detroit was one of the first zoos that was concerned about the diet of the Siberian Tiger and at that time, this is of course not my field at all so I cannot be specific, but at that time it was suggested that the problem with Siberian Tigers was a phosphorus/calcium problem.

RESPONSE: We did surgery on several litters from a sire and dam that were perfectly normal and we always had one to three cubs that were involved with cataracts. We thought we were dealing with a recessive gene. The thing that puzzled us about them is that sometimes we had a unilateral cataract, we would have one eye only and that is not typical of any kind of an inherited cataract and certainly should not be nutritional either. So I think there is something going on that will need much further investigation.

QUESTION: Why does there seem to be a disparity between the wolf and the domestic canine as far as the percentage of animals that develop nutritional cataracts?

RESPONSE: I cannot answer that question. I am puzzled by the fact that the coyote that we also had on the diet, the artificial formula, did just fine and did not develop cataracts. I really do not know, maybe someone else may care to speculate on it.

THE RATCLIFFE DIETS AT THE PHILADELPHIA ZOO
A HISTORICAL PERSPECTIVE

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INTRODUCTION

The maintenance of wild animals in captivity is a complex problem presenting many formidable challenges, not the least of which is proper nutrition. All zoos have had to wrestle with the problems of providing adequate foods to meet the needs of a diverse collection as well as meet the requirements not only for maintenance but also for growth, reproduction, lactation and aging.

THE ZOO'S FOUNDING

The Zoological Society of Philadelphia received its charter from the State of Pennsylvania in 1859. Fifteen years later, on July 1, 1874, the Philadelphia Zoo formally opened its gates to the public. Patterned somewhat after the Zoological Society of London, the Board of Directors of the Zoological Society of Philadelphia clearly stated"that the scientific purposes of the Society shall be carefully regarded".

The Philadelphia Zoo's first research scientist was Professor Henry C. Chapman, M.D., from Jefferson Medical College (now Thomas Jefferson University). Professor Chapman served as the Zoo's first prosector (pathologist). His first report, covering the period from January 1875 to May 1876, listed the causes of death for 113 animals. Concluding his report, Professor Chapman made the following observations: "My experience as Prosector to the Zoological Society convinced me that during the first six months of the existence of the Garden, the principal causes of death were three: 1st, Improper food, both in quantity and quality; 2nd, effects of temperature; 3rd, ill constructed cages, wanting in sufficient space and deficient in necessary appurtenances, such as water to bathe in, trees to climb, soil to burrow in, etc., according to the nature of the animal".

THE PENROSE RESEARCH LABORATORY

The new Zoo in Philadelphia attracted the interest of scientists from many of the local Medical Schools. In the early days, much of the actual technical work was done in the laboratories of the various hospitals. Realizing the potential of the Zoo as a scientific institution, the Penrose Research Laboratory was established in 1901 and formally opened for work on February 11, 1905. The Laboratory was named for Charles Bingham Penrose, M.D., Ph.D., Professor of Obstetrics and Gynecology at the Medical School of the University of Pennsylvania. Dr. Penrose served as President of the Zoological Society of Philadelphia from 1909-1925.

The Philadelphia Zoological Garden and the Penrose Research Laboratory has made many contributions to the art and science of captive animal management. Among these contributions has been the development of scientifically formulated diets.

FORMULATION OF ZOO DIETS

For many years the Penrose pathologists had been acutely aware that malnutrition stemming from inadequate diets was the cause of a complex disease pattern among the Zoo's mammals and birds. In 1923, Dr. Herbert Fox published his now classic book "Diseases in Captive Wild Mammals and Birds" which was based upon the accumulated records of almost 6,000 autopsies. In his book Fox states that "captivity causes numerous physical and mental disorders; unaccustomed, unnatural and unvaried foods, amongst other things, react harmfully on captive animals. Gastrointestinal disease is the commonest disease of wild animals in captivity".

In 1929, Herbert L. Ratcliffe joined the Penrose Laboratory as Herbert Fox's assistant. Joined by Dr. Ellen Corson-White, Herb Ratcliffe set out to formulate zoo diets for all birds and mammals in the Zoo's collection, The most talked-about product of the above effort was "monkey-cake" (zoo-cake) - an uncooked composite ration containing minerals and vitamins. This ration was so well formulated that it remains essentially unchanged today. All of the controlled diets formulated by Ratcliffe between 1930-1935 have been used continuously and almost exclusively up to the present time.

In reporting on the development and success of the diets he formulated, Ratcliffe states, "My aim has been to design diets at reasonable costs that are readily acceptable, that prevent nutritional disease, and that allow animals to develop and maintain high levels of resistance to many of the common agents of disease. Current knowledge of nutrition indicates that this may be accomplished by a number of equally satisfactory formulations".

The statistical analysis compiled during the five year period immediately following the diet changes implemented by Ratcliffe revealed that life expectancy of mammals had increased dramatically. A similar analysis of the avian records shows that a corresponding significant increase in longevity was noted after diet changes for this class of animal. In both instances the only environmental change during the period was in diet.

CURRENT DIET FORMULATIONS

The original diet formulae have been published elsewhere. The following is a list of diets, their formulae and composition by weight currently in use by the Philadelphia Zoological Garden. You will note that the present diets differ little from the original formulations.

Diet A: A Diet for Omnivorous Animals (Zoo Cake)

Material	Weight
Ground yellow corn	15 lb.
Ground whole wheat	15 lb.
Ground whole barley	10 lb.
Ground rolled oats	10 lb.
Cottonseed flour	10 lb.
Soybean meal	10 lb.
Alfalfa leaf meal	5 lb.
Brewer's yeast	10 lb.
Skim milk power	10 lb.
Oystershell flour	2 lb.
Iodized salt	1 lb.
Chicken parts	10 lb.
Proflo oil (cottonseed)	8 lb.
Total dry mixture	116 lbs.
Water	33 lb.
Total zoo cake	149 lb.

Diet A-1 (Marmoset Mixture): A Diet for Debilitated Monkeys, etc.

Material	Weight
Gerbers mixed cereal	62 lb.
Whole milk powder	35 lb.
Wheat germ	2 lb.
Gevral protein	1 lb.
	100 lbs.

Diet A-2 (Regular): A Diet for Caged Birds

Material	Weight
Diet A dry mix	50 lb.
Chicken slurry	20 lb.
Ground hard boiled eggs with shells	8 lb.
A & D feeding oil	2 lb.
	80 lbs.

Diet A-3: A Diet for Flamingo (Coarse)

Material	Weight
Diet A dry mix	18 lb.
Chicken slurry	2 lb.
Roxanthin-red dye	
	20 lbs.

Diet A-3: A Diet for Flamingo (Fine)

Material	Weight
Diet A mix	16 lb.
Mixed cereal	16
Alfalfa meal	6
Skim milk power	6
Chicken slurry	4
Brewers yeast	6 oz.
A & D oil	4 oz.
Salt	1.5

Diet A-4: A Pellet Ration for Ducks and Geese (Breeding Season)

Material	Weight
Ground yellow corn	30 lb.
Ground whole wheat	15
Ground whole barley	10
Ground rolled oats	10
Soybean meal (45% protein)	10
Fish meal (60% protein)	75
Alfalfa leaf meal	5
Brewers yeast (40% protein)	3.75
Cottonseed oil	3
Oystershell flour	5
Iodized salt	.50
DL-methiomine	.20
Copper sulphate	.02
Zinc carbonate	.01
Manganese sulfate (FG)	.02
	Vitamins
Stabilized vit A- usp units	4000/lb.
D-activated animal sterol-ICU	500/lb.
Vit E supplement IU	10/lb.

Diet B: Hervivore Diet

Material	Weight
Alfalfa leaf meal	26 lb.
Ground yellow corn	15 lb.
Brewer's grain	10 lb.
Linseed meal	10 lb.
Ground whole wheat	10 lb.
Ground whole oats	10 lb.
Soybean meal	10 lb.
Brewer's yeast	5.2 lb.
Iodized salt	1 lb.
Oystershell flour	2.5 lb.
Vitamins and trace miners	1.2 lb.
Beet pump	100 lb.
Water	100 lb.
	300.9 lb.

Diet C: A Diet for Carnivorous Animals

Mineral Mix (For use in supplementing meat diets)

Material	Weight
Oystershell flour	50 lb.
Skim milk powder	45 lb.
Iodized salt	5 lb.
	100 lb.

Chicken Slurry (For Small Felids)

Material	Weight
Chicken	86 lb.
Mineral Mix	12 lb.
A & D feeding oil	2 lb.
	100 lb.

Horsemeat (For Large Felids)

Material	Weight
Raw (ground) horsemeat	86 lb.
Mineral mix	12 lb.
A & D feeding oil	2 lb.
	100 lb.

Gelatin Mix (Used in suspending the diet for aquatic reptiles)

Material	Weight
Diet C	7 lb. 6 oz.
Gelatin mix	10 oz.
Water	32 oz.
	20 lbs.

Diet D: For Anteaters and Aardvarks

Material	Weight
Diet A-1	1 cup
Fine ground horsemeat	3/4 lb.
Soft boiled eggs	2
Peanut oil	2 tsp.
Gevral Protein	1 lbls.
Mineral Mix	1 tsp.

Make soupy mixture with water.
Prepare and use immediately.

Diet F: Diet for young (baby) elephants

Material	Weight
Diet A-1	120 gm. - 4 oz.
Pablum	120 gm. - 4 oz.
Rolled Oats	120 gm. - 4 oz.
Raisins	120 gm. - 4 oz.
Karo Syrup	90 gm. - 4 oz.
Bananas	3 med. size and ripe

Diet H: Diet for Vampire Bats

Material	Weight
Cows blood	50 cc.
ADC Vitamin drops	2 dps.

Diet I: Diet for Fruit Bats

Mix Diet A and Diet C; add chopped orange, apple, banana, grape and carrot.

Diet J: Hummingbirds

Material	Weight
Gevral Protein	14 tsp.
Organic Ambrosia Base	1/2 tsp.
Vi Penta	20 drops
Sugar	2 cups
Water	9 cups

Diet K: Elephant Shrews

Material	Weight
Fine ground horsemeat	1 tbs.
Powdered milk	1 tsp.
Evaporated skim milk	1 tbs.
Genral Protein	1 tbs.
Grated hard boiled egg	1/4
Grated carrot	2 tsp.
Apple grated	2 tsp.

Those interested in using the above diets in their own institution may wish to obtain the Directions for Preparation of each diet and Feeding Instructions from the Director of the Penrose Laboratory, Philadelphia Zoological Garden.

In addition to the food items included in the above diets, a variety of materials are available for supplementing rations (Table 1). Among the supplements available are cuttings from certain trees and shrubs on the Zoo grounds (Table 2).

CONCLUDING REMARKS

The search for adequate, nutritious, yet practical diets for captive zoo animals has been the subject of investigation for a long time. In this era of rapidly changing status of fauna in the natural world it is imperative that we apply the best that nutritional sciences have to offer in order to maintain our captive wild stock and indeed provide the essential ingredience for captive reproduction.

The early investigators at the Penrose Research Laboratory pioneered the work leading to the eventual scientific formulation of diets for captive mammals, birds and reptiles by Dr. Herbert L. Ratcliffe. Despite some early criticism of these diets -- especially from Dr. H. Hediger -- they have served us well and continue to be the basis for our animal feeding program. The program continues to be reviewed and refined by the present Director of the Penrose Research Laboratory. Dr. Robert L. Snyder.

It is somewhat ironic that on this occasion when I've reviewed the developments of the now historic Ratcliffe Zoo Diets, that I must report that Herbert L. Ratcliffe died on November 1, 1980. He had an illustrious career. Those of us who knew him well miss him. All of us in the Zoo business will forever be indebted to him and his accomplishments.

ACKNOWLEDGEMENTS

I wish to thank Mr. Richard Simons for taking the photographs used in the oral presentation and to Mrs. Dolores Graff for typing the manuscript.

TABLE 1

SUPPLEMENTS - The following items will be available for supplementing rations.

1. Oranges
2. Carrots
3. Kale and cabbage
4. Escarole
5. Celery
6. Alfalfa Hay
7. Timothy Hay
8. Alfalfa pellets
9. Fish
10. Suet
11. Bird seed - Moroccan Canary Seed
12. Fruit flys
13. Salt and mineral blocks
14. Turkey laying mash pellets
15. Gevral protein
16. Mice
17. Bananas
18. Eggs
19. Crickets
20. Mealworms
21. Rolled Oats
22. Wheat
23. Cracked Corn
24. Sunflower seed
25. Puffed wheat
26. Day old chicks
27. Rats
28. Chickens
29. Corn grubs
30. Romaine lettuce
31. Apples
32. String beans
33. Fruit cocktail
34. White potatoes
35. Sweet potatoes
36. Dog Food Kibbles
37. Alpo horse meat
38. Cut browse from certain trees and shrubs

TABLE 2

List of Shrubs and Trees Cut for Browse at the Philadelphia Zoo

1. Alder (Alnus sp.)
2. Beech (Fagus sp.)
3. Birch (Betula sp.) only in spring
4. Bush Honeyscukle (Lonicera sp.)
5. Butterfly Fush (Buddleia sp.)
6. Cottoneaster (Cottoneaster sp.) in winter
7. Dogwood (Cornus sp.)
8. Elaeagnus (Elaeagnus sp.) in winter
9. Elm (Ulmus sp.)
10. Firethorn (Pyracantha sp.) in winter
11. Forsythia (Forsythia sp.)
12. Hackberry (Celtis sp.)
13. Hazelnut (Corylus sp.)
14. Ilex (Ilex sp.) in winter
15. Japanese Pagoda Tree (Sophora japonica)
16. Jasmine (Jasminum sp.)
17. Kentucky Coffee Tree (Gymnocladus dioica)
18. Kerria (Kerria sp.)
19. Linden, Basswood (Tilia sp.)
20. Mahonia (Mahonia sp.) in winter
21. Maple (Acer sp.)
22. Mock Orange (Philadelphus sp.)
23. Mulberry (Morus sp.)
24. Oak (Quercus sp.)
25. Popular, Cottonwood, Aspen (Populus sp.)
26. Privet (Ligustrum sp.) in winter
27. Prunus (Prunus sp.)
28. Raspberry, Blackberry (Rubus sp.)
29. Robinia (Robinia sp.)
30. Rose (Rosa sp.)
31. Snowberry (Symphoricarpas sp.)
32. Wisteria (Wisteria sp.)

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WILBUR B. AMAND, V.M.D. QUESTIONS AND COMMENTS

QUESTION: Is there chicken in the zoo cake, is it cooked, and do you worry about salmonella?

RESPONSE: There is chicken present as part of parboiled mixture. We have not had a salmonella problem as much as we originally worried about the toxo problem when they were still using meats which were not necessarily cooked as well as they might have been - this was back in the '60s.

QUESTION: What is the shelf-life of this product?

RESPONSE: We only make up enough to last 48 hours. They are made up and left to refrigerate for 24 hours and are fed. Nothing is kept beyond that. As a result, I do not know what the actual shelf-life would be beyond 48 hours.

QUESTION: Have you done a trace mineral analysis?

RESPONSE: No we have not. All the diets are under the control of the Penrose Labs. Robert Snyder, the Director there, is responsible for the formulation of the diets. He sets the proportions of the materials in the diet and decides if substitutions should be made. The actual amounts fed are the responsibility of the Curator. He is the one who sees the animals from day-to-day and can see a waxing or waning situation and whether less or more should be fed. In other words, the proportions stay the same but total amounts can vary. I do not think we have sacrificed quality for economy, but it is the responsibility of the laboratory to review that.

QUESTION: You mentioned longevity, what about breeding success?

RESPONSE: That is a very good question and it is one that I argued with when I first came there. I thought I had walked into a geriatric ward there were so many old animals. For instance, Massa has never produced in his life. Of course, that is not necessarily his fault as he was actually purchased as a female. No one would have dared to have told this story 20 years ago because you probably would have been hung. He was brought in as a female and he was to go into with Bamboo, a known male. I must admit it is not always that easy to tell the sex of an adult Gorilla if you do not have your hands on them at the right place, at the right time. But anyway, he was brought in as a female and after he was there for a while they put Massa in with Bamboo (I don't know why they called it Massa if he was supposed to be a female) and Bamboo nearly killed him. If they had not gotten them apart, I am sure he would have been killed. The Curator at that time could not figure out why there was this reluctance to get these two together, so I guess that after a couple of stiff drinks they tried it again. The same thing happened and I guess it was not until several years later that they finally recognized that Massa was not a she, but a he, and he was never really given a chance. There were no other females that were brought in of appropriate age. However, we do have other gorillas on the diet that he is on and they are producing. I cannot say that the diets they have been on in the last ten years are exactly as they were when zoo cake was begun back in 1935-1940. I do think that of themselves they are maintenance type diets. I do not believe they are necessarily a diet for growth from infants on up and I believe that one would have to be cautious of their pure and simple use if he was going to maximize reproduction. These zoo cake diets have an average protein content of about 16%. When you are maintaining a collection with a lot of older animals and developing the types of degenerative organ disease problems commonly encountered, e.g., kidney disease, one has to take into account the controversy of whether or not a lowering of the protein content would be advisable. These are things we are looking into at this time.

QUESTION: Ratcliffe has published that he noted a significant drop in the mortality rate among the bird collection. A critique of this statement was that the whole nature of the bird collection changed at that time, e.g. more longer lived species were added to the collection. I wonder if you have an historical comment on that?

RESPONSE: Yes, in all due respect to Dr. Ratcliffe and his successors and predecessors on this, I think the facts were manipulated a little bit, not necessarily to sell a product but to sell a concept or philosophy. Still I think the concept/philosophy was good. I think what he had attempted to do was right at the time. But as you well know, you can sometimes manipulate figures to give a desired effect. It was also very clear that arteriosclerosis became much more of a problem after the diets went into effect than it had ever been at any previous time. Dr. Ratcliffe believed that since more animals were living longer and there were larger groups that arteriosclerosis was not a disease of diet but a disease of social pressure and social interaction. Changes were made, antibiotics were used, other things happened but I believe if you give it a fair shake you would have to agree that the dietary quality and refinement was also part of that whole program.

ESTABLISHING THE NUTRIENT REQUIREMENTS OF EXOTIC ANIMALS

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The following studies of nutrient requirements and the development of dietary guidelines for captive wild animals began with the white-tailed deer. This is a major game species in Michigan where white-tails live near the northern limits of their natural range. During the winter, their existence is precarious, and many do not survive. Death may come because food is short, snow is deep, and severe weather lasts too long for body fat to sustain them. To the extent that the deer population and their natural food supply can be managed, the Michigan Department of Natural Resources, Wildlife Division, attempts to keep these two factors in optimum balance. To provide a scientific basis for this management, studies have been conducted at the Houghton Lake Wildlife Research Station since 1959. Over one hundred deer are available for investigations of their physiology and nutrient needs and to permit study of food plants consumed by deer in the wild. This research has resulted in determination of the digestibility of white cedar fronds, aspen shoots, and jackpine and balsam browse (Ullrey et al. 1964, Ullrey et al. 1967a, Ullrey et al. 1968, Ullrey et al. 1971, Ullrey et al. 1972). Dietary requirements for digestible and metabolizable energy (Ullrey et al. 1969, 1970), crude protein (Ullrey et al. 1967b), calcium (Ullrey et al. 1973) and phosphorus (Ullrey et al. 1975) have been determined. Studies of the need for vitamin A (Youatt et al. 1976), vitamin E and selenium (Brady et al. 1978), and of basic physiological parameters (Youatt et al. 1965, Johnson et al. 1968) have also been conducted. Ultimately, a complete pelleted diet was developed (Ullrey et al. 1971) which served as a convenient base for nutrition research and which supported all phases of the deer life cycle. Composition of the current formula is shown in Table 1.

Subsequently, this diet has been adapted for the feeding of other wild ruminants in zoological parks. While specific data are not available on the quantitative nutrient needs of such apparently different species as bison and giraffe, they have the common advantage of a ruminoreticulum inhabited by microbial symbionts which ferment cellulose and hemicellulose and synthesize amino acids, vitamin K and B-vitamins. Thus, bison and giraffe probably have identical qualitative nutrient needs even though their dietary habits are distinctly different. If one formulates a diet which fulfills the quantitative nutrient requirements of the most demanding period in the life cycle of the most demanding species, the nutrient needs of all species can be met. This approach minimizes problems of diet identification, storage and errors in feeding. The unit price for a large order of a single diet is usually less than for smaller orders of several diets. Ad libitum feeding makes the diet available 24 hours a day so that all animals have maximum opportunity to meet their nutrient needs. This is particularly beneficial to small or timid animals that do not compete effectively with dominant pen-mates when feed in available for only a limited time. Species or animals that become overweight on an ad libitum regimen must be fed controlled amounts of this diet or some of the diet must be replaced by forage.

The problem is greatest with older animals which are non-productive, closely confined and members of quiet species such as eland.

Reproduction and lactation performance on this diet has been determined in a controlled study. Forty-eight white-tailed does were exposed to bucks (6 does to one buck) from November 1 to January 31. At least 94% of the does conceived and 90% gave birth to live fawns (1.74 fawns/doe). Of the live fawns born, 95% lived to at least 90 days of age. All but 9 of these were weighed near the time of weaning at an average age of 120 days. Their average daily gain ($\pm$SE) from birth was 0.18 ± 0.004 kg.

Despite the apparent similarity in gastrointestinal morphology among the 142 species of ruminants, Hofmann (1973) has noted that there are appreciable differences in natural dietary habits. Thus, there is continuing concern whether diets for captive wild animals should be formulated more specifically for individual species. Investigation of protein needs of weaned aoudads demonstrated that requirements did not exceed 14% of the dry diet (Brady and Ullrey 1975) and were not different from the needs of white-tailed deer. Thus, for this particular requirement of the aoudad, the white-tailed deer was a satisfactory model.

Nevertheless, one might anticipate that different ruminants, because of differences in relative ruminoreticular volume and digesta passage rate would digest the same diet with different efficiencies. For this reason, Ullrey et al. (1981a) explored the ability of a number of zoo herbivores to digest alfalfa hay, sudan grass hay and oat hay harvested in the early dough stage. If alfalfa hay were fed to an animal as a part of its regular diet, alfalfa hay was fed to that animal during the study. Similarly, with sudan grass. The one exception involved Arabian oryx to which both alfalfa and oat hay were fed at different times, while Arabian oryx were regularly fed oat hay.

The other ruminants fed alfalfa hay included addax, banteng, baringo giraffe, bongo, dorcas gazelle, fringe-eared oryx and gaur. Ruminants fed sudan grass hay included West Caucasian tur and plains bison. Monogastric herbivores fed alfalfa hay included onager and Przewalski's horse. Those fed sudan hay included African and Asian elephants, black and white rhinoceros.

Apparent digestibilities were determined using acid lignin as an internal indicator and determining the change in ratio between nutrients and acid lignin in the feces as compared to the diet (Schneider and Flatt 1975).

Addax, banteng, bongo, gaur and giraffe consumed alfalfa hay of approximately the same composition, and analyses and apparent digestibility estimates are presented in Table 2. Dorcas gazelle were offered alfalfa hay of the same composition but consumed only the leaves. Data for this species are also shown in Table 2. While statistical analyses are not yet complete, addax appeared to more efficiently digest dietary gross energy and crude protein than the other ruminants studied. Although dorcas gazelle were highly selective in their food habits, the digestibility of alfalfa leaves by this species was not greater than digestibility of the entire plant by the other ruminants. Never-the-less, the greater concentration of crude protein in the alfalfa leaves, with equal digestibility, would provide an opportuntity for greater digestible protein intake by dorcas gazelle per unit of metabolic body size.

Data on composition and apparent digestibility of hay consumed by Przewalski's horse, onager, fringe-eared oryx and Arabian oryx are presented in Table 3. Because the Przewalski's horse and onager consumed soil, it was not possible to estimate digestibility of the carbohydrate fractions of the forage (since soil in the feces interfered with dry matter, fiber and ash determination). However, comparisons between these monogastric herbivores and the two ruminant species were possible concerning digestibility of gross energy and crude protein in alfalfa. While there was a tendency for the ruminants to be slightly more efficient, the digestibility advantage over the equidae was small. When Arabian oryx were fed oat hay as compared to alfalfa hay, digestibility of gross energy was somewhat reduced and of crude protein, markedly reduced. Since the crude protein concentration of oat hay was so low, digestible protein concentration was less than 2 percent -- a value unlikely to sustain nitrogen balance without supplementation.

Composition and apparent digestibility of sudan grass hay for West Caucasian tur, plains bison, Asian and African elephant, black rhinoceros and white rhinoceros are shown in Table 4. The plains bison consumed soil, and so data on carbohydrate digestion are not available for that species. The monogastric herbivores were markedly less efficient in digesting gross energy and crude protein than the ruminants, when offered the same forage. White rhinoceros fed sudan grass hay, containing appreciably less acid detergent fiber than that fed black rhinoceros, were much more effective in digesting that forage. It isn't clear whether this difference is a function of the difference in composition of the two sudan grass hays, or whether these two species of rhinoceros are truly different in digestive efficiency.

It is apparent that sudan grass hay is less well digested than alfalfa hay, whether consumed by ruminants or monogastric herbivores. With respect to these two animal types, differences in their ability to digest forages were much greater for sudan grass hay than for alfalfa -- presumably a reflection, in part, of the higher concentration of neutral detergent fiber and acid detergent fiber in sudan grass, and the more limited opportunity for digestion of cell wall constituents by intestinal microorganisms in monogastric herbivores.

Birds pose a major feeding problem in the zoo. Dietary habits vary from those that are seed eaters, much like domestic poultry, to those that are carnivorous or others that subsist largely on fruit or nectar. We have been able to conduct nutritional studies with only a few. A waterfowl breeder diet (Table 5) has been developed which has proved suitable for a number of wild species, and resulted in the production of viable trumpeter swans. More extensive work has been done with rhea and ostriches. Leg development in the young is particularly critical, and exercise as well as an appropriate diet is important. These species consume considerable amounts of plant fiber in the wild, and the ratite diets (Table 6) which have been successful contain much more fiber than is typical for domestic turkey diets which these birds remotely resemble.

When the Detroit Zoo constructed their penguinarium and stocked it with penguins captured in Antarctica, our staff was asked to assist in developing a dietary supplement that could be used with frozen Pacific herring to ensure adequate nutrient intake even when the basic fish diet had been stored for long periods of time. Others had developed similar supplements, but their composition and merits have not been tested. The same is true for the supplement (Table 7) which we have developed, and we do not know whether it is really needed. The amount used varies with species of penguin and the feeding schedule is shown in Table 8.

Reptiles also have unique dietary needs, and little research has been done to define either qualitative or quantitative nutrient requirements. Our laboratory has developed a freeze-dried diet (Table 9) which has been used to study the calcium and vitamin A requirements of the red-eared slider turtle. Certain modifications can be made which will permit nutrient adjustments that allow for tritration of nutrient need. Currently a new experimental turtle diet is under development, patterned after the work of Sergio Oyarzun at the Toronto Zoo. It uses unflavored gelatin to produce a soft-moist consistency that seems very acceptable to this species.

A purified diet can be used for studies with snakes if they are fed by stomach tube. The formula shown in Table 10 has been successfully used for boa constrictors, bull snakes and garter snakes. This has permitted research on the need for dietary choline (boa constrictors do), ascorbic acid (garter snakes don't) and on the ability to convert tryptophan to niacin (bull snakes can).

Carnivorous mammals in the zoo have been plagued in the past by rickets and osteomalacia due to the feeding of unsupplemented muscle meat. Introduction of complete ground, frozen diets has improved the nourishment of these species significantly. By using chromic oxide as an indigestible indicator, it has been possible to estimate the digestibility of these diets (Morris et al. 1974, Barbiers et al. 1981) and to estimate daily digestible energy requirements for maintenance. While these diets are satisfactory sources of nutrients, their soft consistency may result in greater problems with dental plaque and increased oral disease followed by systemic infections and renal pathology. The merits of complete, extruded dry diets in preventing these problems are currently being explored by our laboratory.

The koala is another unique zoo herbivore. It's digestive tract is arranged such that hind-gut fermentation must contribute in a major way to successful use of a Eucalyptus diet. The cecum is unusually long (3.5-4 times crown-rump length) and capacious and, with the proximal colon, provides a suitable environment for microbial symbionts that presumably degrade dietary carbohydrates to volatile fatty acids which are used as sources of energy for their host. These energy sources plus those released by endogenous enzymes in the more proximal portions of the gut are used to balance basal energy expenditures plus the energy costs of food acquisition, digestion and metabolism. By using acid lignin as a digestibility indicator and performing a total fecal collection, it has been possible to estimate the daily digestible energy intake to maintain body weight of adults (Ullrey et al. 1981b). Assuming an acid lignin recovery in the feces of 87%, maintenance digestible energy requirements were 312-439 kJ/$BW_{kg}^{0.75}$/day, a value considerably below that for eutherians but consistent with the observations of Degabriele and Dawson (1979) that the koala has a relatively low basal metabolic rate.

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Table 1. Complete Pelleted[a] Wild Ruminant Diet

Ingredient	%
Corn cob product[b]	35
Corn grain	18.7
Soybean meal (48% crude protein)	23.95
Alfalfa meal, dehyd. (17% crude protein)	5
Cane molasses	5
Wheat	10
Soybean oil	1
Trace mineral salt	0.5
Limestone, grd (38% Ca)	0.4
Vit A,D,E and Se premix[c]	0.25
Calcium propionate	0.2
	100

Analysis (dry matter basis)

Dry matter	90
Crude protein	18
Ether extract	2
Cell wall constituents	40
Soluble carbohydrates	35
Ash	5
Calcium	0.45
Phosphorus	0.32
Digestible energy, kcal/g	3.1

[a]Diameter 5 mm. May constitute the total diet or may be fed with hay.

[b]Consists of bracts and pith (soft parenchyma without vascular bundles). Cell wall constituents 81.2%, acid detergent fiber 37.5% and lignin 6.5%.

[c]Supplies per kg of diet: 3300 IU vitamin A, 220 IU vitamin D, 88 IU vitamin E and 0.2 mg Se from sodium selenite.

Table 2. Composition and Apparent Digestibility (%) of Alfalfa Hay Fed to Wild Ruminants

Item	No. of observations	Gross energy	Crude protein	Neutral detergent fiber	Acid detergent fiber	Starch and sugar
Alfalfa hay composition	24	4.4 kcal/g	17	42	36	26
Apparent digestibility when fed to-						
Addax	2	70	79	57	42	96
Banteng	4	54	63	29	33	90
Bongo	2	57	68	42	42	83
Gaur	2	56	67	38	41	89
Giraffe	2	64	71	54	55	84
Alfalfa hay composition[a]	1	4.5 kcal/g	25	27	21	33
Apparent digestibility when fed to-						
Dorcas gazelle	3	62	72	40	39	86

[a]Primarily leaves.

Table 3. Composition and Apparent Digestibility (%) of Alfalfa and Oat Hay Fed to Wild Ruminants and Monogastric Herbivores

Item	No. of observations	Gross energy	Crude protein	Neutral detergent fiber	Acid detergent fiber	Starch and sugar
Alfalfa hay composition	7	4.3 kcal/g	16	45	37	25
Apparent digestibility when fed to -						
Przewalski's horse	2	51	66	--	--	--
Onager	3	51	64	--	--	--
Fringe-eared oryx	2	54	68	41	19	82
Arabian oryx	2	55	74	33	39	96
Oat hay composition	1	4.0 kcal/g	6	67	41	8
Apparent digestibility when fed to -						
Arabian oryx	2	47	27	49	44	88

Table 4. Composition and Apparent Digestibility (%) of Sudan Grass Hay Fed to Wild Ruminants and Monogastric Herbivores

Item	No. of observations	Gross energy	Crude protein	Neutral detergent fiber	Acid detergent fiber	Starch and sugar
Sudan grass hay composition	9	4.2 kcal/g	8	66	44	13
Apparent digestibility when fed to -						
Caucasian tur	1	50	63	42	47	78
Plains bison	3	50	52	--	--	--
Elephant	5	35	43	31	20	100
Black rhinoceros	2	34	30	33	22	85
Sudan grass hay composition	3	4.4 kcal/g	7	62	35	23
Apparent digestibility when fed to -						
White rhinoceros	2	69	44	67	54	100

Table 5. MSU Waterfowl Breeder Diet[a]

Ingredient	Amt, %
Corn, shelled	51.9
Soybean meal (44% CP)	24.8
Wheat middlings	6.25
Meat and bone meal (50% CP)	3.0
Whey, dried	2.0
Alfalfa meal, dehyd (17% CP)	3.0
Corn distillers dried solubles	2.5
Dicalcium phosphate	1.25
Limestone (38% Ca)	4.5
Salt	0.3
Waterfowl VTM premix	0.5
	100.0
Calculated analysis	
Crude protein, %	19.5
Crude fat, %	3.0
Crude fiber, %	4.4
Calcium, %	2.4
Phosphorus, %	
Total	0.8
Available	0.5
Metabolizable energy, kcal/kg	2663

[a]Formed into 5 mm pellets.

[b]Supplied the following per kg diet: 7,200 IU vitamin A, 2,000 IU vitamin D_3, 80 IU vitamin E, 2 mg menadione sodium bisulfite, 5 mg riboflavin, 10 mg Ca pantothenate, 40 mg niacin, 1.4 mg folacin, 12 μg vitamin B_{12}, 500 mg choline Cl, 225 mg butylated hydroxytoluene, 90 mg manganese, 60 mg zinc, 30 mg iron, 10 mg copper, 1 mg iodine.

Table 6. MSU Ratite Diets[a]

Ingredient	Starter-grower	Breeder
Corn, shelled	27.0	38.4
Soybean meal (44% CP)	19.0	11.6
Oats	10.0	10.0
Wheat middlings	10.0	10.0
Alfalfa meal, dehyd (17% CP)	20.0	15.0
Fish meal with solubles	5.0	3.5
Meat and bone meal (50% CP)	3.5	3.5
Whey, dried	2.0	2.0
Salt	0.25	0.25
Limestone (38% Ca)	1.25	3.75
Dicalcium phosphate	1.5	1.5
Ratite VTM premix[a]	0.5	0.5
	100.0	100.0
Calculated analysis		
Crude protein, %	22.0	18.0
Crude fat, %	3.3	3.5
Crude fiber, %	8.9	7.5
Calcium, %	1.78	2.56
Phosphorus, %		
Total	1.00	0.93
Available	0.75	0.69
Metabolizable energy, kcal/kg	2262	2412

[a]Formed into 5 mm pellets.

[b]Supplied the following per kg diet: 12,000 IU vitamin A, 2000 IU vitamin D_3, 80 IU vitamin E, 8 mg riboflavin, 14 mg Ca pantothenate, 40 mg niacin, 800 mg choline Cl, 20 µg vitamin B_{12}, 500 µg folacin, 100 µg biotin, 3 mg menadione sodium bisulfite, 225 mg butylated hydroxytoluene, 60 mg manganese, 40 mg zinc, 20 mg iron, 2 mg copper, 1.5 mg iodine, 0.2 mg cobalt, 0.2 mg selenium.

Table 7. MSU Penguin VTM Supplement

Ingredient	Amt/unit (0.5 g)[a]
Vitamin A, IU	4,000
Vitamin D_3, IU	400
Vitamin E, IU	40
Thiamin, mg	4
Riboflavin, mg	3
Vitamin B_6, mg	1.6
Ca pantothenate, mg	5
Niacin, mg	16
Folacin, mg	0.2
Biotin, mg	0.1
Vitamin B_{12}, μg	5
Ascorbic acid, mg	60
Manganese, mg	25
Iodine, mg	10
Sodium chloride, mg	150
Butylated hydroxytoluene, mg	50
Corn distillers drd grains with solubles	To 0.5 g

[a]Placed in gelatin capsule and inserted in gills of fish at time of feeding according to schedule in Table 8.

Table 8. Penguin Weights, Metabolic Body Size and Amount of VTM Supplement

Species	Wt, kg	$Wt_{kg}^{0.75}$	VTM, units/d
Rock Hopper	2.7	2.1	0.5
Black Foot	3.2	2.4	0.5
Adelie	5.0	3.3	1
Macaroni	6.8	4.2	1
King	14.0	7.3	2
Emperor	28.0	12.2	3

Table 9. MSU Turtle Diet[a]

Ingredient	Amount
Fresh ground hog heart, g	500
$MnSO_4 \cdot H_2O$, mg	19.1
KIO_3, µg	38
Retinyl palmitate, IU	135
Vitamin D_3, IU	22.5
D,L-α-tocopheryl acetate, IU	4.5
Folacin, µg	135
Ascorbic acid, mg	50
$Ca(H_2PO_4)_2 \cdot H_2O$, g	2.78
$CaCO_3$, g	3.03
Glucose, g	1.12
Corn oil, g	2.25
Ethoxyquin, mg	13.5

[a]Freeze-dried after mixing.

Table 10. MSU Snake Diet (diluted with water to 25 percent dry matter and tube-fed to snakes at 4 percent of their body weight two to three times per week).

Ingredient	% or units/kg
Composition of diet	
Vitamin-free casein, %	34.2
Gelatin, %	10.8
Glucose, %	33.0
Vitamin premix, 97% α-cellulose, %	9.0
Corn oil, %	9.0
Mineral premix, %	4.0
	100.0
Vitamins supplied by diet	
Vitamin A, IU	4000
Vitamin D_3, IU	500
Vitamin E, IU	40
Menadione, mg	4
Thiamin, mg	5
Riboflavin, mg	20
Pantothenic acid, mg	50
Niacin, mg	75
Pyridoxine, mg	5
Biotin, mg	0.5
Folacin, mg	1.5
Cobalamin, µg	10
Inositol, mg	200
Choline, mg	1500
Ascorbic acid, mg	200
Minerals supplied by diet	
Calcium, %	0.7
Phosphorus, %	0.5
Sodium, %	0.15
Chloride, %	0.20
Potassium, %	0.21
Magnesium, mg	500
Iron, mg	85
Zinc, mg	60
Manganese, mg	50
Copper, mg	4
Cobalt, mg	2
Chromium, mg	2
Iodine, mg	0.7
Selenium, mg	0.15

DUANE E. ULLREY, Ph.D. QUESTIONS AND COMMENTS

QUESTION: I was confused about the way you worked the study out with regard to the elephant and the two rhinos. The same diet was fed and yet you came up with a difference in composition of what was eaten. How did you do that?

RESPONSE: Well, there were two things that were done. Firstly, the food that was used for the study was reserved from a single shipment. The shipments in San Diego are large. They come in on large trucks and might have, for example, 20 tons of hay in one load. Apparently, a shipment is not always from any one field. Even though you bring the food into the study area from a single shipment it is not always consistent in its initial composition. Secondly, we observed the behavior of the animals while consuming the food during the collection trial and the keeper attempts to furnish us with the part that the animal actually consumes. We do not analyze the material that was rejected. So our attempt is to determine the digestibility of what was actually consumed not of the total offered. Those two things contribute to the difference in composition.

QUESTION: So the big difference in digestible energy seen in the two rhinos was a function of selectively choosing more or less digestible material?

RESPONSE: I think that contributed to the difference. At this time I really do not know if that was the only explanation. Of course, we had two rhinos in either case and whether or not those are representative of the total population of both black and white rhinos is another question. I try not to make great extrapolations from these findings but I think they are interesting and deserve another look.

BEHAVIORAL CONSIDERATIONS IN THE NUTRITION OF CAPTIVE (ZOO) ANIMALS

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Essential to the survival of any wild animal in a captive environment is its adjustment and acclimation to the new environment. Environmental conditions vary from facility to facility, as do the needs of any given species and individuals within a species. There are, however, certain key elements that must be considered during this period of adjustment. The acclimation of wild caught animals is clearly more difficult than the acclimation of recently received captive born and raised animals, but both types have similar needs. Differences, if any, are only a matter of degree. What follows is based largely on work with mammals although it is equally applicable to birds, reptiles and amphibians. Studies have been carried out in captivity at the zoological garden and in nature in various countries of origin.

Environmental conditions of housing, heat, light and humidity may be varied and manipulated according to individual animal needs, in most circumstances. Suitable retreat areas can be provided through the use of dens, nest boxes, log hollows and similar materials. Personnel can be cautioned about noise levels and the necessity of moving quietly and slowly when dealing with new arrivals. Considerate staff know not to drop pans, slam doors or make similar loud, sharp noises when working with or around both new arrivals and flighty or reactive species. Animals recently received from foreign countries of origin from the wild, or as captive reared individuals, have a special need when arriving in the United States - human caretakers who look the same but sound totally different. Language as a stress factor is often overlooked. Speaking to a new arrival, softly, in its native tongue usually brings a positive response.

Once these basic elements have been provided for the animal, its need for food must be met. The food must be acceptable, palatable, nutritious, readily available, available on a year round basis and economical. Here is one area of the period of adjustment and acclimation that may prove more difficult and pose special problems.

Conscientious staff whether curator, veterinarian or nutritionist, should research the literature for cues and direction in establishing diets for new arrivals - especially for species new to the facility. Natural history accounts and field research reports can yield a wealth of information about actual natural food items, amounts, type and through deduction, the nutritional needs of the species. Seasonality should not be overlooked in this literature analysis, both for the types of food available and for feeding preferences. Training in or an understanding of ecology is an asset in this literature review and analysis. For instance, while it is common knowledge that certain types of armadillos feed freely on a variety of insects, spiders, small reptiles and roots, for a major portion of the year, these food items are not always available to the animals. During dry season or during winter they feed on seed pods and the carrion of those less fortunate and less versatile in their feeding habits (Meritt, 1972). Tropical kingfishers may usually prey on small fish and amphibians but during a seasonal dry season may gorge themselves on crayfish and snails, as waterways become overpopulated, pulsating puddles. Such diversity in feeding habits can be described for a variety of animals exposed to seasonal food fluctuations.

The last decade has seen a dramatic increase in the number and quality of field reports which yield such useful nutritional information. One has only to be aware of their existance and use them as a resource.

Experiences of other facilities are very important in designing a diet for your animal in your institution, under your conditions of food item availability, economics and expertise. Prior experience can save replication of previous mistakes, as well as give guidance for the proper line of approach. Surveys of colleagues, questioning of those with special expertise, and reviews of specific publications are most productive and revealing.

Ideally, this search for background information should take place well in advance of the arrival of the animals themselves. While this is not always possible, it saves considerable effort, minimizes conflict and enhances the survival chances of the animal, if done well in advance of arrival and all dietary ingredients are in hand.

Food size and consistency is important and may be critical to survival. An understanding of whether the animal eats at the food source, or takes food from the source and eats it elsewhere is essential. How the animal takes the food away, using its hands or mouth gives one a clue as to food size. Quite clearly, small primates such as Titi monkeys, Callicebus sp., Marmosets and Saki monkeys, Pithecia monachus, will eat assorted fruits, in most cases eagerly. But if the fruit is not provided in the proper form, no amount of energy on the animal's part will allow it to eat (Meritt, 1980). Large pieces of apple or thick slices of sweet potato cannot be carried away to a secure perching area for consumption, if they are too large, too heavy or dense. In this form they may prove to be totally unmanageable as food items. Dice these same food items into mouth sized or hand sized pieces and the reverse is true. If food is provided in a suitable form, acceptability can be better judged as well as actual amounts eaten. In some cases, previously refused and nutitious food items can become favored items, if offered in proper form.

When food is offered in proper form, actual consumption can increase while wastage decreases. In a series of feeding trials with fresh fruits and vegetables, two-toed sloths that received diced food items increased their daily food intake by nearly 60% and reduced dropped or spilled (wasted) food by up to 80% (Meritt, 1977a). Previously, these mammals had received chunked or food cut in long thin pieces, a nearly standard practice in captivity (Meritt, 1973b).

It becomes quite clear that sloths could use their claws effectively as scoops and did not need to grasp each food items prior to and while eating, as previously described.

How much to feed is largely a matter of a balance between how much does the animal need to remain healthy and viable, versus facility preference. There are strong advocates of feeding only as much as is needed, those who tend to feed slightly less and those who tend to overfeed, ie. provide more food daily than will be consumed by an individual animal. There are logical arguments and proponents of each method. I can only offer our approach for a variety of small mammals and birds over the past decade plus. In most cases, we have chosen to provide slightly more food daily than will be consumed. We have not experienced any serious negative results using this methodology.

The length of time food is available to an animal should also depend upon the specific behavioral characteristics of the species in question. Animals do not know they are supposed to eat between 3 and 5 daily because that is a posted feeding time and/or closing time. Animals do not realize that vermin are a major consideration and that food left in the dark provides sustenance to them as well. However, animals quickly learn these and other schedules and modify their behavior accordingly. Careful assessment of the feeding behavior of individual species will show not only how the animal eats, but how often and when. Ideally, animals should have food available to them when they normally would seek it and for as long as practical, given the limits and constraints of a captive environment.

Whether a species is diurnal, nocturnal or crepuscular will dictate feeding schedules in a captive environment. Nocturnal animals present special problems if not on a reversed lighting schedule using red, blue or dim white light to simulate night. Nocturnal animals will eat during daylight, but usually do not consume sufficient quantities of food to maintain good health or breeding condition. At best, they maintain themselves, but if stressed suddenly by changes in environmental conditions, may collapse without warning. What appears to be a healthy, nutritionally sound animal, is really a marginal survivor.

Crepuscular animals are somewhat unique in their activity patterns, but respond very well to reversed lighting schemes in captivity. Even so, with selected species it may be necessary to feed twice or more daily (with a 24hour cycle) to insure adequate nutrition. Insectivores may require such consideration. Wild caught golden moles, Chrysochloris asiatica require such treatment in order to acclimate successfully to captivity. These mammals require living food, ideally earthworms, mealworms and crickets on a daily basis. Although they will accept high protein meat mixtures (Meritt, 1969, 1977b) and fair well on such diets, natural food is essential to long term survival. Tenrecs, shrews and other moles require similar nutritional management.

Specialized behavioral traits require modification of captive management techniques. These behaviors are much more common than usually recognized, pointing out the need for a careful assessment of life history information and natural history studies. Animals that practice scatterhoarding, cache building and modified cache behavior are but three examples of a wide range of behavioral traits that must be taken into consideration in a captive environment.

Squirrels and related members of the Order Rodentia not only need a place to store or bury their food but also need specialized food to carry out this behavior. While peanuts in the shell, walnuts and various seeds are used as scatterhoarding material, commercial rodent chow, monkey pellets and rabbit pellets are also acceptable substitutes.

Agoutis, *Dasyprocta sp.* also practice scatterhoarding and if not provided with adequate food suitable for burying, will bury stones, small pieces of wood and fruit rinds. Peanut shells, marbles and coins have been buried in an attempt to fulfill this behavior in a captive environment by Central American Agoutis, *Dasyprocta punctata* and Sooty Agoutis, *Dasyprocta fuliginosa*. In these cases, food size, consistency and the presence of a suitable habitat substrate are essential to normal behavior patterns (Meritt, 1978).

Coyotes, *Canis latrans* will build food caches in nature, usually stacks consisting of dead rodents, small birds and carrion. In captivity, these canids, as well as others, show similar and related behaviors and should be provided with food sufficient to allow for these behaviors. Other examples include Kit foxes, *Vulpes macrotis*; Fennec foxes, *Fennecus zerda* and Bush dogs, *Speothos venaticus*.

Members of the Order *Strigiformes* also may show modified cache building, (as usually described for mammals) as a prelude to nest building, egg laying and chick rearing. Additionally, some species require specialized food as an added stimulus to courtship and the subsequent laying, brooding and rearing process. Detailed behavioral studies both in nature and in captivity have given an insight into some of these nutritional requirements.

Barn owls, Tyto alba, in some circumstances, apparently require primarily mammalian origin food to successfully nest and fledge young. Field studies and subsequent captive observations have shown that egg production and hatching success are directly related to the amount and availability of mammalian prey. Barn owls provided with only avian prey, breed less, lay fewer eggs and show reduced fertility than owls which prey or feed upon mammals (small rodents and insectivores). During incubation and as a prelude to hatching, these owls cache supplies of food in and around the nest site. Prey is caught and stored near the nest, both as food for the incubating adult and for hatchlings. It appears that captive owls deprived of natural prey as food during the rearing of hatchlings, are less successful than those provided with freshly killed mice or small rats or this rodent prey in combination with commercial bird of prey diet (Meritt, Unpublished Observations).

Some owl species require large amounts of food on a daily basis to initiate courtship and mating. If only fed maintenance amounts, the probability of breeding success is reduced. Overfeeding some species, at specific times of the year, is indicated to insure successful propagation.

The role of odor in nutrition is often overlooked. In some cases, if the food smells incorrectly, it will not be acceptable to the animal. Wild caught armadillos and anteaters often can be encouraged to accept captive diets by manipulation of the odor and taste of the diet. Armadillos, including Nine banded, Dasypus novemcinctus, Hairy, Chaetophractus villosus and Naked-tail, Cabssous centralis can be stimulated to eat by adding small amounts of over-ripe banana to the meat mixture diet (Meritt, 1973a, 1976). Lesser anteaters, Tamandua tetradactyla, and Silky anteaters, Cyclopes didactylus, are often more receptive to a captive diet if a sweet, malt smelling, protein additive* is included. The addition or deletion of this ingredient can mean the difference between success or failure

* Gevral Powder. Lederle Laboratories

in initiating feeding in these edentates. (Meritt, 1971; Meritt, 1975).

Certain reptiles and amphibians are also stimulated by the odor of food. Hognose snakes, Heterodon contortix, cue to the odor of toads, Bufo sp. Brazilian horned frogs, Ceratophrys ornata, respond to fish and rodent odors as a stimulus to feeding in a captive environment. Caiman lizards, Dracaena guianesis, have been successfully maintained on dead mice rubbed in fish or in snail mucous. Certain lizards can be encouraged to eat canned reptile diet or dog food if small amounts of ripe banana are mixed in. This technique has been successfully used with Tegu lizards, Tupinambis nigropunctatus, Sungazers, Cordylus giganteus and Chuckwallas, Sauromalus obesus.

Sometimes it is necessary to go to "nutritional extremes" to stimulate feeding, using odor as the stimulus. We have on occasion, had reluctant feeders among certain types of small mammals (edentates, mustelids, felines, insectivores, viverrids, procyonids). In these cases we have added ground, aged fish to the diet. Nearly, without exception, feeding began immediately. Perhaps the odor of this partially decomposed fish stimulated inner feeding mechanisms, mimicking the odor of carrion. Two or three days of feeding room temperature ground fish mixed with the routine diet is usually all that is necessary to insure the continued intake of adequate amounts of food without the fish additive.

The question of the need for and role of natural food and synthetic or prepared diets, will no doubt occupy a large portion of the discussions in formal presentations and informal conversations. The benefits of each can be calculated and weighed. Other equally important considerations such as the role of vitamin supplementation, establishment of minimal nutritional requirements, measuring food consumption, feeding strategies and specialized diets will be addressed in this program.

While the overall approach to nutrition at Lincoln Park Zoological Gardens is not unique and perhaps, in some cases, is not ideal, it works remarkably well. The effectiveness of our nutritional approach is reflected in the health, vigor and reproductive success of the animals in our care.

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MILK COMPOSITION AND FORMULA SELECTION

FOR HAND-REARING YOUNG MAMMALS

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INTRODUCTION

Hand-rearing practices inevitably attempt to mimic normal maternal rearing. There are great differences among mammals in the composition and quantity of milk supplied to the young, in the frequency of feeding, and in the length of lactation. Some mammals bear altricial young that require extensive maternal care: nest-construction, provision of body heat, anogenital licking to stimulate elimination, carrying and/or retrieval of displaced young, etc. In other species, neonates are physiologically mature, anatomically developed, and capable of independent locomotion. The task of artificial rearing requires familiarity with species differences and responsiveness to the young being raised. Selection of an appropriate milk formula is only one aspect of hand-rearing, but it is an important one. Use of the wrong formula can lead quickly to diarrhea, growth failure, and death.

Formula selection at zoos has been based largely on practical experience. Prior efforts with the same or similar species are used as a guide for subsequent hand-rearing attempts. To encourage inter-zoo communication, the American Association of Zoological Parks and Aquariums recently compiled summary sheets on successful hand-rearing procedures at various zoos (AAZPA 1979). The International Zoo Yearbook has devoted considerable space to hand-rearing reports for many years (eg. Lyall-Watson 1962).

Published records stress successful attempts; failures are seldom reported. The trial-and-error process is rarely conducted in controlled circumstances that would allow firm conclusions to be drawn about the causes of success or failure. I suspect that fastidious attention to sanitation, liberal use of antibiotics and supplements, prompt medical attention, and early introduction of solid foods have allowed young to survive on formulas that are far from optimal. Our knowledge of the interrelationships of milk composition, amounts to feed and frequency of feeding, gastrointestinal function, postnatal growth and nutrition is limited. The present report will briefly summarize available information and concepts in relation to formula selection. As so few species have been studied the recommendations herein must be considered preliminary, but such is the state of the art. Research in this area is urgently needed.

Prior to recommendations on formula selection, interspecies differences in milk composition, and the relation of milk composition to digestive function and postnatal nutrition will be discussed.

THE MAJOR MILK CONSTITUENTS

The major constituents of milks are water, protein, fat, sugar and mineral matter (ash). Tremendous diversity exists in the relative proportions of these components, however. The dry matter (non-water) fraction varies from less than 10% in black rhino milk to more than 50% in harp seal milk (Table 1). Fat is the most variable constituent, ranging from minute amounts in rhino milk to 40% and more in seal milks. The milks of equiids, rhinos, and the larger primates tend to be high in sugar whereas seal milks contain only traces. Across species, fat and protein levels usually rise with an increase in dry matter content, whereas sugar levels decline. If compared on a dry matter basis to remove the diluent effect of water, the inverse relationship between fat and sugar content is especially evident (Table 2).

The major constituents of milk have been reported for 176 of the approximately 4030 species of mammals (Table 3). Unfortunately many of these reports are unreliable due to probable bias in sampling and/or analytical procedures. In zoos, milk samples are usually collected from lactating animals shortly after birth (e.g., if a neonate dies or must be removed for hand-rearing) or at weaning of the young. Zoo staff may be reluctant to interfere with mother-young relations in mid-lactation if the young are doing well; the risks to the suckling young are considered too great. Yet milk samples obtained in early or late lactation are not representative of the mature milk on which suckling young are primarily nourished prior to weaning. In many mammals the colostrum or initial milk secretion is elevated in protein and perhaps fat, while sugar content is reduced (Oftedal 1981). Late lactation samples also tend to contain increased amounts of protein and fat, but reduced levels of sugar. If milk samples are to be collected for analysis, they should be obtained well after birth but prior to substantial ingestion of solid foods by the young.

Atypical milk analyses can result if the young have not suckled for a prolonged period, whether due to illness, maternal rejection or excessive separation. In the absence of regular milk removal, the mammary glands begin to regress with consequent changes in milk composition. Mastitic mammary glands also do not produce normal secretions. While a period of separation of mother from young prior to milking is useful to allow milk accumulation and to reduce the effect of recent suckling (see below), this period should not be much longer than the normal intersuckling interval.

During the course of milking the percentage of fat rises in many species: the first milk drawn may contain a third or less of the fat content of the last portion collected (Oftedal 1981). Many studies of large ungulates have entailed removal of only a few milliliters of milk whereas mammary capacity may be a liter or more. This portion is apt to be low in fat. If the young have just finished suckling, however, only a small residual milk portion of high fat content remains to be sampled. In the absence of careful sampling procedures entailing prior separation, use of oxytocin to facilitate complete milk removal, and efforts to fully evacuate the glands being milked, one or two milk analyses cannot be considered representative. It is not surprising that the fat levels reported for single samples from the same species often differ widely.

Given these sources of bias, all reported milk analyses cannot be considered of equal value. A restricted list of analyses was prepared (Oftedal 1981) that includes only those species for which at least 3 samples were obtained in mid-lactation without excessive separation (Table 3). Only 48 species, or 27% of those for which analyses are available, were found to qualify. These data provide the basis for the following comments on milk composition. The analyses included in Tables 1 and 2 are from this restricted list.

By and large, the milks of closely related mammals appear to be rather similar, especially if compared on a dry matter basis. For purposes of formula selection, mammalian milks may be divided into at least 6 categories according to dry matter content and the proportions of fat, protein and sugar in the dry matter (Table 4). For each category a model species has been selected, not so much because this particular species is typical of the group but because this allows a reference for formula selection. Mammalian families for which qualifying data are available have been assigned to the 6 categories (Table 4). Such assignments are for the most part tentative as rather few species per family are included.

Categories I through VI are arranged in order of increasing dry matter content. The horses and rhinos (I) produce milks low in dry matter (8-12%). Fat comprises but a very small proportion of the dry matter whereas sugar content is very high. The next group (II) includes most primates that have been studied, although limited data suggest that small primates may secrete milks of higher dry matter, fat and protein content. Primates as a rule secrete milks of moderate dry matter and fat content. Protein levels are very low, while sugar levels are high. Elephants, giraffe, pigs, camels and most bovids secrete milks that are relatively similar to cow's milk (III) and contain medium amounts of all major constituents. Group IV includes several rodent and carnivore families, as well as deer. The milks of these species tend to be of rather high dry matter and protein content; fat levels are moderately high while sugar levels are quite low. Rather few mammals are included in Group V: leporids, beavers, and bears. Among terrestrial or semi-terrestrial mammals these species produce the most concentrated milks. High fat and protein contents are coupled with very low levels of sugar. Group VI species are all aquatic. Seals and sea lions produce extremely rich milks that contain very high fat, low protein and negligible sugar contents. Cetaceans probably also belong to this group; unfortunately none of the milk studies on cetaceans qualify for inclusion on the restricted list due to lack of information on lactation stage.

Only eutherian mammals have been included in Table 4. A few detailed studies are available for monotremes and marsupials (Oftedal 1980) but changes in milk composition over the course of the lengthy lacation require further study prior to assignment to any category. Recent reports on macropodids (kangaroos and wallabies) indicate marked changes in composition at about the time the young emerge from the pouch (Messer and Green, 1979; Green et al., 1980) such that different formulas may be appropriate at different stages of development.

MILK AND DIGESTIVE FUNCTION

Milk is highly digestible. In milk-fed calves and lambs only 3-4% of the amount of fat and protein ingested appears in the feces. Even this material is largely of metabolic origin; the true digestibility of the major milk components approaches 100%. Such high digestibility is attained only with normal digestive function, however. In a diarrheal situation digestibility is reduced.

Diarrhea represents a serious physiological challenge to the neonate. The loss of water and electrolytes can undermine physiological stability. The young animal is less capable of responding to physiological disturbance due to the immaturity of regulatory systems. This is especially true for altricial young such as the newborn of many rodents and carnivores.

Avoidance of diarrhea is a major objective of hand-rearing. Even among human infants, bottle-fed babies experience a greater incidence of digestive disorders than do breast-fed babies. By an understanding of inter-species differences in digestive function it may be possible to reduce the incidence of digestive disorders.

Among adult mammals the stomach serves to regulate the influx of food materials into the small intestine. By this means the likelihood of very rapid influx and overloading of digestive capabilities is reduced. Since milk is a liquid food, special mechanisms are required to permit gastric retention. A fraction of milk protein (the casein) precipitates upon exposure to gastric acid and/or enzyme secretions. This casein precipitate entraps milk fat in a clot in the stomach. The hardness of the clot apparently depends on the casein content of ingested milk: high casein milks produce firm, tough clots that digest relatively slowly. Whereas the non-casein (whey) proteins and milk sugar pass rapidly from the stomach following suckling, slow disintegration of the casein-fat clot results in more gradual presentation to the small intestine.

Limited data on a few domestic and laboratory species suggest several scenarios. Species that nurse their young at frequent intervals tend to produce rather dilute milks in which casein comprises 60% or less of the protein. Following ingestion, the milk forms a soft gastric clot that disintegrates quickly. The influx of fat, protein and sugar into the small intestine is periodic and dependent on the times of suckling. Since suckling is frequent, however, the quantities consumed per suckling bout are relatively small and the absolute amounts entering the small intestine correspondingly low. Species that follow this pattern include some of those in milk categories I, II, and perhaps III, eg. horses, humans and pigs.

By contrast, some species nurse their young at infrequent intervals. The milks produced are apt to be high in casein and fat content, both of which are retained in the stomach for prolonged periods prior to further degradation. Even though milk intake is highly periodic, only whey proteins and milk sugar enter the small intestine as sudden influxes; the amounts involved are restricted by the content of these constituents in maternal milk. Species in this pattern include cattle, sheep, rabbits, and probably others in groups III - VI.

Many species are undoubtedly intermediate between these patterns, as reflected both by milk composition and suckling frequency. In the absence of research on non-domestic species, broad generalizations must be avoided. Nonetheless, casein to whey ratios, fat and sugar content, and suckling frequency are obviously data of importance to formula selection.

The proportion of milk protein comprised of whey proteins is significantly elevated in the colostral or initial secretion of many species. Domestic ruminants, pigs and horses rely on colostrum as a vehicle for the transfer of immunoglobulins from mother to young after birth. At this time the small intestine is capable of the absorption of intact proteins, including immunoglobulins. Thus the young acquire passive immunity against various infectious diseases. As the young mature the gut "closes", i.e. proteins can only be absorbed by degradation to smaller fragments (amino acids and short peptides). Not all young require colostrum for the acquisition of passive immunity: in humans, rabbits and guinea pigs the transfer of immunoglobulins is entirely prenatal (Table 5). In carnivores transfer appears to occur both before and after birth, while rodents exhibit varying degrees and durations of postnatal transfer. Yet even among those species that rely entirely on prenatal transfer of passive immunity, the colostrum may be elevated in immunoglobulin content. In such cases the immunoglobulins may provide local protection of the gastrointestinal tract rather than systemic protection by entry into the circulation of the neonate.

Enzyme levels in the small intestine are probably geared to the particular set of components contained in milk. The suckling young of mammals hydrolyze lactose, the principal sugar of most eutherian milks, via activity of the enzyme lactase. The milks of earless seals (Otariidae) are essentially devoid of lactose and other sugars, however; their young lack lactase activity. With the onset of weaning lactase levels decline precipitously in most mammals, such that tolerance to milk sugar in diets becomes reduced. The escape of undigested sugar into the large intestine can result in rampant microbial fermentation with consequent diarrhea and flatulence. Certain human races, including caucasians, are atypical in that lactase activity remains rather high throughout life in most individuals. As a consequence many adult humans are able to ingest substantial quantities of cow's milk without gastrointestinal discomfort.

If milk formulas are patterned after maternal milk, the relative proportions of fat, protein and sugar should be appropriate to digestive capabilities so long as the frequency of feeding, the amounts fed, and the extent of gastric clot formation approximate normal maternal rearing. Excess fat levels and inappropriate types of fat may lead to fecal fat excretion (steatorrhea), whereas excess sugar intakes can cause diarrhea of microbial origin. Restriction of the amounts offered and dilution of the formula may reduce the incidence or severity of diarrhea, but at the risk of compromising nutrient intakes.

MILK AND POSTNATAL NUTRITION

The relationship of interspecies differences in milk composition to the nutrition of suckling young is not fully understood. The attractive hypothesis that milk protein levels vary in relation to differing growth rates of the young was put forth many years ago, but has recently been challenged (Oftedal 1981). It appears that in some species suckling young consume protein at levels far above expected requirements while in others they ingest just what is needed to support growth. The significance of such a finding to the feeding of hand-reared animals is not clear.

Milk energy intakes prove to be rather predictable, at least at peak lactation. At this stage, most young ingest daily 200 - 250 kcal per kg $^{0.83}$(Oftedal 1981). The volume of milk that must be consumed depends on its energy density: a dilute milk (eg. category I) must be consumed in great quantities whereas more concentrated milks (eg. categories V, VI) provide sufficient energy in lesser amounts. Milk intake at peak lactation usually equals 10 - 25% of body weight per day. Prior to peak lactation suckling young ingest less milk per day, but since they are smaller the amount consumed may comprise an even greater percentage of body weight.

Detailed and minor components of milks can be of nutritional importance. The amino acid composition of milk depends on the relative proportions of constituent proteins. Milks high in casein, for example, tend to have somewhat imbalanced amino acid ratios, with sulphur amino acids most limiting (Oftedal 1981). Differences among species in milk fatty acid composition may reflect differing requirements associated with development of the nervous system (Hall and Oxberry, 1977). The relative concentrations of milk electrolytes vary among species, but the nutritional significance of such variations are not known (Peaker 1977). Other components that may be of importance include sugar constituents, trace minerals and vitamins. Marsupial milks can contain large amounts of sugars other than lactose (Messer and Green, 1979). Pig and ruminant milks are very low in iron content but the young obtain iron from ingested earth if given the opportunity; other milks may have much higher iron levels (Oftedal 1980). Goat's milk can cause anemia if fed to human infants due to the very low levels of the B-vitamin folic acid. Suckling young that require vitamin C (eg. higher primates, many bats, guinea pigs) must obtain it in milk; formulas devoid in this vitamin cannot be safely fed to these species without vitamin supplementation. Although milks generally are rich in nutrients, interspecies differences may limit the value of the milk of one species to the young of another.

RECOMMENDATIONS FOR FORMULA SELECTION

Given the many sources of bias that may affect milk composition results, tabulations of milk composition data (eg. Ben Shaul, 1962; Jenness and Sloan, 1970; Borden Inc., undated) cannot safely be used for the formulation of hand-rearing diets. If the listed data are atypical for the species to be raised, digestive and/or nutritional complications may follow from attempts to duplicate milk composition as reported. An extreme example of a well-intentioned but misguided effort was the attempt to mimic the composition of anteater milk, as listed by Spector (1956), in the rearing of young Giant anteaters (Bickel et al., 1976). The "anteater" data actually refer to an old and unreliable study on echidna milk (Marston 1926), but they have been listed under Edentata by both Ben Shaul (1962) and Borden Inc. (undated).

The six milk categories described in Table 4 provide an initial framework for formula selection. If a species to be hand-reared can be assigned to one of the categories on the basis of taxonomic affiliation (or reliable milk composition data), the choice of an appropriate formula is simplified:

I. Equids, Rhinos. A commercial horse milk replacer such as Foal-lac (Pet/Vet Products, Borden Inc., Box 419, Norfolk, Va. 23501), containing 14% fat, 20% protein and 57% sugar, is the formula of choice for feeding equids. As rhino milk is very low in fat, even Foal-lac may cause digestive problems. A three week rhino calf was successfully reared on a 1:1 mixture of skim milk powder and calf milk replacer, diluted with water and supplemented with vitamins and minerals (Wallach 1969). Equids and rhinos should be fed rather frequently; normal inter-suckling intervals are about 0.5-2 hours.

II. Primates. Most primate infants are reared on one of several human milk formulas. Some human formulas are modified to produce a casein to whey ratio of 40:60, approximating human milk, and may be preferable. New World monkeys require vitamin D-3 (cholecalciferol) rather than vitamin D-2 (ergocalciferol) in their diet. Check the label since many human formulas do not contain D-3. Smaller primates (Callithricids and some cebids) are probably adapted to higher fat and protein, and lower sugar levels, than is provided by human formulas. At NZP a 1:1 mixture of human formula and a dog milk replacer, Esbilac (Pet/Vet Products, Borden Inc., Norfolk, Va. 23501), has been used successfully for spider monkeys. Primates also require vitamin C which may be introduced in the form of liquid vitamin supplements manufactured for human babies.

III. Most ungulates (elephants, pigs, giraffes, camels, bovids, etc.) Cows milk is satisfactory for most ungulates. Some zoos use milk replacers designed for calves or lambs, or reconstituted evaporated milk; these are less expensive than whole milk. Evaporated milk is simply cow's milk with half of the water removed by heat treatment; the relative proportions of dry matter constituents are not changed. The notion that evaporated milk is preferable for species with more concentrated milks is overly simplistic. Small African antelope may have more concentrated milks than larger bovids and might benefit from a formula of 1:1 Esbilac and cow's milk. Unlike milk replacers that contain added iron, cow's milk and evaporated milk are iron-poor and should be supplemented with iron. Sweetened condensed milk should never be employed in feeding young ruminants since these animals lack lack the enzyme (sucrase) required for hydrolysis of table sugar (sucrose).

IV. Carnivores, rodents and deer. Esbilac contains 44% fat, 33% protein and 16% sugar in the dry matter and can be fed to most terrestrial carnivores, rodents and deer (Note that some species fall into category V). Species that have been successfully reared on Esbilac or other dog milk substities include giant anteaters, armadillos, ratels, red pandas, fennecs, maned wolves, hyaenas and various large cats (lions, tigers, leopards, jaguars, snow leopards, etc.). KMR (Pet/Vet Products, Borden Inc. Norfolk, Va. 23501) is intended to be a cat milk replacer and contains a greater proportion of protein (42% of dry matter) than Esbilac. The lower fat (25%) and higher sugar (26%) levels render it less appropriate for most species in category IV, however. In zoos KMR has mostly been used for felids. Some young carnivores have performed poorly on both formulas as indicated by symptoms such as hair loss, poor weight gains and cataracts. Nutritional inadequacy may underlie these problems (eg. Vainisi et al., this volume) but the identity of the deficiency, if it is one, remains to be proven. Deer are usually reared as other ungulates, but on the basis of milk composition data, improved performance would be expected on a dog milk replacer.

V. Rabbits, beavers, bears. No commercial milk replacer is available specifically for species in this category. Various formulas have been tried and some with success. As Esbilac is lower in sugar and higher in fat content than other replacers it is perhaps most suitable, but quantities per feeding should be restricted to avoid excess sugar intakes. Egg yolk can be added to increase the fat and protein content of the formula.

VI. Seals and sea-lions. The intolerance of these animals to lactose precludes the use of commercial milk replacers. Klos (1979) reports rearing a southern elephant seal on a lactose-free milk formula, but growth performance was poor. Other authors recommend feeding eared seals fish with added antibiotics and vitamins from an early age (Reineck, 1962; Cansdale 1970, Cansdale and Yeadon, 1975; AAZPA, 1979). Special formulas based on casein, fish flour, whale oil, cream, and other constituents have been used for sea lions and fur seals with some success (Keyes, 1968; see also Otten and Andrews, 1976). Further work is needed to ascertain the most appropriate formula.

CONCLUSION

Selection of an appropriate formula requires some knowledge of the expected composition of maternal milk. Six categories of mammalian milks have been delineated on the basis of dry matter content and the proportions of fat, protein and sugar. Different formulas may be most suitable for the species of each group. Additional compositional traits may also be important to the maintenance of normal digestive function and the fulfillment of nutritional needs, but further studies are needed before definitive recommendations can be made. Until controlled research comparing alternative formulas is conducted, the relative merits of the various procedures used by different zoos are difficult to evaluate.

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Table 1. The Major Constituents of the Milks of Some Mammals

	Dry Matter %	Fat %	Protein %	Sugar %	Ash %	Gross Energy kcal/100g
Black rhinoceros (*Diceros bicornis*)	8.8	0.2	1.4	6.6	0.3	35
Baboon (*Papio* sp.)	14.0	4.6	1.5	7.7	0.3	80
African elephant (*Loxodonta africana*)	17.3	5.0	4.0	5.3	0.7	88
Mink (*Mustela vison*)	21.7	7.3	5.6	4.5	1.0	120
Striped Skunk (*Mephitis mephitis*)	30.7	13.8	9.9	3.0	---	200
European beaver (*Castor fiber*)	34.1	19.0	11.2	1.7	1.1	250
Harp seal (*Phoca groenlandica*)	51.7	42.2	8.7	0.1	0.7	430

Adapted from Oftedal (1981).

Table 2. Milk Composition Expressed on a Dry Matter Basis

	Fat %	Protein %	Sugar %	Ash %
Black rhinoceros	2	14	75	3
Baboons	33	9	55	2
African elephant	29	21	31	4
Mink	33	26	21	4
Striped skunk	45	32	10	-
European beaver	56	33	5	3
Harp seal	82	16	0.2	1

Adapted from Oftedal (1981).

Table 3. Mammalian Species for which Milk Composition Data are Available.

	Approx. No. of Species in Order	Milk Composition Data: Total No. of Species	Milk Composition Data: Restricted list of Species
Monotremata	3	1	0
Marsupialia	242	6	2
Insectivora	406	7	0
Dermoptera	2	0	0
Chiroptera	853	8	0
Primates	166	18	4
Edentata	31	0	0
Pholidota	8	0	0
Lagomorpha	63	4	2
Rodentia	1690	25	6
Cetacea	84	15	0
Carnivora	253	27	8
Pinnipedia	31	9	6
Tubulidentata	1	1	0
Proboscidea	2	2	2
Sirenia	5	1	0
Perissodactyla	16	9	3
Artiodactyla	171	43	15
Total	4027	176	48

Adapted from Oftedal (1981).

Table 4. Categorization of Milks for Purposes of Formula Selection.

Milk Category	Model Species	Dry Matter %	Composition of Dry Matter: Fat %	Protein %	Sugar %	Mammalian Families
I.	Horse	Low (8-12)	Very Low (2-15)	Low (15-20)	Very High (60-75)	Equidae (2) Rhinocerotidae (1)
II.	Human	Medium (12-16)	Medium (25-35)	Very Low (7-15)	High (50-60)	Hominidae (1) Pongidae Cercopithecidae (2) Lemuridae (2)
III.	Cow	Medium (12-23)	Medium (30-45)	Medium (21-27)	Medium (20-37)	Elephantidae (2) Suidae (1) Giraffidae (1) Camelidae (1) Bovidae (6)
IV.	Dog	High (18-31)	Med./High (32-50)	High (28-42)	Low (10-25)	Muridae (2) Canidae (3) Felidae Mustelidae (2) Cervidae (6)
V.	Rabbit	Very High (30-40)	High (40-50)	High (25-45)	Very Low (5-10)	Leporidae (2) Castoridae (1) Ursidae (1)
VI.	Seal	Extreme (50-65)	Very High (70-80)	Low (10-20)	Negligible (0-2)	Phocidae (4) Otariidae (2)

Based on data summarized by Oftedal (1981). Number of species per family indicated after family name in parentheses.

Table 5. The Timing of the Transfer of Passive Immunity From Mother to Young Among Mammals

Species	Prenatal	Postnatal	Duration after Birth
Quokka	0	+++	180 days
Europ. hedgehog	+	++	40 days
Rhesus monkey	+++	0	
Human	+++	0	
Domestic rabbit	+++	0	
Norway rat	+	++	20 days
House mouse	+	++	16 days
Guinea pig	+++	0	
Domestic dog	+	++	1-2 days
Domestic cat	+	++	1-2 days
Horse	0	+++	24 hours
Pig	0	+++	24-36 hours
Ox	0	+++	24 hours
Domestic goat	0	+++	24 hours
Domestic sheep	0	+++	24 hours

0,+,++,+++ indicate degree of importance of prenatal and postnatal transfer; adapted from Brambell (1970).

IMPROVING EXOTIC BIRD AND MAMMAL REPRODUCTION THROUGH ECONOMICAL NUTRITION

CHARLES HUME
SCIENTIFIC ANIMAL FEEDS, INC. - HUME'S EXOTIC WILDLIFE RANCH

INTRODUCTION

I do not know why I let Dr. Maschgan con me into being on this program with all these distinguished nutritionists. My degrees are in Wildlife Management and specifically in Mammology, and I avoid public speaking like I do hoof and mouth disease. I am too close to home to pose as any kind of an authority.

I had hoped to impress you with the fact that I feed over 50,000 animals all the time and have been doing it for a good many years, but again the problem with being so close to home is that many in the audience know that most of my animals are laboratory white mice.

So all I am going to do is point out a few experiences that have helped me pay my overhead and have kept me in the animal business over the years. When one is in the animal business like I am, the reproduction of the animals I breed is the only way I have to pay my feed bills, my employees and my taxes. I have to feed economically, but above all, I have to make my animals and birds eat the things that will keep them in tip-top shape nutritionally, so that they will give me maximum reproduction. Now that combination of proteins, fats, and fiber can vary with each species, but it is amazing how many species can be fed the same balanced diet successfully.

MOUSE REPRODUCTION

I know that none of you are interested in raising mice and would rather know how to get rid of them, but I want to mention them as an example of a species that has a rather unique nutritional requirement for maximum reproduction. The average laboratory rat and mouse diets contain 20% protein and 4% fat, and they give you an average production of about four young per month per adult female. We set up a controlled test on a portion of our laboratory colony to which we fed a ration of only 17% protein but 11% fat and were able to net an average of six young per month per adult female on this diet. This knowledge about the needs of a mother lactating mouse produces me an extra thousand mice per week in my breeding establishment and therefore, nets me $20,000 per year to help pay my overhead. Perhaps the best lesson to be learned from this little tidbit of information about the house mouse or its albino mutations, is that if you are trying to get rid of them, which most of you are, do not leave any foods around like high fat sunflower seeds or dog foods, because they could increase your eradication problem by 30%. A high fat diet is very undesirable in all the other birds and mammals I produce, especially if they are not in a large exercise area.

ORNAMENTAL PHEASANT PROPAGATION

My first experience in breeding birds dates back to 1955, when I started with the common ornamental Golden and Lady Amhurst pheasants. In those days, I had a lot of spare time, so I built quite a pheasantry with Impyans, Elliotts, Edwards and Hume Bartails, and later got into the Tregapans, Firebacks, and Peacock pheasants. I raised them on the basic Ralston Purina Game Bird pellets that are made in a 30% protein starter ration and a 20% protein game breeder ration and a 19% protein high roughage flight conditioner ration. If I was having trouble getting egg production out of a particular species of rare pheasants, I increased the protein by adding a 40% protein product called Trout Chow. This product with its high fish meal content is made in seven different grades numbering from 00 to #1 through #6. The "00" is a very fine powder for newly hatched trout and the other sizes are made for feeding the baby trout from 1" through 6". The #6 is a pellet about 1/4" in diameter and is fed to all trout over 6" in length. This product is very excellent for feeding fish and crustacean eating birds and has kept my flamingoes in excellent condition for over 20 years. Because of its high protein and its availability in different grinds, it can be used very successfully in mixing and supplementing high protein diets of any kind that you might be trying to formulate.

WATERFOWL AND THE RATITE FAMILY

Ornamental ducks, geese and swans also looked like a challenge to breed, so I tried my luck with some of them. The Cereopsis or Cape Barron Goose from Australia is one of my favorite. My employees call them the man eating geese because of their aggressiveness, but I prefer to call them the Christmas geese because they always produce a clutch of goslings around Christmas. I have seen them hatch goslings and save them all in an open barn in below zero temperatures. These geese, like some of the other fast growing geese and ratite family of ostrich, rea and emu are subject to the development of straddled leg syndrome. The absence of selenium in the diet is believed to be a factor in causing these birds to develop this leg problem. The Anderson Feed Company of Maumee, Ohio researched this selenium deficiency and came out with a ratite breeder diet for the ostrich family birds, which contained all of the selenium that the birds would need if they were in a deficient area.

My theory on slipped tendons is that exercise is one of the major factors in preventing them. As long as I allowed the very active mother Cereopsis to raise her own goslings, I never had a single problem. Of the ones that I took away from the mother and tried to brooder raise, or even when I put them in a large room with the feed in one corner and the heat lamp in the other, they still all developed the leg problem. There was one exception, a little gosling that my secretary made a pet of and walked numerous times daily. Mr. C. C. Irving of Greenfield, Indiana has had the same experience with his ostrich. As long as they are put out to graze in the yard, or left to follow the father around in the field, he doesn't have any leg trouble. Both the goslings I raised and the ones the mother raised were fed on trout chow, which did cause them to grow fast.

I have had very good results in raising most waterfowl of the grazing varieties and swans on an economical 16% protein product called Duck Growena. A pair of my mute swans hatched and raised eight cygnets from one nest, which I thought was a pretty good record, but this year, a pair that I sold Baxter Laboratory in Deerfield, hatched nine cygnets from one next on the same diet. If you have some waterfowl that are more difficult to get egg production from, try putting them on Anderson's 19% protein waterfowl breeder diet or 20% game breeder chow. By adding varying amounts of protein trout chow, you can really build up your protein, if you think the species might need it.

I am not much on feeding corn or scratch feeds. I think they are a poor way to economize, because the cost difference in them and a complete nutritionally balanced higher protein pellet is at the most one or two cents per pound. Then, too, there is the danger of mold, especially in cracked corn, and pesticide contaminations. Duck pellets are cheaper than game bird pellets, and may be used very successfully and very economically to feed mixed collections of pheasants and waterfowl, especially for the fall and winter season.

MACAW BREEDING

In the last ten years I have specialized in breeding macaws and have closed down the pheasantry because of lack of time to artificially incubate the eggs. Breeding macaws offers a very profitable challenge, and since mine all raise their own chicks, we only remove them at five weeks and hand feed them so that they will make nice affectionate pets. I think the single biggest mistake in feeding a breeding flock of birds is to give them a large variety of foods to select from. I persuade my birds to eat what I think is best for them. I may not always be right, but I know better or soon will learn better what is best for them. I know they are not capable of selecting what is best for themselves. In the case of the macaws, if you give them a choice of food, they will live on sunflower, peanuts and fruits. That is a very inadequate diet because both sunflower and peanuts are twice as high in fat as they are in protein, and they are both much higher in phosphorous than calcium, which over a long period of time can cause the calcium to be reabsorbed from the bones and the bird can no longer hold itself on the perch.

My basic diet, in fact almost total diet for the breeding macaws, is Hi-Protein Monkey Chow. The only other thing that I give them is a small cup of sunflower daily to each pair. I give them this strictly as a treat, so that they look forward to our daily visit to the aviary, and are not alarmed or fearful of our bothering their nest. I do not feed any fruit, and I do not mean to indicate that I think it is necessarily bad for them, but I am sure that it is better to feed none, rather than feed too much. In other words, treats are great, but they must be limited. I think at least three-fourths of the breeding macaw diet should be a balanced product like Hi-Pro Monkey Chow. I have raised baby macaws every year since I started. We had 14 this year, and I always feed the babies exclusively on ground Hi-Pro Monkey Chow with no additives, soaked to a softened oatmeal consistency and fed with a spoon three or four times a day, and they grow as well for me as they do for their mothers.

I started recommending the feeding of monkey chow to the large Psittacidae family of birds many years ago, and I think it is pretty widely done now all over the country, but I am sure that many people are not aware there are two different monkey chows. The original or Regular Monkey Chow that is only 15% protein and the newer kind that used to be called Monkey 25, and sometimes designated as the New World Monkey Chow because it was the first to have D3 added, for the Woolies, Spider and other New World monkeys. I argued with Purina for years to get the name changed to Hi-Pro Monkey so that customers could get the higher 25% protein product, and that is what you have to insist on, because in many areas, the dealers do not want to handle both kinds. The cost is only 50¢ more per bag, and the protein is 10% more. That is money well spent. Some people use dog foods in their bird mixes for a protein source, but what they do not realize is that most dog foods are lower in protein and always higher in fat than the Hi-Pro Monkey Chow, which is only

5% fat. Dog foods range from 7 to 20% fat, and I think that is too high for breeding birds.

HOOFED ANIMAL--ECONOMICAL FEEDING

My principle interest in exotic animals is hoofed stock, and I keep over 500 head of deer and elk and some 65 head of llama, a few camels and antelope. I try to keep species of hoofed stock that do well grazing. They have 80 acres on which to roam and graze, which cuts my feed costs in half. I cross fence the acreage into four 20 acre parcels, so that I can rotate the stock during dry periods when the grass is being over grazed. I harvest my hay for winter feeding from another 50 acre parcel. To these animals I feed an economical pelleted dairy feed containing 14% protein with a good digestible roughage in the form of cooked oat hulls. In the winter they consume five tons of feed per week, which we feed from a bulk tank. By pressing a button on the tank, it is augered into the bucket of the tractor and then transported into the feed troughs. This principle of bulk feeding saves me about $200 per week on my hoofed animal feed costs over the traditional bag type feeding. This represents a $10,000 per year savings on feeding costs, which means a lot to an operation like mine where reproduction is the only way I have to pay the feed costs.

Bulk tanks are made by several companies. I am familiar with the one made by Schuld Manufacturing Company. A 12 ton tank with necessary accessories including the electric motor, costs about $2,000. By buying feed in bulk at 10 or 20 ton at a time, you can save about $18 per ton from the company that makes the feed, because they do not have to furnish the bags or have the cost of bagging and handling. The dealer that is handling the feed will handle it for probably $20 less per ton because of the labor in handling and delivering bagged feed. The dealer can have it augered on a bulk semi and delivered directly into the customer's tank. So it breaks down to this. If your bulk tank costs $2,000 and you save $40 per ton, it will take you the length of time that you feed 50 tons to break even for the cost of your bulk tank. I realize that such a program may not be practical for many zoos because the animals are spread too far apart for having all the feed in one bulk location, and there may not be enough that are on the same diet, but if it can be worked out, the cost savings is worth while.

COMMERCIAL FEED COMPANY

I believe in feeding hoofed stock the same as I do in feeding birds. I want my money to go for products that give the animals the best and most economical nutrition. I feed a very limited amount of treats. Apples, bananas and carrots are very expensive feed for large mammals, and what additional nutritional benefit does the animal get?

Water and vitamins are pretty cheap, and they are provided in all good feed products. They do not provide proteins or fats, and that is what it takes to put an animal in good breeding condition. Wayne, Purina and Anderson companies all make good balanced diets, with proper amounts of all the essential ingredients, and they will cost you only 10¢ to 12¢ per pound. The above mentioned fruits and vegetables with water removed cost you 30 times that amount or would you believe $3.50 to $4.00 per pound? Allied Mills or Wayne Feeds puts out Rough and Ready, a complete feed with roughage built in; Calf Krunch with a 16% protein is a very palatable product. Ralston Purina puts out Horse Checkers, a complete feed with built in roughage, Pure Pride Pellets 100, 200, 300 with 10%, 14% and 16% protein respectively and Omolene 100, 200 and 300, a sweet feed with the same protein levels as the Pure Pride products. Anderson Feed Company of Ohio puts out Exotic Ruminating Diet, a complete feed of 16% protein and a Monogastric Herbivore Diet, a complete feed recommended for the single stomach hoofed stock. Both of these last two products were researched and designed exclusively for zoo animals. They have very good vitamin fortification and selenium added to prevent white muscle disease, if you are in a deficient area.

It has been my pleasure to relate my animal feeding experiences to this distinguished group. I hope that some of these ideas will be helpful to you in your complicated task of feeding exotic bird and mammal species.

HYDROPONIC CROPS: A VALUABLE ALTERNATIVE FOR FEEDING ZOO ANIMALS ?

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INTRODUCTION

There seems to be a generalized tendency, particularly from manufacturers of hydroponic systems, to over-emphasize the nutritive value of sprouted seeds. A very common claim from these manufacturers is that hydroponically grown cereal grasses, when fed to animals, exerts a stimulating effect on milk production, enhances reproductive activities, improves health, and promotes growth in immature animals. Apparently some of these beliefs seem to have gained support in the zoo world (5,6).

Considering the fact that the number of scientific investigations on the feeding value of hydroponic grass is very limited and the results highly controversial, it appears that there is no conclusive scientific evidence to support such claims.

Most hydroponic grass research has been done with dairy cattle, and the reports on its effects in improving milk production have shown contradictory results. Work done at the University of Minnesota in 1956 concluded that sprouted oats failed to improve milk production or butterfat content. In 1962 Michigan State University researchers refuted claims that sprouted cereals contained vitamins and biocatalyst which improved animal performance. They said the allegations were not founded on experimental results, but on vain, nutritional misconceptions (8).

In 1965 work done at Cornell University with pregnant gilts showed that hydroponically grown oat grass, at a level of 10% of the dry matter, produced a 60% increase in the number of sows farrowing which in turn increased by 80% and 92% the number of live piglets farrowed and weaned respectively (19).

Apparently the allegations in favor of hydroponic grass seem to derive from misinterpretations of early research done on "unidentified grass juice factors". Many reports published during the period from 1930 to 1950 provided evidence for the existence of unknown factors in green forages that exerted stimulatory effects on the growth of young rats (10), immature guinea pigs (2,11,20), chicks (12), turkey poults (21,27), and weanling pigs (4). KOHLER (13) presents a compilation of the work done during this period.

Most of the biological responses observed in early research with the grass juice factors have been shown subsequently to be due to known nutrients, or to represent phenomena resulting from alterations in the balance or availability of some of the known nutrients. As an example, work done at Cornell University in 1952 by SCOTT & JENSEN (21) showed that an unidentified factor in fresh grass juice (preserved with the addition of 1% of copper sulphate) produced approximately a 50% increase in growth in young poults. At that time no one suspected the possibility that copper sulphate could be in part responsible for the marked growth improvement obtained with the grass juice concentrate. It was later that SCOTT & PETER (22) found that the addition of 100 ppm of copper as copper sulphate, produced a similar growth response in poults to that obtained with the grass juice concentrate.

GARD et al. (4) also found that grass juice concentrate when added at a 3% level to the diet of weanling pigs, significantly increased the growth rate. They postulated that the growth response to grass juice concentrate might be due to its estrogenic activity. They found that 1 ml of grass juice concentrate contained approximately the equivalent of 0.016 mg of estradiol benzoate, thus, the pigs receiving grass juice in their diets may have consumed the approximate equivalent of 0.7 mg of estradiol benzoate daily, a level that when adjusted to body weight agrees with the results of tests in ruminants receiving a synthetic estrogen (Diethylstilbestrol).

Perhaps the growth-promoting effect of the grass juice demonstrated in other animal species (2,10,11,12,20,21,27) could in part be due to the presence of plant-estrogens. ANDREWS (1) mentioned that more than 50 species of plants have been shown to contain orally active estrogens, including cereal grass from oats, wheat, rye, and barley. The estrogenic activity of fresh forages is relatively higher during the early phases of the vegetative growth (9,16). In addition to these facts, enhanced growth rates have been reported in young animals grazing estrogenic pastures, similar to the effects of stilbestrol implants in cattle and sheep under feedlot conditions (16).

Although it is well known that green, leafy forages are a good source of vitamin A activity (carotene), ascorbic acid, vitamin K, vitamin E, riboflavin, and folic acid, we could consequently assume that hydroponically grown cereal grasses also provide a source of the above mentioned nutrients. Whether it produces the biological responses that the manufacturers of hydroponic systems claim still remains to be proven.

HYDROPONIC CROPS AT THE METRO TORONTO ZOO

The production and feeding of hydroponically grown crops at the Metro Toronto Zoo started in September 1977. The hydroponic unit was donated by Agri-ponics Mfg. Co., a Canadian manufacturer. Basically the unit is a conventional walk-in type growing chamber, 12' x 9' in size and with a total capacity for 154 trays, which, in a 7-day production cycle yields approximately 264 Kg of grass per day (22 trays). Temperature, lights, and the watering system are automatically controlled.

Our original intentions for using hydroponic crops were to study their effects on animal reproduction and growth, but unfortunately to date this has not been possible. Instead, we have diverted our efforts to study ways of improving crop production, to reduce production cost, to test production of different types of plants, to determine if it is necessary to add fertilizer, and to determine the chemical composition or nutritive value of the different crops.

Our attempts to produce wheat, corn, and kale proved to be highly unsuccessful. Wheat and corn seeds after 2-3 days in the growing chamber became mushy and fermented even before sprouting. Kale although showing excellent germination, presented the problem of having a very slow growth and development of the seedlings which reached 2" in size after 16 days.

Soybeans and sunflower were selected by taking into consideration information from MORRISON (15) that indicated both plants are utilized in the United States either as green forage or as silage.

Soybeans produced excellent yields in fresh weight, with a very high protein content, but production was discontinued due to problems that will be discussed in a separate section of this report. Although oats produced comparable crops in fresh weight to barley, they were rejected after considering the problems of availability of good quality seeds and references from the literature that indicate this plant may have a tendency to absorb and accumulate nitrate (15). Considering the results of these tests we have been producing barley grass and sunflower sprouts exclusively since then.

Sunflower sprouts are used primarily to provide a green forage for our primates by partially replacing the fresh fruit-vegetable portion of their diets. This crop has proved to be highly palatable with excellent acceptability from all species of primates. Its advantages are that it provides a year-round source of non-contaminated fresh vegetable matter at a much lower cost and with a better nutritional value than most vegetables (Table VI). Barley grass has been included, as a small percentage, in the diet of some of the ungulate species.

Sowing dry seeds vs. sowing pre-soaked seeds.

Considering the fact that labour contributes approximately 64% to the daily operating cost of the hydroponic unit, and that sowing dry seeds directly into the machine saves time, we conducted a trial to see if the normally recommended practice of soaking the seeds before sowing does really improves crop production or if the same crop volume could be achieved by seeding dry seeds and leaving the machine to do the soaking through the spraying cycles.

A trial was set up to compare the effects of three different soaking times versus dry seeding on the total crop volume harvested after a 7-day growing period. A low seed density was selected for this trial (1 Kg seeds/tray) considering results of previous tests that showed a better conversion ratio from seed to grass when using a lower volume of seeds than when using 1.50 Kg or more per tray.

Table I shows the mean values of four replications for each treatment. The results clearly show that soaking the seeds before sowing is a highly desirable practice resulting in higher grass yields. One and one-half hours of pre-soaking produced a 48% increase in the crop harvested as compared to dry-seeds (10.13 Kg of grass vs. 6.85 Kg respectively). Even a short pre-soaking time of one-half hour improved crop production by 23%. The pre-soaking treatment has an effect in speeding-up germination, for the pre-soaked seeds it took an average of 20 hours to visible germination as compared to 30 hours for the dry seeds which tended to remain dormant for a longer time, affecting the final yield.

This practice also provides additional benefits by reducing the slimy sediment (from grain dust) inside the growing chamber which in turn causes obstruction in nozzles and pipe lines demanding extra cleaning time. In addition to this, it also provides a good opportunity for disinfecting the seeds with a mild chlorine solution (1.67 g per gallon of water) which helps in preventing and/or reducing algae, bacteria, and mold growth on the grass, trays, and walls of the unit.

The survey on hydroponics done by the St. Louis Zoo (6) indicates that in some institutions the seeds are soaked in water for periods of up to 24 hours before sowing. Our results have shown that 24 hours of soaking time adversely affects germination and grass crop.

The need for fertilizer in the culture solution.

The St. Louis Zoo survey on hydroponics (6) pointed out that in all zoos in the United States which were growing hydroponic grasses at that time, a soluble fertilizer was added to the culture solution. A 20-20-20 soluble fertilizer was most commonly used. This is a practice that all manufacturers of hydroponic units recommend.

Preliminary results of tests done at the Metro Toronto Zoo seem to indicate that there is no need for adding a source of plant nutrient elements. When all variables were standard, the addition of a 20-20-20 soluble fertilizer at a concentration of 1.50 grams per gallon of water did not substantially increase the fresh weight of the barley grass when compared to using tap water only.

Work done at Purdue University by TRUBEY et al. (24) showed no increase in dry matter, protein, ash, or any mineral element in oat seedlings when mineral elements were added to the culture solution at a concentration similar to that added in commercial hydroponic units. A slight increase in fresh weight and carotene content resulted from the addition of mineral elements, although not statistically significant. The water-soluble carbohydrate content of the seedlings was significantly reduced by the addition of fertilizer. Analysis of 16 elements indicated that the addition of mineral elements at 1/25 the strength of Hoagland's solution had essentially no effect on the content of any element in the seedlings except for zinc. The use of full strength Hoagland's solution resulted in an increase of all 16 elements with calcium, potassium, molybdenum, copper, and boron being nearly doubled.

Based on our preliminary results and the results of TRUBEY et al.(24) and specially considering the short growth period of the seedlings in the hydroponic unit (7-days), we can conclude that there is no need for adding fertilizer to the culture solution, in fact, we discontinued this practice.

In the literature it is also well documented that seedlings up to 8-days-old grow at the expense of the endosperm reserves, starch disappearing approximately on the 7th day after germination. Also plant tissue protein is synthesized by the young seedlings at first from the nitrogenous reserves in the embryo and endosperm, and later on from inorganic nitrogen compounds taken up directly through the roots. In the absence of an external supply of nitrogen, the transfer of nitrogen from the endosperm reserves is most rapid between days 2 to 6 when it coincides with a peak in respiration. Growth of the seedlings at the expense of the reserves is mainly completed by the eighth day.

Our results on this subject will be subsequently published once all the data is analyzed.

Do we gain by sprouting seeds in a hydroponic unit ?

Articles published in farm magazines and advertising from manufacturers of hydroponic units tend to emphasize the fact that in a very short period of time (7-days) the seeds can be converted into a mass of fresh green grass six-times the initial weight. This has proven to be true in our tests, and furthermore we have even been able to obtain greater conversion ratios of 1 to 12 from seed to grass when using good quality, triple-cleaned barley seeds.

This conversion is in fact extraordinary, and is being used to impress people and promote sales, but the question is, what do we really gain by sprouting seeds in a hydroponic system especially with regard to nutrient values ?

In Table II, the chemical composition of 1 Kg of barley grain (calculated from data in Table IV) is compared to that of 8 Kg of 7-day-old barley grass produced from that amount of seed. The figures for the barley grass were calculated by taking into consideration the actual yield of three trays of grass (produced with the addition of a fertilizer as mentioned previously) and the actual analysis of grass samples as shown in Table V.

Despite the fact that this comparison is not valid since barley grain used for this study was not analyzed and nutrient values for that grain were taken from the tables of feed composition, still it may be of academic interest in order to show the changes in nutrient composition that occur when grains are sprouted hydroponically.

The results of this comparison indicate that a decrease in dry matter occurs (890 grams vs. 754.4 grams), representing a net loss of 15.28%. This decrease in dry matter is in turn also reflected in a decrease in the total energy content in the seedlings by a similar magnitude (16.37% loss). Crude protein value in the seedlings increases slightly, with a net gain of 21.68 grams. All the mineral elements show an increase with the exception of copper and potassium which show a slight decrease. Calcium content increased by 70% and zinc shows an extraordinary increase of 175%.

The substantial increase in fat content of the seedlings (by 40.39%) is perhaps the result of oil contamination in the watering system coming from the sunflower sprouts. Both crops are grown simultaneously in the unit, and we have noticed that the water becomes very oily shortly after fresh water is added to the system.

The two most striking changes that occur when sprouting the grain in the hydroponic unit are the extraordinary increase in volume or fresh weight (by 8-times in this particular case)which is the direct result of water up-take by the seedlings, and the increase in carotene, which has been shown to increase by 15-times in our study. Similar results for carotene and fresh weight increases have been reported by TRUBEY et al. (24) with 6-day-old oat grass. These authors postulated that the increase in carotene could be explained by the fact that carotene synthesis is closely associated with chlorophyll synthesis and is greatly stimulated by light.

In summary, considering the insignificant net gains as a result of sprouting the seeds, as well as the cost of producing the grass as indicated in Table V (CAN $ 1.37 per Kg of dry matter), we may conclude that the gains in nutrients have absolutely no practical value and that sprouting the seeds in a hydroponic unit is not an economical alternative when compared to feeding the grains directly to the animals (barley grain CAN $ 0.22 per Kg of dry matter).

CHEMICAL COMPOSITION OF HYDROPONIC CROPS

In Table III the chemical composition of three hydroponic crops produced at the Metro Toronto Zoo is shown. These plants were sprouted simultaneously under standard conditions of light, temperature, and with the addition of fertilizer to the culture solution (1.50 grams of 20-20-20 soluble fertilizer per gallon of water).

The dry matter value of the three crops is approximately the same (9.43% for barley, 10.76% for sunflower, and 11.93% for soybeans). Although there is a slight variation in the percentage of dry matter of the three crops, striking differences can be seen with respect to the composition of the dry matter.

The protein content in soybean sprouts is more than double the level in barley grass and approximately 72% higher than in sunflower sprouts. It seems valid to assume that these striking differences are mainly due to the variations in protein content of the respective seeds (see Table IV). A similar explanation could be drawn from the differences in the fat content of the three plants, sunflower sprouts having almost double the fat content in soybean sprouts and more than 6-times the level found in barley grass. The high fat content in the sunflower sprouts is also reflected in its higher energy value. The differences in the content of mineral elements are less dramatic, with the exception of selenium. In general, if we compare the composition of the seedlings to that of their seeds (Table IV) it seems that the nutrient composition of the seedlings is a direct reflection of the composition of the seeds.

The nitrate and selenium levels found in both sunflower and soybean sprouts deserve a further comment considering the fact that these two components may be potentially toxic to animals.

Nitrate levels in sunflower and soybean sprouts.

The data presented in Table III indicates that soybean sprouts have more than double the nitrate of sunflower sprouts (0.298% vs. 0.146% respectively).

Although a wide variability in nitrate content is common between and within plant species, there is evidence that certain plants have a tendency to absorb and accumulate more nitrate than others. For example, it has been shown that spinach and lettuce tend to have high levels of nitrate (3).

Another example is that most cases of nitrate poisoning reported have been caused in animals ingesting hay or straw from oats but very rarely in animals consuming forages from wheat or barley (15). Perhaps, soybeans have a greater tendency to accumulate nitrate than sunflower, and this could explain the difference in the levels shown for both (both plants were grown in the hydroponic unit under exactly the same conditions).

From information in the literature, apparently the nitrate content in both sunflower and soybean sprouts are acceptable. The little information from studies in humans and monogastric animals tends to indicate that nitrates are rapidly excreted in the urine, a fact that accounts for the low toxicity of nitrates under normal circumstances. In the case of ruminant animals it is generally recognized that nitrate toxicity depends on the ability of the rumen flora to reduce nitrate to nitrite. Since ruminants have a relatively high tolerance to nitrate, rations containing up to 2% nitrate in the dry matter are not likely to cause any problem (3).

Studies with rats have indicated that these animals can tolerate 1% nitrate in their diets for prolonged periods of time without suffering any adverse effect, and up to 5% with only a slight growth depression. Turkeys are apparently more susceptible to nitrate poisoning. High mortality occurs with levels of 4,000 ppm (0.4%) and even levels as low as 600 ppm (0.06%) have been shown to produce a delayed growth effect.

Although the soybean sprouts have a high protein value (46.19% on a dry basis) we rejected them as a possible source of food for our animals, taking into consideration the fact that they showed higher nitrate content than sunflower sprouts and also because soybean sprouts have been reported to produce goitrogenic effects similar to that of cabbage,broccoli, and kale (7) and to the presence of genistein and coumestrol, two of the major plant-estrogens (23).

Plant estrogens in large amounts might affect the reproductive performance of animals, being a contributing factor in cases of infertility in livestock (1,9,16,23).

Raw soybeans, on the other hand, are additionally known to be exceptionally rich in several toxicants, including hemagglutinins and an enzyme-inhibitor known as the anti-trypsin factor (7). The uncertainty still persists regarding the presence of these compounds in sprouted soybeans and how they may affect animal performance. Perhaps this is a subject that deserves further investigation.

Since the sunflower sprouts, at the Metro Toronto Zoo, are being used primarily as a food for primates, it would be interesting to compare the nitrate level in the sprouts with data on human tolerance levels. The World Health Organization has set a standard of 5 mg of nitrate per Kg of body weight as the acceptable daily intake for humans (3).

A black lemur in our collection, consuming 50 grams of sunflower sprouts per day as part of its diet, will have a total intake of 3.93 mg of nitrate per Kg of body weight per day, which is below the accepted level for humans. This, plus the fact that sunflower sprouts have been fed to all our primates in the collection during the past three years without any noticeable adverse effect, may lead one to assume that sunflower sprouts produced hydroponically are a safe foodstuffs for these animals.

From information in the literature (3), there is little doubt that the addition of fertilizer to the culture solution, will increase the nitrate level in the seedlings, particularly if the fertilizer used is one with high nitrogen like 20-20-20 which seems to be the most commonly used (6) and also recommended by the manufacturers of hydroponic units. The fact that most of the zoos in the United States have chosen oats to produce grass (6) and the apparent potential risk of nitrate toxicity with oat forages (15) should deserve further investigation. At this point, no attempts will be made to speculate on this matter since further studies are required before any firm statements can be made.

When selecting a plant species to be grown in a hydroponic unit, special considerations should be given to previous study on its safety as a foodstuff in order to avoid potential problems that might arise from the presence of high levels of selenium, nitrate, as well as any other toxic compound such as estrogens, goitrogenic substances,etc. which might either affect the animals' performance or even be a cause of death.

Selenium levels in sunflower, soybeans, and barley grass.

Another component that deserves some comments is selenium, which is particularly high in sunflower sprouts (3.78 ppm on a dry basis) compared to the selenium levels in soybean sprouts (0.10 ppm) and barley grass (0.035 ppm). A reasonable explanation for these differences could be that the barley grain and the soybean seeds used to grow the crops in this study, were produced in Ontario. It is well known that most of the agricultural land in this province is selenium-deficient. The sunflower seeds used came from the United States and may have been produced on a selenium-rich soil. No references were found in the literature reviewed regarding the ability of these plants to absorb and accumulate selenium, and unfortunately no analysis for selenium was done in the seeds. Based on this limited information we can only speculate that the high levels shown by the sunflower sprouts seem to be due to the origin of the seeds.

Animal species differences in tolerance to selenium appears to be small. The minimum dietary level at which selenium will accumulate in the tissues of animals and ultimately produce signs of toxicity is generally accepted as 3-4 ppm of the dry diet. This can be taken as the minimum toxic or the maximum safe level for animals and man (26).

UNDERWOOD (25) indicated that the toxicity of selenium within one species varies depending with the duration and continuity of intake and with the nature of the basal diet, particularly with its protein, sulphate, and arsenic content. As an example, 10 ppm of selenium in a diet with 10% protein has been shown to be highly toxic to rats, whereas 10 ppm in a diet with 20% protein showed no adverse effects. Increased levels of sulphur or arsenic in the diet also prevents signs of selenium toxicity.

In chickens, 3-4 ppm of selenium does not adversely affect the growth of chicks or the hatchability of eggs; 5 ppm has been found to reduce growth and hatchability slightly, and at 10 ppm chick growth is seriously affected and eggs fail to hatch (26).

Based on the information presented above, it seems that the selenium content in the sunflower sprouts, although high as compared to the other two crops, falls within safe limits. Furthermore, this conclusion is reinforced by the fact that no signs of selenium toxicity have ever been detected in our animals receiving sunflower sprouts as part of their daily rations. In general, manifestations of chronic selenium toxicity normally appear after a few weeks on a diet containing 5-10 ppm (26). This is a subject which we will continue to study further.

COMPARISON OF HYDROPONIC CROPS TO OTHER FEEDSTUFFS

In Tables V and VI the two hydroponic crops are compared to other feedstuffs used at the Metro Toronto Zoo from both an economic and nutritional point of view.

In Table V the chemical composition and cost of hydroponically grown barley grass are compared to three feedstuffs used at the Metro Toronto Zoo for feeding ungulate species. The values for the grass and the commercial pelleted ration for ruminants were determined by actual analysis (mean values of two samples each). The values for Timothy and Alfalfa hays were taken from the tables of feed composition (17). Based on these figures, it seems that the only problem for the hydroponic barley grass is its low calcium level (0.18%, dry basis) and the consequent unbalanced Ca/P ratio. Protein, fat, fiber, and energy are all at reasonable or even higher levels as compared to the other feedstuffs, but from an economic point of view the hydroponic barley grass (several times more expensive than hay and the commercial ration, considering cost per Kg of dry matter) is definitely not a good alternative for feeding ungulates.

Barley grass was not compared to produce, because at the Metro Toronto Zoo this type of foodstuff is not used in the feeding of ungulate species. Griner (5) and Grisham (6) both mentioned that cereal grasses produced hydroponically are good substitutes for lettuce which apparently is being fed to ungulates in most of the zoos in the United States.

In Table VI the sunflower sprouts are compared to some green vegetables presently in use at the Metro Toronto Zoo as part of the regular diets for primates and other small mammals. The composition for produce was calculated from data given on a fresh basis in the tables "Composition of Foods" (28). In general, the sunflower sprouts have a higher protein value (26.8%, dry basis) than the produce listed excepting only spinach (34.4%, dry basis). Fat content in the sprouts is extraordinarily high (21.14%, dry basis) as compared to the vegetables listed. As previously mentioned this high fat level seems to derive from the high fat content in the sunflower seeds.

Calcium content of the sunflower sprouts is very low (0.22%, dry basis) and consequently they too have an unbalanced Ca/P ratio. Despite this problem, if we compare figures shown in Table VI for cost per Kilogram of dry matter, the sunflower sprouts definitely constitute a much cheaper source of fresh vegetable matter with clear advantages for its use as a replacement for produce, particularly in the feeding of primates and other small omnivorous animals. Its freedom of pesticide and herbicide residues, high palatability, and excellent acceptability are some of the additional benefits of this particular hydroponic crop.

THE FEEDING OF HYDROPONIC CROPS AT THE METRO TORONTO ZOO

Due to the limited capacity of our hydroponic unit (average crop of 200 Kg of barley grass and 21 Kg of sunflower sprouts daily), the feeding of hydroponic forage has been selectively restricted to a few of the species in the collection.

The sunflower sprouts are being produced almost exclusively for the primates. Some examples of diets including sunflower sprouts as a partial replacement for fruits and vegetables in the rations of these animals are shown in Table VII. The diets listed correspond to average amounts per animal per day, considering the total number of animals in each group, thus including infants who are still nursing and who only nibble on solid foods. All the primates in the collection have shown a very high degree of acceptance for this foodstuff. Other species receiving sunflower sprouts as part of their regular diets include Moose, Tortoises, Iguanas, Lovebirds, Grizzly bears, Black bears, Spiny mice, Cockatoos, Tree-kangaroos, etc. All diets listed in Table VII have been fed for the last two years and are considered to be transition diets pending further evaluation.

Due to the high cost and limited amount produced, the hydroponic barley grass has been restricted to those ungulate species which have shown a better acceptability during the initial feeding trials conducted in 1977-78. Some examples of present diets including hydroponic barley grass are shown in Table VIII. The elephants are consuming approximately 30% of the total grass produced each day. The barley grass has also been included in a very small proportion to the diets of other species such as Capybara, Dall's sheep, Grizzly bears, Polar bears, Tortoises, Reindeer, Wallaroos, Pygmy Hippos, River Hippos, Bongo, Kangaroos, Wallabies, Swans and Geese.

Primates in general showed a very low order of preference for the barley grass. At present, the gorillas are the only species receiving the roots only of the barley grass, which constitute one of their preferred food items.

The polar bears have readily accepted barley grass since the first day it was offered to them. For over a year these animals have been receiving 1 Kg of barley grass per animal per day, resulting in an extraordinary improvement in their stool consistency.

CONCLUSIONS

There is no scientific evidence to support the claims that hydroponically grown cereal grasses exert a stimulatory effect on reproduction, growth, lactation, etc.

Hydroponic cereal grasses, from an economic point of view, can not compete satisfactorily with either hay or a commercial pelleted ration in the feeding of ungulate species.

Sunflower sprouts, as a replacement for produce,have definite advantages from both economical and nutritional points of view. This is particularly true for the feeding of primates where it also provides a good food from the occupational or psychological point of view.

For those institutions that already have hydroponic units, there are other alternative crops to barley and oat grasses with better nutritional value such as sunflower and soybean sprouts.

Regarding the production of hydroponic forages there are ways for improving the crop both quantitatively and qualitatively. The pre-soaking treatment of the seeds before sowing provides definite advantages particularly in improving grass yield. By shortening the growth-cycle from 7-days to 5 or 6-days, it is possible to increase both the dry matter and energy content of the seedlings.

There appears to be no positive relation between the addition of fertilizer to the culture solution and the fresh weight and chemical composition of the crop. Equally satisfactory results can be obtained by using tap water only. The addition of fertilizer may even have a negative effect by increasing nitrate accumulation in the seedlings, particularly in oat grass.

The chemical composition of the hydroponically produced seedlings seems to be predetermined to a great extent by the composition of their respective seeds.

Areas that require further investigation include the possibility of using hydroponically grown soybean sprouts and/or other plants for feeding zoo animals and its possible effects on the animals' performance.

After three years of feeding hydroponically grown barley grass and sunflower sprouts to some of the species in our collection we have not been able to determine any beneficial nor detrimental effects on the animals' performance. Controlled comparative studies are required before any statements can be made in this regard.

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TABLE I. EFFECT OF SEED TREATMENT (SOAKING TIME IN WATER AT 20°C) ON TOTAL YIELD OF 7-DAY-OLD HYDROPONICALLY GROWN BARLEY GRASS (FIGURES REPRESENT MEAN VALUES OF 4 REPLICATIONS).

SEED TREATMENT	AMOUNT OF SEED/TRAY (Kg)	FRESH WEIGHT TOTAL CROP/TRAY (Kg)	(%)	FRESH WEIGHT AERIAL PART/TRAY (Kg)	(%)
No pre-soaking (dry seed)	1	6.85	100.00	1.60	100.00
½ hour pre-soaking	1	8.45	123.36	1.95	121.88
1 hour pre-soaking	1	9.40	137.23	2.15	134.38
1½ hour pre-soaking	1	10.13	147.88	2.25	140.63

TABLE II. COMPARISON OF TOTAL NUTRIENTS IN 1 Kg OF BARLEY GRAIN WITH THAT OF 8 Kg OF 7-DAY-OLD HYDROPONICALLY GROWN GRASS PRODUCED FROM THAT GRAIN.

ANALYSIS		BARLEY GRAIN	HYDROPONIC BARLEY GRASS
Fresh weight	Kg	1.00	8.00
Dry matter	Kg	0.89	0.754
Crude protein	g	115.70	137.38
Crude fat	g	18.69	26.24
Crude fiber	g	49.84	129.01
Gross energy	Kcal	4,084.00	3,415.62
Calcium	g	0.80	1.36
Phosphorus	g	4.18	4.37
Magnesium	g	1.25	1.51
Potassium	g	5.61	5.58
Manganese	mg	16.29	18.10
Copper	mg	7.65	6.79
Zinc	mg	15.31	42.22
Carotene	mg	1.00	15.20

TABLE III. CHEMICAL COMPOSITION (DRY MATTER BASIS) OF 7 DAY-OLD HYDROPONICALLY GROWN SEEDLINGS (FIGURES SHOWN REPRESENT MEAN VALUES OF TWO SAMPLES).

ANALYSIS		BARLEY AERIAL Pt. + ROOTS	BARLEY AERIAL Pt. ONLY	SUNFLOWER SPROUTS	SOYBEAN SPROUTS
Crude protein	%	18.22	26.41	26.80	46.19
Ether extract	%	3.48	2.65	21.14	10.68
Crude fiber	%	17.11	19.44	8.26	10.50
Gross energy	Kcal/g	4.53	4.61	5.34	5.00
Calcium	%	0.18	0.09	0.22	0.25
Phosphorus	%	0.58	0.66	0.80	0.69
Magnesium	%	0.20	0.12	0.38	0.24
Potassium	%	0.74	1.14	1.11	1.98
Manganese	ppm	24.	21.	15.	20.
Copper	ppm	9.	14.	17.	12.
Zinc	ppm	56.	53.	78.	54.
Selenium	ppm	0.035	0.033	3.78	0.10
Nitrate	%	-	-	0.146	0.298
Moisture	%	90.57	90.92	89.24	88.07

TABLE IV. CHEMICAL COMPOSITION OF BARLEY GRAIN, SUNFLOWER SEEDS, AND SOYBEAN SEEDS (DRY BASIS).

	BARLEY GRAIN (17)	SUNFLOWER SEEDS (14)	SOYBEAN SEEDS (14)	SOYBEAN SEEDS (18)
Crude protein	13.00	18.10	40.50	43.20
Ether extract	2.10	36.40	25.30	-
Crude fiber	5.60	25.80	6.20	6.00
Calcium	0.09	-	0.31	0.28
Phosphorus	0.47	-	0.56	0.66
Magnesium	0.14	-	0.22	0.31
Potassium	0.63	-	1.39	1.77
Manganese	18.30	-	34.00	32.00
Copper	8.60	-	21.50	17.00
Zinc	17.20	-	45.50	18.00
Moisture	11.00	8.40	12.10	9.00

TABLE V. NUTRITIVE VALUE (Dry matter basis) AND COST (December 1980 base) OF 7-DAY-OLD HYDROPONIC BARLEY GRASS AS COMPARED TO OTHER FEEDS USED FOR RUMINANT SPECIES AT THE METRO TORONTO ZOO.

ANALYSIS		HYDROPONIC BARLEY GRASS	TIMOTHY HAY ALL ANALYSIS NAS-NRC (17)	ALFALFA HAY ALL ANALYSIS NAS-NRC (17)	PELLETED RUMINANT RATION
Crude protein	%	18.22	7.70	17.30	19.20
Ether extract	%	3.48	2.60	2.10	3.15
Crude fiber	%	17.11	33.80	31.40	14.07
Energy, gross	Kcal/g	4.53	4.58	4.42	4.09
Calcium	%	0.18	0.37	1.64	0.90
Phosphorus	%	0.58	0.19	0.26	0.73
Magnesium	%	0.20	0.17	0.32	0.28
Potassium	%	0.74	1.66	1.77	1.13
Manganese	mg/Kg	24.00	65.00	51.80	213.00
Copper	mg/Kg	9.00	5.10	13.70	34.00
Zinc	mg/Kg	56.00	17.00	17.00	428.00
Selenium	mg/Kg	0.035	-	-	0.15
Carotene	mg/Kg	20.16	13.70	61.10	-
Vitamin A equiv.	IU/g	33.60	22.80	101.90	17.60
Moisture	%	90.57	12.30	10.30	8.93
COST/Kg. FRESH Wt. (CAN $)		0.129	0.075	0.075	0.258
COST/Kg. DRY MATTER (CAN $)		1.368	0.086	0.084	0.283

TABLE VI. NUTRITIVE VALUE (Dry matter basis) AND COST (December 1980 base) OF 7-DAY-OLD SUNFLOWER SPROUTS AS COMPARED TO SOME PRODUCE USED FOR PRIMATES AT THE METRO TORONTO ZOO.

		SUNFLOWER SPROUTS	SPINACH	LETTUCE ROMAIN	LETTUCE CRISPHEAD	CELERY	GREEN BEANS
Crude protein	%	26.80	34.40	21.67	20.00	15.25	19.19
Ether extract	%	21.14	3.23	5.00	2.22	1.69	2.02
Crude fiber	%	8.26	6.45	11.67	11.11	10.17	10.10
Energy, gross	Kcal/g	5.34	-	-	-	-	-
Energy. dig.	Kcal/g	-	2.80	3.00	2.89	2.88	3.23
Calcium	%	0.22	1.00	1.13	0.44	0.66	0.56
Phosphorus	%	0.80	0.55	0.42	0.49	0.47	0.44
Magnesium	%	0.38	0.95	0.18	0.24	0.37	0.32
Potassium	%	1.11	5.05	4.40	3.89	5.78	2.45
Vitamin A equiv.	IU/g	-	870.97	316.67	73.33	40.68	60.61
Moisture	%	89.24	90.70	94.00	95.50	94.10	90.10
COST/Kg FRESH Wt.	(CAN $)	0.152	2.153	0.608	0.588	0.667	1.71
COST/Kg DRY MATTER	(CAN $)	1.41	23.15	10.13	13.07	11.31	17.27

TABLE VII. EXAMPLES OF PRIMATE DIETS AT THE METRO TORONTO ZOO (As fed basis - average amount per animal per day).

SPECIES	COMMERCIAL MONKEY FEED		SUNFLOWER SPROUTS		MIXED FRUITS VEGETABLES		TOTAL FOOD PER DAY	
	g.	%	g.	%	g.	%	g.	%
Papio hamadryas	412	72.92	100	17.70	53	9.38	565	100.00
Papio sphinx	204	45.34	182	40.44	64	14.22	450	100.00
Hylobates lar	250	58.83	25	5.88	150	35.29	425	100.00
Macaca sylvanus	284	80.68	38	10.80	30	8.52	352	100.00
Cercopithecus patas	204	59.82	137	40.18	-	-	341	100.00
Macaca fuscata	250	75.53	56	16.92	25	7.55	331	100.00
Macaca silenus	150	65.22	20	8.70	60	26.08	230	100.00
Lemur catta	80	45.71	70	40.00	25	14.29	175	100.00
Lemur m. macaco	75	52.45	50	34.96	18	12.59	143	100.00

TABLE VIII. EXAMPLES OF UNGULATE DIETS INCLUDING HYDROPONIC GRASS (as fed basis - average amounts per animal per day).

SPECIES	HYDROPONIC BARLEY GRASS Kg.	PELLETED RATION Kg.	HAY
African elephant	12.00	15.60	Timothy Ad lib
American elk	2.00	5.00	Timothy Ad lib
Black-tailed deer	2.00	1.65	Alfalfa Ad lib
Himalayan tahr	0.30	1.00	Timothy Ad lib
Indian rhino	6.00	12.50	Alfalfa Ad lib
Llama	1.00	1.00	Timothy Ad lib
Malayan tapir	1.50	2.50	Timothy Ad lib
Moose	2.00	6.00	Alfalfa Ad lib
Reeve's muntjac	0.20	0.60	Alfalfa Ad lib

SERGIO E. OYARZUN, M.S. QUESTIONS AND COMMENTS

COMMENT: When you compare the percentage of the ration from the feeds, the hydroponic grass may be providing over 50% of the wet weight. The weight of the grizzly bear diet on a dry matter basis is not nearly that high because it is mostly water.

RESPONSE: I presented this on a fresh weight basis to show that you are feeding mainly water. If barley grass is only 9.3% dry matter, what you are doing if you are sprouting is loosing a tremendous amount of dry matter. The only thing you gain is water, that is water uptake by the seedlings through the roots.

QUESTION: You commented on the fact that the bear's stool was firmed up with an increase in dietary fiber. Do you see that also in the lemur diet?

RESPONSE: We do not seem to have a stool consistency problem in the primates generally.

COMMENT: At the National Zoo we found that if you increase the levels of dry dog food offered to the bears it seems to decrease the firmness of the stools. I was quite skeptical of this observation at first but after conducting feeding trials we confirmed that there did seem to be such correlation. But we also noticed that when the spectacled bears began to consume grass growing in their enclosure, their stool also became more firm regardless of the level of dry dog food in their diet.

COMMENT: There is some evidence to support the feeding of vegetable matter to polar bears since studies have revealed that at least in the summer time the bears do consume a variety of plant materials.

RESPONSE: When I say that I was pretty surprised that the polar bears accepted the hydroponic grass I was confessing my ignorance. I really thought polar bears to be 100% carnivores, that they do ingest a fair amount of vegetable matter in the wild does suprise me.

QUESTION: I wonder if it might not be the way we are presenting the food because in the wild bears are foraging continously and we, in zoos, are meal feeding? In the zoo they are consuming their food very rapidly and perhaps such a large volume is reaching the small intestine at once that it cannot be handled well and it runs right though them.

RESPONSE: Yes, there certainly might be some merit in looking at that aspect of the problem as well.

CALCULATING DIETS

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When you and those preceding you brought animals into confinement and restricted their ability to obtain food by either foraging or preying, you accepted the responsibility for providing their security and food.

Zoological care of animals is an honorable profession preserving for posterity and appreciation by mankind those animals which might otherwise be lost forever or else visually unavailable except to few in some micro-environment. Your responsibility to feed those confined animals to prevent environmental and nutritionally related stresses or discomforts, either by deficiencies or excesses, is obligatory.

In modern animal care the nutritional needs of zoological animals can best be met by providing specific foods formulated and processed to supply indispensible nutrients in quantities and qualities where neither a deficiency nor wasteful excess prevail.

When animals are managed in controlled confinement, food must be brought to the animals since expense prohibits space devoted to efficient food gathering by browsing and grazing by zoological animals. With adequate planning you can provide those nutrient needs with diets varying from high quality hay and trace minerals, with which ruminants can meet their needs, to diets in which 50 plus nutrients must be available for some nonruminants. Modern zoological care requires exacting nutrient supplies which are uniform and available throughout the year. Natural agricultural ingredients vary with soil conditions, climate, plant strains, storage, moisture content and processing; these factors must be considered in feed formulation. An almost constant supply of uniform nutrition can be provided by scientifically blending ingredients and fortifications to yield a uniform precise stabilized food to meet the needs of specific animals. Antioxidants, anthelmintics, hormones, bacteriostats, fungistats, attractants, and humectants are sometimes added to foods and are often necessary. With modern housing, diagnostic methods, biologicals, medications, nutrition and understanding of behavior, there is every reason for an animal in captivity to comfortably excel its noncaptive or feral equivalent.

The natural inclination for keepers and visitors to add individual snacks and supplements, based on anthropomorphism, may be beneficial if supplements are nutritionally balanced.

Some criticism may be expected when visitors observe animals consuming highest quality fruit and vegetables when many people cannot afford that quality of food and may actually be hungry. Justification for feeding commercial food is easy since most animals are capable of utilizing plants, grains and byproducts in complete foods which generally are not suited for human consumption. These ingredients constitute the major portion of animal diets which with scientific fortifications of vitamins, minerals, fats and fatty acids, proteins and amino acids bring the nutrient level of the diet to an optimum balance which can nourish specific animals effectively. Byproducts, such as those remaining after vegetable oils, beer, whiskey, flour, butter and cheese are produced can be used efficiently in animal diets to support growth, reproduction, lactation, maintenance and normal stresses. Nutritional advantages of the ruminant permit microorganisms in the huge "fermentation vat" to use moisture, heat and nutrients to convert nonprotein nitrogen into amino acids capable of being absorbed.

All 50 plus nutrients can by in dry-type foods, liquid diets, purified chemical diets, natural foods, synthesized nutrients or any combination of these since the body tissue cannot differentiate the source of nutrients as long as they are available. This is why you can meet the nutritional needs of your animals with different dietary combinations.

Since most animals eat to satisfy their energy needs, most nutrients are calculated in proportion to the caloric content of the diet. Most dry animal foods contain 3.5 to 4.0 kilocalories per gram. When diets contain excess moisture the volume of water may prevent adequate caloric intake to meet the animal's needs. While lettuce, cabbage, celery and squash contain 95-96 percent water, most dry feed ingredients contain about 10 percent moisture. Since most ingredients used in commercial foods are primarily in the air-dry form the calculations will be done on an air dry basis. Most vitamins and trace minerals vary extensively in food and feed ingredients; therefore, vitamin and mineral supplements such as those shown in the experimental food in table 1 are relatively inexpensive and similar supplements are included in commercial foods to ensure uniformity.

Most manufacturers of commercial foods use computers to calculate all of the nutrients in the diet and print results on a large single sheet. Perhaps the calculation of macronutrient content of a diet will help demonstrate the process of calculation.

Table 2 (macronutrient calculations) lists ingredients and supplements and some of the nutrients they contribute, particularly protein, fat, calcium, phosophorus and ash. The formula is shown in pounds per ton.

To calculate this formula divide pounds per ton by 20 to obtain pounds per 100. The pounds per hundred can be multiplied by the percent of nutrient in each ingredient to obtain the contribution of that ingredient. When this is done for each formula amount, the columns can be added to show the calculated analysis as in table 2 with calculations completed.

With advanced formulation now used commercially the protein column would be replaced with 10-14 columns of amino acids and fats would include a column for linoleic acid.

You need to understand these procedures so you can calculate that lettuce, celery, cabbage and squash with 95-96 percent water and costing your zoo $0.25 per pound delivered adjusts to $5.55 per pound of dry matter and apples and carrots with 88 percent water sold to you for $0.45 per pound calculates to a cost of $3.75 per pound of moisture-free food. Most meat tissues are more than fifty percent water.

With increasing budgetary restrictions, it is easy to justify the use of more dry commercial type foods which cost $0.10 to $0.20 per pound of dry material.

Compare the nutrients supplied by one pound of good dog food with a list of foods which might be consumed during a day (table 3) to supply about the same level of nutrients. Surprised?

TABLE 1. EXPERIMENTAL CAT DIET*

Ingredient	%	Amino acid mixture	%
Amino acid mixture	28.50	L-methionine	.45
Turkey fat	25.00	L-cystine	.45
Cornstarch	18.95	L-arginine·HCl	2.00
Sucrose	19.95	L-histidine·HCl·H_2O	1.20
Salt mixture[a]	5.37	L-isoleucine	1.80
$NaHCO_3$	1.50	L-leucine	2.40
Choline CL	.33	L-lysine·HCl	2.80
Vitamin mixture[b]	.30	L-phenylalanine	1.50
Taurine	.10	L-threonine	1.40
α-tocopheryl acetate		L-valine	1.80
(30 mg/kg)	+	L-tyrosine	1.00
Ethoxyquin (125 mg/kg)	+	L-tryptophan	.40
		L-asparagine·H_2O	1.60
Total	100.00	L-serine	1.60
		L-proline	1.60
		L-glutamic acid	4.80
		L-alanine	.80
		Glycine	3.80
		Total	28.50

[a]Salt mixture (as % of diet): $CaCO_3$, .3; $Ca_3(PO_4)_2$, 2.8; K_2HPO_4, .9; NaCl, .88; $MgSO_4 \cdot 7H_2O$, .35; $MnSO_4 \cdot H_2O$, .065; ferric citrate, .05; $ZnCO_3$, .01; $CuSO_4 \cdot 5H_2O$, .002; H_3BO_3, .0009; $Na_2M_0O_4 \cdot 2H_2O$, .0009; KI, .004; $CoSO_4 \cdot 7H_2O$, .0001; Na_2SeO_3, .00002; total 5.37.

[b]Vitamins per kilogram diet: thiamin·HCL, 150 mg; niacin, 150 mg; riboflavin, 24 mg; Ca-pantothenate, 30 mg; vitamin B-12, .03 mg; pyridoxine·HCL, 9 mg; biotin, .9 mg; folic acid, 6 mg; inositol, 150 mg; paraaminobenzoic acid, 3 mg; menadoine, 7.5 mg; ascorbic acid, 375 mg; retinyl acetate, 15,000 IU; cholecalciferol, 900 IU.

*from Teeter, Robert G., David H. Baker and James E. Corbin. 1978. Methionine essentiality for the cat. JAS, Vol. 46, No. 5, pp 1287-1292.

TABLE 2. MACRO-NUTRIENT CALCULATIONS

INGREDIENTS	Formula per ton	Formula per 100	Protein .%	Protein lbs.	Fat .%	Fat lbs.	Fiber .%	Fiber lbs.	Calcium .%	Calcium lbs.	Phosphorus total .%	Phosphorus total lbs.	Phosphorus available .%	Phosphorus available lbs.
#2 Yellow corn	331	16.55	8.5	1.41	3.8	.63	2.5	.41	.01		.25	.04	.08	.01
Ground wheat	400	20.	11.5	2.3	1.5	.30	2.4	.48	.05	.01	.35	.07	.12	.02
Wheat middlings	200	10.	15.5	1.55	4.0	.40	7.5	.75	.05		.80	.08	.27	.03
Soybean meal, 48%	400	20.	48.0	9.60	.5	.10	3.5	.70	.20	.04	.65	.13	.22	.04
Corn gluten meal	100	5.	62.0	3.10	2.5	.12	2.5	.12	.02		.7	.04	.2	.01
Meat and bone meal	400	20.	50.0	10.00	10.0	2.00	2.8	.56	8.10	1.62	4.1	.82	4.1	.82
Poultry by-product	12	.6	58.0	.35	13.9	.08	2.3	.01	3.20	.02	1.7	.01	1.7	.01
Fish mean Menhaden	12	.6	61.0	.36	9.4	.05	1.0		5.2	.03	2.9	.02	2.9	.01
Fish solubles	12	.6	30.5		7.8	.04	0.5		.05		.5		.5	
Wheat germ	4	.2	24.0	.05	8.0	.02	3.5		.04		.8		.3	
Whey	4	.2	12.0	.02	0.5		--		.90		.70		.7	
Dicalcium phosphate	1	.05							22.0	.01	18.5	.01	18.5	.01
Salt	15	.75												
Vitamin mixture	5	.25												
Mineral mixture	4	.20												
Animal fat	100	5.			100.0									
Phosphoric acid	--										23.7		23.7	
Total	2,000	100.		28.92		8.74		3.05		1.73		1.22		.96

TABLE 3. COMPARISON OF ONE POUND OF DOG FOOD WITH HUMAN-TYPE FOODS

	Amount, gm.	Water, %	Food energy, k cal.	Protein, gm.	Fat gm.	Carbo-hydrate gm.	Vitamin A Equivalent in International Units	Thiamin mg.	Ribo-flavin mg.
One Pound of Good Dry Dog Food	454	10	1511	109	36.3	218	4340	2.05	2.41
4 strips bacon (crisp)	30	16	180	10	16	2	--	.16	.10
1 egg	50	74	80	6	6	-	590	.05	.15
8 oz. skimmilk	245	90	90	9	Trace	12	10	.09	.05
Toast--dry	22	25	70	2	1	13	--	.06	.05
8 oz. fresh orange juice	248	88	110	2	1	26	500	.22	.07
1 chicken drumstick, fried	59	55	90	12	4	trace	50	.03	.15
6 small green onions	50	88	20	1	Trace	5	Trace	.02	.02
1 ear sweet corn	140	74	70	3	1	16	310*	.09	.08
1 piece celery	40	94	5	Trace	Trace	2	100*	.01	.31
1 peach	114	89	35	1	Trace	10	1320*	.02	.05
Shrimp, 3 oz.	85	70	100	21	1	1	50	.01	.03
Baked potato, 1/3 lb.	99	75	90	3	Trace	21	Trace	.10	.04
Braised beef heart, 3 oz.	85	61	160	27	5	1	20	.21	1.04
4 spears asparagus	60	94	10	1	Trace	2	540*	.10	.11
8 oz. fresh milk	244	87	160	9	9	12	350	.07	.41
2 large lettuce leaves	50	94	10	1	Trace	2	950	.03	.04
	1621		1280	108	44	125	4790	1.27	2.70

*Source of vitamin A equivalent

Human-type food data from "Nutritive value of foods," Home and Garden Bulletin No. 72. U. S. Department of Agriculture, Revised August 1970.

Many values on some vitamins and minerals supplied in dog foods are not available for most human-type foods in public form.

MONITORING FEED INTAKE

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The science of animal nutrition is still in its infancy. Nutritional requirements for the chicken and dairy and beef cattle are fairly well defined only through intensive experimentation and close scrutiny by nutritionists. These requirements are published and updated by the National Research Council of the National Academy of Sciences. Similar requirements or guidelines for the horse, sheep, dog, and cat have not yet been so well defined. And we are even further away from establishing dietary guidelines or establishing nutrient requirements for the nondomestic or exotic species. There are few guidelines to conform to when attempting to offer adequate nutrients to an elephant, for example. In domestic animal nutrition studies, requirements were established in controlled experiments and measured by reproductive capacity, pathological changes, and/or level of productivity (pounds of milk produced or number of eggs laid, etc.). And although information gained from such experiments may be helpful from an animal production point of view, it may not be fully relevant to maintenance of a normal life cycle. In exotic animals, the adequacy of the diet can only be qualitatively surmised by evaluating the ability to resist disease, reproductive ability, and longevity.

Experimentation with nutrient levels offered to exotic animals is rarely undertaken; primarily because it is a question of ethics when nutrients believed to be essential are deliberately withheld. Or it may be specifically unwarranted because of the uniqueness of the species.

Yet there are many opportunities that all of us can seize to allow for the growth and expansion of knowledge in this field. The most basic and simple tool that we can employ to assess the general status of the animal is the measurement of feed intake. Many different kinds of scales can be employed depending on the nature of the feed being weighed. A daily record of feed consumption can be made over a number of days, weeks, or months (see Figs. 1 and 2). This information is only useful when coupled with a calculated analysis of the total diet. In this way an accurate assessment of the nutritional status of the animal can be made.

It is not always enough to provide a mixed diet to an individual or a group of individuals hoping that the correct selection of foods will be made. Some variety in diets of captive animals may be desired and necessary but is not always beneficial. In wild primate populations correct selection of food is critical. If a young animal is not shown how, by its parents or others in the group, to make the right choices its chances of survival and subsequent reproduction are greatly reduced. This selective process operates with great success in the wild. Zoo animals, however, do not consistently select (when choices are offered) the necessary food items and there is no selective pressure operating to ensure that they will. Zoos will continue to attempt to propagate all healthy individuals regardless of their food preferences.

A case in point which will help to emphasize the importance of monitoring feed intake and the assessment of the nutrient composition of the diet was reported by Tomson and Lotshaw in 1978. A group of lemurs (Lemur catta and Lemur variegatus) were housed and fed together. By incorrectly selecting foodstuffs high in phosphorus and low in calcium coupled with an inadequate supply of Vitamin D in the diet, some of the animals in the group developed clinical signs associated with nutritional secondary hyperparathyroidism. Radiography and blood chemistry values confirmed the initial diagnosis. Although some of the animals in this group were reported to have recovered successfully, the condition could easily have been avoided had more careful attention been paid to the actual feed consumed.

One of the most important concepts to consider when evaluating feed consumption, especially when two different diets are being compared is the concept of dry matter. Nutritionists use dry matter (or that portion of the feed which contains the protein, fat, carbohydrate, etc.) as a common denominator when comparing different rations. A canned cat food may list a protein content of 8%, a moisture content of 76%; a dry cat food may list a protein content of 27%, a moisture content of 12%. If each of these diets are considered on a dry matter basis, their protein levels will both be 33%. This is calculated by dividing the percent of protein, or other nutrient, by the percent of dry matter; if canned cat food is 76% moisture then the dry matter portion is 24%. Fig. 3 has been included to show comparisons of various food stuffs on an as fed vs. dry matter basis.

A slightly different way to approach this concept is to think of a container of mixed produce, 10 kg, being fed to an elephant. Most produce contains between 80 and 90% water. This 10 kg of produce is really providing the elephant with only 1 or 2 kg of dry matter (or 1 or 2 kg of nutrients) and 8 or 9 kg of water. If 10 kg of a complete pelleted feed with a dry matter percentage of 88 is fed to the same animal, it will be receiving 8.8 kg of dry matter (or 8.8 kg of nutrients). It is imperative that conclusions about the merits of one ration over another not be drawn strictly by comparisons done on an as fed basis.

Zoos are beginning to recognize the need to address the problems of adequate nutritional management in their collections. Gradually data are being collected which relate to feed consumption and calculated composition of the diets fed. In some cases, digestibility studies are being undertaken to establish how well or how poorly nutrients are being utilized. It is and will be a painstakingly slow process to begin to establish guidelines for the myriad of captive wild animals in our care but it is an area that has long been in need of our attention.

FIGURE 1

DIET CARD

DATE: ______________

SCIENTIFIC NAME: ______________ COMMON NAME: ______________

SPECIES I.D.: ______________ NUMBER IN GROUP: __________

DIET PER INDIVIDUAL OR GROUP

FOOD ITEM	UNIT OF MEASURE	FOOD ITEM	UNIT OF MEASURE

SPECIAL INSTRUCTIONS: ______________________________

____

____

APPROVED BY: ______________________ Nutritionist

______________________ Veterinarian

______________________ Curator/Superintendent

FIGURE 2

DAILY FOOD CONSUMPTION FOR MONTH __________ YEAR _____

SCIENTIFIC NAME: ______________________________

COMMON NAME: ______________________________

INDIVIDUAL/GROUP ID: ______________________________

CAGE NO.: ______________________________

BUILDING: ______________________________

DAY	AMOUNT OFFERED	AMOUNT CONSUMED	KEEPER	DAY	AMOUNT OFFERED	AMOUNT CONSUMED	KEEPER
1				16			
2				17			
3				18			
4				19			
5				20			
6				21			
7				22			
8				23			
9				24			
10				25			
11				26			
12				27			
13				28			
14				29			
15				30			
				31			

COMMENTS: ______________________________

____

FIGURE 3

FEED VALUES PER UNIT OF DRY MATTER

FOOD	% WATER	DIGESTIBLE ENERGY (Kcal/Kg) AS FED	DRY
Barley Grain	11	3,375	3,792
Oat Meal	9	4,052	4,453
Melons, whole	94	212	3,527
Sweet potato, tubers, fresh	68	1,157	3,616
Apples, fruit, raw	82	587	3,263

From Table 2-1 Crampton & Harris, 1969

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DIGESTIBILITY TESTS FOR EVALUATING THE NUTRITIVE VALUE OF FEEDS

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INTRODUCTION

Various methods exist for evaluating feeds (Schneider and Flatt, 1975). The simplest evaluation of feeds is a comparison of their gross effects, as in feeding trials. A further refinement is the chemical analysis of the feeds, determining how much protein, carbohydrate, mineral, etc., that each contains. The next step is the determination of the digestible nutrients in the different feeds. The word "digestible" or "digestibility" may sometimes be used in different ways. For example, a feed may be said to be digestible because it is easily digested - that is, it causes no unpleasant sensation after it is eaten - while an undigestible feed may cause gastric or intestinal disturbances. Animal feeds may be judged by their effects and a feed that results in greater animal weight gains is said to be the more digestible. The word "digestibility" as used in animal nutrition has limited meaning. It denotes the percentage of the feed or of any single nutrient of the feed which is dissolved or otherwise acted on in the entire digestive tract so that it can be absorbed and put at the disposal of the body cells. For example, a digestion experiment with a steer may show that out of each 100g of protein in a feed eaten by the animal, 60g are apparently digested and absorbed. The digestion coefficient of the protein in this case is stated to be 60 or that protein is 60% digestible. Digestibility, therefore, is a concept obviously distinct from that of rapidity or ease of digestion. A feed may have no injurious or disagreeable effects and yet may have a low coefficient of digestibility (e.g., straw).

IMPORTANCE OF DIGESTIBILITY MEASUREMENTS

It is only the digestible portion of feeds that can serve to maintain vital body functions, supply energy and form animal products. Chemical composition alone does not determine the value of feed. Value depends upon composition, digestibility and certain other factors. Consequently, certain feeds, by being much more digestible than others, are much more completely utilized. It is also generally recognized that feeding stuffs are not completely digested, that each contains some material which is not retained and utilized in the body. Only that portion which is soluble or is rendered soluble by hydrolysis or some other chemical or physical change can be taken up into the circulation and assist in supplying the animal body with material for building and repair of tissue or supply the energy necessary for body functions. A ration of given composition is useful in direct proportion to the solubility of its constituents in the several digestive fluids and the readiness with which they are rendered available to the body.

METHODS OF DETERMINING DIGESTIBILITY

The accurate feeding of weighed amounts of individual feeds or thoroughly mixed rations and the collection of the excreta without loss are important to the conduct of digestion experiments. No matter what methods are used for other phases of the experimentation, the facilities for feeding are important. It is necessary in all animal experimentation where feed intake is carefully evaluated (as it should be in digestion trials using the total collection method), to have well constructed feeders designed so that no feed is lost.

The most common arrangement for collecting the excreta of animals for digestibility experiments is through the use of metabolism crates. A metabolism crate is actually a stall or box large enough for the animal set on legs from 50 cm to 1 m high. It is so planned as to permit the quantitative collection of feces and urine under it or in the lower part of it. However, a common criticism of digestion studies is that feed intake by animals is sometimes abnormally low and erratic. This lack of appetite is in many cases attributable to the fact that the animal may be too nervous or frightened to eat, resulting from the close confinement made necessary by the very nature of the equipment used. It is important that the experimental animals be sufficiently comfortable so that they will not only eat well but so that fright or pain will not cause any other abnormal function. With some digestion stalls, the method of excreta collection is such that movement of the animal is greatly restricted; that is, the animal must be in a position which will allow the excreta to fall directly into the correct receptacle. On the other hand, too much freedom for the animal may result in excreta falling on the floor. With the kind of cage that has a metal mesh or grid floor, the space allowed the animal may be large enough to permit considerable freedom of movement, which, from the standpoint of animal comfort, is probably an advantage. However, such a floor could hardly be comfortable to lie on. So, conducting a digestion experiment may entail appreciable annoyance to the animal. Some individual animals are temperamentally unsuited to be used in such experiments and may have to be discarded. Some breeds of animal may even be found to be too nervous to be used in digestion trials. It seems logical to believe that most captive wild animals would fall into this category. What, then, are the alternatives?

There has been considerable interest among animal nutritionists in methods of reducing the time and expense involved in digestion experiments by the use of methods where total feces are not collected and weighed but are merely sampled and analyzed. This departure from the former method of determining digestibility has been designated as the indicator or index method (Kotb and Luckey, 1972). In this method, in addition to the chemical analysis of the usual proximate nutrients, the content in the feed and feces of an indigestible reference substance is determined. The substance may be a natural constituent of the feed (internal indicator) or it may be added to the feed (external indicator). Substances used for this purpose include ferric oxide, chromic oxide, lignin, silica, chromogen, acid-insoluble ash (Van Keulen and Young, 1977) and indigestible acid detergent fiber (Waller et al., 1980). A good marker must be strictly nonabsorbable, must not affect or be affected by the gastrointestinal tract or its microbial population, must be physically similar to or intimately associated with the material it is to mark and its method of estimation in digesta samples must be specific and sensitive and not interfere with other analyses. A characteristic of this method is that the digestibility is calculated from the relation between the nutrients and the indicator substance in the feed and in the feces. This method has been called a qualitative method, although this name is not strictly accurate. The digestion coefficient is computed by using the change in the ratio of each nutrient with reference to the special indigestible substance in the feed and in the feces. An example of this is the determination of the digestibility of the dry matter of a feed by the following equation:

$$\text{digestion coefficient of dry matter} = 100 - 100 \times \frac{\%\text{ indicator in feed DM}}{\%\text{ indicator in fecal DM}}$$

By chemical analyses of a suitable feed sample, the ratio of the concentration of the inert substance to that of any nutrient in the feed can also be established. A similar ratio can be determined in the feces and the digestibility can then be calculated without weighing either the feed consumed or the feces produced. Thus, if the percentage of any nutrient in this feed and feces is known and the percentage of the indicator substance is also determined in the feed and feces, the digestibility of that nutrient can be found by means of the following formula:

$$\text{digestion coefficient of a nutrient} = 100 - 100 \times \frac{\%\text{ indicator in feed} \times \%\text{ nutrient in feces}}{\%\text{ indicator in feces} \times \%\text{ nutrient in feed}}$$

When determining the coefficients of digestibility of nutrients by the indicator method, it is assumed that the reference substance passes through the alimentary tract at a uniform rate. If its rate of excretion during the day is inconsistent, special sampling plans, if possible, should be followed to adjust for this diurnal variation. If, on the other hand, the ratio of the indicator and the nutrients is the same throughout the 24-hour period, only a small amount of feces collected at any time of the day or night should be sufficient to give an estimate of digestibility. However, it is unwise to collect only one sample for digestibility determinations. The animal should always be allowed an adequate preliminary period to adjust to the feed and fecal (grab) samples should be collected for several consecutive days and pooled for subsequent analyses.

For indicators which in any experiment are consistently found to be recovered incompletely in the feces, such as is sometimes true of chromic oxide and lignin especially, the factor for percentage recovery may be substituted for 100 in the previous equation. Therefore, the new equation would read as follows:

$$\text{digestion coefficient of a nutrient} = 100 - \frac{\%\text{ recovery of indicator} \times \%\text{ indicator in feed} \times \%\text{ nutrient in feces}}{\%\text{ indicator in feces} \times \%\text{ nutrient in feed}}$$

This method of determining digestibility will hopefully avoid much of the time, labor and expense involved in conducting digestion trials. Also, this method would appear to be the most useful in evaluating digestibilities of feedstuffs fed to captive wild animals.

FACTORS AFFECTING DIGESTIBILITY

There are many factors which may affect digestibility of feeds. Workers over the years have investigated more than 50 different factors that might influence the efficiency of digestion. Some of the most important factors as related to captive wild animals are outlined below.

Level of feed intake

The plane of nutrition is one of many factors affecting digestibility of feed nutrients. Experiments show that livestock usually digest a larger percentage of the nutrients in their feed when fed less ration than when they receive full feed. Most data indicate some depression in apparent digestibility as level of intake is increased. This may be due to a more rapid movement of feed through the tract, thus allowing less time for digestion and absorption.

Particle size

Much data exist indicating that forage digestibility is depressed by grinding to a very fine particle size. Fine grinding also apparently increases rate of passage.

Chemical composition

One of the most significant factors which affect digestibility is the chemical composition of the feeds under consideration or of the rations in which they are fed. Digestion coefficients should never be reported for feeds without reporting also the percentage composition of identical samples in terms of the same nutrients for which the coefficients have been determined. Digestibility of one feed is believed to differ from that of a similar feed because each may contain different contents of certain chemical entities, particularly since some of these diminish the opportunity for the digestive enzymes to come in contact with their respective substrates. On the other hand, digestibility of complete feeds can be enhanced by the additions of relatively small quantities of specific nutrients such as protein or soluble carbohydrate.

Feed processing

Processing feedstuffs is conducted in an attempt to enhance digestibility. Changes in physical form can influence digestibility of the dry matter, energy, protein or any of the organic substances in feed products. Such processes as drying, grinding, pelleting and wafering all act to generally decrease digestibility. On the other hand, ensiling, treating with chemicals and cooking act to improve digestion somewhat.

Exercise

Although some workers have found that exercise hastens the process of digestion in the stomach and intestine of swine, it is generally considered to be a factor of minor importance insofar as it may affect the digestion coefficients of most nutrients.

Age

It is generally felt that animal individuality affects digestibility more than age. However, older animals appear to better digest some nutrients (e.g., fiber, minerals) than do the young of their species. The evidence available indicates that, in general, age itself makes little or no difference in the ability of animals to digest nutrients. In the case of ruminant species, the young cannot digest much roughage until their digestive tracts, especially their rumens, are developed. Also, the ability of old animals to digest feed is often impaired by poor teeth which makes adequate chewing of their feed difficult. Declining health might further adversely affect digestibility at an advanced age. However, the digestibility of feed by younger animals may often be influenced more by the presence of parasites.

Other factors such as frequency of feeding, amount of water ingested and ambient temperature may also affect digestibility but the data are contradictory and work remains to be done on these relationships.

In conclusion, digestibility data can offer insights into the proper feeding of animals, including captive wild species. Therefore, it would appear to be advantageous for those who work with these species to become familar in making these digestibility estimations.

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GEORGE C. FAHEY, Ph.D. QUESTIONS AND COMMENTS

QUESTION: You talked about the effect of stress on feed intake, what about the possibility that stress will affect the rate of passage?

RESPONSE: Yes, certainly it could.

COMMENT: That might be something we have to consider if we are dealing with a flighty animal. To make it easier to collect feces, we might have to confine the animal even more than we ordinarily do, e.g., metabolism cage. We would perhaps be violating the flight distance of the animal in such a case and it may mean that we were not going to get representative values. Even if you decide to use indirect methods of digestibility measurements, it may be wise to select tamer animals - one that have been hand-reared for example, ones that had been more accustomed to human handling.

RESPONSE: Yes, that is a very good point.

THE CENTRAL FEEDING SYSTEM AND NUTRITIONAL PROGRAMS AT THE METROPOLITAN TORONTO ZOO

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Wild animals have been studied extensively and there is a large body of published literature concerning the natural feeding habits of each species.(6,10,13,17) However, observations made in the field, and stomach analysis studies, provide only an insight into the nutritional requirements of many species commonly kept in zoological gardens. Natural feeding habits can be used as a basic guide in establishing a diet in captivity.(19,20) Specific diets must be formulated for many species kept in zoological gardens.

The Goals of the Zoo Feeding Program

Fiennes provided us with the functions that a diet must perform in captivity.(7)

1) Ensure employment of the teeth and digestive organs in such a way as to keep them healthy.

2) Provide all the necessary nutrients which the animal requires.

3) Provide occupation and contentment as regards the feeding process.

4) Allow for seasonal changes both of the external environment and of sexual activity.

5) Avoid the psychological dangers of stress, which is so intimately linked with nutrition.

These basic criteria are valid and form the basis for diet formulation at our zoo.

General Considerations in Zoo Nutrition

We are all familiar with the traditional cookbook approach to feeding zoo animals. It is our feeling that diets should be based on scientific studies and all known nutrients should be provided. Emotion should not dictate the diet regime. The comparison between commercial or whole rations and natural feeding has provided one of the most interesting controversies in the zoo world. International Zoo Yearbook VI provides interesting reading on this subject.

The Retort Theory (Retorten-Auffassung) holds that the digestive system of a wild animal is such that one only has to feed carefully balanced amounts of nutrients to the animal in order to keep the animal alive.(11) This theory was studied extensively by Ratcliffe and resulted in a number of whole diets that provided nutrients based on the animal species' feeding characteristics; eg. carnivore, omnivore, herbivore. The number of special diets formulated was expanded over the years as new diets were developed at the Philadelphia Zoo.(18) Wackernagle took this principle of feeding and studied it further at the Basle Zoo in Switzerland. Working with Hoffman-La-Roche Pharmaceuticals, vitamin/mineral supplements were developed for zoo animal rations. The breeding success and longevity records set by animals under this regime are well documented.(18,24)

Hediger, and others such as Dittrich, have studied diets fed to animals in captivity, and have expressed concern for the zoo animals' mental well being. The feeding program must reflect behavioral considerations that are inherent in each species in the wild. In the wild, the feeding process occupies a signficant time period in many species activity chart. The natural foods and the method of presentation are very important in the occupation of animals in captivity.(5,11)

It must be emphasized that the behavioral occupation will vary tremendously in many species. This is most important in primates, especially great apes. By comparison some species of zoo animals, such as waterfowl and pheasants, may have much less consideration in diet formulation.

It is important to note that so-called 'natural foods' are often products that are not found in a species' wildlife feeding profile. In captivity 'natural' foods presented to an animal are important to stimulate interest and increase the period of daily activity involved with feeding.

The following are some examples used to compare 'natural' with complete diets.

Comparison of "Natural" versus Whole Commercial Rations

Considerations	"Natural" Diet	Complete Diet
Nutrient content	Inadequacies.	'Balanced' ration.
Trace elements	Often deficiencies improper ratios.	Can be added as prescribed eg. Vitamin "E" & Selenium.
Occupation	Best palatability. Better in general.	May not be as good, can be adequate in some species.

Considerations	"Natural" Diet	Complete Diet
Dentition	Better use of mouth parts, but sometimes harmful. Whole animal may be best suited.	Not as good. Improved pellet design may help.
Behavior	Dominance may create a problem.	Uniform nutrition to all in the group.
Variety	Seasonal variation provides variety in diet. Especially important in some species, eg. great apes.	Uniform diet with no variety. May be important in more intelligent species.
Economy	Most expensive, more wastage.	Store easily. Good economics. Minimum wastage.
Other factors	Possibly some unknown breeding factors, eg. 'grass factor' in hydroponics. Pine nuts - thick-billed parrot. Breeding did not occur in captivity until offered in the diet.(16)	Good overall nutritional plane can increase reproduction. Massive contamination or imbalance could result due to manufacturing error, eg. PCB poisoning.

Hintz points out that in captive ruminants fed entirely on pelleted rations, there is a high incidence of soil ingestion. Both ruminants and non-ruminants develop vices such as wood chewing and hair chewing. Feeding a coarse roughage diet such as hay in addition to pelleted food is desirable.(12) Dittrich does point out that some licking behavior in zoo ungulates may not be a symptom of a mineral or other nutrient deficiency. He contends that the lip and tongue movements employed during a long drawn out feeding period in the wild animal are not satisfied in the rapidly consumed prepared feeds. This may be most important in some groups such as true browsers (eg. moose, giraffe, and white-tailed deer).(5)

Another behavioral consideration is the fact that in captivity the feeding site may become a focal point for social interaction. One must consider the fact that socially submissive animals may not be receiving the best foods in sufficient quantity. To maintain good health, nutrients must be available in the proper proportions to all individuals in the exhibit.

Although domestic animal values are well established for many nutrients, the zoo animal species still lack significant data. Feeding trials carried out by the zoo in conjunction with a laboratory or feeding companies should be encouraged. This will result in a true establishment of scientific criteria on which to base zoo feeding programs.

Specific Considerations

The giraffe is an example of a specialized species. In the wild the giraffe is a very selective browser that chooses the choicest parts of leafy branches. The analysis of the whole branch is misleading and shows a much lower level of protein than actually eaten. Field studies show protein content varying in rumen samples from 17-22% during the rainy season when there is an emergence of new green leaves. In the dry season browse selection is limited to 12-18% protein content. Anatomical studies show that the giraffe's feeding habits are aimed at the protein/nitrogen rich food of great digestibility. The forestomach mucosa offers a relatively greater absorptive surface than that of any other ruminant species under study. The microflora and microfauna are not adapted to handling a high fiber and high cellulose diet.(8,4)

In feeding the giraffe in captivity it is felt that we must upgrade the protein level.(8) If choice alfalfa hay is fed, the dominant animals in the group may select the green leafy parts and leave the stems which are more fibrous and have a lower protein content. Thus the animal low on the peck order may be receiving a much lower protein content when analyzed. The zoo keeper must realize that although the hay may appear uneaten, the green leaves may be selectively removed. Consequently, fresh hay should be added several times daily. Tongue activity is important in the giraffe. Browse or leafy forages should be continuously offered. The formulation of a ration for the giraffe must include both nutritional and behavioral factors.

Nutritional Problems in Captivity

Traditionally, a high incidence of disease related to nutrition has been documented in captivity. Hyperparathyroidism and various mineral and vitamin deficiencies are described.(1,3,9,24,25,26,27)

In recent years the general nutrition of zoo animals has improved significantly. Nutritional disease is not as common today in the larger zoos. Commercially available products for zoo animals or for domestic and laboratory animal fields have improved the quality of nutrients offered most zoo species.(1,2,15,22)

New syndromes have been described and recognized in captive zoo animals. An example is the vitamin E and selenium-responsive muscular deficiency syndrome seen in zoos especially in eastern North America.(20)

Consequently, the nutritional deficiencies seen in a collection should be closely monitored and studied. A diet control system should exist in the zoo, and be subject to regular review. Alterations should be based on scientific assessment and clinical findings. This requires a change in philosophy in many institutions in which emotion often dictates the zoo diet. The humanizing factor in zoo diet formulation is significant.

Development of the Metro Toronto Zoo's Nutritional Program

The Metro Toronto Zoo is an open concept facility that has approximately 3,500 specimens housed on 710 acres of land. Many exhibits are semi-natural in appearance and allow ample space for animal activity.

Dr. William Rapley joined the staff of the zoo 15 months before the official zoo opening to the public in August, 1974. The veterinarian, in conjunction with existing zoo staff, had responsibility of organizing temporary diets as animals arrived. This modern site presented a unique opportunity to fashion a diet program without the hindrance of long established or fixed diets commonly seen in older zoos. The new zoo environment also allowed for the establishment of a "no public feeding" program prior to the public opening. Scheduled feedings of various animal species, by the keeping staff, were planned for public observation and enjoyment. An opportunity presented itself to have a diet control system which has been effective.

In June, 1974, Sergio Oyarzun joined the staff. Sergio is a nutritionist with M.Sc. training at Davis, California. He has a background in animal husbandry and research. Sergio has acted as Commissary Supervisor, which involves co-ordination of food preparation and distribution from a well organized central facility.

Administratively, the animal nutrition program is part of the Animal Health Unit. Diet input is received from all zoo animal staff, including both curatorial and keeping areas. With the nutritionist on staff, the feeding programs can be reviewed and improved and new diets can be formulated and evaluated.

The important criteria to be emphasized is that in order to have a scientific and effective feeding program, it is important to have a control system that is highly organized and meticulously maintained.

Diet Formulation

In arriving at our present regime, the following steps have been taken:

a) A literature search was undertaken to obtain available information on the natural feeding habits of the species in the wild.

b) Diets used in other institutions were evaluated. The nutrient composition of these diets was calculated and reviewed. The established nutrient requirements of the related domesticated species were considered.

c) Commercially available products were obtained and reviewed. In Canada, limitations existed in that some commonly used zoo products in the United States could not be imported or were very expensive to obtain. Consequently, locally available products were utilized. Many specialized diets had to be formulated and prepared by zoo staff.

d) Although several companies were dealt with, the United Co-operatives of Ontario were the most successful in assisting our zoo in diet formulation, especially pelleted rations. Company nutritionists researched the zoo literature and with the assistance of our staff nutritionist developed many zoo pelleted feeds that are locally made.

e) The zoo nutritionist, working with staff, developed on his own initiative many special diets that could be manufactured by our staff in the commissary. Diet formulation is based on the above criteria.

f) The diet is tested through a feeding trial, including acceptability and palatability. The performance of the animal is evaluated, including body condition, weight changes, and reproduction. Time spent in this area is labour related. Some species have been more extensively studied.

The Centralized System in Operation

A) Facilities - A centralized facility with central handling exists at our zoo. The modern facility has separate unloading and shipping docks. There is a large capacity to hold frozen meat, fish, and other frozen products, and special areas of cooler space for thawing and produce storage. The commissary facilities provide a situation in which there is a maximum central handling of food items and controlled food hygiene. Some minor preparation is undertaken in the keeping areas of the zoo but an effort is made to minimize this where possible.

The nutritionist provides direct supervision of this operation. The Animal Health Director provides input, especially in the veterinary area and is responsible for administration.

B) Staffing - In addition to the nutritionist, there are 6 people assigned to the commissary to handle food preparation on a 7 day a week basis. The recent trend has been to give newly hired keepers a period of time in this area as part of the training process. Supervisory duties are shared with one of the commissary workers who has lead hand designation. In addition, other members of the Animal Health Unit assist.

In the evaluation of this staffing situation, it is important to note that keeping responsibilities in food handling are greatly minimized, resulting in an overall labour reduction. Our zoo has a varied collection that is spread out over a large site. There are about 70 full time keepers on staff.

C) Centralized Program

i) Prepackaged Delivery - There is a daily delivery system in the zoo that provides prepackaged diets to the animal areas. Final preparation of some items does occur but is at a bare minimum and of a minor nature. Plastic bags are used to package much of the food distributed.

ii) Weighing Control - The diets are meticulously calculated out and a precise control is made by weight of each ingredient in the diet. In many cases specific amounts are tailored to each individual that is fed.

iii) Diet Sheets - Since 1976 detailed diet sheets have been set up to control each individual feeding unit in the zoo. This system includes a typed detailed account of diet components, listing specific amounts by weight. These sheets are now used for all animals except fish. To avoid the development of diet variation, duplicate copies are sent out for each change made to the appropriate staff including animal management, veterinary, curatorial, and keeping factions.

All diet sheets are co-signed by the nutritionist and veterinarian. However, it is important to note that input in diet composition is made from all levels of the staff and evaluated.

Responsibility is placed on the keeper to weigh out the food and assist in maintaining an accurate record of food intake on a daily basis. The keeping staff are instructed to follow the established program. At first there were some difficulties in establishing this system. However, today it is well received by staff in general. An important point is that we have an accurate account of what an animal is really being fed at a given time. Prior to the introduction of this system this was not the case.

A new diet sheet is issued when any diet change is made. Adjustments are made when an animal dies or leaves the zoo or is hospitalized. The nutritionist and his staff co-ordinate this activity. The system requires the meticulous maintenance of the diet sheets.

Major changes in the diet are scheduled over a period of time (4 weeks) in order to minimize any possible stress to the animal. With the control system firmly established, one can review, revise, or change an existing diet. In a system in which natural foods are fed as part of a diet the exact percentages can be controlled and well established to all persons concerned.

Some Specialized Diets Fed At the Zoo

A) Carnivore Mixes - The three mixes presently in use were developed by the nutritionist and are manufactured on site. Horse meat and beef by-products are the basic ingredients which are mixed with a carnivore supplement powder that provides the vitamins and minerals. The mixes are prepared twice weekly using a Hobart* mixer/grinder. The meat is cut into strips 8" long by 2" square. Before grinding, the appropriate carnivore supplement is added and mixed. After this is done the resulting mixture is ground. The mix is collected as it passes out of the machine and weighed at that time.

The carnivore supplement is a modified version of the Basle Zoo formula and is manufactured to our specifications by United Co-operatives of Ontario.

The following is the chemical composition of meat diets used at the Metro Toronto Zoo.

TYPE OF DIET	DRY MATTER %	GROSS ENERGY Kcal/g.	CRUDE PROTEIN %	FAT %	CRUDE FIBER %	Ca %	P %
Feline	33.96	1.90	18.98	8.20	0.26	0.68	0.58
Polar Bear	43.45	2.49	18.64	14.39	0.48	1.17	0.87
Plain Meat	35.52	1.94	21.31	7.88	0.24	0.82	0.64

Some carnivore mix is made into sausages which has increased acceptance in a number of small carnivores. The sausages can be heated to body temperature for reptiles which also increases acceptance. To get some species to eat sausages, they can be rubbed on a food animal to be scented prior to initial feeding.

The carnivore mixes produced are economically sound, including labour costs.

* The Hobart Manufacturing Co. Ltd., 124 Shorting Road, Agincourt, Ontario.
M1S 3S4, Canada
Meat Power Saw Model 5514 HS
Meat Mixer-Grinder Model #4346

Comparative Cost of Feline Diets

Metro Toronto Zoo Feline Diet	-	Can.	$0.5152	per pound *
Zu/Preem Frozen Feline I	-	Can.	0.9750	per pound **
Zu/Preem Frozen Feline II	-	Can.	0.9310	per pound **

* includes labour.
** includes transportation cost.

B) Gelatins - Based on an idea for a fish gelatin used at the National Aquarium in Washington, D.C. a number of gelatin diets have been formulated and made in the commissary since 1975. Examples of these diets are turtle gelatin, soft-billed bird gelatin, primate gelatin, gorilla gelatin, hornbill gelatin, fruit bat gelatin, etc. Gelatin powder is used as a binding substance for the rest of the ingredients. This type of diet has several advantages; flavouring can be added to improve palatability, and it can serve as a vehicle for administration of medication and parasite control drugs. Some of the formulas for these products will be presented in the paper by the nutritionist at this conference.

C) Pelleted Rations - In conjunction with the United Co-operatives of Ontario a number of specialized rations have been developed. These include various shapes and forms of products designed for different species. (See Table I)

Some other commercial products also used include laboratory monkey chow, trout chow, and fish products. The pellets are used as a basic part of the diet but are not the sole ration. Natural forages, seeds, etc. are fed as well. More specialized pellets are in the developmental stages.

Since 1973 all pelleted rations have been supplemented with Vitamin E and Selenium. This, together with a newborn hoofed stock injection program, has resulted in a low incidence of white muscle disease in our collection.

D) Hydroponics - Hydroponic studies have been undertaken for 3 years. Generally, barley is used as a grass product. An interesting product utilized is sprouted sunflower seeds which provide an improved source of protein and other nutrients as compared to fruits and vegetables. Sunflower sprouts are widely used in the zoo, especially by primates. This will be the subject of a separate paper.

E) Produce - The amount of fruit and vegetables used is minimized under a controlled situation. Some produce has been replaced by hydroponics, gelatins, and browse clippings. The fruit and vegetables have been classified according to nutritional content to allow for replacement by available and in-season produce as an economic measure. Much of the produce handling is efficiently performed in the central facility.

F) Fish - Considerable difficulty has been encountered in the fish feeding area. Utilizing the guidelines of others, especially Dr. Joe Geraci of the University of Guelph, the fish quality has been improved significantly. Pacific herring, sea smelt, and capelin are utilized. Thawing by cold water is commonly used but is strictly controlled. The criteria are described in the literature. This minimizes the need for extensive vitamin supplementation. Basic supplements that we use include salt, thiamine, multiple vitamins, and essential minerals.(9)

Commissary Operation

The economic savings in cost of goods and labour can be significant with a centralized facility under the supervision of a nutritionist. Maximum hygiene can be maintained.

A system of delivery inspection has been established. Samples of products such as fish and hay are inspected prior to purchase commitment. This has resulted in improved quality and pricing. Food products can be evaluated prior to commitment to purchase or rejected within a reasonable time once received. An examination and rejection clause is written into the purchase order.

Behavioral Considerations

The criteria outlined earlier by Fiennes has been given extensive consideration in formulating a diet program at the zoo. An effort has been made to provide some "natural" foods as a part of the diet in most cases in the zoo. The occupation and contentment of the animal has been generally attended to. With a central system established, it is possible to calculate nutritionally balanced diets and maintain occupational and anatomical requirements of the animal. When utilizing natural foods in the diet it is important to keep records of actual consumption and to be able to control amounts fed.

Examples:

a) All large carnivores are fed beef heads and large bones as part of the diet. Smaller carnivores are fed whole small animals one to three times weekly, depending on the species involved. The food animals are carefully purchased and laboratory tested prior to feeding.

b) All ruminants are fed roughages in significant quantity. The browsing animals are fed branch clippings, hydroponics, and good quality alfalfa hay.

The whole man-made or commercial diet is rarely the sole diet for a particular species.

"Natural" Foods Used at the Metro Toronto Zoo

a) Roughage - hay - i) grass - timothy

ii) grass/legume mixtures
iii) legume - alfalfa

b) Browse - plant clippings - poplar, dogwood, cherry, apple.
- tropical plants from pavilions - fig, banana, bamboo, etc.
- large branches fed to elephants.

c) Hydroponics - barley grass and sprouted sunflower seeds.

d) Fruits and vegetables.

e) Insects - mealworms, crickets, white worms.(14,22)

f) Whole animals - mice, rats, hamsters, guinea pigs, rabbits, chicks (culture and exam technique).

g) Beef heads, ox-tails, bones - to larger carnivores.

h) Fish, both frozen and live.

Micronutrients

a) Vitamin E and Selenium is added to all pelleted rations.

b) Trace mineralized salt blocks and loose essential minerals are utilized in the hoofed stock feeding program.

c) A commercially available palatable mineral and vitamin supplement* is used extensively for supplementing fruit and vegetable portions of diets as well as in diet formulation.

d) Vitamin and mineral supplementation is calculated by the nutritionist. Some prescriptions are set up by the veterinary staff to cover clinical considerations.

e) Studies involving mineral analysis of feeds and animal tissues have been initiated.

Studies Ongoing at the Zoo

a) Animals and diets are weighed where possible to establish growth rates and actual food consumption curves. This is invaluable in diet review or adjustment.

b) Numerous feeding trials are undertaken. The keepers assist in evaluating new products for palatability and acceptance. The refuse is saved and weighed for special studies.

c) Fibre digestion trials - fecal wastes are collected and analyzed. Tom Foose completed digestibility trials on a number of species in our zoo comparing alfalfa and timothy hays as part of his requirements towards a Ph.D. at the University of Chicago.

d) Approximate analysis and detailed analysis. Analyses have been provided on some products from commercial firms. An independent analysis is being performed on our diet items and products including those commercially obtained. This is providing detailed data on the accurate nutrient composition of various foods. Products used initially, based on calculated values, are re-evaluated when actual analytical values are available.

e) Animal cycles - detailed information has been obtained on food consumption on many representative species. Our goal is to establish and tailor specific diets based on seasonality. An example is shown as

* SA-37 Powder - Rogar/STB, Box 2005, Wilton Grove, London, Ontario. Small animal vitamin mineral supplement.

described in Table II regarding the Black-tailed deer (*Odocoileus hemionus columbiana*) at the Metro Toronto Zoo. The average daily food intake was obtained by accurate measurement of food offered minus food refused (see attached Table II). The cycle shows that, in winter, food consumption drops drastically. This corresponds to the protein/energy cycle seen in wild cervids.(25)

By increasing the food quantity or quality offered in summer and early fall, it is felt that the animals will be in better conditon during winter. Furthermore, the females will be able to handle parturition and nursing in the spring. In 1979, increased food was offered, and consumption has increased significantly. Animals can be studied in this manner in the zoo environment and a contribution made towards a better feeding program for each species. At our zoo significant body condition or haircoat improvements have been seen in white-tailed deer, black-tailed deer, reindeer, dall's sheep, and lowland gorilla as a result of concentrated evaluation and diet review.

The goal of our program is to develop special diets that consider animals at different times of year. In addition, specific rations are adjusted for various stages of the biological cycle including pregnancy, parturition, growth, and maintenance.

An important concept is to look at nutritional cycles in nature and study how they might be followed in a zoo environment.

Criteria for Evaluation of the Feeding System

a) Palatability and acceptability tests - keeping staff play an important role in evaluation. The weighing of rejected foods is important in providing a conclusive study.

b) Animals' general condition - animals are observed throughout the year and the condition evaluated. Hair coat, body weight, antlerogenesis in cervids, and activity are all important to develop exhibit criteria.

c) Reproductive success - successful rearing of offspring.

d) Post-mortem exam - body condition noted and any abnormalities. Poor nutritional state requires investigation. Histopathology is performed at the Ontario Veterinary College on a routine basis.

e) Assay - hair and organs may be analyzed to examine the level of specific nutrients, especially heavy metals such as copper.

When abnormalities are found, an investigation is indicated. This feedback mechanism is important to improvise a diet change that may alleviate a deficiency or surplus. The control sheet system allows for this type of evaluation and correction. The incidence of nutritional diseases seen under intensive surveillance has been very low to date.

Conclusion

A well-organized central preparation system exists at the zoo. A nutritionist directs the feeding program and supervises food preparation and handling. The control of animal feeding is important in establishing a zoo program. The goal is to provide exhibit animals in an excellent state of health and improved reproduction.

The feeding regime in the zoo is the basis of a preventative medical program. Consideration is given to both nutrient requirements and the biological status of each animal.

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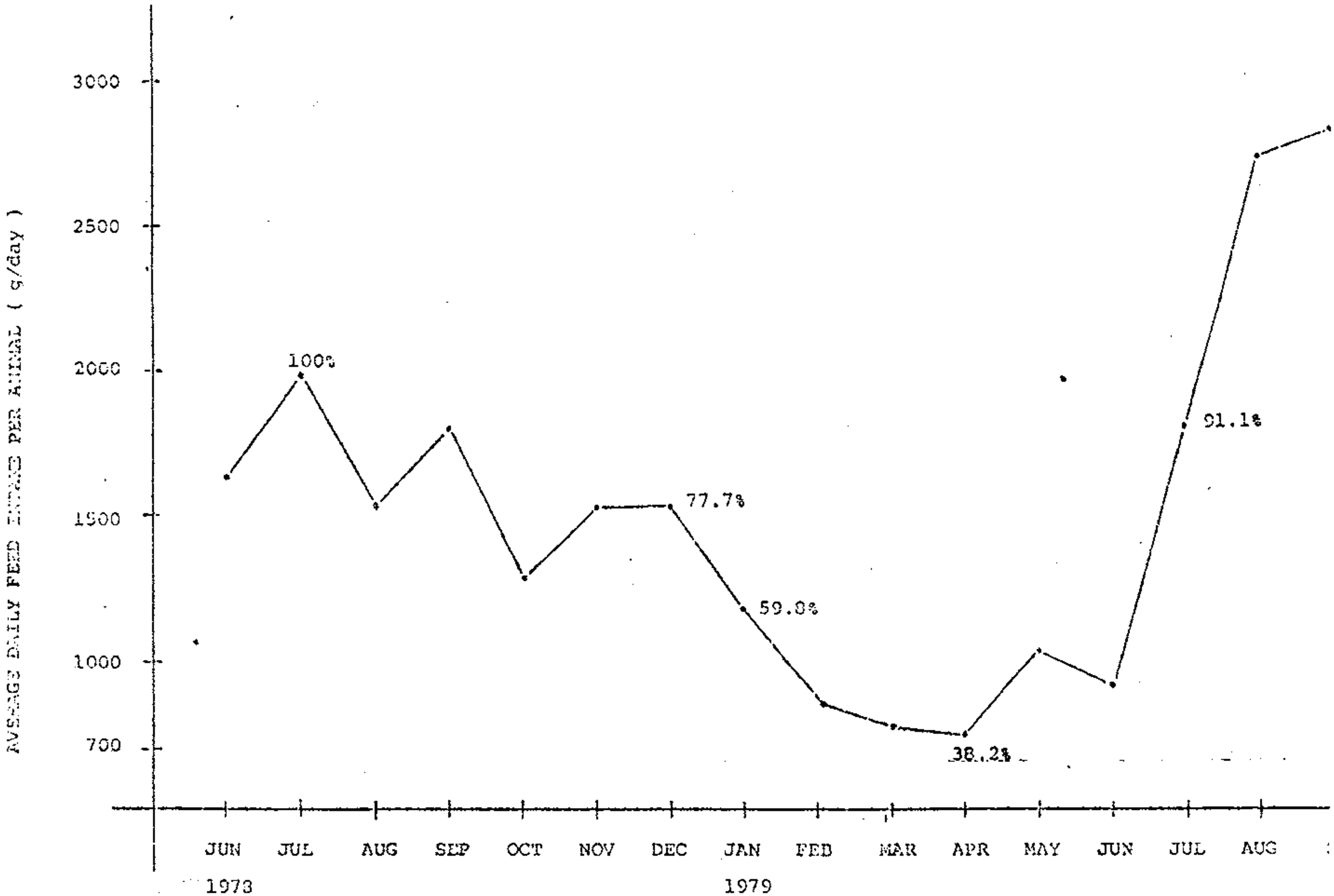
TABLE I

CHEMICAL COMPOSITION OF FEEDS USED AT THE METRO TORONTO ZOO

TYPE OF RATION	CRUDE PROTEIN %	FAT %	CRUDE FIBRE %	Ca %	P %	Se ppm	VIT.A IU/Kg	VIT.D IU/Kg	VIT.E IU/Kg	GROSS ENERGY Kcal/g
Herbivore Monogastric	14	1.0	16	0.7	0.5	0.15	6,600	1,100	31.0	4.0
Herbivore Ruminant	16	2.5	16	0.5	0.4	0.15	17,600	4,420	17.6	3.73
Herbivore Small Ruminant	20	2.5	13	0.6	0.5	0.17	22,880	5,756	23.0	3.77
Rodent-Lagomorph	15	3.0	14	0.8	0.5	0.10	8,800	1,650	30.0	3.90
Waterfowl	18	2.5	5	2.5	0.8	0.10	12,760	3,742	22.0	3.55
Hi-Boy Dog Chunks	24	7.0	4.5	2.0	1.4	-	10,120	3,432	55.0	3.98
Purina Monkey Chow #5045	25	5.0	4.0	1.0	0.6	-	35,000	6,600	-	4.20
Purina Monkey Chow #5038	15.5	5.0	4.0	0.9	0.5	-	30,000	6,600	-	4.18
Pheasant Starter	30	4.5	4.0	1.3	1.05	0.20	11,000	4,000	30	-
Pheasant Grower	24	5.0	4.0	1.1	0.85	0.20	9,000	4,000	15	-
Pheasant Hatcher	19	2.0	5.0	3.25	0.70	0.20	11,000	4,000	30	-
Foal Starter	18	3.0	8.0	0.65	0.60	-	6,600	1,100	16.5	3.88

TABLE II



SEASONAL CYCLE OF VOLUNTARY FEED INTAKE OF A GROUP OF BLACK-TAILED DEER (*Odocoileus hemionus columbiana*) AT THE METRO TORONTO ZOO.

SO/October 1979.