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

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

Proceedings of the Second Annual

DR. SCHOLL NUTRITION CONFERENCE

A Conference on the Nutrition of Captive Wild Animals

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Barbara A. Thomas, D.V.M.
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Dedicated to the memory of

Dr. Erich Maschgan

TABLE OF CONTENTS

Opening Remarks — 1
Thomas P. Meehan, D.V.M.

Complete Feeds or Cafeteria Style — 2
Mary E. Allen, M.S.

Comparative Anatomy and Physiology of the Herbivore Digestive Tract — 8
C. E. Stevens, D.V.M.

Application of Fundamental Principles of Nutrition in Feeding Captive Wild Animals — 17
Robert L. Cowan, PhD.

Utilization of Fibrous Feedstuffs by Herbivores — 25
George C. Fahey, Jr., PhD.

General Session Panel Discussion — 42

Digestive Efficiency and Protein Requirements of the Collared Peccary — 45
Gary R. Carl
Robert D. Brown, PhD.

African Elephant and Hippopotamus: The Results of Nutritional Research — 47
Wouter van Hoven, PhD.

Nutritional Implications of Dental Problems in Elephants — 63
T. A. Reichard, D.V.M., M.S.

Comparitive *In Vitro* Digestive Efficiency of Cattle, Goats, Deer, Collared Peccary and Nilgai Antelope — 68
James C. Priebe
Robert D. Brown, PhD.

Digestive Efficiency of Various Diets in Giraffe with Comparisons to Some Other African Ungulates — 70
Wouter van Hoven, PhD.

Hoofed Stock Panel Discussion — 82

Protein and Energy Nutrition of Geese — 87
Maureen L. Storey, PhD.

Do Emus Have to be Legless Too? — 102
Duane E. Ullrey, PhD.

Scientific Formulation of Diets for Captive Birds — 105
John C. Chah, PhD.

Avian Panel Discussion — 126

Ruminating About Primates — 128
Duane E. Ullrey, PhD.

Marmoset Nutrition — 133
James D. Ogden, D.V.M.

An Evaluation of the Anthropoid Ape Diets at the Woodland Park Zoological Gardens — 137
Daniel L. Higginbottom, M.S.

Nutrition of Herbivorous Edentates Two-toed and Three-toed Sloths — 153
Dennis A. Meritt Jr.

The Giant Panda-an Herbivorous Carnivore — 159
Olav T. Oftedal, PhD.
Ellen S. Dierenfeld, M.S.

General Panel Discussion — 165

OPENING REMARKS:

I'd like to tell you a little bit about how the conference is set up and some of the thoughts we had coming into it. Very early on in the planning for the 2nd Conference we thought that we'd like to narrow this hige field down into one smaller area. What we hit upon is to specialize this time in herbivorous animals. Not the group of herbivores that you think of in the narrow sense, but all the animals that are not meat eaters. So you'll see from the program that's what we've done. In years to come we hope to hit other groups and just see how the conference runs.

The other thing we did was get people from a broad range of backgrounds to speak. These are all people with a good background in nutrition, but a lot of them aren't zoo people. They're all people with expertise in various areas of captive animal diets whether it be in zoos or in research areas. What we hope to do is have these people speaking to a group composed primarily of zoo people, and hope to generate a lot of questions. We've left plenty of time open for panel discussions and questions to the speakers. Again the proceedings will be published the same as they were for the First Conference along with the panel discussions.

I'd like to thank a few people; Duane Ullrey, Olav Oftedal, and Mary Allen. A special thanks to Mary for helping get together a list of speakers who were all strangers to me. I think they gave me a list of people that are going to make a pretty good conference. Of course, Dr. Lester E. Fisher and Kevin Bell who've been helping put this thing together all along, and my assistant Dr. Barbara Thomas, without whom this conference would have come together just fine, except it would have come together next April or May. I would also certainly like to thank the Dr. Scholl Foundation, and the Lincoln Park Zoological Society for the funding involved in getting the conference going.

COMPLETE FEEDS OR CAFETERIA STYLE

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One of the unresolved topics historically and currently in the feeding of zoo animals concerns the nature and the form of the food stuffs offered (Hediger, 1966; Wackernagel, 1966). Do we feed foods that mimic the animals' natural diet, allowing them to self-select from an array of foods? Fresh fruits and vegetables for primates and whole animal carcasses for carnivores might seem appropriate. Or should we use diets containing a mixture of ingredients formulated to contain all the nutrients considered essential, and present such rations in baked, extruded, pelleted, canned or frozen form? The feeding practice employed will depend on the animal and its species-specific feeding and foraging strategy. The commissary budget, keeper schedules and exhibit design will also influence policy.

The choices available can be thought of as existing on a continuum. The ultimate in providing a natural diet would be to offer animals the same items they would select and consume in the wild. Seasonal and spatial fluctuations in availability of plant and prey species would be duplicated. This would necessitate field expeditions to native habitats, collection of food plants and insects, preservation by freezing and shipment back to the zoo. And it might include raising and maintaining species for captive exotic carnivores that would best represent their normally encountered prey.

The opposite end of this food continuum would be to provide a homogeneous diet containing nutrients from readily available and inexpensive raw ingredients. Feeds formulated by nutritionists and commercially prepared and packaged would be the only items offered. They would meet the estimated nutrient requirements of the captive exotic species for which they were intended. They could be made to minimize the cost and to maximize the ease of storing and handling. They would be considered complete feeds. Just as this extreme might seem an anathema to some zoologists, the ultimate natural diet might seem wasteful and unnecessary to most nutritionists. Bargains must be struck along the way.

The feeding practice adopted inevitably and obviously represents a trade-off between behavioral, nutritional, and practical considerations. An elephant spends seventy to eighty percent of its waking hours foraging, consuming hundreds of pounds of coarse plant material (Eisenberg, 1981). It cannot practically be maintained in a similar way in captivity. Yet simply feeding seventy or eighty pounds of a complete pelleted feed to the captive elephant, who can consume that amount in well under an hour, likewise doesn't seem appropriate. Zoos commonly offer a smaller amount of a pelleted or mixed grain ration, and make up the difference with grass or legume hay. This extends the time spent feeding considerably. In some instances, for a variety of reasons, apples, carrots, sweet potatoes and other produce are fed. Yet the only thing about produce that is similar to items in the animals' natural diet is that fruits and vegetables are succulent. Pelleted feeds and hays are not. We must be cautious in claiming that we feed "natural" diets when an orange is no more natural to an elephant than is grass hay; perhaps even less so.

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Assessing benefits and drawbacks requires consideration of cost, psychogical and physiological well-being. To determine where we should end up, as we slide along the continuum from complete feeds to cafeteria style feeding, we must weigh the advantages and disadvantages of various feeding strategies.

CAFETERIA STYLE

Advantages

Because the zoo salad is more interesting than a monkey biscuit the animals appear to be less bored at meal time. They are likely to spend more time feeding which will tend to decrease idle time. Zoo staff usually favor and encourage the use of such foods. Watching animals consume foods with gusto rather than indifference is heartening to keepers and curators. The animals appear more content. Zoo visitors also seem to respond favorably to watching animals consume more "natural" diets.

Frequently prophylactic and therapeutic treatments must be administered orally. Medications are more likely to be ingested if disguised in a palatable and novel food. This may be especially important with animals that have good manual dexterity, as do primates and many small mammals. If animals are interested in the food offered they are more likely to cooperate with their caretakers at meal time when shifting from one exhibit or holding area to another is required.

Disadvantages

Presenting the captive exotic animal with an array of food items from which to choose is a little like allowing a child to select his or her own diet. There isn't much evidence to support the idea that animals or children possess much nutritional wisdom. A child would probably choose a hot-fudge sundae rather than an omelet and a macaque bananas, rather than monkey biscuits.

Disproportionate consumption may be voluntary on the part of the animals or involuntary. If certain items in a diet are offered because they help reduce overall cost or because they are more palatable, nutrient imbalance can also result. When a complete feed was diluted with corn by approximately fifty percent by a well-intentioned animal caretaker and offered to white-tailed deer, a serious health problem resulted (Schmidt, et al.,1981). A likely explanation was that corn was selected preferentially by some of the deer. Compression fractures of the fifth lumbar vertebrae were attributable to the addition of a low calcium feed, corn, to an otherwise complete ration. The calcium in the pelleted feed was diluted which resulted in weakened and decalcified bone.

Another reason for disproportionate consumption of foods is the hierarchy in a group. Dominant animals will usually have the pick of the choice foods offered. Subordinates will get what remains, ironically often the more nutritious less palatable items.

Because the foods offered in this cafeteria approach may be well-balanced only if consumed in the correct proportions, supplementation with vitamins and minerals is often practiced. In many zoos a powdered supplement is applied to the "salad" just prior to feeding. This has not always been entirely successful (Tomson, et al., 1980). It does not guarantee that the animals' estimated requirements for micronutrients will be met. The supplement may adhere very well to apples and oranges but not to green beans or celery.

The expense of purchasing, storing, handling and preparing a fruit and vegetable ration are substantial. In major U.S. zoos annual produce costs of $75,000 are not uncommon. This figure doesn't include handling and preparation time. Part of the expense represents produce that is used to supplement herbivore rations. It becomes significant when one considers the size and the numbers of herbivores in a large zoo. A two thousand pound rhinoceros consumes sixty pounds of food per day, including fifteen pounds of produce at a cost of about $3,219 per year (Fig. 1.). In the interest of saving money, the produce could be reduced to five pounds per day, thereby lowering the cost of the diet to $2,186 per animal per year. This represents a savings of thirty-two percent (Fig. 2). Compelling arguments in favor of feeding produce are needed to justify the expense involved.

Produce is also expensive to prepare. Most primate and small mammal keepers spend significant portions of the day preparing fruits and vegetables for consumption.

COMPLETE FEEDS

Advantages

The benefits from using complete feeds have been realized for decades by those breeding and raising domestic livestock, dogs and cats. If food intake is at the prescribed and recommended level, based on age and physiological state, the animal is virtually guaranteed to receive nutrients in the correct amounts. In producing such diets the manufacturer can homogeneously mix the various ingredients prior to pelleting, extruding, freezing, canning, etc. and be certain the diet is uniform. There is no opportunity for self-selection by the eland or tiger, and as long as the diet is consumed, there is very little waste.

Storage of dry pelleted feeds is relatively inexpensive and not labor intensive. There is no equipment cost relative to processing since grinding, mixing and supplementing are done at the feed mill. Frozen diets are more expensive to store and handle but still labor-saving if there is no elaborate preparation required, other than thawing before feeding.

Disadvantages

The difficulties in feeding complete rations to captive exotics are real. The most problematic issue appears to be that of boredom. Many animals spend significant amounts of time foraging and hunting in their natural habitats. For primates most carnivores and many herbivores behavioral problems may result from the use of simplified diets. And if the complete and balanced rations are unpalatable the outcome may be more serious. Lethargy, noncooperation, health and reproductive problems can ensue. It doesn't matter how nutrient-rich a diet may be by analysis. If it isn't consumed, it can't be nourishing.

Another problem, perhaps not as obvious, relates to oral health. If the animal does not encounter food that stimulates teeth and gums adequately calculus accumulation, dental caries and gum disease may develop. In addition, systemic health may be compromised if bacteremia and subsequent renal complications result (Fagan, 1980).

DISCUSSION

It seems reasonable to attempt to satisfy the requirements of animals, staff and zoo visitor alike by a series of compromises. Both cafeteria style and complete feeds may be employed where appropriate. Group feeding situations can be monitored closely and special arrangements can be made for subordinate animals considered jeopardized by their social status. Feed can be distributed widely in an enclosure and scattered in a substrate of shredded paper or hay to encourage foraging. This may help to minimize usurpation of "favorite" items by dominant animals. Consumption of a cafeteria style diet can be monitored with the help of interns and volunteers so that potential problems can be spotted more quickly. Because there is little evidence of nutritional wisdom, mixed diets must be carefully and accurately formulated. If self-selection cannot be carefully controlled then substitution of more nutritious items in the mixed diet can be made. Nutritionists can play a particularly important role in the formulation of such diets.

To promote more natural behavior in captive animals many zoos supplement with browse for herbivores and bones for carnivores on a periodic basis. Offering less feed more frequently throughout the day may encourage activity and help to simulate natural conditions.

Behavioral engineering is another approach to the feeding dilemma that may encourage "species-typical behavior" according to Markowitz (1979). Allowing an animal to take an active part in provisioning its own food through the use of a feeding apparatus can promote increased activity (Markowitz, et al., 1978). These exhibits can be educational and well-received by the zoo visitor (Chasan, 1974). Unfortunately such exhibits require extensive planning, can be costly and therefore may be impractical.

CONCLUSION

Zoos cannot possibly duplicate natural diets or foraging and hunting conditions. The responsibilility in feeding zoo animals must include an honest recognition of the limitations that captivity imposes and a willingness to establish feeding programs with as non-anthropomorphic yet thoughtful an attitude as is possible.

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Figure 1

RHINO DIET WITH FIFTEEN POUNDS PRODUCE

Item	Pounds Consumed		Cost
	As Fed	Dry Matter	$
Pellet	12	10.6	$1.68
Alfalfa Hay	33	29.0	2.64
Produce	15	1.5	4.50
	60	41.1	$8.82

Cost/year - $3,219

Figure 2

RHINO DIET WITH FIVE POUNDS PRODUCE

Item	Pounds Consumed		Cost
	As Fed	Dry Matter	$
Pellet	13.3	11.6	$1.85
Alfalfa Hay	33.0	29.0	2.64
Produce	5.0	0.5	1.50
	51.3	41.1	$5.99

Cost/year - $2,186

COMPARATIVE ANATOMY AND PHYSIOLOGY OF THE HEBIVORE DIGESTIVE TRACT

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Herbivores are distinguished by their ability to subsist largely on a diet containing only the fibrous portion of plants. This provides advantages in the amount and range of food available to them, allowing their wide distribution even in deserts and at high altitudes where plant and other animal life are limited. The ability to efficiently utilize plant fiber as a major source of food is accomplished by a digestive tract capable of subjecting large volumes of food to microbial digestive processes. The structural and functional characteristics of the herbivore digestive tract that allow for this process also provide limitations on how they should be fed. The following discussion will attempt to summarize strategies developed for efficient microbial digestion and some of the advantages and limitations of this process.

Microorganisms indigenous to the digestive tract are capable of converting sugars, starches, cellulose, hemicellulose and other carbohydrates to volatile fatty acids (VFA); principally acetate propionate and butyrate. The VFA are rapidly absorbed and can provide the major or even the entire source of energy required by the animal. The microorganisms also are capable of converting low grade protein and nonprotein nitrogen into the essential amino acids required by the host. In addition, they can synthesize the required B vitamins. Although, the process of microbial digestion and synthesis has been most extensively studied in the forestomach of ruminants, a similar process has been demonstrated in the stomach of many nonruminant mammals, the gut of some invertebrate herbivores and the large intestine of amphibians, reptiles, birds and mammals. For example, the large intestine of the dog (7), bushbaby (4), vervet monkey (4), pig (2) and pony (3) each contain VFA at concentrations equal to or greater than those found in the ruminant stomach. VFA also are absorbed by large intestinal mucosa at rates similar to that of rumen epithelium (12). Therefore, the principal advantages herbivores hold over carnivores and omnivores are in the larger quantity of VFA produced and in both the area of gut lumen and the time available for their absorption. Herbivores are more efficient in digestion of plant fiber due to their ability to ingest larger quantities of plant material, retain it for longer periods of time and provide the fluid and buffering environment required for the microbial digestive process.

The prerequisites for efficient microbial digestion of large quantities of plant material are provided by the presence of either a voluminous, complex stomach or a voluminous, complex large intestine. The latter appears to have evolved first. Few nonmammalian vertebrates are herbivores. The cecum and proximal colon of the herbivorous iguana are enlarged and contain projections of mucosal folds that delay passage of digesta (6). The ceca of the herbivorous birds such as the rhea are large and usually drawn into sacculations by longitudinal bands of muscle. Retention of digesta in the large intestine of reptiles and birds is further aided by antiperistaltic waves of contraction initiated at periodic intervals from a pacemaker located in the muscular wall of the cloaca.

Parra (8) noted that the relative volume capacity of the digestive tract decreased with a decrease in a species' body weight. From this, and the fact that the rate of metabolism per unit body mass tends to increase with a decrease in body weight, he concluded that small herbivores would require different strategies for processing large volumes of plant material. In the rabbit (Fig. 1-A), the cecum provides the major site of digesta retention and microbial digestion (9). A pacemaker, located in the proximal colon, aids in the retention of cecal digesta. Periodic and relatively rapid passage of cecal contents through the large intestine provides the soft feces which are ingested and recycled through the upper digestive tract, allowing digestion of microbial protein and absorption of amino acids and B vitamins. A similar construction of the digestive tract and process of microbial digestion is seen in herbivorous rodents and other small herbivores, although this is not always associated with coprophagy.

The large intestine also is the site of microbial digestion in larger herbivorous primates, the Perissodactyla (equids, rhinos and tapirs) and the elephants. In these animals, however, the colon is sacculated and much more voluminous with the proximal colon serving as the major site for microbial digestion. The colon of equids (Fig. 1-B) also is compartmentalized into ventral, dorsal and small colonic segments and a pacemaker has been demonstrated at the junction of the ventral and dorsal colon (10). The colon of the rhinoceros (2-A) and the elephants (2-B) are constructed in a similar manner.

Some mammalian herbivores adopted an arrangement for microbial digestion quite different from that of lower vertebrates and other mammals. The stomach became the major site with the advantage of allowing digestion of microbial protein and absorption of amino acids as well as B vitamins by the upper digestive system. The ruminant stomach (Fig. 3-A) typifies this system. The bovine stomach contains 70 times the volume of the human stomach and 14 times the volume/kg body weight. It is complex in structure and functions to retain plant fiber for the prolonged periods of time required for microbial digestion. A similar arrangement is seen in other ruminants. Complex voluminous stomachs are found also in many other Artiodactyla, such as the peccary and hippopotamus, as well as the Sirenia, sloths (Fig. 3-B), kangaroos (Fig. 4-A), and some rodents and primates (Fig. 4-B). It also is seen in some nonherbivorous species such as the whales, the vampire bat and many frugivorous bats.

Mammalian herbivores can, therefore, be divided into two major groups; those in which the stomach is the major site for microbial digestion and those in which the large intestine provides the major site. Among the latter, the cecum tends to provide the site for microbial digestion in the smaller herbivorous mammals, while the proximal colon provides the major site in the herbivores of larger body size. The categorization of all herbivores into ruminants vs nonruminants is an oversimplification which confuses understanding. Nonruminant herbivores include many species among the Artiodactyla and five other orders in which microbial digestion is also accomplished in a complex voluminous stomach, plus all herbivores in which the large intestine provides a similar function. Use of the term "cecal digesters "for all herbivores in which the large intestine is the major site of microbial digestion also is incorrect.

In spite of differences in strategy for microbial digestion, herbivores have some common characteristics that should be considered in planning their diet and dietary regimen. Their digestive tract is organized to process large volumes of food low in sugar and starch but high in fiber content. They accomplished this, in their natural habitat, by spending a large percentage of their time feeding. This may amount to 18 hours a day for zebra and elephants or a lesser time for animals that ruminate or practice coprophagy. None of these animals, however, would normally consume its daily intake in one or two, time-limited meals.

Some results of improper diets or dietary regimens can be demonstrated by considering their effect on the major end products from microbial digestion of carbohydrate. The VFA, which are the principal end products, have a pK_a of 4.8. The microorganisms responsible for their production cannot survive at a pH below 5.5. Digesta is normally maintained at a relatively neutral pH by rapid absorption of VFA and secretion of large quantities of HCO_3 by the salivary glands, pancreas and digestive tract. Ingestion of excessive amounts of starch or sugar results in rapid production of VFA in the forestomach of ruminants. This can rapidly decrease the pH of digesta, increase the rate of VFA absorption and replace normal microorganisms with lactobacillus which produce lactic acid. The rapid production of VFA and, especially, lactic acid can result in a hypertonic digesta that draws water into the rumen producing a systemic dehydration. The rapid absorption of VFA can produce necrosis and ulceration of rumen epithelium, rumen atony (immotility) and a systemic acidosis. Similar results can be expected with overfeeding starch or sugar to other herbivores in which the stomach is the major site of microbial digestion. This can result from rapid conversion to high starch diets, feeding this type of diet to entice anorexic animals to eat, or allowing the public to give captive animals food high in sugar or starch content.

A similar syndrome can occur in herbivores in which the large intestine is the major site for microbial digestion. Substantial quantities of starch and sugar can escape into the large intestine under normal feeding conditions when concentrates are fed in a single meal and this can be increased by increasing the amount of dietary starch or feeding normal levels to starved animals (14). Malabsorption of carbohydrate by the upper digestive tract, as a result of various digestive diseases, can have the same effect. Addition of excessive amounts of starch or sugar to the large intestine results in a similar production of VFA, lactic acid and hypertonic digesta. This can result in diarrhea as well as other diseases of the large intestine.

The earliest mammals are believed to have been small carnivores that fed on insects or other invertebrate species. The herbivores appeared much later. Their ability to subsist on plant material low in starch, sugar, essential amino acids and B vitamins is accomplished by complex structural and functional adaptations of their digestive tract. The diet and feeding schedule of captive herbivores should be organized with this continually in mind.

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Figures

Figure 1. Gastrointestinal tracts of a rabbit and a pony from Stevens (11).

Figure 2. Gastrointestinal tracts of a rhinoceros and an elephant from Clemens and Maloiy (5).

Figure 3. Gastrointestinal tracts of a sheep from Stevens (11) and a sloth from Stevens (13).

Figure 4. Gastrointestinal tracts of a kangaroo from Stevens (11) and a cololus monkey (Drawing by Erica Melack).

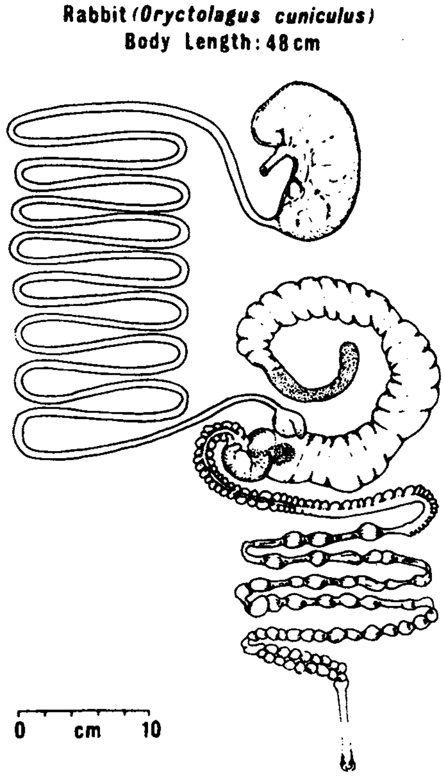

FIG.1-A

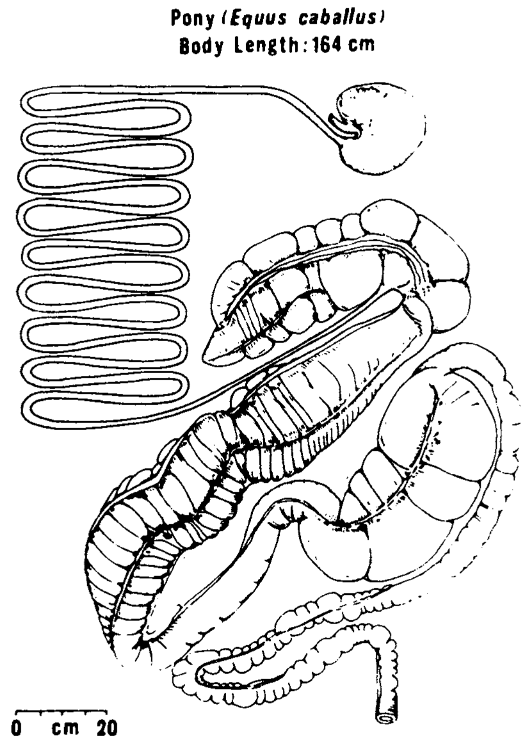

FIG.1-B

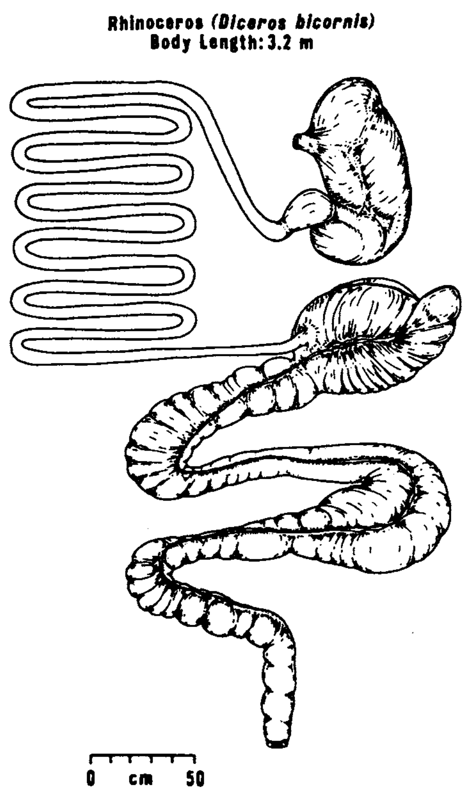

FIG.2-A

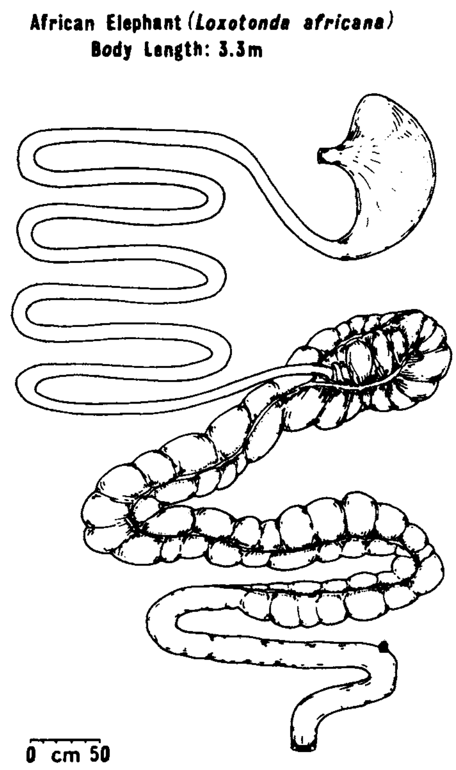

FIG.2-B

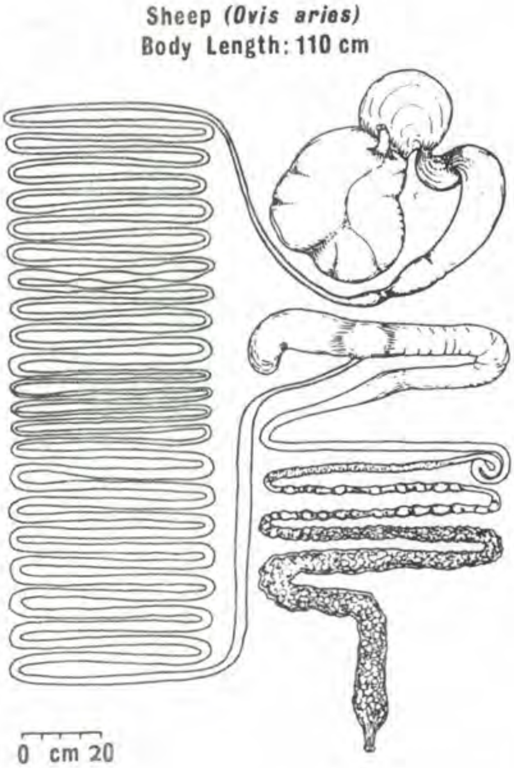

FIG.3-A

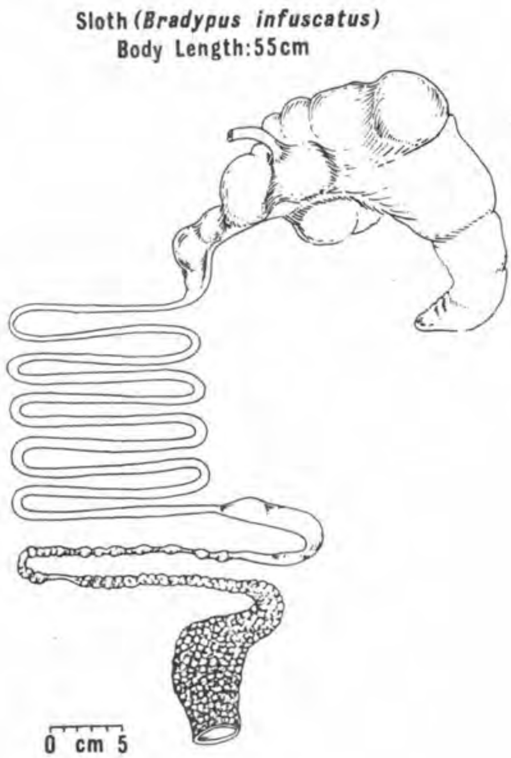

FIG.3-B

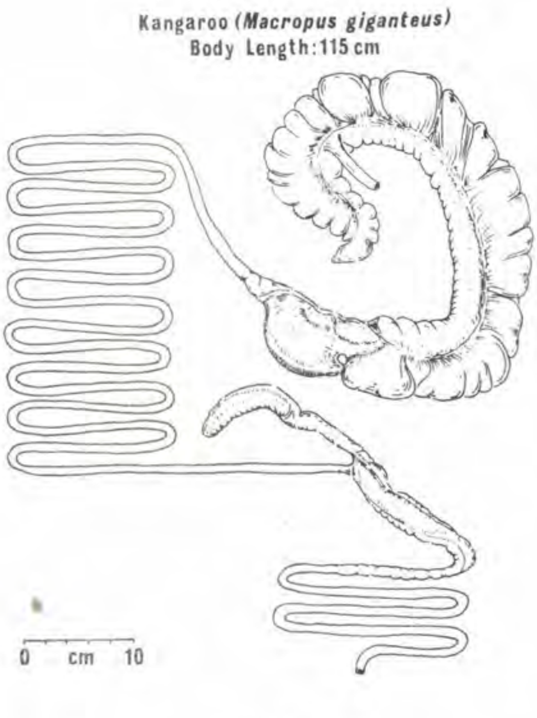

FIG.4-A

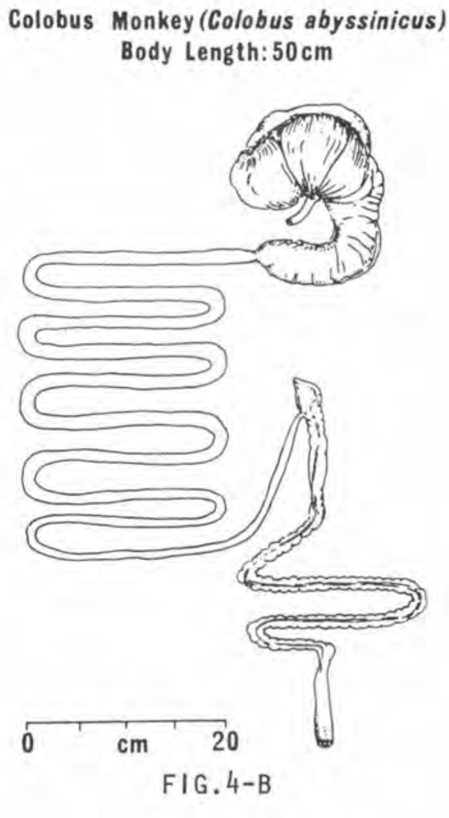

FIG.4-B

APPLICATION OF FUNDAMENTAL PRINCIPLES OF NUTRITION IN FEEDING CAPTIVE WILD ANIMALS

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I look forward to learning a lot during this conference. I feel at a disadvantage being so early on the program, and I expect that some of what I say will be either duplicating or in disagreement with statements of subsequent speakers. Whichever is the case, I look forward to some stimulating discussion before the conference closes.

In preparation for this talk, I reread Dr. Ullrey's chapter on "The Nutrition of Captive Wild Ruminants" in Church's book on Digestive Physiology and Nutrition of Ruminants (1). In the last ten pages of the chapter, Duane has anticipated most of my thoughts on the subject, and has expressed them very adequately and diplomatically; therefore I strongly recommend this chapter as a source of practical knowledge on the feeding and management of zoo ruminants and will repeat little of it here.

In the first four pages of his chapter, Dr. Ullrey quotes extensively from a text by Hoffman (2) entitled "The Ruminant Stomach." Hoffman discusses in great detail the anatomical differences he found in the digestive tracts of many species of African ruminants. On the basis of these differences as they relate to the natural diets of the animals, he attempts to classify ruminants as concentrate selectors, bulk and roughage eaters, or intermediate feeders, and concludes that the habitat type and thus the diet of a wild ruminant is dictated by the anatomy of its stomach. Hoffman's book, and other dietary preference researches, are widely quoted among wildlifers and zoologists, who I feel are sometimes unduly concerned about problems of mimicing natural diets in selecting foods for captive animals.

An outstanding characteristic of the ruminant suborder, well recognized by animal nutritionists, is the ability of individuals to adapt to a great variety of food types. It is known that such anatomical characteristics as structure, density, and distribution of rumen papillae, and the relative volume capacity of stomach compartments, implied by Hoffman to be evolutionary, can be altered in domestic ruminants by simply altering types or proportions of roughages to concentrates in the diet. Thus the detailed strucuture of the ruminant's stomach may be largely determined by rather than the determinant of what the animal eats.

So I am pleased to see that Dr. Ullrey, after concluding that these differences in gastrointestinal anatomy and dietary habits may have adaptive advantages in a natural ecological setting, concludes that "forutunately most wild spcies, just like domestic ones, require specific nutrients not specific feedstuffs." He then proceeds to draw upon his experience and fundamental knowledge of animal nutrition and animal husbandry in discussing management considerations for captive wild ruminants. I believe the background of his introduction to research in the nutrition of wild ruminants was similar to mine. We were both animal nutritionists who got side-tracked into studying the nutritional requirements of white-tailed deer. Dr. Ullrey's experience in zoos is considerably broader than mine, as I believe he has spent some time (sabbatical) researching in a zoo. My personal experience in this area has been limited to working with deer at Penn State, with blue duikers in several zoo settings, and (if this could be considered pertinent) a few years of research in ranch mink nutrition.

When I was asked 25 years ago to work on determining the nutritional requirements of deer I agreed to undertake the research, but suggested then that, deer being typical ruminants, their requirements should be similar to those of sheep, and that until specific deer requirements could be determined, values for sheep might be applied at least temporarily. After many years of feeding trials with deer, we developed the equation $Y = 0.1144X + 18.47$ (Y= wt. change in grams/W.75 kg/day and X= daily intke of DE in Kcal/W.75 kg) representing our best estimate of the relationship between digestible energy (DE) intake and weight gain or loss of deer. This equation yields maintenance requirements for deer very comparable to those arrived at independently by Ullrey in Michigan (3) and Thompson et al (4) in New Hampshire.

Table 1 (3 slides) shows exerpts from the table of sheep requirements in the 1968 edition of the National Research Council publication on Nutritient Requirements of Sheep (5), with an additional column I have inserted which shows excellent agreement between daily DE needs of sheep, and those of deer calculated by plugging sheep weights and daily gains from the first two columns into the above deer equation and solving for X. This concordance strengthens our confidence in our equation, and tends to confirm results of comparative digestion trials in which feed utilization by sheep and deer were found to be comparable (6, 7). It also strengthens our conviction that "nutrition is nutrition" and "a ruminant is a ruminant" and that much livestock nutrition can be applied to similar wild species.

NUTRIENT REQUIREMENTS OF SHEEP/DEER

Body WT (KG)	GAIN (GM)	Feed: PER ANI-MAL (KG)	Feed: % LIVE WT.	Daily Nutrients Per Animal: TDN (KG)	DE (MCAL) SHEEP	DE (MCAL) DEER*	PRO-TEIN (GM)
EWES							
27	136	1.2	4.5	.68	3.0	3.1	136
36	91	1.4	4.0	.73	3.2	3.2	127
45	64	1.5	3.4	.77	3.4	3.4	118
54	32	1.5	2.8	.77	3.4	3.5	109
RAMS							
36	181	1.4	4.0	.91	4.0	4.0	145
45	136	1.7	3.7	.95	4.2	4.0	145
54	91	1.9	3.5	.95	4.2	4.0	145
64	45	2.1	3.3	1.04	4.6	4.6	145
73	45	2.2	3.0	1.09	4.8	4.4	145
LAMBS							
27	159	1.2	4.5	.68	3.0	3.3	145
32	181	1.4	4.4	.82	3.6	3.8	154
36	204	1.5	4.3	.95	4.2	4.1	163
41	204	1.7	4.2	1.04	4.6	4.4	163
45	181	1.8	3.9	1.09	4.8	4.4	163

Manuals such as the one referred to above are available from the National Academy Press* covering nutrient requirements of at least 15 categories of domestic animals including dogs, cats, sheep, horses, dairy cattle, beef cattle, rabbits, mink and foxes, poultry, swine, non-human primates, laboratory animals and three classes of fish. Each of these was compiled (and updated every few years) by expert species subcommittees of the Committee on Animal Nutrition of the National Research Council (NRC). I suggest that this full set should be most useful in any zoo, and that much valuable information on nutrition, care, and management of most zoo animals could be gleaned from the NRC manual for their respective most closely related domestic species. Nutrition nowadays is an advanced science and there should be little "voo-doo" involved in applying fundamentals of nutrition which have been established by research on domestic and laboratory animals. Neither should rations for zoo animals be much more expensive than livestock feeds. I once made a respected wildlife biologist friend very angry by insisting that a temporary problem we were having

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*National Academy Press, 2101 Constitution Avenue. N.W., Washington, D.C. 20418.

with a recently captured blue duiker was not nutritional, and rejecting his idea that we should return to the bush to try to find the magic plant with the missing nutrient that could cure the ailment.

I realize that even with complete knowledge of an animal's requirements, and having concocted the perfectly balanced ration, it is useless unless the animal eats it. I also recognize that many animals have appetites and food preferences that are learned, inherited, or instinctive but in my experiences have not found any that would not adapt to a prepared diet given adequate patience and ingenuity. For instance mink kits were weaned onto dry diets by first offering a thin slurry with milk which was gradually dried up by reducing the milk content until the kits were eating dry pellets. Crocodile ranchers have told me they quickly train hatchlings [which instinctedly recognize only moving (live) objects as food] to accept prepared food by dropping particles through the water where the babies may see them fall. Little as I know about bird or reptile nutrition, if I were a zoo nutritionist and saw thousands of dollars being spent for live crickets, I would feel a definite challenge to try developing something more practical.

Our success with inexpensive pelleted diets for mink (over protest from traditional mink ranchers who said mink must have fresh meat) convinced me that most carnivores could be fed dry diets, and I assume that such are now available even for zoo animals - but I also realize that the public would get little pleasure from seeing a zoo keeper feed his cats from a bag of "Friskees" or "Gravy Train" - so some compromise is no doubt necessary.

In my behind-the-scenes experience in zoos I have formed a personal impression that several more or less nutrition-related problems are prevalent, and that any one or combinations of these can make the difference between success and failure in maintenance and/or propagation of animals.

First there is difficulty of medical diagnosis of diseases or problems, sometimes aggravated by quarantine restrictions which limit use of outside-the-zoo diagnostic laboratories, etc. Coupled with this is the reluctance of some zoo veterinarians to experiment with treatment of valuable animals without definitive diagnosis such as culture and positive identification of specific disease organisms. There is also the tendency to label disease problems as nutritional or "stress-related" disorders if other answers are not apparent; probably less prevalent in zoos with professionally trained staff nutritionists.

All of these problems are exaggerated by what I see as the weakest link in the zoo-animal management chain. The zoo keepers I have dealt with have been mostly good conscientious workers who are dedicated to their jobs and have a genuine love for the animals in their care. However, only one of them had had a little training in animal husbandry, and that was backed up by very limited experience. Most keepers I know are city people with little previous experience with animals, and they are restricted by union and zoo regulations to work schedules that leave most of the animals unattended for at least twice as many hours as they are attended. Weekly time-off, holiday, and vacation schedules often result in fill-in workers with even less experience who get their instructions from a mimeographed sheet on the bulletin board. These keepers are the people who have the most important jobs in the zoo-daily contact with the animals, and supposedly the responsibility for reporting problems to a supervisor (often a person with similar background but more seniority). Many of them do not know how to recognize signs or symptoms that an animal is in trouble until it is down and often beyond help.

Perhaps in fairness it should be admitted that some animals are housed in poorly lighted areas and some are in group housing situations where individual feed consumption is difficult to observe, etc. Also both keepers and supervisors may be "spread too thin" and must rush to complete chores on schedule. But if there is, in my opinion, an area where zoos could "save money by spending money" it would be in employing adequately trained staff in sufficient numbers to be sure that every animal is closely observed, at least daily, by someone who knows animals. Savings in animal replacement could more than cover, such costs.

These few slides are shown partly to illustrate my point about recognizing healthy animals and partly, I admit, because I can't finish any conversation without bragging about Penn States' blue duikers. Note the glossy hair coat - the bright eyes and alert appearnce - clean ears - good color - the "bloom" of perfect health in both mother and baby. Another good indication that both are healthy is that the lamb is just under three weeks of age and has more than doubled its birthweight. We weigh all lambs daily from birth, and all adults weekly. We also record feed consumption daily for each pen, most of which house trios (1.2). This herd now numbers 24 (6.17) including 5 (1.4) young born since September 6, and 18 (5.3) adults which arrived at Penn State on April 12, 1982 after having been individually caged in tea boxes since capture and during a full year of battling quarantine and import arrangements.

The appearance of these animals is typical of our entire herd. In addition to the 5 young born to date, at least six (probably eight or nine) other females are pregnant and we anticipate few lambing problems. We've lost one lamb born prematurely (during my absence) and one case of dystocia was successfully handled because a vet was called in the early morning. We see no reason this herd should not multiply to at least two hundred in five years.

Five years ago when we imported 6.10 blue duikers to another zoo, an administrator told us we would be doing well if we had a dozen offspring eligible to move to Penn State in five years. This judgment was based upon his experience and knowledge of the reproductive success record of zoos. The actual count in that herd after 5 1/2 years is seven surviving offspring and 0.3 surviving of the original 16 adults.

I draw this comparison in full recognition that "there's many a slip twixt cup and lip," and our success may fall short of my long-range predictions. We must also acknowledge the possibility that our success may be partially owed to lessons learned from our disastrous first effort. We also appreciate the relative complexity of problems in a major zoo compared to our tiny zoo with only two species on exhibit, one of which our University values sufficiently to have assigned a professor of animal nutrition the responsibility of finding and capturing the animals, arranging their importation, presonally caring for them during quarantine and serving as director of the zoo and keeper of the herd. This latter arrangement in effect bypasses some of the above-mentioned personnel problems associated with union-regulated work schedules, etc. However, such problems are not peculiar to zoos - the University has a good share of them too, which must be worked around if we are to be successful in training students and demonstrating our leadership in the field of animal production.

To a large extent this success is accomplished by employment of good staff-exempt herdmen in each species facility. Also round-the-clock surveillance of herds and flocks, taken for granted as necessary especially in seasons of lambing, calving, etc., is partly accomplished by employing live-in students, some of which are part-time and thus exempt from rigid work schedules. What I'm saying is that, even though I'm personally looking after our duikers, I'm only applying routine husbandry practices accepted as essential to any good livestock operation.

To conclude quickly I have attempted to sum up impressions, gleaned from a variety of experiences in support of my argument that more extensive application of fundamental animal husbandry and nutrition in operation and management of zoos would result in more effective accomplishment of their important function in propagation and protection of rare and endangered species.

Being just three weeks short of retirement, I may have felt less than usual reluctance to stick my neck out in making some of these statements and predictions. Therefore, I look forward to hearing the papers and discussions to follow, with an open mind. If my ideas are too far out of line with yours, please convince me.

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UTILIZATION OF FIBROUS FEEDSTUFFS BY HERBIVORES

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INTRODUCTION

Fibrous feedstuffs are an integral component of both ruminant and non-ruminant herbivore diets. Fibrous material is the insoluble structural matter of plants that is resistant to animal digestive enzymes (Van Soest and Robertson, 1976). The term "non-nutritive" is often applied to this group of substances, but the use of this term ignores the fact that fibrous carbohydrates may be nutritionally available through fermentation and contribute significant digestible energy to non-ruminant animals. Also, fiber can contribute in a nutritionally beneficial way by influencing transit of feed and the environment of the lower digestive tract.

Chemical Properties of Fiber

Plant substances can be divided into two groups: one fraction, often termed "cell solubles" and generally completely digestible by animals, is active in plant metabolism, respiration and growth and includes nucleic acids, sugars, storage carbohydrates, protein and lipids, all of which are metabolizable by animals (Van Soest, 1977). The other category is the structural matter forming the cell wall of the plant. Animal digestive enzymes to degrade these structural substances have not evolved. On the other hand, some bacteria and fungi have enzymes to degrade most of the substances in the plant cell wall (Gibson, 1968). The use of structural matter as feed for animals is dependent upon a symbiotic association with gastrointestinal organisms with the requisite ability to degrade plant structural matter (Hungate, 1966).

Resistance to digestion arises from several features of the chemical structure. Linkages resistant to animal enzymes allow for the possibility of microbial fermentation (Table 1). Microbial enzymes exist that will hydrolyze most glycosidic linkages occurring in plant cell walls (Wood, 1970). Polysaccharides will be fermented provided that the bond is accessible to attack. However, very crystalline celluloses (e.g., cotton, straw) may remain undigested because of the intensive crosslinking of chains through hydrogen bonding. The maximal rate of fiber digestion varies an order of magnitude between various sources (Table 2). It is for this reason that the determination of only one fibrous moiety, such as cellulose, as a feed characteristic is a relatively useless endeavor in the effort to evaluate feedstuffs of plant origin. The cellulose fractions of plant sources vary in nutritive quality through their intrinsic characteristics, as well as that of their association with other plant carbohydrates.

The non-cellulosic carbohydrates of the cell wall include primarily the hemicelluloses. These are a diverse group of sugars and may contain residues of xylans, uronides, arabans, galactans and mannans. Hemicellulose is also incompletely digestible. In ruminants, digestibility is closely related to that of cellulose in the same plant source. In non-ruminants, hemicellulose is relatively more digestible than cellulose.

Lignin is the main non-carbohydrate component of plant fiber. It is an aromatic polymer containing continuous carbon to carbon linkages which are very resistant to hydrolysis. Degradation of lignin in the digestive tract is limited by the absence of oxygen in the cellulolytic fermentation and no significant degradation of the core molecule occurs (Gibson, 1968).

Fiber Methodology

Although still in common use today, the crude fiber method of feedstuff analysis is unable to differentiate between nutritionally available and unavailable plant fractions. In approximately 30% of the tabular values of feedstuffs, crude fiber is as digestible as the nitrogen-free extract, even though the main purpose of their division was to separate the unavailable from the available nutrients. The principal fractions that are not recovered in crude fiber are hemicelluloses and lignin. An alternate method which is superior to that of crude fiber has been developed by Goering and Van Soest (1970). Using this method, a more accurate assessment of plant fiber content of feedstuffs can be obtained. A fractionation scheme using detergents is used to isolate specific fiber fractions (Table 3).

Microbial Fermentation of Fiber

Fibrous substrates are fermented by bacteria present in the gut of herbivores, resulting in the formation of volatile fatty acids (VFA), carbon dioxide, methane, and microbial cells. Methane and carbon dioxide are generally of no value to the host and are considered to be excretion products. As noted by Howard (1967), the magnitude of any biochemical change brought about in the alimentary tract by microorganisms depends on several factors including (1) the capacity of the tract, (2) the concentration of microbes in the suspension and (3) the metabolic activity of the individual organisms. The microbial population requires from the host a set of conditions in order to express its maximum activity (Parra, 1978). Some of these conditions are: anaerobiosis, closely controlled temperature of the digesta, retention of digesta, buffering capacity, continuous removal of end-products and supply of substrate at a given rate. More important than any other factor is the quality and quantity of the diet selected by the host.

Herbivores and folivores can be classified into two broad categories according to their digestive strategy and the part of the gut which is enlarged to accomodate microbial fermentation (Parra, 1978). The first category includes those animals with an enlarged foregut which is the main site of microbial activity. In this case, microbial fermentation precedes gastrointestinal digestion. The most obvious representatives of this group are animals such as cattle, sheep, goats, giraffes, deer, antelopes, camelids, hippos, macropod marsupials, sloths and leaf-eating monkeys. The second category includes those animals with an enlarged hindgut in which gastrointestinal digestion occurs before microbial fermentation. Some of the most important representatives of this group include equines, tapirs, rhinos, rabbits and hares, capybara and smaller rodents, hyrax and elephants. This classification does not imply that, in a given animal, there is only one site of microbial fermentation since, in ruminants, there is considerable microbial activity in the cecum and colon, and in the horse, hamster and rabbit, there is significant fermentation in the stomach (Alexander and Chowdhury, 1958; Alexander and Davies, 1963).

Fermentation efficiency is affected by several factors, one of which is rate of digesta passage. Blaxter (1963) noted that maximal digestion occurred only if passage of feed was subjected to a delay at those sites where microbial action occurred. He also noted that, when rate of passage was increased, the depression in apparent digestibility was greater for poor quality feeds than for those of high quality. Any effect of rate of passage on digestibility will be mainly on the fiber components of the diet since they are those most affected by microbial action.

The microbial population of the digestive tract of herbivores is mainly the consequence of host animal diet, both with respect to composition and numbers of bacteria present. It does not seem probable, therefore, that differences between ruminant and non-ruminant herbivores relative to the efficiency with which they digest the diet could be accounted for only by intrinsic differences in the microbial population. The general characteristics of the fermentation sites of both types of herbivores are similar and the microbes have the capacity to adapt to changing environments, more specifically, the availability of substrates.

Nutrient Digestion as Affected by Fiber

The digestive ability of an animal is generally measured by digestibility trials in which some components of feed and feces are measured and compared. Available data indicate that few if any differences among ruminant and non-ruminant herbivores occur with respect to digestion of soluble plant fractions. Results obtained with cattle (Van Soest, 1967) and sheep (Parra et al., 1972) show no effect of lignification on digestibility of cellular contents. The effect of lignin was restricted to the fibrous carbohydrates. Similar results were obtained with horses (Fonnesbeck, 1969). This evidence conflicts with the hypothesis that availability of cell components is lowered by entrapment in lignified cells (Drapala et al., 1947; Bell, 1971). Argenzio and Hintz (1971) found that less of the available dietary carbohydrate was digested enzymatically by horses as cell wall content of the diet increased and, in other studies, fiber content depressed the digestibility of all other nutrients to a much greater extent in the horse than in ruminants (Olsson and Ruudvere, 1955; Olsson, 1969). Lowering of nutrient digestion as fiber level increases may be due to the inverse relationship that exists between concentration of soluble ingredients and fibrous ingredients. Also, feed intake is usually reduced as fiber level increases, resulting in a marked reduction in intake of solubles, followed by a drop in apparent digestibility of the fraction. Nevertheless, it is generally concluded that there are no major differences in digestion of cell contents among ruminant and non-ruminant herbivores. Cellular contents are nearly entirely available to the animal, regardless of lignin content of plant material. However, sites of digestion and means of digestion of cellular contents can vary greatly in the two types of herbivores. In ruminants, most of the cellular contents are fermented before reaching the site of enzymatic digestion in the midgut. In nonruminant herbivores, the tendency is for enzymatic digestion to occur first with a consequent higher efficiency of cellular content utilization (Argenzio and Hintz, 1971).

In regard to utilization of cell wall components by herbivores, writers of several reviews (Hintz, 1969; Olsson, 1969; Vander Noot and Trout, 1971) concluded that nonruminant herbivores have less ability to digest fiber components than do ruminants. However, the superiority of ruminants in digesting fiber is marked only when considering nonruminant herbivores of small size (rabbit, vole). Large nonruminant herbivores (horse, pony, zebra, capybara) digest cell wall carbohydrates nearly as well as do ruminants (Table 4). Several possible factors contribute to these differences. Digesta passes through the tract of small nonruminant herbivores at a faster rate than occurs with their larger counterparts, thus leading to lower fiber digestion. Source of fiber is another important factor determining the relative extent of fiber digestion. Data in Table 5 indicate that different sources of fiber required different retention times for optimal fiber utilization.

One reason why lower fiber digestion could occur in nonruminant herbivores relates to composition of the substrate reaching the fermentation site. In the case of hindgut fermentation, the substrate reaching the cecum and colon has been deprived of most of the soluble components since enzymatic digestion has already occurred, leaving only the more refractory material which would have a slower digestion rate. In addition, nutrients essential for maximal microbial activity might be deficient in the substrate because they were absorbed before reaching the hindgut (Mehren and Phillips, 1972). On the other hand, the hindgut fermentors might gain advantage through the pre-treatment of fiber with gastric pepsin at a low pH, causing a partial solubilization of the hemicellulose, or acting on lignin-hemicellulose linkages, or both.

Utilization of Fermentation End-Products

The main products of bacterial fermentation are VFA of which acetic, propionic and butyric acids are found in the largest quantity. Most of the available information is on VFA concentrations in the foregut of domestic ruminants, with little information on hindgut concentrations of VFA in nonruminant herbivores. The high concentration of VFA in the cecum of nonruminant herbivores indicates the importance of the hindgut as a fermentation site (Table 6). The general tendency is for higher VFA concentrations in animals with foregut fermentation. The shorter retention time of fibrous material in the hindgut of nonruminant herbivores, particularly in smaller animals, reduces the amount of fermentation. In addition, composition of substrate reaching the cecum and colon has already been subjected to enzymatic digestion, leaving mainly the fibrous portion of the diet and little of the solubles, which are more readily fermented.

Another expression of fermentative activity is rate of VFA production. Relatively little information is available on this subject, probably due to difficulties encountered with the technique. Values are variable and as a whole do not seem to indicate any specific pattern for ruminants as compared to nonruminants (Table 7).

Absorption of VFA from the foregut of ruminants has been extensively studied (Annison, 1965; McDonald, 1969; Stevens, 1970). There are estimates of 76% of ruminal VFA being absorbed from the rumen, 19% from the omasum and abomasum and 5% passing into the small intestine (Weston and Hogan, 1968). Nonruminant herbivores can absorb VFA from the hindgut and the major difference between this process and absorption from the rumen is in the rate of epithelial tissue metabolism of fatty acids. Absorption of VFA from the hindgut of nonruminant herbivores is important in order that VFA might be utilized as an energy source but the information available for these animals is very limited. An estimate of the total energy obtained from VFA for both ruminant and nonruminant herbivores is presented in Table 8. Ruminants obtain most of their energy from the products of fermentation and the values shown for small hindgut fermentors are considerably lower than those for foregut fermentors. This could be a consequence of the diets selected by small nonruminant herbivores which make them less dependent on fermentation for obtaining their necessary energy. However, in the case of large nonruminant herbivores, VFA are the most important source of energy for animals consuming diets high in fiber.

CONCLUSION

Results to date indicate that fiber digestion by hindgut fermentors can be comparable to that of foregut fermentors even though it has been proposed that nonruminant herbivores have a less potent cellulolytic microflora in their fermentation chambers due primarily to higher rates of digesta passage through these chambers (Koller et al., 1978). Animal size alone may be an extremely important factor in determining fiber digestion efficiencies. Small animals require relatively higher digestible energy intakes than do large ones when expressed on the basis of metabolic body size. Also, hindgut fermentors appear to have fewer restrictions on the flow of particulate digesta as compared with ruminants where selective retention of fiber is a major feature of reticulo-rumen function (Uden and Van Soest, 1982). Such considerations may be important in evaluating feeding programs for herbivorous animals.

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Table 1. Availability of plant fractions to animal enzymes

Substance	Linkage	Sugar Components	Nutritive Property[a]
sucrose	1-2	glucose and fructose	digestible
starch	1-4	glucose	digestible
pectin	mixed	galactose, galacturonic acid and arabinose	resistant but fermentable
cellulose	1-4 cross chain hydrogen bonds	glucose	resistant but fermentable
hemicellulose	varied and linked to lignin	xylose, arabinose mannose and glucuronic acid	resistant but partly fermentable
lignin	condensed	none	resistant to animal and anaerobic digestion systems

Van Soest (1977)

[a]Availability to animal digestive enzymes.

Table 2. Fermentability by microorganisms of plant fibers

Fiber Source	Fermentation Lag[a]	Rate[b]	Maximal extent[c]	15 h digestion coefficient
	h	%/h	%	%
Cauliflower	4	42	94	93
Corn bran	5	10	94	54
Wheat bran	3	6	43	33
Alfalfa	4	12	59	32
Bagasse	4	4	45	23
Cotton	17	4	98	18

Van Soest (1977)

[a]Lag determined by the zero intercept of the regression of log residual fermentable fiber against time.

[b]Regression slope of natural log of residual fermentable fiber upon time.

[c]Maximal digestion at 72-100 h.

Table 3. Scheme of fractionation of plant feedstuffs with detergents

Fraction	Organic Components
Cell contents	protein, sugars, starch, lipids, pectin, gums
Neutral detergent fiber residue (NDR)	lignin, cellulose, hemicelluloses, cell wall protein
Acid detergent solubles	hemicelluloses, some cell wall protein
Acid detergent fiber residue (ADR)	lignin, cutin, cellulose, heat damaged protein
Crude lignin	lignin, cutin, heat damaged protein
Crude cellulose	cellulose, cutin

Goering and Van Soest (1970)

Table 4. Comparative digestibilities of fiber fractions by various non-ruminants[a]

Species	Body wt., Kg	Feed	Hemi-cellulose, %	Cellulose, %
Elephant	1930-3400	Alfalfa	49-68	56
		Timothy	52-54	45-47
Rhinocerus	1701-2041	Alfalfa	54-65	59-66
		Timothy	47-56	46-53
Hippopotamus	1500-1800	Alfalfa	45-77	60-71
		Timothy	56-57	50-55
Horse				
Domestic	388-460	Alfalfa	55-72	45-66
		Timothy	37-45	33-43
Zebra				
Grevy	340-386	Alfalfa	51-55	59-63
		Timothy	54-58	39-48
Plains	272-300	Alfalfa	43-52	56-63
		Timothy	52-60	42-48
Mountain	204-270	Alfalfa	36-48	54-64
		Timothy	47	38-43
Tapir				
Asian	160-380	Alfalfa	10-27	33-35
		Timothy	36-57	29-47
Pigmy Hippo	125-205	Alfalfa	64-66	66-83
		Timothy	33-51	30-35
Beaver	15-22	Poplar + grass	--	30
Rabbit	3	Timothy	11-13	7-9
Vole	.05	Alfalfa	39	34
		Grasses	24-38	18-29

[a]Data taken from Van Soest (1982)

Table 5. In vitro dry matter digestibility (DMD) of different substrates (incubated in nylon bags inside goat's rumen)[a]

Substrates	Maximum DMD, %	Time for reaching maximum DMD, h	DMD at 4 h, as % of maximum DMD
Honeysuckle leaves	89	8	98
Mature mixed forbs	49	72	80
Immature Elbon Rye	94	32	75
Mature woody twigs	33	96	72
Mature mixed grass	57	168	27

[a]Short et al. (1974) and cited by Parra (1978).

Table 6. Volatile fatty acid concentration (micromoles VFA/g of dry digesta)[1]

Animal	Diet	Rumen or Stomach	Cecum	Colon
Cattle	variable	919		
Sheep	variable	892		
Deer	alfalfa + corn	816		
Presbytis cristatus[2]	leaves	766		
Presbytis entellus[2]	leaves	883		
Sloth (choloepus)	fruit + leaves	1156		
Horse	straw + mangolds		970	
Horse	hay:concentrate 1:0		640	260
Horse	hay:concentrate 3:2		698	296
Horse	hay:concentrate 1:4		564	160
Rabbit	bran + oats + mangold		320	
Rabbit	mixed diet, low fiber		227	
Rabbit	mixed diet, high fiber		219	
Wild rabbit[3]	mossen and lichen		368	291
Wild rabbit[4]	mossen and lichen		317	226
Porcupine	natural	89	511	338
Beaver	natural		498	419
Guinea pig	commercial		380	

[1]Data taken from Parra (1978).

[2]Leaf-eating monkeys.

[3]Measured at daytime

[4]Measured at nighttime.

Table 7. Fermentation rate (micromoles of VFA/g of dry digesta/h)[1]

Animal	Rumen	Cecum	Colon
Lactating cow	240		
Cattle (Zebu)	125	37	45
Deer	93		
Camel (female)	92	46	32
Camel (male)	59	69	56
Grant's gazelle	233	45	58
Thompson's gazelle	142	42	42
Eland	70	53	53
Suni	629	79	64
Langur monkey	475		
Quokka[2]	135		
Rabbit (low fiber diet)[3]		205	
Rabbit (high fiber diet)[3]		175	
Porcupine		184	
Pig (low fiber diet)[4]		345	
Pig (high fiber diet)[4]		271	

[1]Data taken from Parra (1978).

[2]Assume 15% D.M. in forestomach content.

[3]Assume 20% D.M. in cecal content.

[4]Assume 15% D.M. in cecal content.

Table 8. Estimates of energy obtained from volatile fatty acids (Parra, 1978)[a]

Animal	Fermentation site: Foregut	Fermentation site: Hindgut
	$Kcal/W^{.75}(kg)$	
Cattle	70–80	0–15
Sheep	57–79	
Goat	37–46	
Deer	25	
Langur monkey	>100	
Rabbit		8–12
Porcupine		6–39
Beaver		19
Rat		9
Pig		5–28
Man		.7–10

[a]Taken from Van Soest (1982).

GENERAL SESSION: PANEL DISCUSSION

Q: I'D LIKE TO ASK DR. SHELTON WHAT ANALYTICAL PROCEDURES RALSTON PURINA USES?

SHELTON: RALSTON PURINA HAS TO USE THE AOAC PROCEDURES. THIS IS THE ONLY THING THAT IS SO CALLED LEGAL. HOWEVER, WE DO A LOT OF DEVELOPMENT WORK FOR PROCEDURES AND THEY ARE PRESENTED TO THE AOAC PEOPLE FOR APPROVAL. SO WE HAVE A LOT OF REFEREES IN OUR LABORATORIES.

Q: DO YOU USE DETERGENT ANALYSIS?

SHELTON: YES, MOST OF US ALL HAVE OUR PRODUCTS BEING ASSAYED BY THE VAN SOEST DETERGENT METHOD AS WELL AS CRUDE FIBER. YOU STILL HAVE TO PUT A GUARANTEE OF CRUDE FIBER BY STATE REQUIREMENTS. THERE IS NO ACTION TO MY KNOWLEDGE THAT THERE IS ANY ATTEMPT TO MOVE TO THE DETERGENT FIBER SYSTEM. NEARLY ALL OF US FOLLOW THAT, SO WHEN THE DAY COMES WE'LL BE PREPARED.

Q: HOW DO YOU SET UP YOUR FEEDING STRATEGIES? SHOULD YOU USE A GRASS HAY OR A LEGUME HAY?

STEVENS: GRASS HAY ARE MORE SLOWLY FERMENTED, SO THEREFORE IF YOU KNOW SOMETHING ABOUT THE DIGESTIVE TRACT OF THE PARTICULAR HERBIVORE THAT YOU'RE FEEDING THEN YOU CAN ASSUME THAT IN THOSE ANIMALS THAT YOU THINK WILL HAVE HIGHER RATES OF PASSAGE, IT WOULD BE BETTER TO FEED THE LEGUME. THE ANIMAL WOULD GET MORE NUTRITION FROM THE LEGUME BECAUSE THE BUGS COULD ATTACK THE FIBER OF THE ALFALFA FASTER. WITH LEGUME HAYS THE RATE OF DIGESTION IS FASTER, BUT THE EXTENT OFTEN TIMES IS EXACTLY THE SAME AS FOR GRASS HAYS. SO YOU GET A CLASSICAL GRAPH WHERE ONE CURVE IS STEEP AT FIRST AND THEN TAPERS OFF AND ONE CURVE IS MUCH SLOWER. BOTH CURVES MEET IF THE FERMENTATION TIME IS LONG ENOUGH. SO YOU HAVE TO KNOW SOMETHING ABOUT THE TRACT. NOW I'M NOT AN EXPERT IN VARIOUS DIGESTIVE TRACTS SO I DON'T KNOW WHICH ANIMALS YOU ARE TALKING ABOUT SPECIFICALLY. BUT, I THINK THAT'S WHY LEGUMES ARE OFTEN THOUGHT OF AS BEING MORE VALUABLE IN FEEDING PROGRAMS BECAUSE FIBER IS FERMENTED FASTER.

COMMENT: A LOT OF THE DETERMINATIONS IN THIS MATTER ARE BASED ON NATURAL HISTORY RATHER THAN THE ANATOMY OF THE DIGESTIVE TRACT. FOR INSTANCE, IF YOU HAVE A RUMINANT WHO IS A BROWSER AND NOT A GRAZER THAT TENDS TO IMPLY THE USE OF A FEAFY LEGUME TYPE OF FEED, ALTHOUGH YOU'RE TALKING ABOUT A RUMINANT WHO OUGHT TO BE MORE EFFICIENT DIGESTING THE GRASS TYPE HAY.

STEVENS: I CAN APPRECIATE YOUR PROBLEM BECAUSE WE HAVE THE SAME PROBLEM IN DOMESTIC RUMINANTS. AND, OF COURSE WE KNOW THAT THE NUTRITIVE VALUE OF GRASSES AND LEGUMES VARY TREMENDOUSLY. YOU CAN HAVE VERY BAD ALFALFA. THERE'S A LOT OF BAD ALFALFA BEING SOLD. THAT'S WHY I ENCOURAGE NUTRITIONAL ANALYSIS OF THIS MATERIAL. IF YOU'RE GOING TO BUY 500 TONS, A PERSON BETTER KNOW WHAT THE COMPOSITION IS. BECAUSE YOU HAVE A LOT OF BEDDING THAT YOU THOUGHT YOU WERE GOING TO FEED.

Q: I HAVE A QUESTION FOR DR. SHELTON REGARDING THE CHANGE IN THE AVAILABILITY OF THIAMINE AFTER ESTRUDING THE PRODUCT TWICE.

SHELTON: I DON'T KNOW WHY IT BECAME MORE AVAILABLE UNLESS THERE WERE MORE CELL WALLS RUPTURED IN THE PROCESS SOMEWHERE. THE DIFFERENCE ISN'T REALLY ALL THAT STRIKING. I THINK THE POINT I WANTED TO MAKE WAS THAT WE DID'T LOSE THIAMINE IN THAT PROCESSING WHEREAS IN THE AUTOCLAVING OF FEEDS YOU DO LOSE A LOT OF THE THIAMINE IN PROCESS. SO IT IS A HEAT SENSITIVE KIND OF VITAMIN. HOWEVER, WE KNOW THAT A LOT OF VITAMINS THAT ARE DESTROYED IN DRY HEAT PROCESSING ARE NOT DESTROYED WHEN THEY ARE PROCESSED IN VERY MOIST CONDITIONS. I DON'T KNOW ALL THE CHEMISTRY INVOLVED HERE.

Q: HAVE YOU COMPARED DIGESTIVE EFFICIENCY OF THE BLUE DUIKER WITH THE WHITE TAILED DEER?

BROWN: UP UNTIL NOW OUR EFFORTS WITH THE BLUE DUIKER HAVE BEEN MAINLY AIMED AT PROPAGATION AND PRODUCING NUMBERS. WHEN WE HAVE A FEW SURPLUS MALES WE'LL DO SOME COMPARATIVE TRIALS. THE ONLY COMPARATIVE DIGESTIVE TRIALS I'VE DONE HAVE BEEN WITH SHEEP, AND WE GOT DIGESTIVE CO-EFFICIENTS WITH DUIKERS ON ALFALFA THAT WERE COMPARABLE TO SOME THAT HAD ALREADY BEEN EVALUATED IN SHEEP.

Q: WHERE WERE THE BLUE DUIKERS CAPTURED AND WHAT DID YOU FEED THEM IMMEDIATELY AFTER CAPTURE?

BROWN: THEY WERE CAPTURED IN THE NATAL PROVENCE OF SOUTH AFRICA DOWN ALONG THE EAST COAST SOUTH OF DURLIN. THEY WERE INITIALLY FED RABBIT PELLETS AND ALFALFA. I'VE HAD SUCH GOOD LUCK WITH THAT, THAT WE'RE STILL FEEDING IT. WE'LL EVENTUALLY FORMULATE OTHER DIETS, BUT WE'RE GETTING GOOD REPRODUCTION WITH THAT DIET.

Q: TO WHAT EXTENT DO YOU FEED PRODUCE TO HOOFED STOCK, AND REASONS FOR DOING IT?

OFTEDAL: AT THE NATIONAL ZOO, PRODUCE WAS CUT OUT OF MOST OF THE LARGE HOOFED STOCK LIKE ELEPHANTS. THIS CUT THE FOOD BUDGET TREMENDOUSLY. BECAUSE THE QUANTITY OF PRODUCE THAT THEY CONSUME IS TREMENDOUS. THERE ARE CERTAIN ANIMALS WHICH THE MANAGEMENT STAFF AT THE ZOO HAVE BEEN VERY RELUCTANT TO REMOVE PRODUCE FROM BECAUSE OF THEIR SUCCESS. BONGOS AT THE NATIONAL ZOO ARE DOING VERY WELL AND THERE IS A LOT OF RESISTANCE TO ANY DIETARY MANIPULATION AT ALL. THIS IS DUE TO THE PROBLEMS THAT HAVE BEEN SEEN WITH BONGOS AND THEIR EXTREME VALUE.

ALLEN: THAT IS THE SAME SITUATION WITH OKAPI, THEY ARE ALSO EXTREMELY VALUABLE AND FAIRLY DIFFICULT TO MAINTAIN. THE BROOKFIELD ZOO IS STILL FEEDING PRODUCE TO THE OKAPIS THERE.

BROWN: I HAVE MORE OF A COMMENT THAN A QUESTION. A COUPLE OF THINGS THAT NEED TO BE CONSIDERED WHEN YOU'RE LOOKING AT A PRICE WOULD BE TO CONSIDER STORAGE PRICE. PARTICULARLY OF FROZEN OR REFRIGERATED FOODS, WHEN YOU'RE OFTEN DEALING WITH PRODUCE. ANOTHER FACTOR IS THE LABOR COST INVOLVED IN HAVING TO DEAL WITH A RATHER EXOTIC OR COMPLICATED DIET. A FEW YEARS AGO I HAD THE MISFORTUNE OF BEING IN CHARGE OF A HORSE PROGRAM FOR A COUPLE OF YEAR, AND WE HAD, I BELIEVE, EIGHT DIFFERENT CLASSES OF HORSES, EVERYTHING FROM OUR WORKING STOCK, OUR CUTTING HORSES, TO LACTATING MARES, FOALS, ETC. WITHIN THOSE CLASSES THERE WERE DIFFERENT WEIGHTS, AND SO THE REQUIREMENTS VARIED TREMENDOUSLY BY INDIVIDUAL ANIMALS. WE FOUND THE WAY TO GET AROUND THIS WAS TO BUY VERY EXPENSIVE HIGH PROTEIN PELLETS, ABOUT AN 18% PROTEIN PELLET, AND THEN THE CHEAPEST THING AVAILABLE, ABOUT A 10% PELLET, IT TURNED OUT THAT DIDN'T WORK BECAUSE THE UNSKILLED LABOR THAT WE HAD FEEDING COULDN'T TELL THE DIFFERENCE BETWEEN THE PELLETS. THEY WOULDN'T READ THE LABELS. SO, WE EVENTUALLY WENT TO A 10% CORN AND OATS TYPE MIX. ALSO WE HAVE THE PROBLEM IN SOUTH TEXAS OF ALFALFA HAY COSTING ABOUT \$6.50 TO \$7.50 A BALE. SO, WE JUST FEED ENOUGH ALFALFA TO KEEP THE RUMENS HEALTHY AND OTHER THAN THAT I WOULD VENTURE TO SAY BETWEEN THOSE TWO FEEDS THE 18% PELLETS AND THE 10% MEAL WE COULD FEED EVERY HERBIVORE WE HAVE FROM OUR COLLARED PECCARY TO OUR NILGIA, OUR DEER, OUR CATTLE, HORSES, ETC. USING THE PELLETS, THE MEAL MIX AND THE ALFALFA HAY. SO I THINK WHEN YOU'RE LOOKING AT BUDGETS SOMETHING YOU COULD CONSIDER IS WHAT COMMERCIAL FEEDS ARE AVAILABLE WITHOUT GETTING TOO EXOTIC IN YOUR OWN MIXING. HORSE FEEDS TEND TO BE A LITTLE EXPENSIVE BECAUSE HORSE PEOPLE HAVE MONEY. THEY HAVE THE ADVANTAGE OF NOT HAVING UREA IN THEM WHICH SOME HERBIVORES MAY NOT BE ABLE TO HANDLE. DAIRY MIXES ARE ANOTHER GOOD ONE, THEY USUALLY DON'T HAVE UREA AND ARE VERY HIGH IN ENERGY, WHILE BEING HIGH IN FIBER, WHICH IS A DIFFERENT THING TO GET IN A FEED. SO I THINK A GOOD RULE FOR ZOO PEOPLE WOULD BE TO WATCH YOUR LABOR COST AND KEEP YOUR DIET AS SIMPLE AS POSSIBLE.

MEEHAN: I'M CURIOUS IF THIS PANEL HAS ANY RECOMMENDATIONS ABOUT AN OPTIMUM TIME TO FAST AN ANIMAL PRIOR TO AN ELECTIVE IMMOBILIZATION PROCEDURE.

STEVENS: IN RUMINANTS, WHERE THIS IS DONE QUITE A BIT, IT IS USUALLY A GOOD IDEA TO KEEP AN ANIMAL OFF FEED FOR 24 HOURS. THIS IS BECAUSE WITHIN ABOUT 4-6 HOURS THE MAJOR MICROBIAL DIGESTIVE PROCESS IS OVER WITH, AND AFTER THAT IT DOESN'T MAKE MUCH DIFFERENCE BECAUSE THE DIGESTIVE CONTENTS ARE GOING TO BE THE SAME. IT DOESN'T CHANGE VERY MUCH. IT IS A MAJOR PROBLEM WITH THEM BECAUSE OF THE DANGER OF BLOATING AND THE DANGER OF REGURGITATION AND PNEUMONIA. WITH THE HORSES AND ANIMALS OF THAT SIZE, I THINK IT MAKES LESS DIFFERENCE. IT TAKES ABOUT 8 HOURS FOR THE MEAL TO GET TO THE LARGE INTESTINE. IT'S THERE FOR ANOTHER 24 HOURS, IN A HIGHLY FERMENTABLE FORM. YOU DO NOT HAVE TO WORRY ABOUT REGURGITATION AND ASPIRATION PNEUMONIA. SO, I GUESS IN BOTH CASES 24 HOURS WOULD BE SUFFICIENT.

MEEHAN: MY EXPERIENCE AT ST. LOUIS AND AT LINCOLN PARK ZOO WITH ALL SORTS OF HOOFED STOCK, PARTICULARLY RUMINANTS, IS THAT I DON'T FEED THE ANIMALS THE MORNING OF AN ELECTIVE PROCEDURE. SO, IF WE'RE TALKING ABOUT THE CHANCES BEING LESS AFTER 4 HOURS, THEN I GUESS I AM FASTING THEM OVERNIGHT AND THEN IN A TYPICAL ZOO SITUATION YOU HAVE THE ANIMAL OFF FEED FOR 12 TO 18 HOURS, DEPENDING ON HOW MUCH THE ANIMAL FINISHES OF THE EVENING MEAL. SO, THE ANIMAL IS FASTED AT LEAST 4,6 TO 8 HOURS, BUT I HAVEN'T DONE IT ANY MORE THAN THAT. AND, I'VE RUN INTO LITTLE IF ANY ADVERSE EFFECTS FROM THAT AMOUNT OF FEEDING IN COMPARISON TO COLLEAGUES I HAVE TALKED TO.

Q: DOES THE NORMAL TEMPERATURE OF AN ANIMAL AFFECT THE TYPES OF MICROBES AND THE FERMENTATION PRESENT?

FAHEY: I THINK CERTAIN SPECIES OF MICROBES WILL PROLIFERATE AND OTHERS WILL DIE OFF, DEPENDING UPON THE CONDITIONS. MANY FACTORS RESULT IN A PARTICULAR MICROFLORA BEING THERE. THE INTERESTING THING IS THAT THERE HAVE BEEN EXPERIMENTS CONDUCTED THAT SHOW THAT INGESTA CAN BE DECREASED IN TEMPERATURE QUITE A BIT. THERE HAVE BEEN SEVERAL STUDIES, AT KANSAS STATE UNIVERSITY, WHERE THEY INFUSE ICE COLD WATER TO SEE WHAT HAPPENS TO RUMEN BACTERIA AND THE DIGESTIVE PROCESS, AND IT'S AMAZING HOW RESILENT THE WHOLE PROCESS IS. THE DATA ARE NOT ABUNDANT IN THAT PARTICULAR AREA, BUT IT DOESN'T SEEM TO AFFECT IT TOO MUCH. CERTAINLY THE MICROBIAL COMPOSITION WOULD BE EFFECTED BY SOME OF THESE THINGS.

Q: JUST A COMMENT. THE UNIVERSITY OF NEBRASKA IS USING AN HYDROXYL COMPOUND ON STRAW OR RESIDUES AND BREAKING DOWN THE LIGNIN AND TURNING IT INTO A FEED PRODUCT THAT CAN PUT WEIGHT ONTO CATTLE. I KNOW THERE ARE SOME PROBLEMS, BUT MAY-BE THIS WOULD BE AN IDEA THAT WOULD BE HELPFUL TO ZOOS.

ULREY: THERE ARE LOTS OF PROBLEMS WITH SODIUM HYDROXIDE. MORE IMPORTANTLY THEY'RE LOOKING AT AMMONIUM HYDROXIDE WHICH IS MUCH BETTER BECAUSE IT INCREASES THE CRUDE PROTEIN CONTENT OF THE LOW QUALITY FEEDSTUFF. YOU HAVE THE PROBLEM WITH SODIUM HYDROXIDE OF A SODIUM OVERLOAD, NOT ONLY IN THE ANIMAL BUT IN THE SOIL ALSO. THIS PRODUCT DOESN'T REDUCE THE LIGNIN CONTENT AT ALL, BUT IT DOES BREAK THESE LIGNIN CARBOHYDRATE LINKAGES WHICH FREES UP THE CARBOHYDRATE FOR FERMENTATION BY THE BUGS. THE LIGNIN CONTENT IS ABOUT THE SAME, AND THEN THEY'VE LOOKED AT CALCIUM HYDROXIDE, SODIUM HYDROXIDE COMBINATIONS, MAINLY WITH THE IDEA OF PROVIDING CALCIUM FOR THE ANIMAL. SO I THINK WE'RE GOING TO SEE SODIUM HYDROXIDE GO OUT THE WINDOW, IT'S HARD TO WORK WITH, THE SODIUM OVERLOAD IS BAD NEWS. THE AMMONIA HYDRO-XIDE MIGHT BE WORTHWHILE. THERE ARE ENOUGH GOOD QUALITY ROUGHAGES THAT DON'T REQUIRE ANY TREATMENT, LIKE CORN PLANT RESIDUES. CORN COBS ARE VERY HIGHLY FERMENTABLE, THEY HAVE ONLY 4-5% CRUDE PROTEIN, OF WHICH VERY LITTLE IS DIGESTIBLE, BUT IT HAS A TDN VALUE IN THE 60% RANGE. THEY ARE VERY FERMENTABLE, VERY HIGH IN HEMICELLULOSE AND LIGNIN ATTACHMENTS ARE SUCH THAT LIGNIN IS NOT AS REFRACTORY A MATERIAL IN CORN COBS AS IT MIGHT BE IN WHEAT STRAW OR RICE HULLS OR SOMETHING LIKE THAT. SO, THERE ARE THESE THAT EXIST. DAMON SHELTON TALKED ABOUT WHEAT MIDDLINGS, THEY ARE USED QUITE A BIT IN THE FEEDING OF PIGS NOW, BECAUSE THEY PROVIDE BULK TO THE DIET BUT ARE NOT TOTALLY REFRACTORY.

Abstract

Digestive Efficiency and Protein Requirements of the Collared Peccary

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Three digestion trials were conducted each using the same 6 adult collared peccaries (_Dicotyles_ _tajacu_) to study their digestive efficiency on 2 diets differing in fiber content and on the same diet at 2 different _ad libitum_ intake levels. Digestive efficiency of all nutrients except either extract was higher ($P<0.05$) for the low fiber diet (dry matter digestibility: 90%) than for the high fiber diet (62%). Digestible energy intake was the same for both diets and above maintenance (83 Kcal/kg/day). Digestive efficiency of all nutrients was higher ($P<0.01$) for the same diet when _ad libitum_ intake was below maintenance (75%) than when _ad libitum_ intake was above maintenance (62%).

Mean rate of digesta passage was 52.5 hours on the high fiber diet when intake was above maintenance energy requirements.

Mean daily feed intake was higher ($P= 0.01$) during a 4 week winter period (35.2 g/kg/day) than during a comparable 4 week summer period (25.0 g/kg/day).

A nitrogen balance study was conducted to determine the protein requirements of adult collared peccaries. Six peccaries were each fed 4 pelleted, isocaloric diets containing 8, 13, 19, and 24% crude protein. Dry matter

intake per unit metabolic body weight (74.5 g/kg$^{0.75}$/day), dry matter digestibility (63.6%), and digestible energy (99.5 Kcal/kg/day) were not significantly different ($P>0.75$), for the 4 diets. Digestible energy intake was above that required for maintenance. Linear regression showed maintenance protein requirements to be 7% truly digestible protein. Regression analysis showed that the peccaries were able to efficiently metabolize diets having 7-20% truly digestible protein.

AFRICAN ELEPHANT AND HIPPOPOTAMUS: THE RESULTS OF NUTRITIONAL RESEARCH

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INTRODUCTION

In cooperation with the South African National Parks Board nutritional research was done on the African Elephant (Loxodonta africana) and Hippopotamus (Hippopotamus amphibius) during culling operations in the Kruger National Park.

Elephants are opportunistic feeders and are normally non-selective with their diet often containing more than 100 plant species (Douglas-Hamilton 1972, Williamson 1975, Guy 1976). In the Acacia woodlands of central Africa elephants preferably browse in the cold or hot dry season, but prefer grasses in the wet season. These season-dependent food preferences are related to the protein content of the available food (Guy 1977, Williamson 1975, Wyatt and Eltringham 1974). In general the majority of woodland plant species in Southern Africa are utilized in quantities approximately proportional to their occurrence, although some species are favored (e.g. Colophospermum mopane and Combretum sp.) while other plants are avoided (e.g. Capparis and Securinega sp.). Elephants in Africa occur in diverse habitats, open savanah-grassland in parts of central Africa, bush or woodland such as is found in Kruger National Park, dense forest such as the Knysna forest in South Africa and in desert conditions in the Kaokoland just south of Angola. Laws (1970) states that an increasing proportion of grass in the diet is correlated with an increasing degree of habitat change.

The Hippopotamus, as opposed to the Elephant, feeds almost exclusively on grass and is an unselective grazer preferring short grass which it grips with its wide lips and tears off with a sideways swing of the head. The wide structure of the mouth together with the fact that it is a nocturnal grazer virtually rules out any degree of feed selection and also explains why on occasion a beer can was found in the stomach. Being a nocturnal feeder further makes the Hippo an unpopular choice for students of feeding behavior and data on feed composition are based on analysis of stomach content. Young (1966) found that the stomachs of Hippo culled in Kruger National Park contained almost exclusively grass and the species ratio resembled the availability. Only traces of reeds (Phragmites communis) were found pointing again to the fact that Hippo make very little use of aquatic plants.

While some knowledge has become available about their diet, virtually nothing is known about the actual processing of food in the guts of Elephant and Hippopotamus. Benedict (1936) indicated that methane is formed during fermentation in the gut of African Elephant. Laws, Parker and Johnstone (1975) and Sikes (1971) stated that fermentation of structural plant carbohydrates may occur in the gastrointestinal tract and that especially the caecum and colon acts as fermentation chambers in the Elephant. van Hoven, Prins and Lankhorst (1981) give a more detailed view on the digestive physiology in the African Elephant, while Eloff and van Hoven (1980) studied the protozoa in the gut.

The Hippopotamus was reported to harbor protozoa in the stomach by Dinnik et al. (1963) and Moir (1965) drew attention to the fact that fermentative digestion takes place in these animals. Thurston et al. (1968) went further and demonstrated high concentration of total volatile fatty acids and a diverse population of ciliates in the stomach compartments of hippo. Arman and Field (1973) compared the digestive efficiency of hippos from Uganda with ruminants, while Thurston and Grain (1971) and Thurston and Noirot-Timothée (1973) described the stomach protozoa from hippo of the same region. The presence and distribution of protozoa in the stomach compartments of hippos in South Africa were reported by Van Hoven (1974) and aspects of the fermentation rate and digestive physiology were reported by van Hoven (1977, 1978). A detailed and precise description of the hippo stomach is given by Langer (1975, 1976).

ELEPHANTS

The information reported here is mainly based on measurements, determinations and in vitro experiments performed on 50 freshly killed elephant in the Kruger National Park, South Africa during the period 1975 to 1980. The elephants were rounded up by helicopter and shot from the air with a dart injecting an overdose of succinyl choline chloride. Within minutes after the elephant had fallen the digestive tracts were removed.

Since the anatomy of the gastrointestinal tract in the elephant has not been studied adequately, locations of sampling were chosen quite arbitrarily and may not be precise in anatomical terms (see Fig. 1). Table 1 lists the names, numbers, location and content of the intestinal areas investigated.

Fermentation of digesta by microbes plays an enormous role throughout most of the elephant's intestinal tract. Sugars and starches, the two important soluble carbohydrates, are in excess in the upper parts of the gut and are partially fermented there to lactic acid. With the pH in the stomach in the order of 2, it is likely that some sugar is liberated from starch by acidity. The presence of protozoa in high concentrations in the small intestine is unique and casts some doubt on the significance of enzymatic digestion by the host.

The fermentation of soluble sugars is completed in the caecum and no free sugar remains detectable. Lactic acid is formed in the upper parts of the intestinal tracts and is fermented in the caecum and colon to volatile fatty acids, the main fermentation end-products in these compartments. The VFA fermentation pattern is reminiscent of the pattern in the rumen of a hay-fed cow with a high percentage of acetate. In the caecum and colon, fermentation of starch and cell wall polymers occurs in addition to sugar lactate fermentation. Rates of starch and cellulose breakdown measured as starch hydrolysis (loss of iodine staining property) and rate of cellulose disappearance (gravimetric procedure) in vitro are low. Assuming that on average 3,5 g of cellulose can be hydrolysed per litre of gut fluid (caecum and colon) per 24 h, it can be calculated that in the total gut of an average elephant with a volume of 408 (caecum and colon) 224 g of cellulose could maximally be hydrolysed each day. Inspection of Table 2 and calculation of cellulose contents of ingesta corrected for lignin (assuming no solubilation or digestion of lignin) discloses a value of ± 10% cellulose disappearance between small intestine and posterior colon. Poor digestion of dry matter was observed by Benedict (1936) in the Indian elephant.

It can be concluded that the colon is a site of continued fermentation of starch, soluble polysaccharides, cellulose and protein. A very high capacity for fermenting lactic acid was found, pointing to an important role for lactic acid as an intermediate in the fermentation process (Counotte and Prins 1978).

Rates of VFA formation are also low and are about half those generally recorded in rumens (Hungate 1966). Yet, calculations of the amounts of VFA produced (van Hoven and Boomker 1981) show that these can cover a large part of the energy expenditure in the elephant. Assuming a mean total volume of 408 l in the caecum plus colon and an average production rate of VFA of 1,5 mmol per 100 g wet weight per h, a daily production results in 147 mol of VFA. Assuming molar percentages of the main acids: acetic, propionic and butyric acid to be 75,12 and 10% respectively, their energy value would be 19264, 54148 and 51544 kJ with a total of 298256 kJ. Benedict (1936) showed that the total heat production of the Indian elephant Jap (3 672 kg) while standing at a barn temperature of 20°C was 27170 kJ per 24 h. This included basal metabolism and energy required for standing and feeding.

The percentage of branched-chain VFA (i - C_4, 2-methyl-butyrate and 3-methyl-butyrate) in the colon can be explained on the basis of an increased amino acid breakdown. That the colon is a site of protein fermentation is also borne out by the results of the semi-quantitative tests for hydrolytic enzymes which showed peptidase and proteolytic enzymes to be present more in the colon fluid than in the caecum. Another possibility is that the branched-chain VFA were formed by the many nematodes which were seen in the colon (for a review see Salzert 1972).

From the feed composition it can be deducted that the feed consumed by elephants in winter in the northern half of the Kruger National Park is low in quality with a fibre content of about 47% when dry. Studies on the Indian elephant (Elephas maximus) by Nair and Ananthasubramaniam (1979) showed that the roughage consumed contained 38,8% dry matter, 2% protein, 9,3% crude fiber, 1,1% fat and total ash 3,5%.

Concentrations of some major minerals (Na, K, Mg, Ca, P) were somewhat comparable to the concentrations of these elements in the rumen fluid of cattle fed alfalfa hay (Bennink, Tyler, Ward and Johnson 1978) except that K was much lower and Mg and P much higher in the caecum and colon fluids of the elephant.

HIPPOPOTAMUS

Figure 2 is a schematic representation of the stomach complex of the hippopotamus with the symbols indicating the various compartments and areas within these compartments that were studied. The symbols correspond with those used in the tables, and in sequence from A to J follow the route of food passing through the stomach complex.

The pH in the visceral blindsac was higher than in the parietal blindsac. The highest pH recordings were made in the connecting chamber. Total volatile fatty acid concentration (TVFA) was lower in the visceral blindsac than in the parietal blindsac and vestibulum, and the lowest TVFA concentrations were recorded in the connecting chamber. The enzymatic stomach, not being a fermentation chamber and corresponding with the abomasum of ruminants, had an average pH of 3.2 and TVFA concentration of 4,02 mmol/100 g (Table 3).

The volumes of the stomach compartments are also given in Table 3, together with the factor of increased surface area (FISA) and minimum epithelial thickness in the stomach regions as reported by Langer (1976).

Figure 3 indicates a clear relation between the time in the morning the hippopotami were shot and the time it took for the carcasses to float to the surface of the river. The depth of the water varied between 2 and 4 m. It is assumed that gas production due to fermentation in the stomach and the fact that the gas is trapped as a result of reflex closure of the cardia leads to buoying up of the carcass. It therefore seems probable that fermentation is much more rapid in the early morning, soon after the animals have returned to the water after nocturnal grazing, and gradually decreases later. This could explain why such a large variation was found in the *in vitro* fermentation rates of the different stomach regions.

The methods used in determining the chemical composition of the diet of the hippos have a shortcoming since the food could already have been subjected to a minor degree of digestion. The mean protein content of the diet during August 1976 was 5,30%. The mean value for ether extract (fat) was 0,37% and the crude fiber content was 14,18% Ca 0,21%, P 0.11%, K 0.41% Mg 0,05% and Na 0.71%.

Hippos feed almost exclusively on grass and the species identified in this analysis largely confirm what was found by Young (1966) in hippos from the same area:

Rhodes grass	(*Chloris gayona*)
Quick grass	(*Cynodon dactylon*)
Couch grass	(*Hemarthria altissima*)
Buffalo grass	(*Panicum maximum*, *P. meyerianum* and *P. deustum*)
Red grass	(*Themeda triandra*)
Bulrush	(*Typha* sp.)
Wild willows	(*Salix* sp.)
Mopane	(*Colophospermum mopane*)
Reeds	(*Phragmites communis*)

In the connecting chamber the fermentation rate increased from anterior to posterior and inversely the TVFA concentration decreases. It seems therefore that the connecting chamber must be an important absorptive region, in particular the posterior region. The connecting chamber has an average volume of 116 litres comprising 51,96% of the total stomach volume. There are also ten transverse septa from anterior to posterior which contribute to the enlargement of the absorptive surface. The FISA due to the presence of papillae are 3,94 and 3,32 on the oral and aboral septa. The ventral oral and aboral surfaces of the connecting chamber have a FISA of 3,35 and 3,25 respectively, as opposed to 1,98 for the visceral blindsac, 2,64 for the parietal blindsac and 1,25 for the vestibulum (Langer 1976). These facts, together with the finding of Langer (1976) that the minimum epithelial thickness of 65 µm occurs in the posterior connecting chamber, emphasizes this region as an important site for the absorption of fermentation end products.

It is known that approximately 77% of the VFA's in ruminants entering the omasum is absorbed (Badawy et al. 1958b). In view of the low concentration of VFA's in the enzymatic stomach, this region could also be the most important site for VFA absorption in the hippopotamus.

Different species of ruminants, on a wide variety of diets, show quantitatively the same end products of fermentation in the rumen. This can be extended to include the hippopotamus. In ruminants a high-roughage diet appears to give rise to a high proportion of acetic acid relative to the other VFA's, with the proportion of propionic acid exceeding that of butyric acid. The results indicate that this is also true for hippos on a high-roughage diet. This is further emphasized by Barcroft et al. (1944) who proved that the rate of VFA absorption increased with a decrease in the molecular mass of the acid.

The concentration of TVFA is about six times lower in the hindgut of hippos than in sheep and black-tailed deer, according to Allo et al. (1973). The VFA concentration in the small intestine and colon of hippos corresponds well with the result obtained from the small intestine and colon of sheep fed different rations by earlier workers (Barcroft et al. 1944, Elsden et al. 1946, Boyne et al. 1956 and Badaway et al. 1958a). These workers attributed the gradual increase in VFA concentration from less than 1 mmol/100 g in the proximal small intestine to up to 6,4 mmol/100 g in the colon of the sheep to micro-organisms passing the ileocaecal junction. The hippopotamus, however, has no caecum and a microbial population in the hindgut must therefore be regarded as a definite feature of hippos.

The high $C_2:C_3$ ratio (15,78) measured in the proximal small intestine indicates a very slow fermentation process (Prins and Van Geelen 1971). The $C_2:C_3$ ratio in the posterior extreme of the colon is much lower (5,87), indicating a higher fermentation rate. This gradual lowering in the $C_2:C_3$ ratio from anterior to posterior in the hindgut indicates an increased fermentation activity which is emphasized by the steady increase in TVFA concentration over the entire hindgut.

The major end product of rumen microbial fermentation of nitrogen compounds is ammonia. It is also the major nitrogen source for microbial protein synthesis. Thus, the concentration of ammonia nitrogen in rumen fluid is important for assessing the efficiency of nitrogen utilization in ruminants (Wohlt et al. 1976). From Table 3 it seems that a higher NH_3-N samples were not always collected from the same spot within a compartment, the animals did not always lie (during skinning) in the same position and the samples were not collected at the same time of day (van Hoven 1977). Wohlt et al. (1976) report on a large variation in NH_3-N concentration from dorsal to ventral regions within a rumen. This might also be so in the fermentative chambers of the hippo.

It has been determined that there are eight protozoan species in the stomach complex of the hippos of the Kruger National Park (van Hoven 1974). Five are holotrichs and the other three entodiniomorphs. Ruminants on the other hand are known only to have three holotrich species in the rumen, and all three seldom occur in the same animal. The many studies on the biochemistry and physiology of the rumen holotrichs have been adequately reviewed (Danforth 1967 and Hungate 1966). Prins and van Hoven (1976) and van Hoven and Prins (1978) pointed out the role of holotrichs in storing surplus soluble carbohydrates after feeding in the form of amylopectin in the cells.

For an animal such as the hippo which only eats at night, it would be beneficial to contain high numbers of holotrich protozoa. If the metabolism of the holotrichs in the hippo stomach is assumed to be similar to those in the rumen, soluble carbohydrates would be stored in the form of amylopectin in the cells during the nocturnal grazing. If the retention time of soluble carbohydrates could be prolonged in the stomach in the form of storage amylopectin in these protozoa it would contribute to more efficient utilization of nutritionally important substances.

When the cellulolytic activity of hippos is compared to that of cattle and the three deer species listed by Prins and Geelen (1971), it becomes evident that hippos have superior ability to ferment cellulose. The highest value for ruminants is listed for cows on a grass diet, namely 13,8 g cellulose hydrolysed per litre rumen fluid per 24 hours. The average value for hippos was found to be 16,48. The low values recorded for the amylolytic activity in the various stomach regions of hippos and the average value of the whole stomach of 3,33 g soluble starch hydrolysed per litre of rumen fluid per hour is found to be lower than the results listed by Prins and Geelen (1971) for the four ruminents mentioned above.

The values found for the cellulolytic and amylolytic activities in the stomach complex prove the hippopotamus's ability to ferment these substances. These values would not be affected by the rate of total fermentation in the stomach which decreased during the day (van Hoven 1977). Substrate volume was not a limiting factor during the experiments.

CONCLUSIONS

Being a monogastric herbivore the limitation on the amount of food elephants can process is the availability and speed by which they can eat it. An adult elephant, depending on its size, takes more than a hundred kilograms of dried hay per day. It is not necessary to feed elephants the more expensive high protein lucerne which is commonly used for ruminants. With their much more rapid through flow rate than most ruminants, they process more food per time unit making up for lower quality of the food.

Hippopotamus should have adequate nutrients when fed about 60 kg of dried hay per day. Their typical stomach structure ensures optimal digestion of low quality food.

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Table 1. Names, numbers, location and content of intestinal areas investigated. The figures are based on the average of 10 adult elephants.

Intestinal area number	Name	Location[a]	Volume (1)	Content kg(wet)	Protozoa Number per mi x 104^{4}
1	Stomach	Anterior	60 ± 5	51 ± 4	0
2	Dueodenum	First 8 m from stomach	21 ± 3	20 ± 3	1,0 ± 0,4
3	Ileum	Second 8 m from stomach	19 ± 4	18 ± 4	3,2
4	Caecum	At small intestine and colon junction	90 ± 10	86 ± 9	4,1
5	Anterior colon	First 2 m behind caecum	180 ± 16	157 ± 14	4,6
6	Middle colon	Second 2 m behind caecum	109 ± 7	96 ± 6	4,4
7	Posterior colon	Third 2 m behind caecum	40 ± 6	36 ± 7	3,8
8	Mesocolon	Hind 2 m	36 ± 9	23 ± 5	1,1
Total		Length: 27 m	555 ± 60	487 ± 52	

[a]See Figure 1.

Table 2. Composition of dry matter along the digestive tract of elephant.[a]

Sampling area	Crude prot. (%) N x 6.25	Fat (%)	Fibre (%)	Ash (%)	Ca (%)	P (%)	Cl (%)	NDR (%)	ADF (%)	HC	c	L	Kj/g	DM (%)
1	7,65	5,15	47,15	7,6	1,12	0,12	1,34	72,8	52,05	20,7	31,5	20,65	20,08	15,2
2	9,15	3,2	46,2	10,4	1,19	0,11	1,19	72,3	55,4	15,5	29,4	23,0	19,12	17,0
3	9,40	3,3	43,4	10,3	0,98	0,13	2,16	73,1	53,4	22,5	40,0	18,3	20,92	10,0
4	6,4	3,2	39,0	8,2	0,95	0,14	0,54	78,6	59,8	17,0	34,0	22,1	22,34	8,1
5	6,8	4,8	37,0	7,4	0,98	0,16	0,48	79,7	58,5	20,0	36,3	22,0	20,20	9,7
6	7,0	3,2	26,8	6,9	0,97	0,18	0,52	77,3	60,0	14,9	34,5	23,9	20,94	8,2
7	6,75	2,6	37,3	5,4	0,97	0,18	0,44	79,7	60,8	16,5	32,7	23,5	19,87	11,8
8	7,5	6,6	52,6	5,0	1,09	0,17	0,56						21,78	13,6

NDR - Neutral detergent residue
ADF - Acid detergent fibre
HC - Hemicellulose
c - Cellulose
L - Lignin

[a]Results based on samples of four elephant lumped together.

Table 3. The pH value, total volatile fatty acid and NH_3 nitrogen concentration, FISA, epithelial thickness and volume in the various stomach compartments (Mean ± s.e.).

Stomach area[a]	pH	TVFA mmol/100g	NH_3-N	FISA[b]	Min. epithelial thickness (µm)	Volume (1)	% of total vol.
A	6,43 ± 0,07	13,13 ± 1,09	205 ± 109			45	20,16
B	6,43 ± 0,12	12,94 ± 0,98	234 ± 125	1,98	74		
C	6,30 ± 0,20	14,64 ± 0,73	257 ± 101				
D	6,20 ± 0,05	15,00 ± 0,32	226 ± 81	2,64	90	48.5	21,70
E	6,15 ± 0,15	14,96 ± 0,99	165 ± 58	1,25	95		
F	6.38 ± 0,03	13,97 ± 0,13	174 ± 78	Vent 3,35	80		
G	6,63 ± 0,03	12,38	260 ± 152	Sept 3,94			
H	6,65 ± 0,05	11,94	145 ± 50	Vent 3,25	65		
I	6,50 ± 0,00	11,60	107 ± 21	Sept 3,32			
J	3,2 ± 0,4	4,02	227 ± 60			14	6,16

[a]Symbols refer to those used in Fig. 2.

[b]Factor of increased surface area (From Langer 1976)

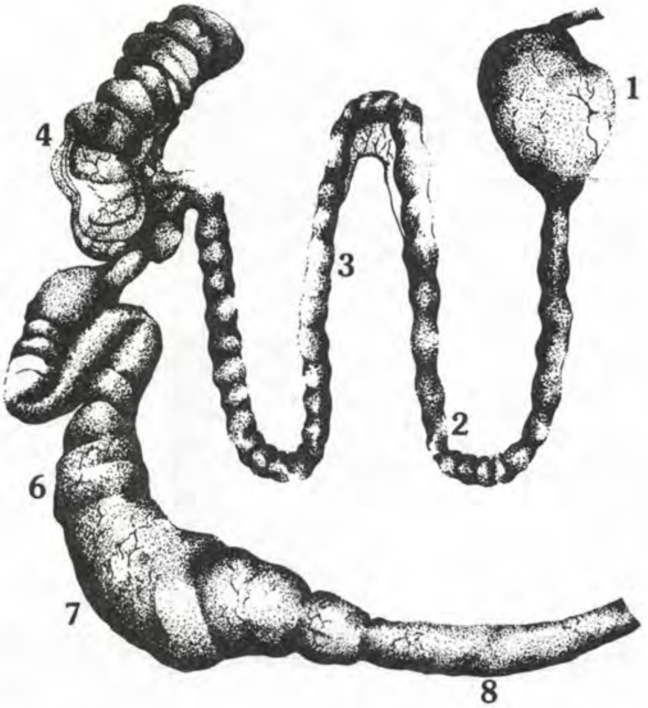

Figure 1. Gut of adult elephant. 1- Stomach. 2- Small intesting (duodenal). 3- Small intestine (ileal). 4- Caecum. 5- Anterior colon. 6- Middle colon. 7- Posterior colon. 8- Mesocolon.

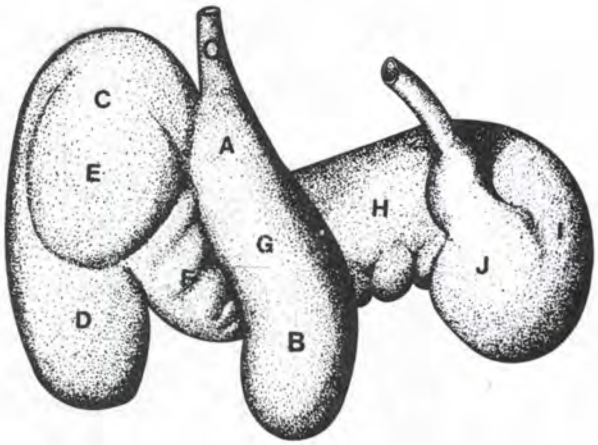

Figure 2. The stomach complex of the hippopotamus. O: Oesophagus A: Dorsal visceral blindsac B: Ventral visceral blindsac C: Dorsal parietal blindsac D: Ventral parietal blindsac E: Vestibulum F,G,H,I: Connecting Chamber J: Enzymatic stomach.

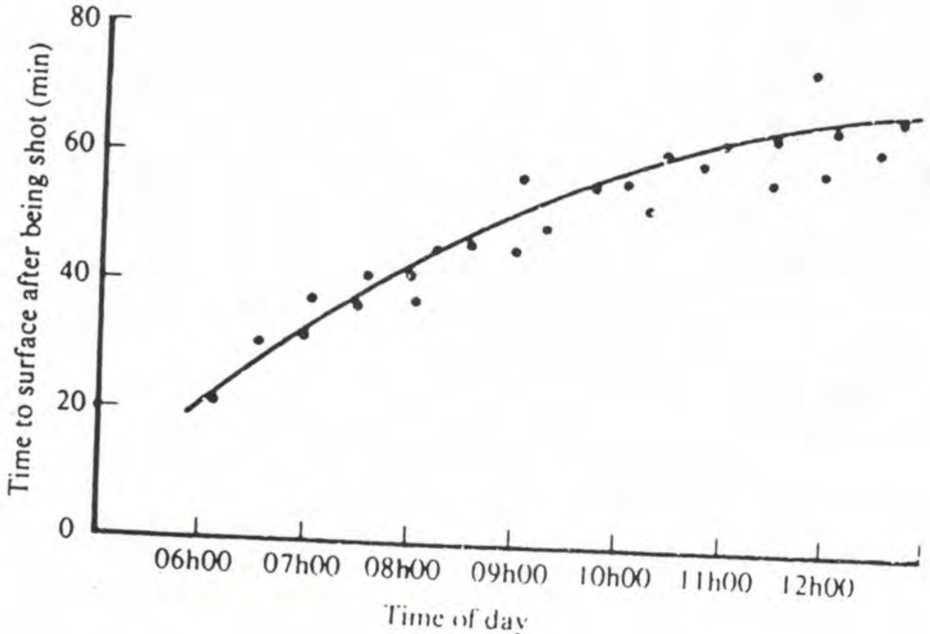

Figure 3. The relation between time of death of hippopotami and the reappearance of the carcasses on the surface of the water.

NUTRITIONAL IMPLICATIONS OF DENTAL PROBLEMS IN ELEPHANTS

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INTRODUCTION

One of the common dental problems in elephants is a malfunction in the forward progression of molar teeth expecially the sixth molars (3). The elephant has six molar teeth in each half of the jaw which are not simultaneously functional. The newborn elephant has molars one and two functional at birth (4). The first set is worn away and the roots resorbed as the second molar comes forward. Subsequent molars are continually produced in the alveolar pocket of the proximal jawbone. As each successive molar is pushed forward in the jaw by the replacement tooth behind it, the rostral molar crown gradually wears down and fractures transversely in sections. The fractured sections of crown are either swallowed or spit out and the roots are resorbed.

Maldevelopment of the molars often causes poor mastication, weight loss and a generalized deterioration in the elephant's physical condition (3,4). One female elephant starved to death because fragments of the 5th molar became wedged in the jaw and prevented the sixth molar from progressing forward in the alveolus(3).

This paper presents a case history of an Asian elephant *Elaphus maximus* with molar maldevelopment and the nutritional problems experienced by the animal as a result of this lesion.

HISTORY AND CLINICAL FINDINGS

A 42 year old female Asian elephant named Lucky, had experienced weight loss over the past two years. An examination conducted one year earlier had revealed negative reactions to intradermal testing for *Mycobacterium tuberculosis*, *bovis* and *avium*, and blood samples taken at that time had revealed low normal to below normal values of total protein (6.8 g/dl), packed cell volume (37%) and hemoglobin (13 g/dl). There were no other significant findings, however an oral exam had not been done.

The keepers now noted an increase in Lucky's appetite, volume and coarseness of her feces. The daily diet had consisted of Sudan grass hay (approximately 7% crude protein) or oat hay (approximately 4% crude protein), a bucket of a rolled oats - barley mixture and a few apples, oranges, and carrots. An examination revealed Lucky's feces from a primarily oat hay diet to have coarser stems of undigested hay and more oat kernels than the feces of another elephant in the enclosure, an approximately 40 year old female Asian elephant named Maya.

An oral exam revealed a retained fifth molar on the left maxilla. The tooth was determined to be the 5th molar based on the animal's age (2,3). The crown, approximately 8 cm x 6 cm, was displaced laterally and was eroded and pitted. There was a purulent discharge from sites of sharp crown projections into the gingiva. An estimated 75% of the sixth molar crown was erupted and in wear.

A tentative diagnosis was made of weight loss due to poor mastication and digestion of food stuffs due to a retained, infected 5th molar.

RESULTS AND DISCUSSION

The treatment plan consisted of conducting a feeding trial to determine possible problems in the digestibility of food stuffs and then to make dietary adjustments based on these results. And second to extract the retained molar.

The digestibility studies consisted of feeding oat hay to Lucky and Maya for a preliminary period of at least 5 days followed by collection (on different days) of hay and fecal samples for analysis. Apparent digestibility estimates were made using the lignin ration technique and a 100% recovery of dietary lignin in the feces was assumed.

The apparent digestibility was similar for all nutrients except crude protein. Maya had an apparent digestibility of 44% crude protein vs. 8% crude protein for Lucky. (Table 1). Similar studies conducted on Sudan grass hay three years earlier had shown both elephants to have essentially the same apparent protein digestibility. (Table 1).

Based on these findings, the diet was changed by adding alfalfa hay (approximately 16% crude protein) and herbivore pellets (approximately 18% crude protein)to the diet.

The tooth was extracted under xylazine (a) and etorphine hydrochloride (b) anesthesia. The tooth was elevated and extracted using a variety of tools including power drill, modified rachet wrench, crowbar, chisel and channel lock. Blood samples taken at time of extraction again revealed low total protein (6.8 g/dl) packed cell volume (38%) and hemoglobin (13 g/dl) values. Follow up care included hydrotherapy of the alveolus to remove food particles and necrotic debris.

An examination under xylazine (a) sedation one month after the surgery revealed necrotic material and a small piece of the 5th molar remaining in the alveolus. Blood samples showed a further decrease in total protein (6.4 g/dl) packed cell volume (32%) and hemoglobin (12 g/dl) values. The day after the exam the animal showed signs of colic. This was thought to be due to her being fed a large amount of feed post recovery and possibly poor mastication of the feed due to pain at the alveolus. The animal responded to a treatment of analgesic injections, flunixin melgumine (c) and oral administration of bran and mineral oil.

Digestibility studies were repeated 2 months after tooth extraction with Maya again having a much higher crude protein digestibility. (35% vs. 9% for Lucky) (Table 1.)

Over the next year the animal slowly gained weight, her mastication improved and the feces contained more finely digested hay stems.

An exam approximately one year later revealed the sixth molar to have moved rostrally filling in one-half to three-fourths of the alveolus of the fifth molar. The small piece of the fifth molar was being pushed out of the alveolus. The total protein, packed cell volume and hemoglobin values had increased to 7.8 g/dl, 41% and 13.5 g/dl respectively. The low to below normal protein, packed cell volume and hemoglobin values recorded before and immediately after tooth extraction possibly were a physiological manifestation of the low protein digestibility.

The digestibility studies were again repeated approximately one year after tooth extraction but the results are pending. If poor mastication was not the cause of the lower protein digestibility of Lucky, the mechanism is unknown.

CONCLUSIONS

Based on this case and the experience of others, maldevelopment of molars can lead to poor mastication and loss of condition. Clinical signs often include weight loss and a change in appetite and fecal characteristics. An oral exam should be conducted in all cases to evaluate the dentition. Recommended therapy includes increasing the amounts of digestible nutrients in food stuffs and extraction of the problematic tooth. Because mastication on coarse objects such as branches, roots and rocks may aid in the fracturing and removal of molar crown sections, it is recommended that elephants have access to these items in their enclosure.

PRODUCTS MENTIONED IN THE TEXT

a. Rompun[R] - Cutter Labs, Inc, Shawnee, Texas

b. M-99[R] - D-M Pharmaceuticals, Inc, Rockville, Md.

c. Banamine[R] - Schering, Kenilworth, New Jersey

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Table 1. Apparent digestibility estimates of the nutrients in sudan or oat hay when consumed by Lucky or Maya.

Item	No. of samples	Composition (% or kcal/g) or apparent digestibility (%)[a]								
		DM	CP	EE	NDF	ADF	AL	Ash	SS	GE
May,1978										
Sudan Hay	3	93.2	7.4	4.2	68.0	43.4	5.2	9.3	11.1	4.26
Lucky	3	41	50	29	36	25	-	-	100	37
Maya	3	37	45	33	30	18	-	-	100	34
Mar,1981										
Oat hay	2	93.1	4.1	3.0	58.4	38.1	5.9	6.2	28.3	-
Lucky	7	36	8	12	22	9	-	-	81	-
Maya	7	29	44	38	3	10	-	-	92	-
Aug,1981										
Oat Hay	3	92.9	3.7	2.9	62.2	36.7	4.2	5.5	25.6	4.37
Lucky	3	40	9	4	33	22	-	-	86	43
Maya	3	35	35	36	22	1	-	-	100	42

[a]Composition expressed on dry matter basis. Acronyms identified as follows: DM, dry matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; ADF, acid detergent fiber; AL, acid lignin; SS, starch and sugar; GE, gross energy.

Comparitive In Vitro Digestive Efficiency of Cattle, Goats, Deer, Collared Peccary and Nilgai Antelope.

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The in vitro digestive efficiencies of rumen/stomach inocula from cattle, goats, white-tailed deer (Odocoileus virginianus), collared pecarry (Dicotyles tajacu), and nilgai antelope (Boselaphus tragocameleus) fed a pelleted ration were compared. A modification of the two-stage Tilley and Terry (1963) technique was used to evaluate five substrates: the pelleted ration (47% NDF), cellulose (100% NDF), coastal bermudagrass hay (72% NDF), alfalfa hay (41% NDF), and granjeno browse (28% NDF). In vitro dry matter digestibility of the pellets came closest to in vivo values in cattle, deer and javelina, while overestimating dry matter digestion in goats and nilgai. Overall mean dry matter digestibilities across substrates ranged from 70.9% for nilgai to 51.9% for javelina. Analysis of variance indicated that there was no significant difference ($P<0.05$) between in vitro digestion using inocula obtained from cattle, goats or nilgai. Both deer and javelina inocula were significantly different ($P<0.05$) from each other and the other herbivores. Overall dry matter digestion of forages by inocula from all animal species decreased as cell wall content increased, while cell wall digestibility in

ruminants was irrespective of cell wall content. Differences in *in vitro* dry matter and organic matter digestion of forages, between deer and the other ruminants, could be explained by differences in the utilization of cell walls. Mean cell wall digestibility across forages were as follows: cattle (33.6%), goats (33.8%), nilgai (34.6%), and deer (20.2%). In the javelina, dry matter and organic matter digestion of low fiber substrates were greater than or equal to that of the ruminants studied, while values for higher fiber substrates were considerably lower. It was concluded that donor animal species has an effect on *in vitro* digestion and the use of one animal species inoculum to predict *in vivo* digestibility of forages in another may be erroneous.

DIGESTIVE EFFICIENCY OF VARIOUS DIETS IN GIRAFFE WITH COMPARISONS TO SOME OTHER AFRICAN UNGULATES

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INTRODUCTION

Several studies on the feeding ecology of giraffe in Africa have been made. Dagg and Foster (1976), in a book on the giraffe of South Africa, review many of these studies that have been made. Hall-Martin (1975) and Sauer (1977) deal with the feed selection of giraffe in the eastern Transvaal lowveld of South Africa and extend these studies to the quality and nutritional value of giraffe diets based on analysis of rumen content and also by analysis of hand picked samples of the preferred feed of giraffe and also the browse which they do not take.

Data on the digestive physiology of giraffe are however very limited and in this paper some *in vitro* experiments and the results thereof are presented and compared to some other antelopes. The experiments were conducted on eight giraffe which were shot in the winter in and near the Kruger National Park, one in the summer, and also captive giraffe in the Johannesburg zoo. The giraffe in the zoo were immobilized twice and rumen fluid was obtained by insertion of a tube through the lower abdominal wall into the rumen. With the animals that were shot the digestive tract was removed within minutes after death and samples were taken for the experiments.

The microbial population of the rumen of an individual giraffe within a herd is regarded as being representative of the entire herd. This is due to the herd eating in the same area and selecting for the same browse and because a degree of constant transfaunation between animals in the herd takes place. By sacrificing one animal from the herd to obtain enough rumen fluid to do five replicates of an *in vitro* digestibility experiment would therefore be just as accurate as to sacrifice five individuals from the herd for the same purpose.

In animal nutrition one must know the amount of energy required by an animal for a specific function, be it meat production, growth, milk production, etc. The energy requirements are influenced by growth, production, work, body size, age, species and environmental conditions. To meet these requiremens the energy value of feeds per se is important, but one must not overlook the balance of nutrients. Animal metabolism is primarily concerned with the utilization of chemical energy.

Between 75-90% of the energy requirements of ruminants are provided by volatile fatty acids (VFA) produced during fermentative digestion of the feed. The ability of an animal, in this case the giraffe, to generate VFA from its food is thus of great importance. It was found in this study that although some food is digested more rapidly than others the amount of VFA produced in the process varies considerably. The ratios of the VFA's also differs which means that although two plants may produce the same amount of VFA during a certain period of fermentation in the rumen, the energy value may differ due to variance in this ratio.

Feed Digestion

The total amount of energy produced in the form of VFA during a 20 hour in vitro incubation period was compared using the same amounts of ground substrate from different feeds. This is compared to the rate of fermentation of the substrate as monitored in terms of gas produced over time, the dry matter disappearance and methane produced. The laboratory technique and analytical procedures used is described in van Hoven et al. (1981) and van Hoven and Boomker (1981).

Figures 1a, b and c illustrate the fermentation rates in vitro of three different substrates utilized by giraffe in their natural habitat. The eight lines represent eight repetitions of the experiment using rumen fluid from eight different giraffe. Numbers 1-6 are six giraffe that were shot during the winter from six different herds from varying localities in the eastern Transvaal of South Africa. The rumen fluid extracted from these giraffe were filtered thru double layers of cheesecloth, kept anaerobic with CO_2 and mixed with a buffer solution (Hungate, 1966) and incubated at 39°C with the same amounts of substrate for 20 hours. The substrate used in Fig. 1a is a mixture of equal amounts of Dichrostachys cinerea collected from July to August. Fig. 1b illustrates the results obtained using Acacia exuvialis as substrate. These leaves are described as a preferred food plant for giraffe and Hall-Martin (1975) found a 55% utilization of this species when available. The results obtained with Combretum apiculatum collected during the fall is shown in Fig. 1c. The leaves from this tree are not a preferred food source and this is particularly so during the fall with a less than 5% utilization. Line number 7 in these three figures represents the result obtained with rumen fluid obtained from a giraffe in the Johannesburg zoo and line number 8 from a giraffe sacrificed in mid-summer from the same general area as numbers 1-6.

From Figs. 1a-c it can be concluded that Dichrostachys cinerea and Acacia exuvialis, two preferred food species, are overall fermented more efficiently than Combretum apiculatum. Furthermore, very little difference in the fermentative ability of the rumen fluid obtained from the six different giraffe in winter is exhibited. The microbial population of the zoo giraffe rumen, line 7, exhibits an inferior fermentative capacity as compared to free ranging giraffe in their natural habitat. In contrast to this the rumen fluid obtained from giraffe in summer exhibits a superior fermentative ability of the same substrates.

Figures 2a-e compare the energy generated by means of total VFA production to the rate of fermentation of the substrate. The amount of energy in joules per 20 ml produced during the 20 hours incubation period is noted on the broken line representing the VFA production rate. The percentage of methane in the gas produced and the in vitro dry matter disappearance (IVDMD) during the incubation is also given.

With Acacia exuvialis the highest energy return (Fig. 2a) in the form of VFA was noted. With A. gerardi (Fig. 2b) this was somewhat lower (257 as opposed to 290 joules with the former). IVDMD was found to differ very little with these two feeds and this was also the case with the methane content of the gas produced. When, however, comparing the results obtained with the Acacia species, which are preferred food by giraffe, to Combretum apiculatum (Fig. 2c) which is not preferred, particularly during the fall, it becomes evident that this substrate is poorly fermented. The rate of fermentation is much lower and VFA production is almost negligible with IVDMD less than a third as compared to the Acacia species.

During 1980 some giraffe in the Johannesburg zoo, South Africa, died of what was thought to be a nutritional or digestive problem. They were fed a combination of lucern (Medicago sativa) and a commercially marketed concentrate in a pellet form known as antelope cubes. The same tests as reported above were done with these two feeds as a substrate and the results are summarized in Figs. 2d and 2e. Gas production during fermentation in both cases was substantially higher as compared to the rate of fermentation with natural feeds. With the antelope cubes (Fig. 2d) this was the highest. IVDMD was also found to be higher than was found with any of the 34 other natural feeds tested. From this alone a deduction can be made that these feeds are superior in digestibility. However, the VFA production which is the major metabolic energy supply is abnormally low in both cases as compared to the giraffe's naturally preferred food. Fig. 3 compares the IVDMD and energy value in joules for total VFA production, when some natural feeds and the zoo rations were used as substrates in in vitro digestion trials using giraffe as inoculum donor.

Discussion

This report is regarded as a preliminary report since more information is to be gathered on giraffe. With further investigation attention is to be given to the rate of passage. From casual observations it seemed that the zoo giraffe had a significantly more rapid rate of passage than their kin in the wild. With antelope cubes and lucern as diet little fibrous bulk is provided, the latter contributing to a longer retention time of food in the rumen. Within the context that rumen size relative to body mass increases thru the row from small ruminants to large ruminants (Hofmann, 1973; Prins and Geelen, 1971), giraffe should top the scale with the largest rumen size relative to body mass and thus also the longest retention time of food in the rumen. The addition of more roughage in the form of natural branches with leaves should improve retention time in the rumen of giraffe and lead to better feed utilization.

The fermentation rate in vitro of a concentrate such as antelope cubes was tested with five other African antelope in the semi-desert Kalahari Gembok National Park. Specimens of Eland (Taurotragus oryx), Gemsbok (Oryx) (Oryx gazella), Blue Wildebeest (Connochaetes taurinus) and Springbok (Antidorcas marsupialis) were shot in their natural habitat and fresh rumen fluid was used as inoculum source, in the in vitro incubations. The results (Fig. 4) indicate that a variation in the rumen microbial population is evident in these species in their natural habitat since various rates of fermentation of the same substrate is exhibited. Results on comparative IVDMD are presently in the process of being analyzed and will be published elsewhere. From these initial results, however, it seems that more emphasis should be put on the inoculum source when interpreting in vitro digestibility values for rations.

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Fig. 1a-c. The *in vitro* fermentation rates as measured by gas production of three natural diet components using 8 different giraffe as inoculum source.

Fig. 2a-e. The VFA production rate and *in vitro* fermentation rate of five substrates with giraffe rumen fluid. Figures for energy value of total VFA produced, IVDMD and CH_4% is given.

Fig. 3. The IVDMD and energy value in joules for total *in vitro* VFA production during a 20 hr. incubation with different substrates using giraffe rumen fluid.

A - *Acacia exuvialis*
B - *A. nigrescens* (leaves)
C - *A. nigrescens* (flowers)
D - *Combretum imberbe*
E - *C. zeyheri*
F - *Terminalia prunioides*
G - *Medicago sativa* (lucern)
H - Antelope cubes

Fig. 4. The *in vitro* fermentation rate of antelope cubes as measured by gas production using rumen fluid as inoculum for six different ruminants.

1 - Eland
2 - Blue Wildebeest
3 - Red Hartebeest
4 - Oryx
5 - Springbuck
6 - Giraffe

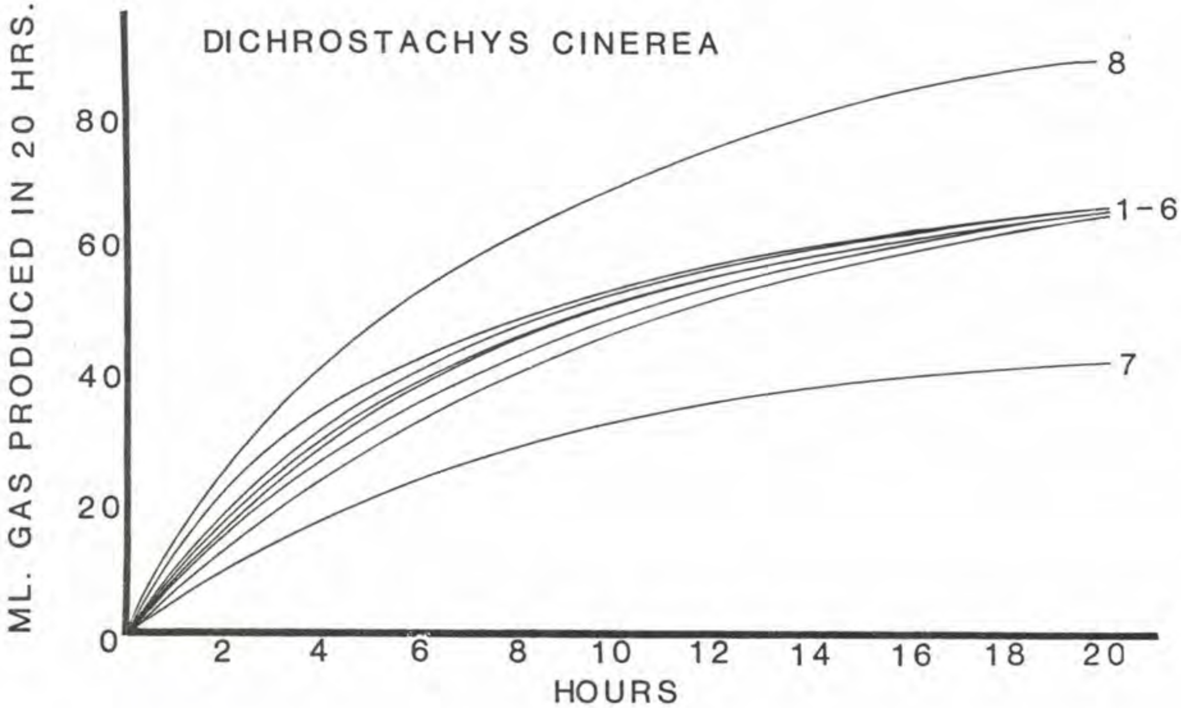

FIGURE 1-A

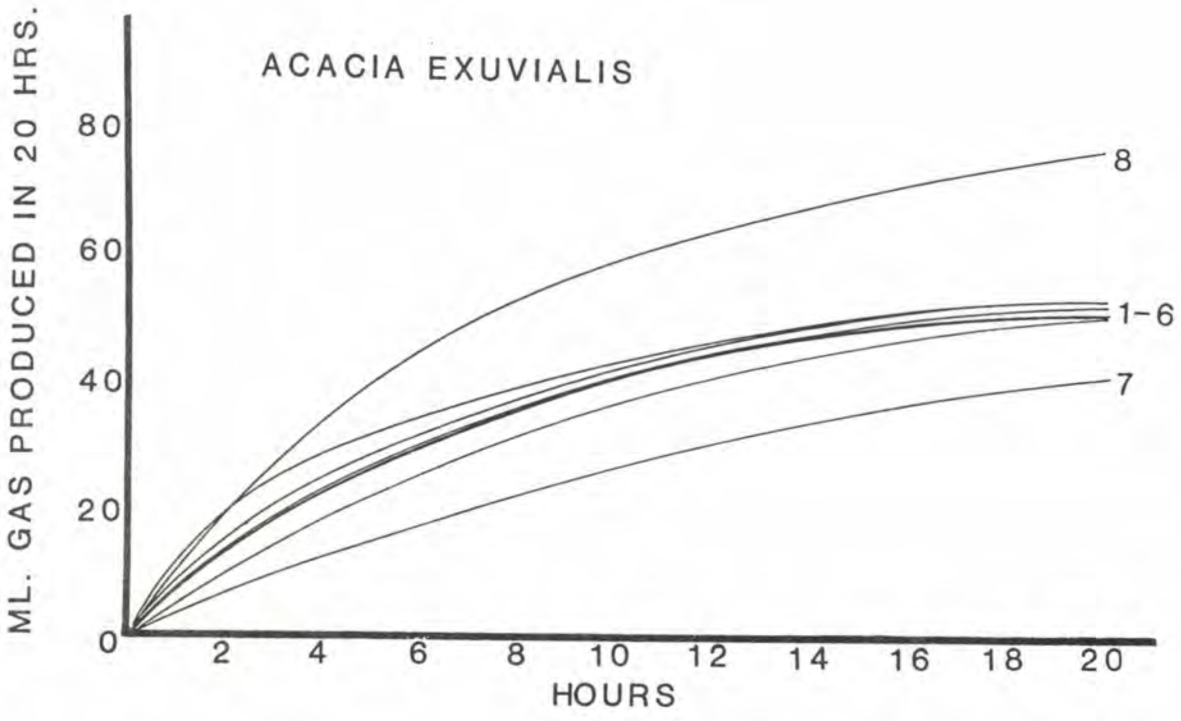

FIGURE 1-B

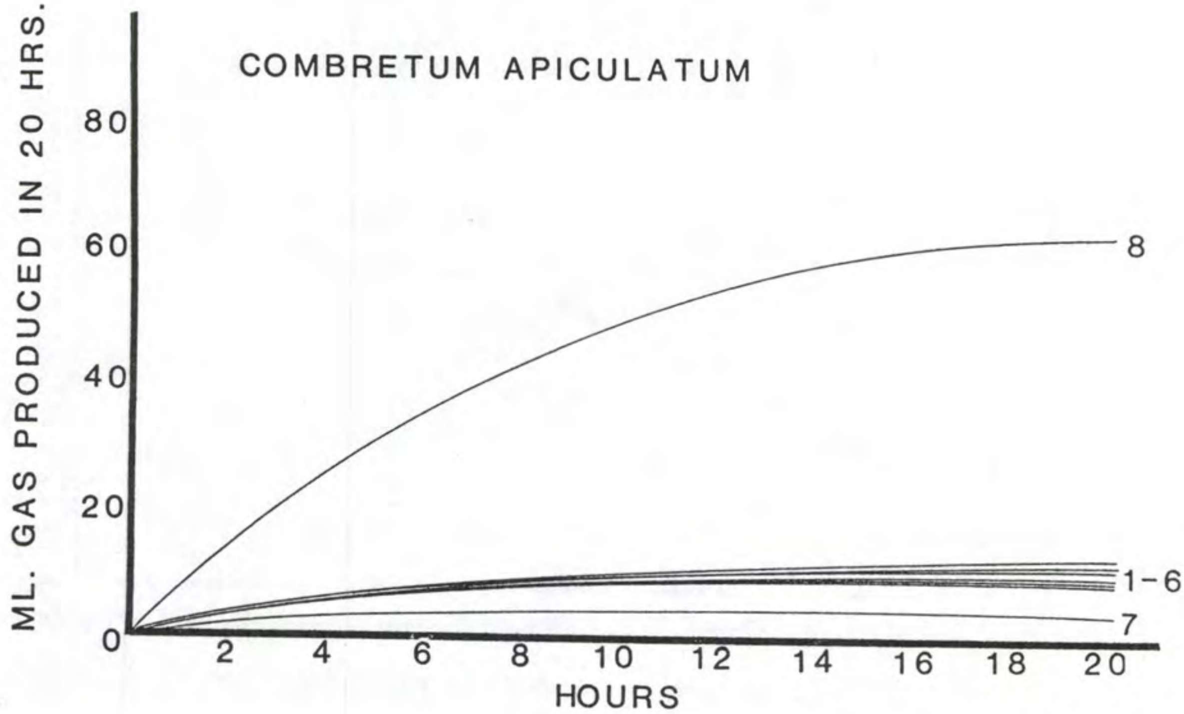
COMBRETUM APICULATUM
ML. GAS PRODUCED IN 20 HRS.
80
60
40
20
0
2
4
6
8
10
12
14
16
18
20
HOURS
8
1-6
7

FIGURE 1-C

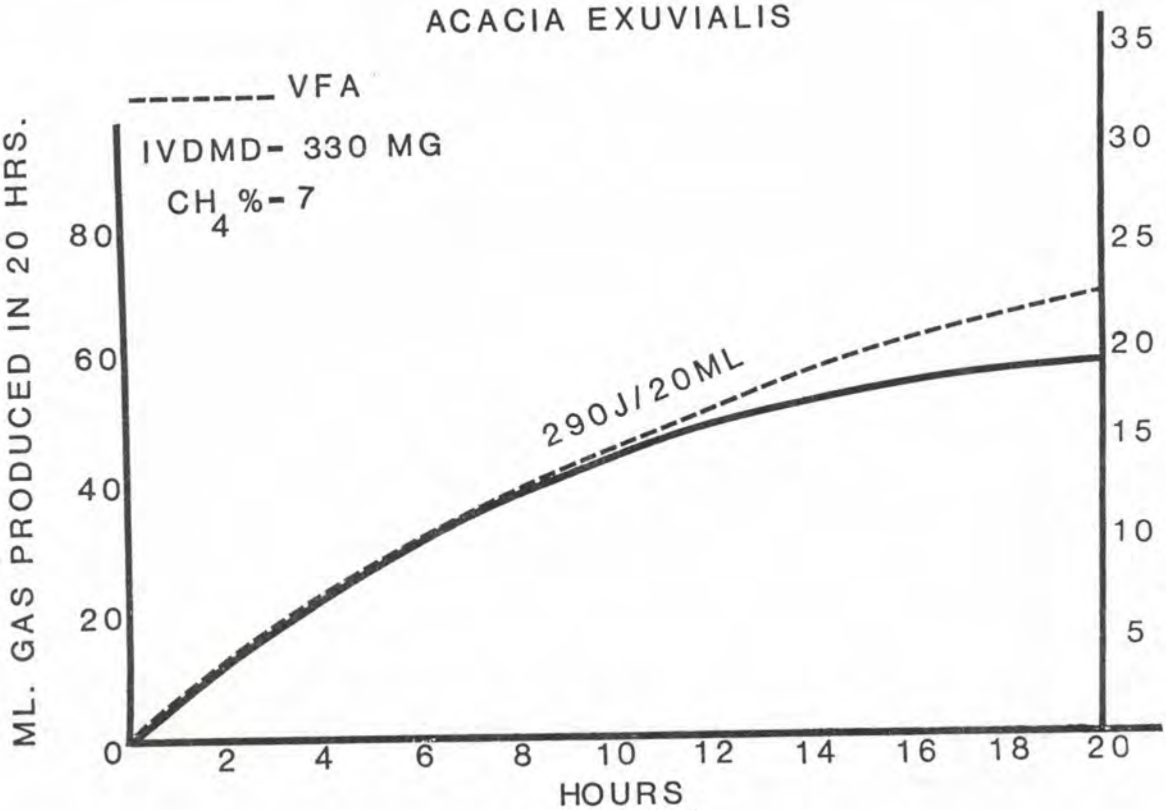

FIGURE 2-A

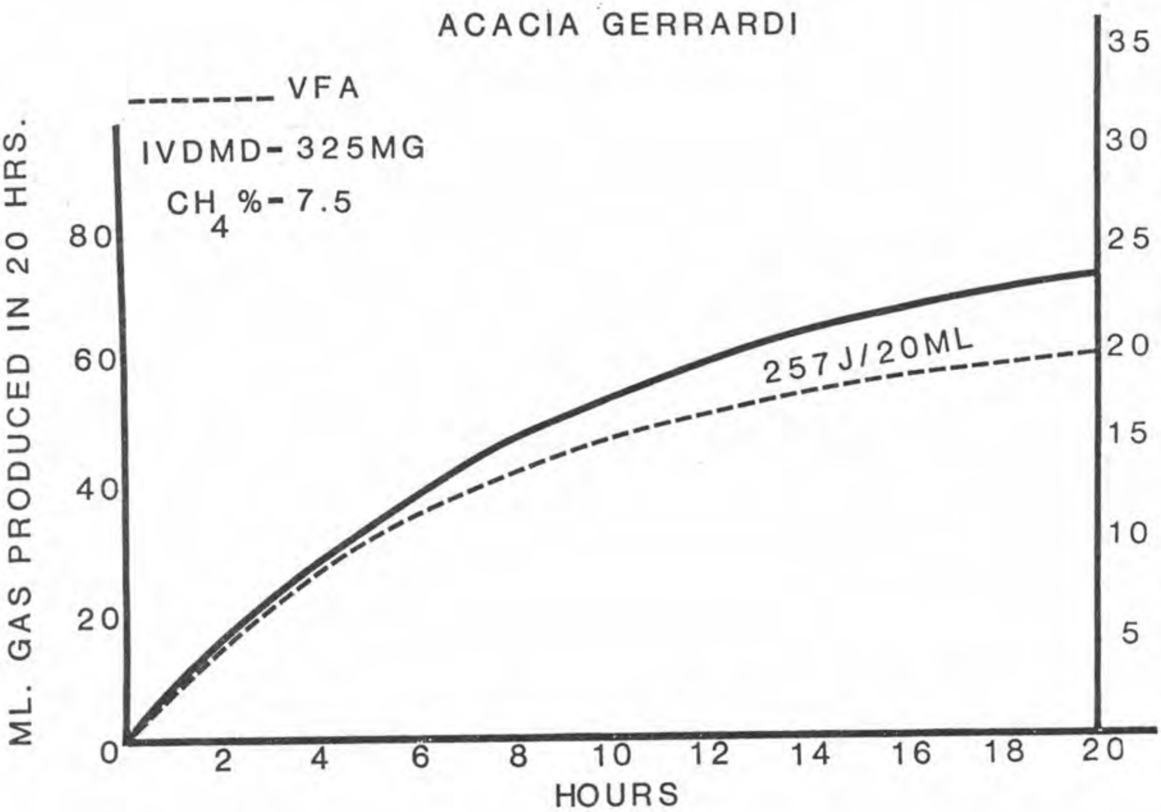

FIGURE 2-B

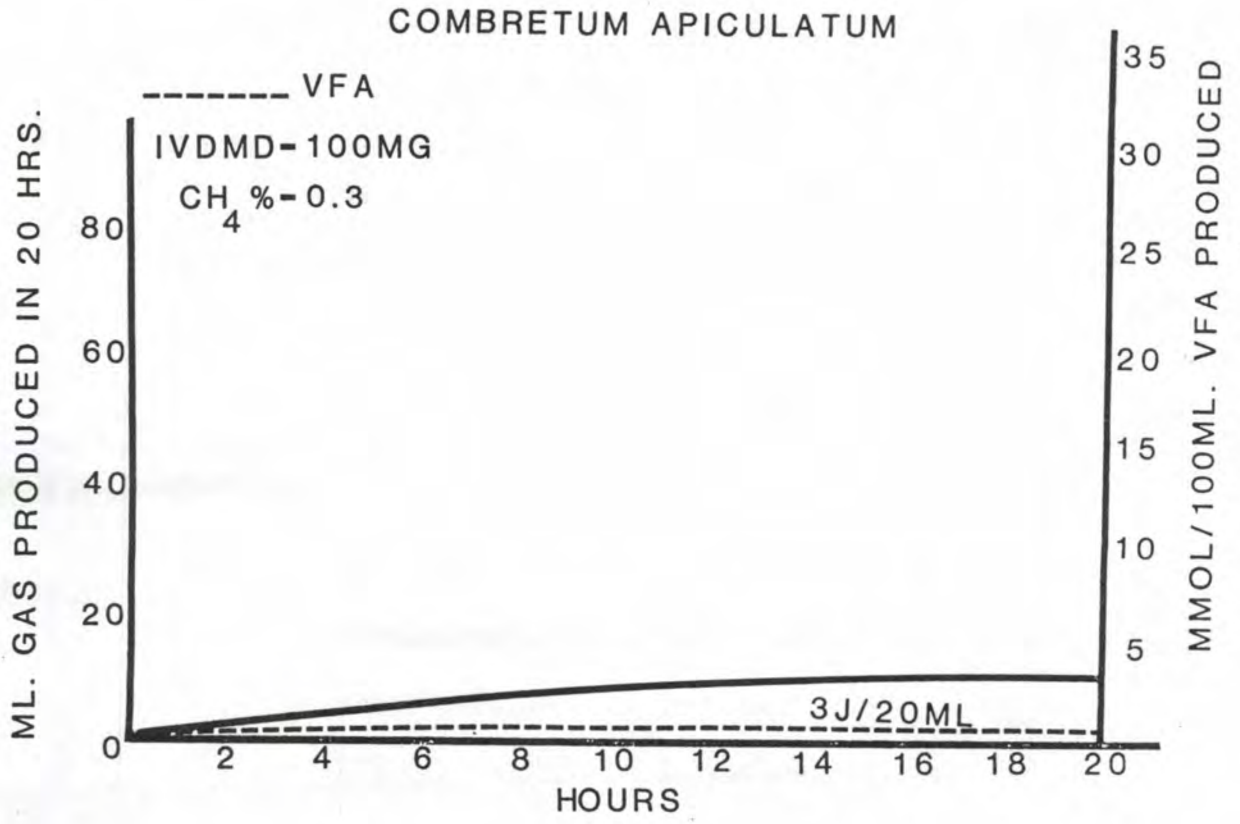

FIGURE 2-C

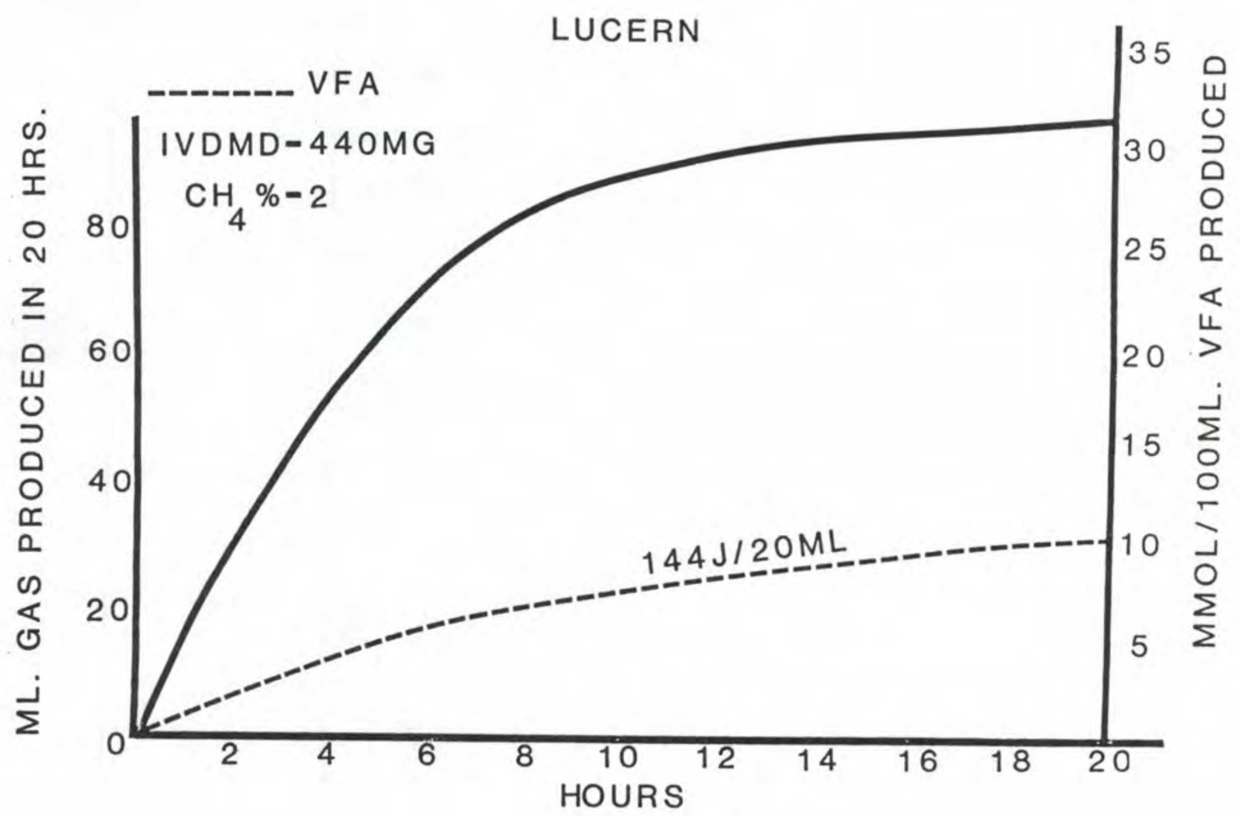

FIGURE 2-D

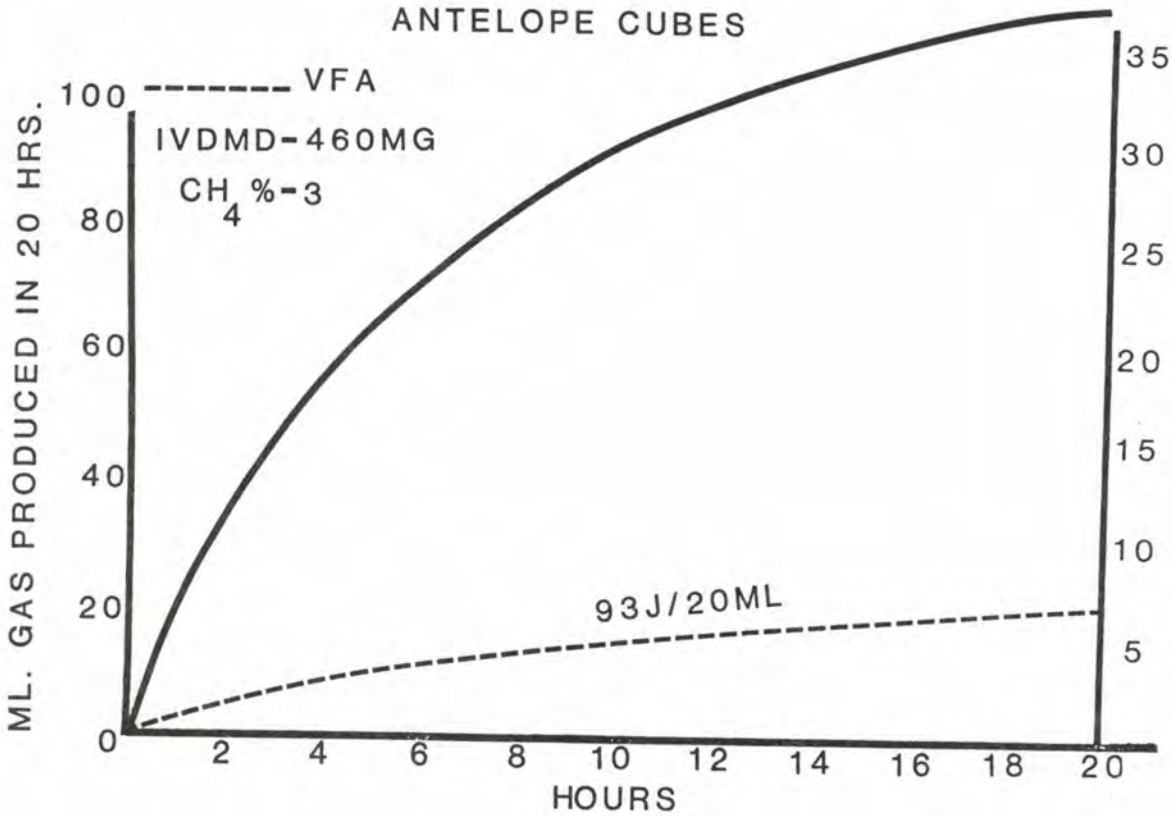
ANTELOPE CUBES
VFA
IVDMD-460MG
CH_4%-3
93J/20ML
ML. GAS PRODUCED IN 20 HRS.
MMOL/100ML. VFA PRODUCED
HOURS
0
20
40
60
80
100
5
10
15
20
25
30
35
2
4
6
8
10
12
14
16
18
20

FIGURE 2-E

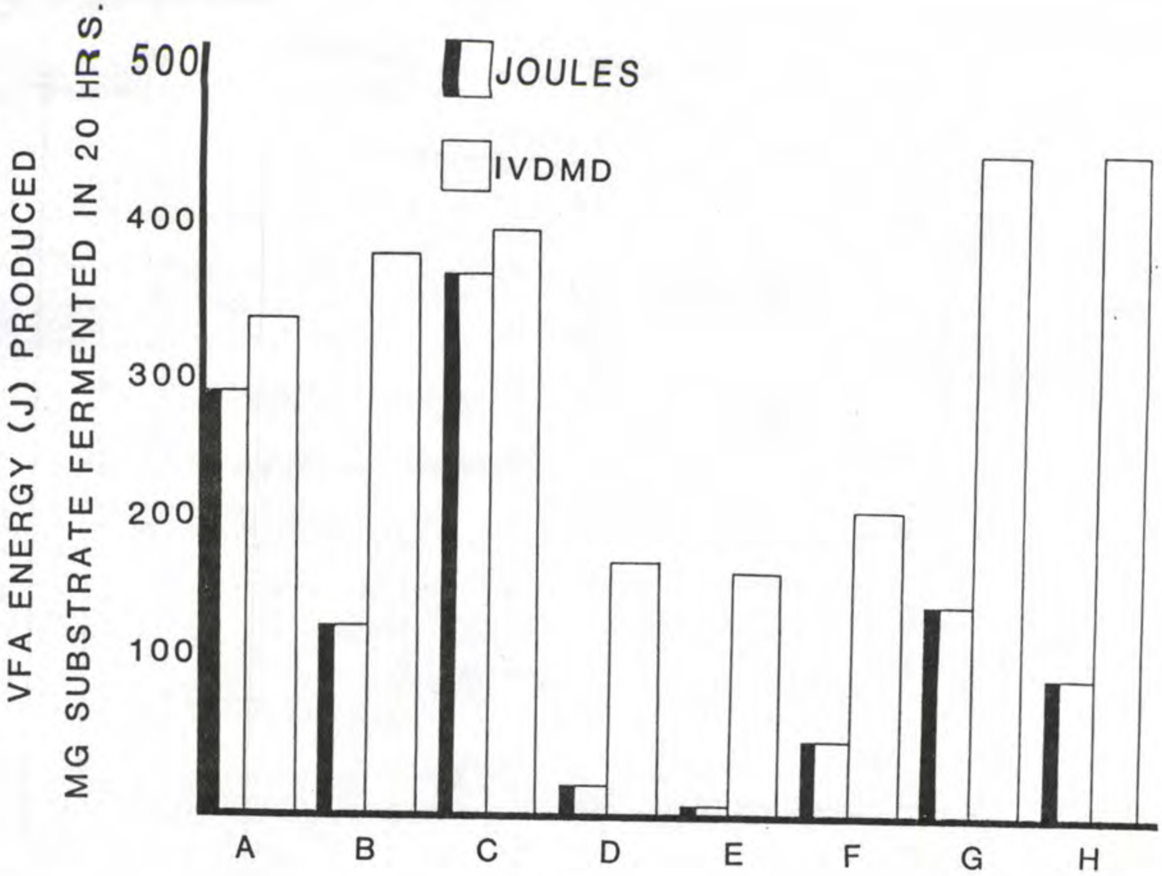

FIGURE 3

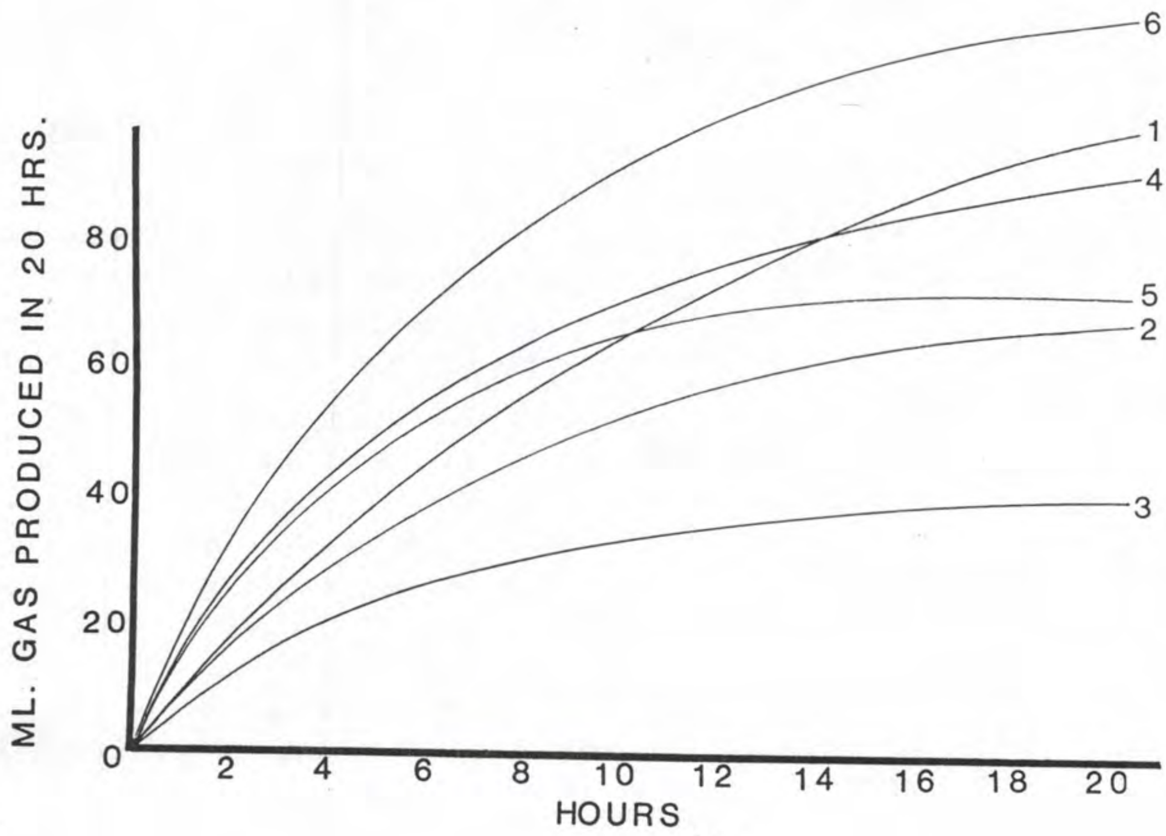

FIGURE 4

HOOFED STOCK PANEL DISCUSSION

OYARZUN: FIRST, I HAVE TO APOLOGIZE BECAUSE THE PAPER I WAS SUPPOSED TO PRESENT UNFORTUNATELY IS NOT READY. I DIDN'T HAVE THE TIME TO PUT ALL OF THE INFORMATION TOGETHER. SO FAR WE HAVE HEARD QUITE A LARGE NUMBER OF SPEAKERS TALKING ABOUT DIFFERENT ASPECTS OF FEEDING ZOO ANIMALS OR WILD ANIMALS. NO ONE HAS MENTIONED ANYTHING REGARDING THE FEEDING PROGRAMS, THE WAY IN WHICH WE SHOULD FEED THE ANIMALS IN THE ZOO. SO FAR WE HAVE ACCOMPLISHED QUITE A LOT BY HAVING PELLETED FEEDS, COMMERCIALLY PREPARED, WHICH SUPPLY ALL THE NEEDS OF THE ANIMAL, OR AT LEAST WHAT WE FEEL ARE THE NUTRIENT REQUIREMENTS OF THE ANIMALS. BUT, IT ALSO IS IMPORTANT WHEN YOU ARE DEALING WITH CERTAIN SPECIES OR ANIMALS TO CONSIDER SOME OTHER ASPECTS IN THE FEEDING PROGRAM. A GOOD EXAMPLE IS THOSE SPECIES LIKE THE NORTHERN HEMISPHERE CERVIDS, WHITE TAILED DEER, BLACK TAILED DEER, MOOSE, REINDEER, CARIBOU, ETC., ALONG WITH SOME OF THE WILD GOATS AND SHEEP, LIKE THE DALL SHEEP. THESE ANIMALS FOLLOW A COMPLETELY DIFFERENT PATTERN WITH REGARD TO FOOD INTAKE AS COMPARED TO THE DOMESTIC RUMINANTS, SUCH AS CATTLE OR SHEEP. THEY FOLLOW A SEASONAL CYCLE REGARDING METABOLIC RATE WITH A REDUCTION IN METABOLIC RATE DURING THE SUMMER TIME. APPARENTLY, THERE ARE QUITE A LARGE NUMBER OF PAPERS PUBLISHED IN DIFFERENT JOURNALS WHICH DEAL WITH THIS SUBJECT. DR. ULLREY IS ONE OF THE AUTHORITIES ON THIS SUBJECT AND WILL BE ABLE TO DISCUSS IT FULLY DURING THE PANEL.

IN 1974, AT THE METRO TORONTO ZOO, THIS GROUP OF WHITE TAILED DEER WAS FED A DIET CONSITING MAINLY OF PRODUCE. I WOULD SAY ABOUT 40% OF THE DAILY RATION OF THESE ANIMALS CONSISTED OF SLICED CARROTS AND APPLES. THESE ANIMALS ALSO HAD FREE ACCESS TO ALFALFA HAY, BUT APPARENTLY THE DEER AREN'T HAY EATERS. CONSUMPTION OF HAY IS VERY LOW ACCORDING TO OUR DAILY RECORDS, WHICH WE HAVE MAINTAINED SINCE THAT TIME. THE OTHER FACTOR INVOLVED RESULTING IN SUCH A POOR BODY CONDITION OF THESE ANIMALS WAS THE VERY STRONG FEELING AMONG ZOO STAFF, ESPECIALLY SENIOR ZOO STAFF, THAT ANIMALS IN A ZOO SHOULD BE DISPLAYED FOR THE PUBLIC IN A RATHER LEAN BODY CONDITION THROUGHOUT THE YEAR. UNFORTUNATELY, YOU CAN'T DO THIS WITH THIS TYPE OF ANIMAL. THESE ANIMALS REACT DIFFERENTLY THAN CATTLE OR SOME OF THE OTHER RUMINANT ANIMALS, SUCH AS AFRICAN ANTELOPES. DUE TO THESE SPECIAL ADAPTATIONS THROUGH THEIR NATURAL EVOLUTION I GUESS, THEY RESTRICT THEIR METABOLIC RATE DURING THE WINTER TIME. NOT ONLY DO THEY RESTRICT METABOLIC RATE, BUT ALSO THEY REDUCE THEIR FEED INTAKE. SO, NO MATTER HOW MUCH FOOD YOU OFFER THEM DURING THE WINTER TIME THEY JUST DON'T EAT. THEY ALSO REDUCE ACTIVITY IN ORDER TO CONSERVE ENERGY. THAT'S THE BASIC POINT OF THIS BEHAVIOR, THE ADAPTATION OF THESE ANIMALS IN ORDER TO CONSERVE ENERGY.

THE SLIDES I HAVE SHOW THE RESULTS OF THE POOR FEEDING PROGRAM THAT WE HAD AT THE METRO TORONTO ZOO, BACK IN 1974. THIS WAS PRIMARILY DUE TO THE FEEDING OF PRODUCE AND THE DECISION TO SHOW ANIMALS IN A LEAN BODY CONDITION. THE PICTURES WERE TAKEN IN JUNE, 1974. MOST OF THESE ARE LACTATING FEMALES, AND YOU CAN SEE THE VERY POOR BODY CONDITION. MOST OF THE ANIMALS ARE WALKING SKELETONS; NO FLESH AT ALL.

SINCE THAT TIME WE STARTED TRYING TO CONVINCE ZOO STAFF THAT WITH THESE ANIMALS WE HAVE TO DEVELOP A DIFFERENT FEEDING APPROACH OR FEEDING SYSTEM. THESE ANIMALS CAN NOT BE FED ON A RESTRICTED BASIS. I FORGOT TO MENTION THAT OTHER THAN THE PRODUCE AND THE HAY THESE ANIMALS WERE RESTRICTED TO A LIMIT OF 600 GMS/PER ANIMAL PER DAY OF THE PELLETED RATION. A LEVEL THAT WAS ABSOLUTELY INSUFFICIENT TO PROVIDE THE ENERGY THAT THEY NEED IN THE SUMMER TIME IN ORDER TO ACCUMULATE BODY FAT WHICH THEY CATABOLIZE AND USE AS AN ENERGY SOURCE DURING THE WINTER TIME WHEN METABOLIC RATE GOES DOWN AND WHEN FEED INTAKE GOES DOWN. SINCE THEN WE HAVE BEEN KEEPING RECORDS OF THE FEED INTAKE OF SEVERAL SPECIES. WE HAVE ABOUT 4 YEARS RECORDS OF MOOSE, A GROUP OF DALL SHEEP, A GROUP OF BLACK TAILED DEER, WHITE TAILED DEER, ETC. ALL THESE ANIMALS FOLLOW THE SAME PATTERN. SEVERE HEAVY LOSSES OF BODY WEIGHT IN THE WINTER TIME LEADING TO BODY FAT DEPLETION, WITH A SEVERE LOSS OF BODY WEIGHT AT THAT TIME IN ORDER TO GET THEIR ENERGY. THEY CATABOLIZE THEIR BODY FAT DURING THE WINTER TIME TO GET THE ENERGY. THE DATA ALSO INDICATED THAT ALL THESE SPECIES

SHOWED THIS VERY MARKED SEASONAL PATTERN OF FEED INTAKE.

SO SINCE THAT TIME I WAS ABLE TO CONVINCE ZOO STAFF THAT WE SHOULD CHANGE OUR FEEDING APPROACH TO FEEDING THE PELLETED FEED ON AN AD LIBITUM BASIS. AFTER WE DID THIS WE SOLVED ALL THE PROBLEMS WITH THE DROP OFF OF WEIGHTS.

Q: IS YOUR MOOSE DIET A PELLETED FEED?

OYARZUN: YES, WE ARE FEEDING THE MOOSE FOR THE LAST THREE YEARS A CUBE DIET. WITH A RUMINANT RATION, 16% PROTEIN, 16% FIBER. WE ALSO FEED MOLASSES PELLETED BEET PULP AND ALFALFA HAY ON A FREE CHOICE BASIS. THESE ANIMALS ALSO RECEIVE HYDROPONICALLY GROWN BARLEY GRASS AS A TREAT. THAT'S THE BASIC DIET FOR THE MOOSE. THESE ANIMALS DON'T RECEIVE ANY BROWSE, THEY HAVEN'T SEEN ANY BROWSE FOR THE LAST 4 YEARS. THEY ARE KEPT IN VERY REASONABLE BODY CONDITION. WE DON'T HAVE ANY MAJOR PROBLEMS WITH THEM. IN FACT, 2 OF THE ORIGINAL ANIMALS HAVE PRODUCED A CALF, IN 1979, WHICH IS STILL IN THE COLLECTION. ON TOP OF THOSE FEEDS WE ALSO OFFER THE TRADITIONAL TRACE MINERALIZED SALT BLOCKS ON AN AB LIBITUM BASIS. WE ALSO USE A CALCIUM-MINERAL SUPPLEMENT POWDER, WHICH PROVIDES ABOUT 14% CALCIUM, 14% PHOSPHORUS, PLUS SOME TRACE MINERALS PLUS VITAMINS A & D.

Q: WHAT ARE YOUR THOUGHTS ON THE DIETS THEY'VE DONE RESEARCH ON IN ALASKA, ON THE ASPEN SAW DUST DIET?

OYARZUN: I HAVE ONLY BEEN FAMILIAR WITH THAT DIET FOR ABOUT A WEEK NOW. I DID NOTICE HOWEVER THAT THE COST OF THAT DIET IS ABOUT $260/PER TON. YOU CAN COMPARE THAT COST WITH OUR COST WHICH IS $258/PER TON OF FEED WITH MORE EXPENSIVE INGREDIENTS. I WOULD THINK THE COST OF SAWDUST IS JUST TO GO AND PICK IT UP. I DON'T KNOW TO WHAT EXTENT IT IS WISE TO USE IT SINCE SO FAR WE HAVE HAD VERY GOOD RESULTS WITH OUR DIET. I WOULDN'T CONSIDER INCLUDING SAW DUST IN A DIET FOR MOOSE AT THIS POINT.

OFTEDAL: I WAS TALKING WITH BOB WHITE FROM ALASKA AND HE SAID HE WAS NOT TOTALLY HAPPY WITH THAT DIET, AND THEY ARE STILL MAKING MODIFICATIONS AT THIS TIME.

OYARZUN: APPARENTLY THE GROWTH RATE OF THE ANIMALS THEY HAVE TRIED THE DIET WITH HAS BEEN REASONABLE.

Q: DR. VAN HOVEN, WHAT DID YOU DO TO CORRECT THE GIRAFFE DIET IN THE JOHANNESBURG ZOO?

VAN HOVEN: WE ADDED MORE ROUGHAGE TO THE DIET. WE'VE BEEN ADDING ON A REGULAR BASIS NATURAL LEAVES FROM TREES THAT WERE CUT FRESH. THIS SEEMS TO HAVE INCREASED THE RETENTION TIME OF THE FEEDS AND THAT SEEMS TO HAVE SOLVED THE PROBLEM. THERE HAVEN'T BEEN ANY MORE MORTALITIES AND THEY SEEM TO BE IN PRETTY GOOD SHAPE. IN FACT, I MUST ADD THAT THE RESULTS THAT I SHOWED YOU WERE VERY PRELIMINARY AND WE'RE STILL GOING TO CONTINUE WITH THIS NEXT YEAR. FOUR MONTHS AFTER WE CHANGED THE DIET WE DISCOVERED THAT THE LOWER LINE HAS BEEN ELEVATED SUBSTANTIALLY SO THE MICROBIAL POPULATION HAS BETTERED ALMOST A 100%.

Q: DR. VAN HOVEN, YOU WERE SHOWING THE DEVIANT LINES OF THE WINTER ANIMALS ON THESE DIFFERENT TYPES OF MATERIALS IN YOUR IN VITRO DIGESTION STUDIES. WERE THE BROWSE MATERIALS COLLECTED AT THE SAME TIME AS YOUR INOCULATE MATERIALS? IN OTHER WORDS WERE YOU LOOKING AT DIFFERENCES IN THE COMPOSITION OF THE MATERIAL YOU WERE DIGESTING AS WELL AS DIFFERENCES IN THE INOCULATE INVOLVED?

VAN HOVEN: THE COLLECTIONS WERE BASED ON VISUAL OBSERVATIONS OF THE FEEDS SELECTED BY THE ANIMALS. WE TRIED TO IMITATE THE PART OF THE PLANTS AND ALSO THE HEIGHTS AT WHICH THE ANIMALS SELECTED. THE PLANTS WERE COLLECTED ABOUT 3 WEEKS PRIOR TO THE EXPERIMENTS BEING DONE. THREE WEEKS TO DRY IT OUT AND PREPARE IT TO MAKE IT READY FOR THE IN VITRO WORK.

Q: SO THE WINTER SAMPLES THAT YOU SHOWED WERE COLLECTED IN THE WINTER AND THE SUMMER SUBSTRATE IN THE SUMMER?

VAN HOVEN: THAT DID NOT APPLY FOR THE SUMMER ONE. FOR A COMPARATIVE, WE USED THE SAME SUBSTRATE COLLECTED IN THE WINTER TIME TO COMPARE THE EFFICIENCY OF DIGESTION OF THE SAME SUBSTRATE BY RUMEN FLUID FROM THE GIRAFFE IN THE SUMMER.

Q: DR. VAN HOVEN, I AM INTERESTED IN THE METHANE PRODUCTION FOR THE ELEPHANT. IS THERE OTHER INDIVIDUAL VARIATION IN THE COMPOSITION OF THE GAS THAT WAS FOUND IN THE GUT OF ANIMALS ON DIFFERING DIETS?

VAN HOVEN: WE DID FIND INDIVIDUAL VARIATIONS. AS I POINTED OUT WE HAD ONE THAT WAS UP TO 80%. NOW THAT WAS MUCH HIGHER THAN AVERAGE. SO WE FOUND SUBSTANTIAL VARIATION, THERE WAS A STANDARD ERROR OF PLUS OR MINUS 20 IN THAT METHANE PRODUCTION SPECIFICALLY. THEY WERE DONE IN VARIOUS AREAS SO THERE WAS A DEGREE OF DIFFERENCE IN THE DIET ALTHOUGH IT'S NOT MUCH. THE AREAS CHANGED ABOUT 200-300 MILES. THERE IS PROBABLY ALSO VARIATION DUE TO AGE.

Q: THE PROTEIN COMPOSITON OF THE GIRAFFE DIET IN THE WILD, I UNDERSTAND VARIED QUITE A BIT IN SUMMER AND WINTER. FROM VERY LOW PROTEIN COMPOSITION DIET TO VERY HIGH PROTEIN COMPOSITION DIET, DID YOU SEE THE SAME EXTREMES IN OTHER UNGULATES THAT YOU WORKED WITH?

VAN HOVEN: YES, THAT IS INDEED THE CASE. SUMMER DIETS, FROM AUGUST TOWARD APRIL, THERE IS A PERIOD WHERE HIGHER PROTEIN IS BEING TAKEN IN THAN IN THE WINTER TIME. BUT, ONE DOES FIND THAT THE ANIMALS VARY THEIR DIET SELECTION PATTERN. SO, TO JUST LOOK AT THE PLANT'S PROTEIN COMPOSITION DOESN'T ALWAYS GIVE YOU THE RIGHT PICTURE. WE'VE FOUND THAT THE ANIMALS ARE QUITE CLEVER IN THAT THEY TRY TO MAINTAIN THE SAME PROTEIN INTAKE LEVEL. THEY CHANGE THEIR DIET SELECTION PATTERN IN ORDER TO TRY AND GET THE MAXIMUM EVEN IN WINTER TIME OUT OF WHEAT IF AVAILABLE.

BROWN: I SHOULD MENTION WE FOUND THE SAME THING IN SOUTH TEXAS, WE'VE DONE SIMILIAR STUDIES WITH THE DEER, CATTLE, GOATS, HAVELINA AND NILGIA. THE ANIMALS VARY IN THEIR ABILITY TO SHIFT AND THEIR REPRODUCTIVE SUCCESS AND PRODUCTIVITY SEEMS TO VARY WITH THAT ABILITY. WE'VE ONLY DONE THE ANALYSIS OF THE DEER DIETS. WE FIND THAT THEY'RE ABLE TO STAY ABOVE MAINTENANCE (AROUND 7%) DURING OUR SUMMER MONTHS, OUR ROUGHEST MONTHS, BUT BELOW AN OPTIMUM (14%) FOR REPRODUCTION. THEY'LL GO DOWN AROUND TEN TO 12% PROTEIN DURING AUGUST AND SEPTEMBER. THE TEXAS PARKS AND WILDLIFE DEPARTMENT HAS DONE SOME STUDIES BETWEEN SIKA DEER AND WHITE TAILS, AND FOUND THAT SIKA DEER ARE FAR MORE PROLIFIC THAN THE WHITE TAILS AND THEY ATTRIBUTE THAT TO THE SIKA'S ABILITY TO SHIFT TO GRAZING DURING PERIODS OF DROUGHT. THE WHITE TAILS, ON THE OTHER HAND, WERE NOT AS ADAPTABLE. SO, WHEN YOU GET INTO TOUGH TIMES THE WHITE TAILS WOULD JUST DIE OUT AND STARVE, WHEREAS THE SIKA DEER WOULD SURVIVE.

Q: GOING BACK TO THE PROTEIN INTAKES OF THE GIRAFFE, DR. VAN HOVEN, DO YOU HAVE A MEASURE OF THE PROTEIN ON A DRY MATTER BASIS OF THE BROWSE THAT WAS CONSUMED?

VAN HOVEN: THE SUMMER BROWSE IS ABOUT 13 TO 14% PROTEIN, BUT THE WINTER BROWSE GOES DOWN TO ABOUT 7%. I'D LIKE TO ADD SOMETHING ABOUT THE PROTEIN LEVEL IN THE BROWSE. DURING MY STAY AT THE COLORADO DIVISION OF WILDLIFE OVER THE PAST FEW MONTHS, WE HAVE BEEN LOOKING INTO THE NUTRITION AND DIGESTION IN MULE DEER, AND WE'VE FOUND SOMETHING THAT IS VERY APPLICABLE ON THE BROWSE SITUATION IN SOUTH AFRICA. WE'VE GOT THE GREATER KUDU, WHICH IS PROBABLY FAMILIAR TO YOU, WHICH IS A STRAIGHT BROWSER. LATELY WE'RE ENTERING A DROUGHT CYCLE AGAIN. OVER THE PAST 3 YEARS THE MORTALITY OF THESE FREE RANGING KUDU IN THE WINTER TIME HAS GONE UP QUITE A BIT. IF YOU GO AND ANALYZE THE PROTEIN CONTENT OF THE BROWSE, WHICH THEY DO TAKE AND WHAT IS AVAILABLE, YOU FIND THAT THEY SHOULD NOT DIE OF MALNUTRITION. SOMETHING WHICH WE HAVE NOT TAKEN INTO CONSIDERATION IS THE PRESENCE OF PHENOLS IN THE BROWSE, PARTICULARLY THE CONCENTRATED TANNINS IN THE BROWSE, ON THE EFFICIENCY OF BROWSE BEING A FOOD FOR THESE ANIMALS, WE SHOULD GET SOME INTERESTING RESULTS. ONE OF THE THINGS THAT IS BEING DONE AT THE LABORATORY AT CORNELL IS THAT THEY ARE LOOKING AT THE CONCENTRATION OF THESE TANNINS IN THE BROWSE. WHAT THESE TANNINS ACTUALLY DO IS FORM A COMPLEX WITH THE PROTEIN

AS SOON AS THEY GET INTO THE RUMEN. SO YOU MIGHT THINK YOU'VE GOT GOOD PROTEIN QUALITY IN YOUR PLANT AND DISREGARD THE PRESENCE OF THE CONDENSED TANNINS. THE CONDENSED TANNINS FORM A COMPLEX WITH THE PROTEIN MOLECULE AND THE RESULT IS THE PROTEIN IS NOT ABSORBED. YOU LOOK AT YOUR FECES AND YOU THINK THAT THERE IS A HIGH NITROGEN IN THERE, SO YOU THINK THAT THE ANIMAL HAS AN APPARENT LOW PROTEIN DIGESTIBILITY. MEANWHILE, IT'S THE COMPLEX THAT ISN'T ABSORBED. SO I THINK THE TREND IN THE FUTURE IS TO GIVE QUITE A BIT MORE ATTENTION TO THE PRESENCE OF PHENOLICS IN PLANTS AND THEIR AFFECT ON PROTEIN DIGESTIBILITY. THIS MIGHT BE OUR PROBLEM WITH KUDUS IN SOUTH AFRICA TOO.

Q: DO YOU HAVE ANY DATA ON THE LIGNIN VALUES IN THE BROWSE THAT YOU ARE USING? AND, ALSO IF THERE IS A PROBLEM WITH MORTALITY WITH IMMOBILIZATION OF THE WILD ANIMALS?

VAN HOVEN: LIGNIN VALUES ARE FAIRLY HIGH IN A LOT OF THESE BROWSES, ESPECIALLY IN WINTER. I DON'T REMEMBER THE EXACT FIGURES RIGHT OFF OF MY HEAD. AS FOR MORTALITY IN THE IMMOBILIZATION, WE GET VERY SELDOM MORTALITIES IN THE GAME. WE USE VARIOUS TYPES OF DRUGS. WE WOULDN'T USE FOR EXAMPLE SOME OF THE DRUGS WHICH AFFECT THE HEAT CYCLE ON SOME OF THESE ANIMALS THAT ARE SHADE LOVING. IF YOU TAKE ALL THESE THINGS INTO ACCOUNT AND THE GUIDELINES IN THE USE OF THE DRUGS, THEN YOU GET VERY LITTLE PROBLEMS WITH DEATH DURING IMMOBILIZATION.

Q: WHAT DRUGS WERE YOU USING TO DESTROY THE ELEPHANT?

VAN HOVEN: SUCCINYL CHOLINE CHLORIDE

Q: I'M INTERESTED IN THE BLIND SACS YOU DISCUSSED IN THE HIPPOPOTAMUS, WHAT ADVANTAGE IS THERE IN THIS?

VAN HOVEN: THIS ANATOMY WORK WAS DONE BY DR. PETER LANGUER FROM THE ANATOMY INSTITUTE IN GERMANY, AND HE WAS WITH ME AT THE TIME THAT WE DID SOME OF THESE EXPERIMENTS, SO HE DID THE ANATOMICAL WORK. THE ACTUAL FLOW PATTERN WAS FROM HIS DESCRIPTION. THE ADVANTAGE OF GOING INTO THESE BLIND SACS IS THE MICROBIAL POPULATION FOUND IN THEM. THE HIPPOPOTAMUS DOES NOT CHEW HIS FOOD AND THERE IS NO REGURGITATION LIKE THE RUMINANT. ONCE IT'S IN IT'S IN. SO, IT IS SPECULATED THAT THE MICROBIAL POPULATION IN THE BLIND SACS ATTACK THE CELLULAR WALLS AND THAT THIS IS A MEANS BY WHICH THE CELLULAR CONTENT IS LIBERATED. THEREFORE, YOU GET MORE LIBERATED CELLULAR CONTENT IN THE CONNECTING CHAMBERS AFTER IT HAS BEEN LIBERATED IN THE 3 BLIND SACS WHICH TEND TO HAVE A LONGER RETENTION, THEREBY GIVING THE CELLULYTIC BACTERIA TIME TO FERMENT THE CELLULAR WALLS. THIS ACCOUNTS FOR THE HIGHER FERMENTATION AND VFA VALUES IN THE CONNECTING CHAMBERS FOLLOWING THE BLIND SACS.

OFTEDAL: I'D LIKE TO MAKE A COMMENT TO SERGIO THAT THEY'RE DOING SOME WORK AT THE RESEARCH INSTITUTE IN SCOTLAND ON SUIS SHEEP, WHICH ARE SHEEP FROM THE SUIS ISLANDS WHICH HAVE BEEN LIVING IN A FERAL STATE FOR ABOUT A THOUSAND YEARS. THOSE ANIMALS SHOW A VERY MARKED SEASONALITY IN THEIR INTAKE AND BODY CONDITION, JUST AS IN THE WHITE TAILED DEER. SO, PROBABLY PART OF THE DIFFERENCE BETWEEN DOMESTIC BOVIDES AND NORTH TEMPERATE CERVIDS ARE SEASONAL ADAPTATIONS.

BROWN: I'D LIKE TO COMMENT ON DEER PELLETED RATION. I'VE FOUND THE TRICK IS TO GET A HIGH ENERGY, MEDIUM PROTEIN, BUT HIGH FIBER. THE TRICK IS THE FIBER. VERY OFTEN THESE THINGS WILL BE VERY HIGH IN PROTEIN. THEY TEND TO GIVE YOU MORE PROTEIN THAN YOU REALLY WANT BECAUSE IT LOOKS GOOD, BUT THEY TEND TO BE VERY LOW IN FIBER. SO, YOU HAVE TO BE CAUTIOUS ABOUT THAT.

Q: EVEN THOUGH WE HAVE ADVANTAGES WITH PELLETED DIETS, WITH HOOF STOCK, IN REGARDS TO WEIGHT AND SIZE, IS THERE NOT A PROBLEM WITH HOOF OVERGROWTH AND CALVING PROBLEMS?

BROWN: WE HAVE A PROBLEM WITH OUR DEER BUT ONLY WHEN THEY'RE IN SMALL ENCLOSURES. I THINK IF YOU KEEP YOUR FIBER HIGH ENOUGH YOU'RE NOT GOING TO HAVE AN OVER CONSUMPTION PROBLEM.

ULLREY: I DON'T THINK THAT THERE IS ANY QUESTION THAT THOSE HOOVES DO GROW FAIRLY WELL IF YOU HAVE A HIGH PROTEIN LEVEL YEAR ROUND. JIM SIKARSKIE SUGGESTS THAT IN NATURE WHERE YOU DO A SEASONAL CHANGE IN LIQUID INTAKE IN A WAY THAT MAY RESTRICT PROBLEMS LIKE THAT. IT'S OBVIOUS THAT WHEN YOU HAVE A DEER IN A ZOO SETTING THEY DON'T HAVE QUITE THE OPPORTUNITY TO WEAR THOSE HOOVES OFF. AS FAR AS DYSTOCIA ARE CONCERNED THERE DO SEEM TO BE SOME SPECIES THAT ARE KEPT IN CAPTIVITY WHICH DO HAVE A GREATER TENDENCY TO BECOME FAT ON A PELLETED RATION AS COMPARED TO SAY WHITE TAILS WHICH ARE YOUR HARDER KEEPERS. IN CONTRAST TO THE POSITION THAT AT LEAST ONE PERSON HAS TAKEN, I DON'T BELIEVE HOOF OVERGROWTH IS A SIGN OF PROTEIN TOXICITY OR PROTEIN POISONING. SEEMS TO ME THAT HOOF GROWTH IS RESTRICTED BY THE SUPPORT OF THE HOOF, WHICH IS USUALLY GENETICALLY DETERMINED. IF THE FOOT IS COLD IN THE WINTER TIME THERE MIGHT BE LOWER LEVELS OF METABOLIC ACTIVITY AT THE SIGHT OF HOOF GENERATION AND ANIMALS THAT ARE PROTECTED AND NOT COLD AND GIVEN BETTER PROTECTION THAN IN THE WILD, THEN YOU MIGHT SEE A BIGGER PROBLEM. IT'S AN INTERESTING QUESTION, BUT WE DON'T REALLY HAVE AN ANSWER.

VAN HOVEN: I'D LIKE TO ADD THAT I AGREE VERY MUCH WITH YOU THAT THE WEARING IS PROBABLY THE SINGLE MOST IMPORTANT FACTOR THERE. IF I THINK OF THE SITATUNGA IN THE SWAMPS OF AFRICA, THEY WALK JUST IN THE SWAMPY AREAS AND THEIR HOOVES ARE GROWN OUT QUITE A LONG WAY. THIS MAKES THEM ALMOST UNABLE TO RUN WHEN THEY ARE ON NORMAL DRY LAND AND APPROACHED BY PREDATORS. THE END RESULT IS THAT THEY GET CAUGHT BY PREDATORS VERY EASILY ONCE THEY ARE OUT OF THE SWAMPS. ALTHOUGH THEY ARE SUBJECTED TO THE SAME SEASONAL CHANGES IN INTAKE, THE FACT THAT THEY ARE ALWAYS IN THE SWAMPY AREAS AND DON'T HAVE ANY WEAR ON THEIR HOOVES, THEY GROW OUT SO MUCH WHILE OTHER ANTELOPES ON NORMAL LAND DON'T HAVE THIS PROBLEM. SO, I THINK THE WEAR AND TEAR IS QUITE AN IMPORTANT THING.

REICHARD: I WOULD AGREE WITH THAT, WE'VE HAD CASES WITH HARTMANN'S MOUNTAIN ZEBRAS WHERE IN A ZOO THEY ARE ON A MUCH SOFTER SUBSTRATE. AT SAN DIEGO THERE'S A SIMILAR PROBLEM WHERE THERE'S NOT ENOUGH ROCKY SUBSTRATE TO ABRADE THE HOOF DOWN. WE'VE ALSO SEEN INDIVIDUAL DIFFERENCES WITH ANIMALS WHO'VE BEEN ON THE SAME SUBSTRATE AND SAME DIET. CERTAIN ONES WILL HAVE THE ABNORMAL HOOF GROWTH, SO I THINK THERE ARE PROBABLY SOME GENETIC FACTORS RELATED TO IT.

Q: IF ABRASION IS THE ONLY FACTOR, DR. VAN HOVEN, WOULD YOU NOT EXPECT TO SEE SITATUNGA WITH TERRIBLY OVERGROWN HOOVES IN THE WILD? THERE MUST BE ANOTHER FACTOR, BE IT NUTRITION OR SOMETHING ELSE, THAT SETS A NORMAL LIMIT TO AN ANIMAL IN THE WILD STATE FOR NORMAL DEVELOPMENT. SOMETHING HAPPENS IN THE CAPTIVE SITUATION, BE IT GENETIC, NUTRITION THAT MAKES A DIFFERENCE.

VAN HOVEN: IT IS INDEED AN INTERESTING QUESTION, WHAT MAKES IT STOP GROWING? I'D IMAGINE THERE MUST BE A SIMILAR SITUATION THAT STOPS AN ANIMAL'S HAIR GROWTH AT A CERTAIN TIME OR STAGE. THE SITATUNGA DO GROW OUT QUITE LONG, BEFORE THEY SEEM TO STOP.

PROTEIN AND ENERGY NUTRITION OF GEESE

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INTRODUCTION

The nutrient requirements of chickens and turkeys have been studied exhaustively for many years. Evidence of the extensive research efforts in the nutrition of these birds at any age is listed in lengthy tables of amino acid, vitamin, mineral and energy requirements. Geese have been less fortunate and have received little or no attention from the scientific community with regard to their nutrient requirements. Small research budgets and unprestigious facilities are probably responsible for this lack of interest or indifference among poultry scientists. Even goose producers who would benefit directly from goose nutrition research are skeptical and reluctant to support nutritional research either financially or operationally.

Generally, goose producers practice antiquated management techniques. Market geese are provided initially with a 20% protein ration for two weeks. The geese are gradually weaned from the complete diet and are forced to satisfy their daily nutrient requirements by foraging. Two weeks prior to marketing the geese are "fattened" by adding cracked corn to their grass diet. While some producers believe this is the most economical method to raise geese, geese grow slowly and inefficiently when provided only marginal, high fiber feeds during their most active growth period.

Maximum weight gains may not be the primary objective of the avian zookeeper or zoo veterinarian but a better understanding of goose nutrition and metabolism can take some of the guesswork out of formulating appropriate, well-balanced rations for their charges.

PROTEIN

Protein is probably the single most important factor to consider in formulating rations for growing birds. The protein requirements of six species of birds are shown in Table 1. Geese have the fastest initial growth rate (Milby and Hendersen, 1937) but the lowest protein requirement (National Research Council, 1977) while ironically, the relatively slow-growing pheasant has the highest protein requirement. Roberson and Francis (1963) found that the weight gain of White Chinese goslings increased as the protein level of the diet increased from 16 to 20 and 24%. Allen and Storey (1979) reported that White Embden goslings require at least 20% protein up to four weeks of age. These goslings exhibited greater weight gains with 22% protein (N. K. Allen, unpublished data, 1978), the highest level fed in the study. This indicated that White Embden goslings may require 22% protein or more up to four weeks of age. Further research is needed either to affirm the National Research Council's (NRC) current 22% protein recommendation or to establish an alternative recommendation based on statistically sound, up-to-date data.

METHIONINE

In corn and soybean meal-based diets, methionine is the most limiting (most deficient) amino acid for poultry. Consequently, poultry diets must be supplemented with methionine to assure maximum weight gains. The methionine requirement of the broiler chick to three weeks of age is 0.50% of the diet (Table 1; NRC, 1977). Turkey poults require 0.53% dietary methionine up to four weeks of age (Table 1; NRC, 1977). The methionine requirement of the gosling is unknown.

During the first nine and one-half weeks of life White Embden geese gain ten or more pounds of body weight. They concurrently develop their first complete set of feathers, which contain high levels of methionine and cystine. Therefore, like chicks and poults, the methionine requirement of goslings is probably not met by a corn and soybean meal diet.

In two experiments conducted at the University of Minnesota 208 White Embden goslings were used to determine the effect of methionine supplementation of corn and soybean meal diets on weight gain and feather growth. The starter (0 - 28 days of age) and grower (28 - 66 days of age) diets are presented in Table 2.

DL-methionine was added at 0, .08, .16 and .24% of the starter diet during the first experiment and at 0, .04, .08, and .16% of the starter diet during the second. The grower diets were supplemented with 0 or .08% methionine during both experiments. With no supplemental methionine the basal starter diet contained 0.29% methionine and the basal grower diet contained 0.24% methionine. Male and female geese were kept separately at all times. One of each methionine-supplemented diets was fed *ad libitum* to one pen of male and one pen of female geese between 0 and 28 days of age. Between 28 and 66 days of age two pens of male and two pens of female geese were fed either the 0 or the .08% methionine-supplemented, grower diet. The results of these two experiments are summarized in Tables 3 and 4.

Between 0 and 28 days of age (Table 3) the goslings exhibited greater weight gains with .16% supplemental methionine (0.45%

dietary methionine). The goslings fed the .24% supplemental methionine diet (0.53% dietary methionine) did not show greater weight gain than those fed the .16% diet. This suggests that the methionine requirement of geese up to 28 days of age is between 0.45 and 0.53% of the diet. Feed consumption increased as methionine supplementation increased, however, feed efficiency (lb. gain/lb. feed) increased only slightly with .16% supplemental methionine.

Between 28 and 66 days of age, the geese fed the .08% supplemental methionine grower diet displayed greater weight gains (Table 4). Feed consumption and feed efficiency were not affected by the additional methionine.

Although the results of these experiments do not specifically define the methionine requirement of geese, goslings probably require between 0.45 and 0.53% dietary methionine up to 28 days of age. In addition, geese seem to benefit from the addition of .08% methionine to their grower diet.

The goslings fed no supplemental methionine during the experiments showed slightly abnormal feather development. Although the feathering abnormality was not a serious problem with processing the commerical geese, an abnormal pattern of feather development could be disadvantageous in the wild.

ENERGY

To maximize weight gains, birds require energy to utilize efficiently the protein and amino acids provided by the diet. Chickens and turkeys do not metabolize high fiber, marginal feeds well and derive little or no energy from them. A common misconception is that geese differ from chickens and turkeys and effectively utilize fibrous materials. Some scientists have speculated that through bacterial fermentation and digestion in the ceca the goose derives energy from marginal feed. However, Mattocks (1971) reported that geese do not digest an appreciable amount of cellulose in feeds due to a lack of cellulolytic bacteria in the digestive tract, including the ceca. Geese do not metabolize marginal feeds well even when these feeds constitute the major component of the natural diet. Burton et al. (1979) reported that three-square bulrush rhizomes, the natural diet of Lesser Snow Geese are metabolized poorly (1.41 - 1.45 kcal ME/g).

One reason geese seem to thrive on poor quality feedstuffs is the rapid passage rate of food through their digestive tracts. Another reason is the relatively large muscular gizzard (1.65% of live body weight of a broiler chicken, North, 1978 vs. 3.10% of live body weight of a 9 - 10 week old Embden goose, Neil K. Allen, unpublished data, 1978), which facilitates rapid mechanical food processing.

Research conducted at the Univeristy of Minnesota determined the effect of a low fiber, corn-soybean meal or a high fiber, alfalfa haylage diet on the amount of time required to empty the digestive tract of the goose (Storey and Allen, 1982a). The effect of the length of fasting time on the hourly dry matter excretion of geese is illustrated in Figure 1. Only random variation in the amount of excreta dry matter per hour occurs after 12 hours of fasting. This indicates that any food the goose consumed prior to fasting had been metabolized and excreted in 12 hours. There was no difference in the amount of excreta dry matter from the geese fed either the low fiber, corn-soybean meal diet or the high fiber, alfalfa haylage diet. Cecal droppings were evident in the excreta following photostimulation. At 16 and 20 hours of fasting ("dark" periods), the lights were turned on for excreta collection. Cecal droppings were also evident at these times.

The results of this experiment indicate that geese achieve a postabsorptive state with 12 hours of fasting regardless of their previous diet.

A second study conducted at the University of Minnesota determined the passage rates of four feedstuffs through geese (Storey and Allen, 1982b). Corn, wheat, oats and rice hulls were each force-fed to four female geese. The feed had been dyed with red food coloring in order to identify the excreta produced from the unmetabolizable portion. The rate of passage of these feedstuffs (Table 5 and Figure 2) were determined by the method described by Goodrich and Meiske (1979). All of the feedstuffs had a similar and rapid passage rate through the goose regardless of the proximate composition (ie., fiber, ash or protein content). Therefore, even though the goose metabolizes rice hulls poorly (10.5% metabolizability) compared with corn (85.5% metabolizability), the passage rates of these two vastly different feedstuffs are quite similar. In conclusion, the goose metabolizes as much energy as possible from the feed and then rapidly eliminates the unmetabolizable remainder as excreta.

In a third study conducted at the University of Minnesota 18 feedstuffs were each force-fed to four female geese to determine the true metabolizable energy (TME) (Storey and Allen, 1982b). The TME values are listed in Table 6. When these energy values are compared with the energy values of feedstuffs to roosters (Sibbald, 1976a, 1976b, 1979; Chami et al., 1980; Kessler and Thomas, 1980) one finds that geese do not derive more energy from marginal feedstuffs (eg., alfalfa meal and alfalfa haylage) than do chickens.

Geese tolerate poor quality, high fiber feeds probably because of their ability to consume large quantities due to a relatively large gizzard and to a rapid rate of food passage.

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TABLE 1. PROTEIN AND METHIONINE REQUIREMENTS OF BIRDS

	Age (wk)	Protein requirement (%)	Methionine requirement (%)
Pheasant	0-6	30	
Bobwhite quail	0-6	28	
Turkeys	0-4	28	.53
Chicken (broilers)	0-3	23	.50
	3-6	20	
Geese (Chinese)	0-6	22	
(Embden)	0-4	20+	?
Ducks	0-2	22	

TABLE 2. THE COMPOSITION OF CORN AND SOYBEAN MEAL DIETS FOR STARTING AND GROWING GEESE

Ingredient	Amount (%)	
	Starter	Grower
Corn, ground yellow	63.22	76.64
Soybean meal (45%)	29.06	20.39
Hyd. animal/veg. fat	1.00	---
Fish solubles (100% dried on SBM)	2.50	---
Vitamin premix	0.50	0.50
Salt (iodized)	0.50	0.25
Dicalcium phosphate	1.94	1.29
Calcium carbonate	1.20	0.87
$MnSO_4$ (27%)	0.025	0.025
ZnO (72%)	0.0025	0.0025
$CuSO_4$ (FG)	0.004	---
$FeSO_4 \cdot 7H_2O$	0.05	---
Niacin (99.5%)	0.0033	0.0033
DL-methionine	---	---
Composition (Calculated)		
Protein (%)	20.0	16.0
ME (kcal/kg)	2973.4	3095.2
Calcium (%)	1.00	0.70
$Phosphorus_i$ (%)	0.50	0.35
Methionine (%)	0.29	0.24

TABLE 3. WEIGHT GAIN, FEED CONSUMPTION AND FEED EFFICIENCY OF GEESE FED DIFFERENT LEVELS OF METHIONINE BETWEEN 0 AND 28 DAYS OF AGE

	Level of Supplemental Methionine (%)				
	0	.04**	.08	.16	.24*
Weight gain (g/goose)					
Expt. 1	1957	----	2166	2273	2251
Expt. 2	1834	1941	1878	2080	----
Mean	1896	1941	2022	2176	2251
Feed consumption (g/goose)					
Expt. 1	3753	----	3964	3948	4106
Expt. 2	3676	3881	3692	3804	----
Mean	3714	3881	3828	3876	4106
Feed efficiency (G/F)					
Expt. 1	.52	---	.55	.58	.55
Expt. 2.	.50	.50	.51	.55	---
Mean	.51	.50	.52	.56	.55

*.24% supplemental methionine - Expt. 1 only

**.04% supplemental methionine - Expt. 2 only

TABLE 4. WEIGHT GAIN, FEED CONSUMPTION AND FEED EFFICIENCY OF GEESE FED DIFFERENT LEVELS OF METHIONINE BETWEEN 28 AND 66 DAYS OF AGE

	Level of Supplemental Methionine (%)	
	0	.08
Weight gain (g/goose)		
Expt. 1	2162	2395
Expt. 2	2218	2534
Mean	2190	2464
Feed consumption (g/goose)		
Expt. 1	11,000	11,083
Expt. 2	11,963	12,078
Mean	11,482	11,580
Feed efficiency (G/F)		
Expt. 1	.20	.22
Expt. 2	.18	.21
Mean	.19	.22

TABLE 5. PASSAGE RATES AND HALF-LIFE OF CORN, WHEAT, OATS AND RICE HULLS THROUGH THE GOOSE

Feedstuff	Passage-rate (%/hr)	Metabolizability (%)	Half-life (hr)
Corn	15.9	85.5	4.3
Rice hulls	14.7	10.5	4.7
Oats	23.9	72.4	2.9
Wheat	24.4	68.0	2.8

TABLE 6. TRUE METABOLIZABLE ENERGY OF EIGHTEEN FEEDSTUFFS FOR GEESE

Feedstuff	TME (kcal/g)[1]
Corn	4.265
Wheat	3.450
Oats	3.520
Alfalfa meal	1.457
Barley	3.506
Rye	2.932
Soybean meal 1	3.388
Soybean meal 2	3.151
Sesame meal	3.697
Fish solubles	3.085
Wheat middlings	2.899
Molasses	3.038
Dried brewers grains	3.252
Steamed, rolled oats	3.994
Milo	4.034
Alfalfa haylage	2.091
Corn oil	7.762
Animal/vegetable fat	6.934

[1]Expressed on dry matter basis

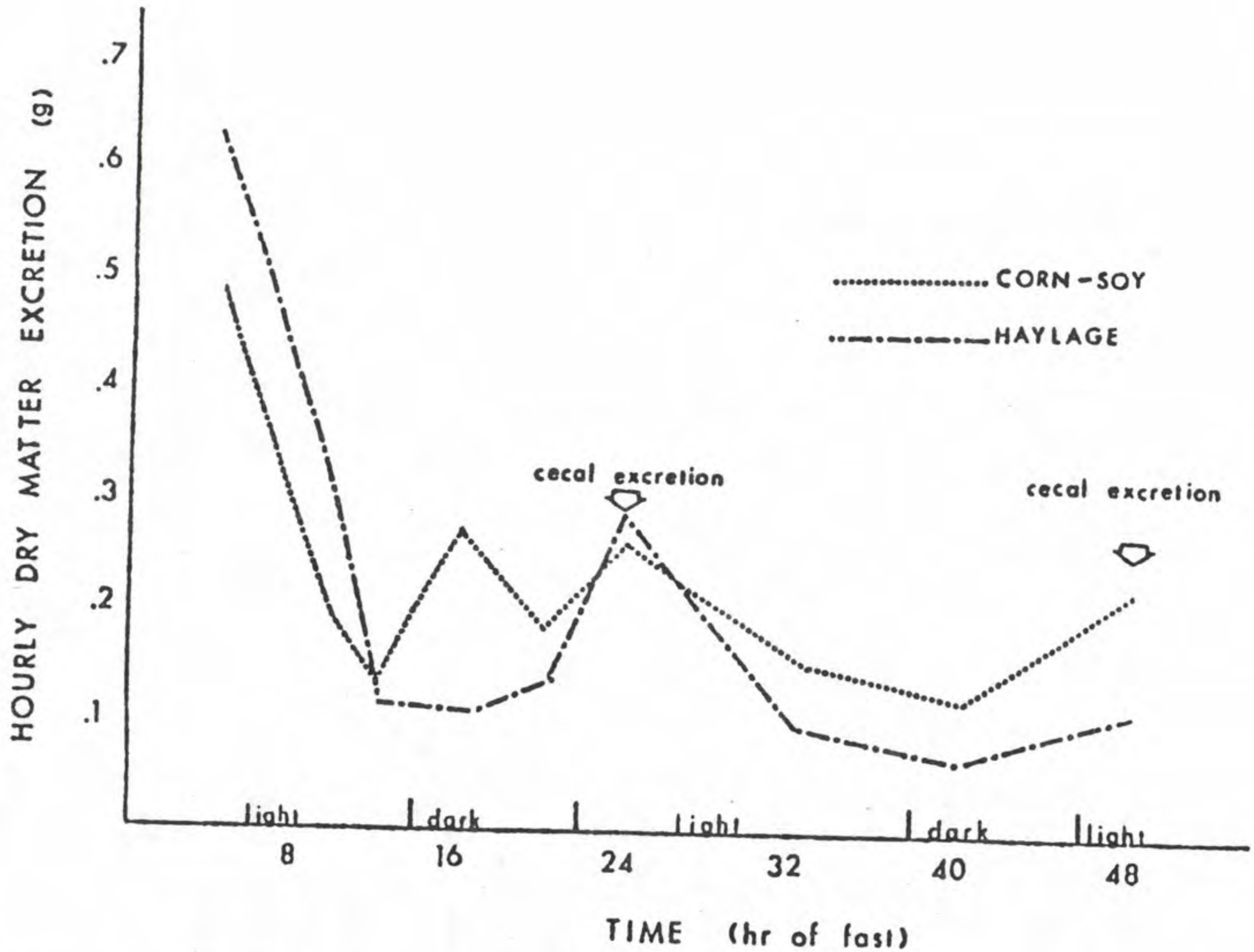

Figure 1. Effect of starvation time on hourly dry matter excretion of geese

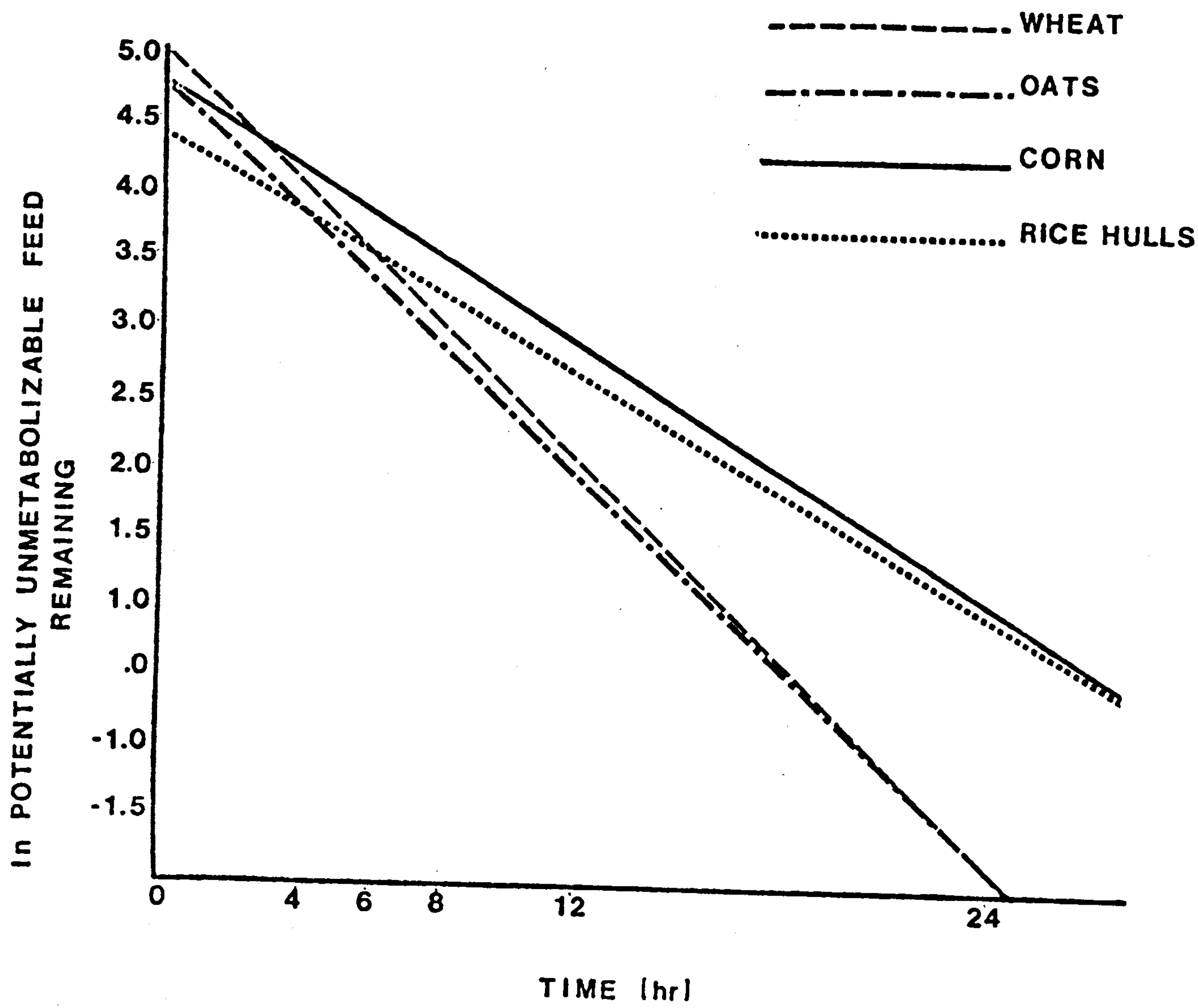

Figure 2. Composite of the rates of passage of corn, wheat, oats and rice hulls through the goose

DO EMUS HAVE TO BE LEGLESS TOO?

Duane E. Ullrey[1]

The question posed by the title might be asked relative to all ratites. A common feature of captive ostrich, rheas, cassowaries and emus - in addition to flightlessness - is the tendency for young birds to develop leg problems. These are seen most often within 8 weeks of hatching and superficially resemble perosis. The condition is usually unilateral, involving lateral rotation of the distal tibia and proximal tarsometatarsus. Seldom does the achilles tendon slip from between the condyles. The problem is more likely to develop if exercise is restricted, and it is exacerbated by slippery floors and rapid growth rate.

An additional problem associated with feeding ratites in captivity is the small numbers in any age class and the difficulty in finding a feed manufacturer who can produce appropriate diets in small volumes. As a consequence, it would be very useful if a single ratite diet could be developed which would support maintenance, reproduction and growth while preventing leg problems.

To this end an experiment has been initiated at the San Diego Zoo. Thirty-nine newly hatched emu chicks were assigned to one of four diets with the calculated analyses shown in Table 1. All diets contained modest metabolizable energy concentrations. Diets 2 and 4 contained 22% crude protein versus 18.5% in diets 1 and 3. Diets 1 and 2 contained 1.2% calcium versus 1.6% in diets 3 and 4. The diets and water were provided ad libitum and the

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chicks were weighed periodically. Any which died or developed leg abnormalities were necropsied.

The birds are now 6 months old or older. The numbers of birds with abnormal legs/birds started on each diet are 1/9, 0/11, 2/10 and 0/9 for diets 1-4, respectively. Since diets 2 and 4 have produced nearly equal results to this point, birds on these two diets will be raised to reproductive age and their egg production, fertility and hatchibility assessed.

Table 1. Calculated analyses of experimental ratite diets

Item	Diet 1	2	3	4
Metabolizable energy, kcal/kg	2350	2250	2350	2250
Crude protein, %	18.5	22.0	18.5	22.0
Calcium, %	1.2	1.2	1.6	1.6
Phosphorus (total), %	1.0	1.0	1.0	1.0
Phosphorus (avail.), %	0.8	0.8	0.8	0.8
Lysine, %	1.0	1.2	1.0	1.2

SCIENTIFIC FORMULATION OF DIETS FOR CAPTIVE BIRDS

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Introduction

Nutrient requirements for animals and birds are generally expressed in terms of quantities per day or as proportions of the diets. Thus the protein requirement of a 1.0 lb. parrot may be stated as 10g of protein per day or as 15% protein in the diet. Regardless of which expression is used, it is essential that the requirements be specified in terms of allowances, a practice which is widely used in practical feeding of animals and birds. The dietary allowances are greater than the minimum requirements by safety margins which allow for variation between individuals and for nutrient losses associated with processing and storage of the finished feeds. The purpose of this article is to present the scientific basis for the establishment of nutrient allowances for exotic captive birds and to describe briefly how Zeigler Bros. has developed diets for these species and has tested these to determine and establish their acceptability and nutritional adequacy.

Estimation of Energy Requirements

An animal is in a state of maintenance when it neither gains nor loses weight; when its body composition remains constant; when it gives rise to no product such as egg and when it performs no work on its surroundings. Thus the requirement for maintenance is the minimum quantity promoting an exact body balance.

At an early stage in the study of maintenance (basal) metabolism, it was recognized that fasting heat production is more nearly proportional to the surface area of animals than to their weight. The surface area of animals is difficult to measure. Methods were, therefore, devised for predicting it from their body weight.

According to early studies of Brody (1945) and Kleiber (1961), the daily net energy (NE) requirements of adult mammals for maintenance can be calculated from the formula: 70 Kcal x body weight (kg) $^{0.75}$. The basis for such methods is that, in bodies of the same shape and of equal density, surface area is proportional to the three quarters power of body weight (B.W.). Maintenance requirement of birds is somewhat higher since they have a higher body temperature than most mammals. An equation for maintenance NE for adult birds has been suggested by Scott et al (1976), NEm=83 Kcal x B.W. (Kg) $^{0.75}$. This standard is usually expressed in terms of metabolizable energy (ME) which is approximately 18% higher than NE values. The energy requirements for activity depend upon the degree of activity of the animal. NE for caged birds might be only 50% or greater under the natural environments. Animals under climatic extremes may need more energy for maintenance.

In young animals, the requirements for growth depend upon the daily rate of growth. Four Kcal of NE per gram of protein gain, and 9 Kcal of NE for each gram of deposited fat are required (Table 1).

For most captive birds, the major need for energy is for maintenance and activity. Energy required for egg production represents a relatively small and transitory increase. Many experiments have shown that almost all species of animals have an innate hunger for energy and they will consume exact amounts of energy to meet their daily requirements. Feeding studies to date with canaries, finches, lories, parakeets, parrots, flamingos, ratities, pheasants, wild ducks and cranes appear to confirm these calculations as valid assessments of energy requirements (Oftedal, 1980; Serafin, 1980).

Estimation of Protein Requirements

Daily protein requirements of adult birds for body maintenance may be calculated from the following equation:

$$Protein_m = \frac{0.201 \times B.W.^{0.75}}{0.55} \times 6.25$$

(Scott et al, 1976)

$Protein_m$ is the daily protein requirement in grams. The constant, 0.201, is derived from the daily endogenous nitrogen excretion multiplied by 6.25, which converts nitrogen to protein. The equation assumes that most animals, including wild birds, consume similar diets and have an efficiency of 55% in converting dietary proteins into body and feather proteins.

For growing birds, daily protein requirements for tissue growth may be calculated by multiplying the daily gain in body weight (in grams) by 0.18 (18% protein in tissues) and dividing by 0.55 (55% efficiency of utilization of feed protein). The endogenous nitrogen loss in growing birds has been determined to be approximately 250 mg per kg of body weight. Since feathers represent about 4-7% of the body weight and the protein content of feathers is about 82%, the daily protein requirement for feather production can be determined (Table 2).

The following formula may be used to calculate the daily protein needs of growing birds:

$$\text{Daily protein requirement (gms)} = \frac{\text{Daily gain (gms)} \times 0.18}{0.55} + \frac{0.0016 \times \text{B.W. (gms)}}{0.55} + \frac{(0.05) \times \text{Daily Gain (gms)} \times 0.82}{0.55}$$

The essential amino acids must be present in adequate amounts in the diet at all times for optimum growth and health.

Minerals and Vitamins Requirements

Minerals have many functions: they are essential for skeletal growth, regulation of osmotic activity and pH, transport of oxygen, and activation of enzyme systems. The requirements vary with the sex, age and state of reproduction. The young have more exact requirements than adults. Mineral deficiencies may be manifested by leg weakness, loss of feathers and other symptoms.

Minerals required by avian species are: calcium, phosphorus, sodium, chloride, magnesium, potassium, manganese, zinc, iron, copper, iodine, molybdenum and selenium. The need for both phosphorus and sodium is presumed to be greater in omnivorous birds.

Seedeaters should be given grit for their gizzards. A hard insoluble grit is recommended; the size should be selected in relation to the size of the birds.

Vitamins other than ascorbic acid, as an integral part of enzyme systems, are required as a protection against metabolic disturbances. Vitamin allowances must be at least high enough to prevent signs of deficiency and not to restrict the rate of growth. The form of vitamin D required by birds is vitamin D3.

Practical Considerations in Developing Diets for Captive Birds

Unlike commercial poultry production, for most captive birds reared in aviaries and zoological parks, there is no economic incentive for rapid growth and a quick turnover of stock. The main goal is longevity and sustained breeding.

Diversity of the Alimentary Canal System

A basic understanding of the avian digestive system is very useful in developing a new feeding program. A major feature distinguishing avian from mammalian digestive systems is the reduction of the anterior parts to the minimum required to procure foods. A light horny beak replaces teeth; the jaw has a relatively light-weight, fragile skeleton and correspondingly less bulky musculature. The long esophagus is large in diameter and may have a storage as well as transfer function. A gizzard is usually present. Beyond the gastric area, the avian digestive system does not differ greatly from that of mammals (Sturkie, 1965).

The beaks of birds have evolved to accommodate a number of feeds. For example, the parrot has a hooked beak that acts as a powerful and efficient nutcracker, yet the bird's tongue is supple enough to extract the kernel from a cracked nutshell. Certain birds have beaks adapted to breaking open oyster shells, while other species have beaks more capable of spearing prey. Flamingos feed on organic matter found in mud. Their curved bills are lined with hairlike laminae that filter out and retain minute plants and animals. Insect gleaners characteristically have short, thin beaks. The broad flat bills of swallows and flycatchers facilitate the capture of insects in the air. Predators such as hawks and owls have strong, hooked beaks adapted to tearing flesh into pieces small enough to swallow. Some species are capable of swallowing whole mice and other small animals. The bills of hummingbirds are adapted to plucking arthropods from cracks in bark, and their tongues are long and tubular, suitable for extracting nectar from flowers. The woodpecker's tongue is very flexible, enabling it to penetrate deep into holes to retrieve invertebrates.

Natural Feeding Habitats

Ingestion is a very complex event involving not only the sensory organs, but many other physiological processes. Hunger and recognition of feed are important to feed acceptance, along with other factors such as: color, odor, flavor, physical form, time of feeding, social characteristics, methods of presentation, quantity and frequency of feeding (Chah, 1971).

The color of a diet may enhance its acceptance. For example, young ducks, swans, geese, and gallinaceous birds and rheas are attracted by green feeds.

Food odor is usually not important. Although some oilbirds and kiwis are believed to locate feed by its odor, most species do not seem to have a strongly developed sense of smell.

Feed taste appears to have something to do with preference. Most species seem to have taste buds, which may account for their preference for a sweet feed over other taste. Birds also rely on vision for feed recognition.

The shape, size and physical form of the feed are very important to acceptability. Certain feeding drives must be met if conditions are to simulate the natural habitats. For example, the seed cracking beak of parrots and bill strainer of a flamingo must be kept in use, lest these structures overgrow. Again, feed should be supplied to those species that tend, in nature, to eat frequently during the day in such a way as to occupy a substantial amount of time. The daily cycle of the species in question is important as it relates to the time of presenting feed. Such nocturnal birds as owls will not eat until dark. Many birds (i.e. insectivorous species) feed in nature only on live, moving objects.

Social factors influence the feeding habits of birds. For example, chickens in groups eat more and gain more weight than when fed in isolation. Newly captured birds are more readily trained to feed when placed with others of their kind. When birds are kept in groups, competition must be considered in their dietary program. Feeding areas must be numerous and wisely spaced.

Formulated Diets for Captive Birds

The formulation of diets for captive birds is indeed an exercise in comparative nutrition. Since information on the nutritional requirements of most captive birds is limited, the requirements can be estimated based on available knowledge for domestic poultry (National Research Council, 1977).

These formulated feeds have many advantages. They are uniform in nutrient composition; less likely to have errors in preparation; nutrients are stable; choice of diet is designed for particular growth and reproductive stages; and minimal need for inventory and mixing facilities. Thus, in recent years, the demand for these balanced feeds for captive birds has been very strong.

The formulas of avian maintenance and avian breeder diets and their nutrient levels are presented in Tables 3 through 6. These rations are well suited for many species such as pheasants, geese, ducks, waterfowls, quails, and partridges. The nutrient levels included are generous and allow a substantial margin of safety.

Since ratites have a digestive system that can handle a rather high fibrous diet, high roughage ingredients, hence low levels of gross energy, were selected in an attempt to restrict energy intakes and growth rates among young birds (Tables 7, 8).

Seed eating birds, canaries, finches, parakeets, etc., are traditionally fed mixed seeds that may be deficient in protein (amino acid), vitamins and certain trace minerals. These species have been readily induced to consume small (3/32"), hard pellets of balanced composition. Free choice oyster shell or cuttlebones are placed in the cage along with some extra green feeds during the breeding season.

Diets for parrots and cockatoos present a particular challenge for development. Several versions of pelleted feeds utilizing altered size, texture, flavor and color have been tested. Currently, the best of these diets is available in pellets (3/8") with a firm texture. Similar products were also devised for soft-billed birds (toucans and hornbills, etc.). The successful feeding program at this stage appears to be one utilizing approximately three parts of a formulated feed and making up the balance with various supplements. Fruit eating birds are supplemented with fruits that are seasonally available such as apples, oranges, bananas, etc. Meat eaters are given either live or freshly killed rodents or chickens. Invertebrates that may be offered in limited amounts to captive birds include fruit flies, mealworms, bee larvae, earthworms and crickets.

The pigment content of feed is important to some species such as flamingos and woodpeckers. The dietary pigments or their derivatives are transferred to the bird's feathers, beak, shanks, and flesh. Specially formulated flamingo pellets (5/32") containing both shrimpmeal and carotenoids are now used. This diet is designed to maintain its integrity in the water.

Table 9 shows a series of formulated diets. Many others are still in the experimental stage. The long-term effects on health and reproduction have yet to be determined even if diets are successfully incorporated into regular feeding programs.

Summary

The chemical composition and nutritional requirements of domestic avian species for different stages of growth, maintenance and reproduction are well documented in the literature. Information on the requirements of game birds and captive zoo birds, however, are very limited. Based on available knowledge of natural dietary habitats of these species and other well-established nutritional principles, a series of experimental diets were developed to provide adequate amounts of proteins, calories, vitamins and minerals. Subsequent feeding studies to test these diets were conducted with many exotic captive birds at universities, zoological parks and federal research agencies. The data obtained from the studies indicated that these complete diets can readily be used for the various captive birds such as canaries, finches, parrots, flamingos, pheasants, wild ducks, cranes, quails, wild turkeys and ratites. The findings also suggested that the other important practical considerations in developing these diets are such criteria as physical forms (meals, pellets, crumbles), textures (hard, firm, soft), flavors and taste of diets in order to promote acceptability and palatability for each target species of birds. Constant observations and appropriate adjustments are required to promote the successful use of these diets and to prevent the development of irreversible clinical manifestations of nutritional disease.

Acknowledgments

Most of the experimental diets described herein represent the joint effort of Dr. M. L. Scott of Cornell University, Dr. O. T.

Oftedal of National Zoological Park, Dr. T. R. Zeigler of Zeigler Bros., Inc. and the author. An earlier version of this paper was presented at the 1981 annual meeting of the American Federation of Aviculture in San Diego, CA.

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TABLE 1. ESTIMATION OF ENERGY REQUIREMENTS

a) MAINTENANCE

- o Brody (1945) and Kleiber (1961)

  $NEm = 70\ Kcal \times B.W.\ (Kg)^{.75}$ for Mammals

- o Scott et al (1976)

  $NEm = 83\ Kcal \times B.W.\ (Kg)^{.75}$ for birds

b) GROWTH

4 Kcal N.E./g. Protein Gain

9 Kcal N.E./g. Fat Gain

c) EGG PRODUCTION

- o Romanoff & Romanoff 1949

  Composition of Eggs

  Protein 11.8 - 14%

  Fat 11.7 - 14.4%

  Carbohydrate 1.0%

TABLE 2. ESTIMATION OF PROTEIN REQUIREMENTS

Scott et al (1976)

a) MAINTENANCE

- o Daily Protein Loss (g)

$$= \frac{0.201 \times B.W.\ (Kg)^{.75} \times 6.25}{0.55}$$

b) GROWTH

- o Daily Gain (g) for Body Tissue Growth and Feather Production
- o Endogenous Nitrogen Loss

$$G = \frac{\text{Daily Gain (g)} \times 0.18}{0.55}$$

$$+ \frac{0.0016 \times B.W.\ (g)}{0.55}$$

$$+ \frac{(0.05) \times \text{Daily Gain (g)} \times 0.82}{0.55}$$

c) REPRODUCTION

- o $\frac{\text{Daily Protein Output of Egg}}{0.55}$

TABLE 3. AVIAN MAINTENANCE DIET (OPEN FORMULA): INGREDIENTS

Ingredient	Percentage by Weight
Corn, yellow, No. 2, ground	62.73
Barley, pulverized	20.00
Soybean meal, 44% protein	10.00
Fish meal, 65% protein	2.00
Alfalfa meal, 17% protein	2.50
Dicalcium phosphate	1.50
Limestone	0.50
Salt	0.25
DL-Methionine	0.02
Vitamin and mineral premixes	0.50

TABLE 6. AVIAN BREEDER DIET (OPEN FORMULA): NUTRIENT STANDARDS

Crude protein	18.0 %	Mimimum
Crude fat	3.0 %	"
Crude fiber	6.0 %	Maximum
Lysine	0.85%	Minimum
Arginine	1.0 %	"
Methionine	0.36%	"
Tryptophan	0.18%	"
Calcium	2.3 %	"
Phosphorus	0.6 %	"
Magnesium	.06%	"
Sodium Chloride	0.4 %	"

1. Purina High Protein Monkey Blocks, Purina, St. Louis, Missouri

2. Zu/Preem, Hill Packing Company, Topeka, Kansas

3. Clovite, Fort Dodge Company, Fort Dodge, Iowa

4. Sustagen, Mead Johnson & Company, Indianapolis, Indiana

5. Methiscol Capsules, U.S. Vitamin Corporation, Tuckahoe, New York 10707

6. Aqueous Vitamin D_3 10,000 IU/ml, Freeman Industries, Tuckahoe, New York 10707

7. Pediatric Folic Acid Solution, 100 mgc/ml prepared in Rush-Presbyterian-St. Luke's Medical Center Pharmacy

8. Aquasol-A 20,000 IU/ml, Freeman Industries, Tuckahoe, New York, 10707

9. Aquasol-E 50 IU/ml, Freeman Industries, Tuckahoe, New York, 10707

TABLE 3. AVIAN MAINTENANCE DIET (OPEN FORMULA): INGREDIENTS

Ingredient	Percentage by Weight
Corn, yellow, No. 2, ground	62.73
Barley, pulverized	20.00
Soybean meal, 44% protein	10.00
Fish meal, 65% protein	2.00
Alfalfa meal, 17% protein	2.50
Dicalcium phosphate	1.50
Limestone	0.50
Salt	0.25
DL-Methionine	0.02
Vitamin and mineral premixes	0.50

TABLE 4. AVIAN MAINTENANCE DIET (OPEN FORMULA): NUTRIENT STANDARDS

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

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

TABLE 5. AVIAN BREEDER DIET (OPEN FORMULA): INGREDIENTS

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

TABLE 6. AVIAN BREEDER DIET (OPEN FORMULA): NUTRIENT STANDARDS

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

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

TABLE 7. RATITE DIET (OPEN FORMULA): INGREDIENTS

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

TABLE 8. RATITE DIET (OPEN FORMULA): NUTRIENT STANDARDS

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

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

TABLE 9. SUMMARY OF FORMULATED FEEDS FOR CAPTIVE BIRDS

Diet	Feed Texture	Pellet Size
*Avian Maintenance	Dry	5/32"
*Avian Starter/Breeder	Dry	5/32"
*Ratite	Dry	5/32"
*Crane Maintenance	Dry	5/32"
*Crane Starter/Breeder	Dry	5/32"
*Game Bird Maintainer	Dry	Crumble
*Game Bird Grower	Dry	Crumble
*Game Bird Breeder	Dry	Crumble
Flamingo	Semi-moist	5/32"
Soft-billed Bird	Semi-moist	5/32"
Finch/Canary	Dry	3/32"
Cockatiel/Lovebird	Dry	1/4"
Parakeet/Lories	Dry	3/32"
Parrot/Cockatoo	Dry	3/8"
Frugivore	Gel	Meal
Avian Vitamin Premix	Dry	Meal
Avian Mineral Premix	Dry	Meal

*Open formula diets.

AVIAN PANEL DISCUSSION

Q: Do you think rice hulls would be a food source geese would choose?

Storey: No, I don't think very many animals would choose rice hulls as a food source. But, that was the bedding we were using at the time and given that it was such a horrible feed stuff we wanted something that was very, very high, and wanted to see the differences between the corn which was very easily digestible and something that was not digestible at all. We wanted to see what those passage rates would be and as you could see from the slides the passage rates weren't different, even though it was just horribly indigestible and unmetabolizible. We ground them thru a 1/40 inch mesh screen, and we did that because that was what was available.

Q: When I read a label from a feed stuff which reports protein as no less than 18%, can I assume that in the formulation or mixing of that diet that you add some portion in excess of that, so that it is at least 18%?

Chah: It is general practice on the part of feed companies to come up with guarantees of approximate composition, which is namely protein, fat and fiber, and to some extent moisture. We usually allow 5-10% over and above the minimum or maximum guarantee of approximate compositions, which is usually shown on the tag. The minimum protein guarantee may be 20%, the actual formulation usually has about 21 - 21.5% protein, to insure the final protein concentration of that feed would be at least 20%, by analysis. Again, you also recognize the kind of variation for the chemical assays for that particular parameter. It is a well accepted fact that these approximate composition assays ranges somewhere in the neighborhood of 5-10%, depending upon the kind of sample, sampling error, or analytical error, or all sorts of combinations that we might think of. So even if we guarantee say 20% on the part of regulatory agencies the actual assay may say 19%, the agencies don't really raise a serious issue. If the variation is more than 10%, then they raise serious questions.

Q: You mentioned the diets you provided to the National Zoo, and you mentioned cricket crumble, is it used for crickets or insectivores?

Chah: Olav might be better able to answer this. It is my understanding that some zoo animals love a moving object. Crickets is one that they (National Zoo) provide to marmosets. Out of necessity, we raise crickets and what we want to do is analyse crickets, to formulate the diets for crickets. Based on the nutritional wisdom of Olav, we modified the chemical composition of crickets. We have provided this diet for quite some time.

Allen: The diet that you saw mentioned on one of Dr. Chah's slides was the cricket crumble diet that was developed with Dr. Chah and Dr. Oftedal and used experimentally at the National Zoo earlier this year with some crickets for about 3 months. It is my understanding that the diet, as of yet, is not commercially available. Currently I'm testing the effect of this high calcium cricket diet on crickets and feeding the crickets to tree frogs and geckos at Michigan State University. We're calling it an experimental diet because we know the cricket calcium level can be effected by feeding the cricket a high calcium diet, but we don't know what will happen when we feed those high calcium crickets to experimental animals. Once we find out whether we're doing what we think we're doing, then the diet may be available on a commercial basis.

Q: Large psittacine breeders are using monkey chow, or other primate diets to feed psittacines. How does the prepared diet at Zeigler's differ from the use of primate diets?

Chah: There are several differences there. First of all the nutritional profiles for the diets we have in terms of

PROTEIN, FAT AND FIBER FOR PSITTACINES ARE QUITE DIFFERENT FROM MONKEY CHOW. SECONDLY, MONKEY CHOW HAS QUITE A SLUG OF ADDITIONAL MACRONUTRIENTS. THEY PROVIDE PERHAPS ENOUGH ASCORBIC ACID TO MEET THE REQUIREMENTS OF VITAMIN C FOR PRIMATES, WHEREAS OUR PARROT DIET DOES NOT CONTAIN ANY VITAMIN C BECAUSE BIRDS USUALLY DO NOT REQUIRE THAT NUTRIENT. THE TEXTURE OF THE 2 DIETS IS ENTIRELY DIFFERENT. ONE IS COMPLETELY EXTRUDED TYPE OF PRODUCT AND OUR DIET IS PELLET WHICH IS SMALL IN SIZE. THE TEXTURE IN TERMS OF HARDNESS IS RATHER SOFT WITH OUR DIET, AND YET IT'S FIRM. THIRDLY, WE INTRODUCED SOME FLAVORS TO THIS PRODUCT. WE TRIED ABOUT 8 DIFFERENT FLAVORS WITH THE SAME PHYSICAL FORM. WE REALIZED, THROUGH OUR STUDIES, THAT PARROTS HAVE SOME SPECIAL TASTE BUDS. THEY PREFER CERTAIN FLAVORS, THEREFORE, WE INTRODUCED THAT TO OUR PARROT DIETS. THESE WILD BIRDS ALSO WASTE A LOT OF FEED, THEY CONSUME MAYBE 5% OF THEIR BODY WEIGHT ON A DAILY BASIS. IN FACT, THEY EAT ABOUT 5%, BUT YOU NEED TO PROVIDE 10% OF THEIR BODY WEIGHT.

Q: HOW CAN WE OBJECTIVELY ASSESS THE EFFECT OF A DIET ON BIRDS IN ZOOS OR OTHER ANIMALS IN ZOOS WHEN WE CAN'T GO ON FACTORS SUCH AS RATE OF GAIN, EGG PRODUCTION, MEAT PRODUCTION, ETC. HOW DO WE OBJECTIVELY ASSESS HOW WELL THE ANIMAL LOOKS, HOW NICE THE FEATHERS OR FUR LOOK, OR THE REPRODUCTIVE CAPACITY?

CHAH: WELL THE STATE OF ART OF ZOO NUTRITION IS NOT THAT SOPHISTICATED AS YET. THEY'RE NOT AT PRESENT INTERESTED IN THE EFFICIENCY OF ANY GIVEN FEED. PERHAPS, DOWN THE ROAD, THEY HAVE TO SET A SERIES OF STUDIES TO REALLY ADVANCE THEIR FEEDING PRACTICES IN TERMS OF ESTIMATING THE EFFICIENCY OF ANY GIVEN FEED FOR ANY TARGET SPECIES. THAT SHOULD BE IN ORDER IN THE NEAR FUTURE.

ULLREY: CERTAINLY WE'RE NOT TRYING TO FATTEN ANIMALS OR MAXIMIZE THEIR GROWTH, ALTHOUGH SOME OF THE FACTORS WE'VE USED IN DOMESTIC SPECIES MAY HAVE SOME RELIVANCE TOO. LONGEVITY, REPRODUCTIVE SUCCESS AND A REASONABLY LONG LIFE ARE ALL A PART OF THE PICTURE WE'RE TRYING TO EVALUATE RELATIVE TO THE FEEDING OF WILD ANIMALS IN CAPTIVITY. SO, YOU MAY BE RIGHT THAT CONVENTIONAL MEASURES OF FEED EFFICIENCY MAY NOT BE THE MOST IMPORTANT. ULTIMATELY HOWEVER, YOU HAVE TO PAY FOR THE STUFF AND SO AN ECONOMIC FACTOR GETS INTRODUCED, EFFICIENCY IN THE TOTAL OPERATION IS IMPORTANT, BUT IT MAY NOT BE THE MOST IMPORTANT.

RUMINATING ABOUT PRIMATES

Duane E. Ullrey[1]

It seems reasonable to ruminate about sheep and goats and cows, and even giraffes, but why would one ruminate about primates? Certainly its appropriate to consider them thoughtfully, just as a cow seems to contemplate life while chewing her cud. But if the fellow who assigned the title to this paper meant to imply that monkeys and ruminants have something in common, everyone knows that's not true - right? Wrong!

It's true that primates don't chew their cud - although I've seen a chimpanzee chew bubble gum and a cowboy chew tobacco - but some primates have a digestive system very much like a cow. In fact, leaf-monkeys of the subfamily Colobinae have a stomach with four parts - a sacculated and capacious presaccus and saccus, a long tubus gastricus and a short pars pylorica (Bauchop and Martucci 1968). The forestomachs provide an environment suitable for microbial symbionts, the pH ranges from 5-7, and a dense population of anaerobic bacteria convert dietary fiber to volatile fatty acids, methane and carbon dioxide (Drawert et al. 1962, Ohwaki et al. 1974) just as they do in ruminants. The pyloric region has an acid pH much like the abomasum, and with the exception of cud-chewing, these primates seem very much like animals that ruminate.

These gastrointestinal adaptations admirably equip colobids for life in the forest, and, by analogy with ruminants, suggest that some fiber must be present in the diet to support optimum gastrointestinal function. The diets that are currently manufactured in the United States for nonhuman primates are

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generally low in fiber (Table 1) and were designed primarily for rhesus monkeys (Macaca mulatta). When used as the sole diet for colobids, they are likely to produce digestive upsets similar to those from the exclusive feeding of concentrates to cattle and sheep. Thus, for reasons of nutrition and health and to provide occupational therapy, it is important to include fruit, vegetables and browse in the diet. Not only should such higher fiber foods be offered with commercial primate diets, but the time of offering various food items is important. For example, if colobids are fed twice a day, each meal should include a fiber source to avoid the excessive rates of microbial fermentation that would be expected if only concentrates were fed.

The ability of three species of colobids to digest such a diet has been explored at the San Diego Zoo. Douc langurs (Pygathrix nemaeus), purple-faced langurs (Presbytis senex) and silvered leaf monkeys (Presbytis cristatus) were involved. The primate diet shown in Table 1 was offered morning and afternoon. The morning feeding also included eugenia (Syzygium paniculatum), while the afternoon feeding also included fruits and vegetables (apples, bananas, snap beans, cabbage, carrots, oranges, spinach and sweet potatoes). The digestibility of diet dry matter, gross energy, crude protein and acid detergent fiber is shown in Table 2. It is apparent that digestibility of this diet was high, including the fiber fraction, the latter due to the anaerobic microbes in the compound stomach. Important nutrients such as protein, calcium and phosphorus were supplied in large measure (58-78%) by the primate diet. Thus, the primate diet was an important source of nutrients even though it provided little fiber. Indeed, even with browse and fruits and vegetables, fiber intakes were much less than in the wild. As a consequence, a higher fiber primate diet is under development to play its continuingly important role as a nutrient source and to more nearly mimic the fiber sources consumed by free-ranging colobids.

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Table 1. Label information on Zu/Preem®

dry primate diet (product code 6990)[a]

Guaranteed analysis	Amount
Crude protein, min. %	20.0
Ether extract, min. %	5.0
Crude fiber, max. %	2.5
Moisture, max. %	10.0
Ash, max. %	5.5
Calcium, min. %	0.5
Phosphorus, min. %	0.4

Ingredients

Corn, wheat, soybean meal, sucrose, wheat germ meal, dried whole egg, animal fat (with BHA, propyl gallate, citric acid), brewers dried yeast, dicalcium phosphate, calcium carbonate, iodized salt, iron carbonate, zinc oxide, magnesium oxide, manganous oxide, copper oxide, cobalt carbonate, choline chloride, vitamin A palmitate, D-activated animal sterol, α-tocopherol, niacin, calcium pantothenate, riboflavin, thiamin, pyridoxine hydrochloride, menadione sodium bisulfite complex, folic acid, biotin, vitamin B_{12} supplement.

[a]Manufactured by Hill's Pet Products, Inc., P.O. Box 148, Topeka, Kansas 66601.

Table 2. Digestibility (%) of diet containing primate diet, eugenia and fruits and vegetables

	Species of colobids		
Item	Douc	Purple-faced	Silvered leaf
Dry matter	81	84	83
Gross energy	78	81	81
Crude protein	63	63	62
Acid detergent fiber	71	72	70

MARMOSET NUTRITION

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Our thanks to the Board of Health, City of Chicago for the space in which we maintain our colony.

Nutrition of Callithricids is comparatively simple and yet agonizingly difficult. The basic requirements (e.g.protein, carbohydrate, and fat) are well known to all of us, but which source of protein, amount of fat, type of carbohydrate, various trace ingredients, vitamin D_3 origin, et al, pose challenges to all of us to properly maintain our marmosets and tamarins.

To further compound this situtation, each of the some 43 species and subspecies of marmosets and tamarins appear to require varying amounts of the above ingredients and definitely consume vastly different volumes of fluids on a per kilogram bodyweight basis.

Closely related (actually enmeshed in their overall health status) are their widely varying behavioral needs. To meet their nutritional parameters and ignore their "psychological" ones, or vice-versa, will result in a mutual conclusion---unthriftness, rough pelage, weight loss, poor reproduction, and ultimately will result in their deaths.

Marmoset colonies maintained in zoological parks possess a distinct advantage over those in biomedical research facilities such as ours, in that, the former can more closely simulate the animals' natural diet and ambient conditions than we are capable of. Because each species of animal life possesses its own indigenous virus(es) and because our fields of endeavor are primarily in virological areas, we dare not feed "raw" (non-sterilized) animal food sources lest we contaminate our "clean" animals with viral agents that could lead us to incorrect conclusions following our investigational procedures.

Further, as most biomedical research facilities are located in very expensive structures, cost efficiency is a prominent feature causing us to maximize every square foot of animal space and this usually results in sub-optimal housing for the animal.

One basic tenet that I acquired 15 years ago was to "keep 'em wet and warm" --- namely, maintain a relative humidity of at least 50% and a temperature approximating 75-80^{o} farenheit. Even though acclimated marmosets are extremely adaptive to ambient temperatures, etc., I feel this tenet still holds true today.

Lastly, many of the animals in a research facility are subjected to the periodic stresses of being palpated, having venipunctures and biopsies performed upon them as well as being subjected to other anesthetic and surgical procedures. Hopefully, such is not the case with animals under your jurisdition.

The diet that we are currently utilizing consists of the following:

1. Early morning

   per animal
   Offer <u>2</u> mini-marshmallows when checking animals.

2. Mid-morning

   Per animal
   A. 1 dry block (1)
   B. 2 soaked blocks (1)* or MAD*
   C. 1/8 can of canned Marmoset Diet (2)

3. Afternoon

   Per animal

Monday	1/8 apple and 1" banana
Tuesday	3 grapes
Wednesday	Vi-Daylin
Thursday	2-3 peanuts
Friday	1/8 hard-boiled egg
Saturday	3 grapes
Sunday	1/8 apple

<u>*Soaked Blocks</u>

Add 400 monkey blocks (1) to 3 quarts of tapwater (in which additives have been mixed). Soak for 10-15 minutes. Stir blocks 2-3 times.

*MAD (Marmoset Adapted Diet)

Add 200 blocks to 4 quarts of tapwater (in which additives have been mixed).

Additives for mixing water:

Daily:

100 cc Karo syrup
2 # Applesauce
2 Tbsp Clovite (3)
2 Tbsp Sustagen (4) Powder (vanilla flavor)
5 Methiscol Capsules (5)

Additives for mixing water (continued)

Monday	5 cc	Aqueous Vitamin D_3 (6)
Tuesday	20 cc	Pediatric Folic Acid Solution (4)
Wednesday	10 cc	Vitamin A (8) + 1" grated carrot
Thursday	2 Tbsp	Ascorbic Acid Powder
Friday	7 cc	Aqueous Vitamin E (9)
Saturday	1 cup	Raisins
Sunday	2 Tbsp	Ascorbic Acid Powder

The amount of food offered (and hopefully consumed) daily should approximate (on a dry-weight basis) 5% of the animal's bodyweight. As the bodyweights of the marmosets vary from some 125 gm (Cebuella pygmaea) to more than 800 gm (Leontocebus sbsp.), the servings can vary considerably --- the larger animals receiving less/Kg bodyweight than the smaller and vice-versa.

Water intake, as mentioned earlier, varies widely with the species and also with the amount of fluid in that day's diet (e.g. fruit, MAD, etc.).

Do not overlook the behavior aspects --- basically, give these animals the maximum cage space available, especially in the vertical dimension. Without adequate housing and personnel that move slowly and quietly the best diet will prove insufficient for your colony.

Vitamin D_3 requirements may be met nutritionally as we have attempted, or may be attained via natural sunlight (outdoor housing) or utilization of U-V lights, keeping in mind that the common sunlamp's output of U-V radiation is greatly diminished after 1 meter distance from the source.

Summarily, adequate nutrition when coupled with warm, moist, quiet, and spacious housing together with caring personnel should result in a self-sustaining marmoset colony.

1. Purina High Protein Monkey Blocks, Purina, St. Louis, Missouri

2. Zu/Preem, Hill Packing Company, Topeka, Kansas

3. Clovite, Fort Dodge Company, Fort Dodge, Iowa

4. Sustagen, Mead Johnson & Company, Indianapolis, Indiana

5. Methiscol Capsules, U.S. Vitamin Corporation, Tuckahoe, New York 10707

6. Aqueous Vitamin D_3 10,000 IU/ml, Freeman Industries, Tuckahoe, New York 10707

7. Pediatric Folic Acid Solution, 100 mgc/ml prepared in Rush-Presbyterian-St. Luke's Medical Center Pharmacy

8. Aquasol-A 20,000 IU/ml, Freeman Industries, Tuckahoe, New York, 10707

9. Aquasol-E 50 IU/ml, Freeman Industries, Tuckahoe, New York, 10707

AN EVALUATION OF THE ANTHROPOID APE DIETS AT THE WOODLAND PARK ZOOLOGICAL GARDENS

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INTRODUCTION

The evaluation of the ape diets at the Woodland Park Zoo in Seattle did point out several factors of potential value. The study included the examination of the gorilla, orangutan, and gibbon diets. Recent and past blood surveys were also considered. The more significant of these findings which I will discuss included reproduction and the gorilla, dietary considerations of the geriatric animal, and obesity and the introduction of alternative feed items.

REPRODUCTION AND THE GORILLA

Reproductive success through the years has generally been quite poor for gorillas in captivity. The first birth of a gorilla in a zoo was at Columbus, Ohio in 1956. Through 1977, there have been 460 gorillas kept in captivity and 174 births (Olney, 1978). A recent survey by Beck (1982) indicates that there have been few recent captive births and the captive population may be in danger of not sustaining itself.

For several years, electroejaculation has been used to evaluate fertility in the great apes. Abnormal sperm morphology and low sperm counts are a common finding indicating that a high percentage of the animals ejaculated are infertile (Platz, 1979). Testicular biopsy has been another safe and valuable technique to evaluate fertility in gorillas. Biopsies from 6 captive adult gorillas were collected or solicited from other zoos by Dr. Jim Foster of the Woodland Park Zoo (Foster and Rowley,1982). The most significant finding was that spermatogenesis was interrupted in the spermatid stage in each case examined. There was a failure for the development to continue to the spermatazoa stage. This maturation arrest occurs in about one-third of human male infertility cases.

Maturation arrest in spermatogenesis is currently not well understood. A number of explanations have been suggested for the gorilla. Among these are exposure to noxious environmental agents such as insecticides in the zoo setting. Also, considering the anatomy of the gorilla with testicles close to the body, their sitting resting position, and oftentimes radiant heat on the floor, excessive heat to the testicles could result in this reproductive problem.

Our gorilla diets are quite similar in composition and nutrient analysis to other zoos surveyed. This diet consists of over 40% lettuce, celery, and cucumbers. About 25% of the diet is made up of spinach, broccoli, tomatoes, and carrots. They receive about 10% starchy vegetables such as potatoes, 10% fruits, and 10% higher protein feeds. The diet is fortified with a vitamin/mineral supplement. Bamboo is offered to the gorillas upon availability (Table 1).

The feed analysis is adequate for most of the nutrients (Table 2). Crude protein at 18.81%, calcium at 0.48%, and phosphorous at 0.39% exceed or closely approach the NAS, NRC (1978) guidelines. The B vitamins and most trace minerals are present in quantities greater than the NRC guidelines.

A nutritional cause that has been suggested in the past for male gorilla infertility has been a vitamin E deficiency. Steiner et al. (1955) reported on the necropsy of a 22-year-old male gorilla. They found nearly complete atrophy and sclerosis of the seminiferous tubules. He speculated that these findings were characteristic of a vitamin B complex or vitamin E deficiency. Testicular degeneration has been associated by others with a vitamin E deficiency in a variety of animals including the chicken, dog, and rat (Scott et al., 1976).

Both vitamin E and selenium are involved as tissue antioxidants. However, only vitamin E is thought to play a role in testicular development. As a biological antioxidant, vitamin E may prevent damage to the lipid layer of cell membrances and lipid structures of the mitochondria. Vitamin E also functions in the metabolism of nucleic acids.

Most of the zoos surveyed had low dietary levels of vitamin E compared to the NRC recommended level of 50 mg/kg of diet (Table 3). The Lincoln Park Zoo in Chicago has reported a good degree of success in gorilla reproduction with 14 births since 1970 and 7 in the last 5 years. In its history, the Woodland Park Zoo has had 3 gorilla births. The vitamin E intake at the Lincoln Park Zoo is markedly higher than most other zoos. Milk is fortified with 105 IU/quart. The adult males are receiving an estimated 420 mg/kg vitamin E on a dry matter basis.

Blood levels of vitamin E and total plasma lipids were analyzed for the 2 adult males at Woodland Park (Table 4). The plasma vitamin E levels for Kiki and Pete were 1.14 and 2.28 mcg/ml, respectively. Both were below the human normal range of 5 - 20 mcg/ml. Tocopherols in plasma are associated with the lipoproteins. It is felt that a more accurate measure of an individual's vitamin E status can be evaluated if plasma lipids and vitamin E are determined together (Bieri, 1976). Research indicates that values above 0.8 mg vitamin E per gram total plasma lipids would provide an adequate vitamin E status. Our gorillas were well below this level with values of 0.15 and 0.37. Recent fertility testing has shown that Kiki is sterile while Pete is still fertile. All of the Woodland Park Zoo gorilla diets are now supplemented with 400 IU vitamin E per individual. * Editors note.

NUTRITION OF THE GERIATRIC ANIMAL

The evaluation of the gibbons' diet emphasized the need to be aware of the special nutritional requirements for the geriatric animal compared to the young adult. As the animal ages, there is evidence of less efficient absorption or utilization of a number of nutrients (Watkin, 1968).

The diet of the 2 11-12-year-old gibbons that Woodland Park had at the time of this nutritional evaluation was essentially the same as that for 2 young adult gibbons that the zoo had several years ago. This ration consists primarily of fruits and vegetables with a lesser portion of the Zu/Preem Primate Diet which contains 15% crude protein on a dry matter basis. This diet contains about 40% apples and oranges, 33% lettuce, 11% bananas, 11% yams, and 4% of the primate diet (Table 5).

The nutrient analysis shows that the protein level is about 9% (Table 6). The calcium and phosphorous values are 0.31% and 0.24%, respectively. The NRC recommended levels are 15% protein, 0.5% calcium, and 0.4% phosphorous for nonhuman primates.

This diet provided 2.5 gram protein/kilogram body weight. A study by Robbins and Gavan (1966) has shown that adult rhesus monkeys of about the same weight as the gibbons in this study maintained satisfactory nitrogen balance on 2-3 grams protein per kilogram of body weight. The plasma protein levels for the younger gibbons indicated that this level of dietary protein was adequate to maintain apparently normal blood values (Table 7). It has been established that old dogs require about 50% more protein per unit of body weight than young adults to maintain nitrogen balance (Wannemacher and McCoy, 1966). This greater protein need is shown in the blood protein values for the older gibbons. They are about 25% lower than the values for the younger gibbons and by human blood standards--below the normal range. The calcium and phosphorous blood values also show a decline for the older gibbons. By taking the average of the blood values for the 2 gibbons, there was a calcium drop from 10.5 mg/dl to 8.3 mg/dl and a phosphorous decline from 4.5 mg/dl to 2.3 mg/dl.

There are homeostatic mechanisms that operate to restore plasma calcium levels to normal when dietary levels are inadequate. This occurs in part by resorption of bone. The release of bone calcium to the blood results in a loss of bone mass. Since we are seeing declines in the plasma levels, we should be especially concerned about the resultant effect on bone strength.

In addition to protein, calcium, and phosphorous, it is reported that reduced plasma levels of certain vitamins and other minerals are present in elderly people fed diets qualitatively adequate for young adults. Among these are a number of the B vitamins, iron, and zinc (Watkin, 1968). Administering increased levels of those nutrients did help reduce symptoms of senility, anemias, and dermatoses.

The recommended revised diet for the gibbons included increasing the consumption of the primate diet, the introduction of yogurt, and a vitamin/mineral supplement.

In planning diets for animals in multiple life stage exhibits, one still does need to remember that the nutrient demands are the greatest during growth, gestation, and lactation. However, an adequate diet for the young adult may not serve to provide optimal health for the older individual.

OBESITY AND ALTERNATIVE FEEDS

Obesity is occasionally found to be a problem among the great apes in zoos. The 3 adult orangutans at Woodland Park are overweight. They can afford to lose roughly 20 - 25% of their 225-275 pounds.

In addition to the health problems and shorter life span associated with obesity, having overweight animals reflects a poor image to the public on the quality of health or nutritional care the animals are receiving. This is something the visitor notices immediately and seems to remember when he leaves the zoo. Also, it is a problem that should be easily correctable.

The orangutan diet contains a fairly wide variety of fruits and vegetables (Table 8). The diet contains over 50% vegetables such as lettuce, celery, and broccoli, 12% starchy vegetables, 25% fruits, and about 10% Purina High Protein Monkey Chow and eggs. They also receive a vitamin/mineral supplement.

The nutrients are supplied in excess of requirements with the exception of vitamin E (Table 9). The diet contains 19% crude protein, 0.66% calcium, and 0.45% phosphorous. The blood values indicate that these nutrients are present within normal ranges.

It was calculated that the already overweight orangutans were gaining about 2.5 pounds per month. By eliminating bread, reducing banana and yam consumption by one-third, and reducing Monkey Chow intake from 48 to 42 ounces for 3 orangutans, we are aiming to have each orangutan lose about 2 pounds per month. They seem to be doing well and accepting this diet. We will probably make further caloric cutbacks before too long.

High caloric density feeds such as nuts or raisins are scattered throughout enclosures to provide a source of activity for the gorillas or orangutans. If obesity is a problem, an alternative feed item may be desirable. We are currently considering the addition of hay cubes to the diet to be scatter-fed. This would provide a source of activity, supply additional fiber to the diet, and not contribute a great excess of additional calories.

* Editors note: Since it has not been conclusively established that there is a direct relationship between low dietary vitamin E levels and sterility in great apes, further documentation of dietary levels and reproductive status of captive gorillas is needed.

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TABLE 1-GORILLA DIET COMPOSITION

Feed Item	% of Total Feed
Lettuce, celery, cucumber	43.3
Spinach, broccoli, tomato, carrot	24.7
Potato, yam, squash	12.3
Apple, orange, grapes, raisins, banana	9.8
Milk, yogurt	3.8
Purina Monkey Chow (25% CP)	2.9
Peanuts	1.8
Eggs	1.4
Abdec Vitamin Supplement	-

TABLE 2-GORILLA DIET NUTRIENT ANALYSIS

Nutrient	Composition (Dry Matter Basis)
Crude protein	18.81 %
Ether extract	8.99 %
Crude fiber	5.90 %
Metabolizable Energy	3852 Kcal/Kg
Calcium	0.484 %
Phosphorous	0.395 %

TABLE 3-VITAMIN E COMPARISONS FOR GORILLAS AMONG ZOOS

Zoo	Dietary Vitamin E (mg/kg DM)
Lincoln Park	420
Brookfield	58
Woodland Park	34
Bronx	27
National	23
Philadelphia	16
Columbus	12

Editors note: Vitamin E levels are for entire diet

TABLE 4-GORILLA VITAMIN E STATUS

Blood Value	Kiki	Pete	Human Norms
Vitamin E, mcg/ml	1.14	2.28	5-20
Vitamin E / Total Lipids, mg/g	0.15	0.37	0.8 +

TABLE 5-GIBBON DIET COMPOSITION (2 ADULTS)

Feed Item	Amount (ounces, as fed)
Apple	16
Orange	10
Lettuce	20
Yam	7
Banana	7
Primate Diet (Zu/Preem)	2.5

TABLE 6-GIBBON DIET NUTRIENT ANALYSIS

Nutrient	Composition (Dry Matter Basis)
Crude protein	8.72 %
Ether extract	2.65 %
Crude fiber	5.04 %
Metabolizable energy	3615 Kcal/kg
Calcium	0.310 %
Phosphorous	0.239 %

TABLE 7-BLOOD VALUE COMPARISONS OF GIBBONS

Blood Survey	3-year-old		12-year-old		Human Norms
Ca, mg/dl	10.1	10.8	8.5	8.1	8.5-10.5
P, mg/dl	4.1	5.0	1.2	3.3	2.5-4.5
Protein, g/dl	7.5	7.6	5.7	5.1	6.0-8.0

TABLE 8-ORANGUTAN DIET COMPOSITION (3 ADULTS)

Feed Item	Amount (ounces, as fed)
Banana	21
Apple	30
Orange	60
Yam	42
Potato	18
Lettuce	80
Celery	90
Broccoli	84
Raisins	8
Eggs	5
Wheat Bread	3
Purina Monkey Chow (25% CP)	48
Abdec Vitamin Supplement	1.8 ml

TABLE 9-ORANGUTAN NUTRIENT ANALYSIS

Nutrient	Composition (Dry Matter Basis)
Crude protein	19.18 %
Ether extract	3.87 %
Crude fiber	5.26 %
Metabolizable energy	3769 Kcal/kg
Calcium	0.664 %
Phosphorous	0.452 %

Food composition tables compiled from:

National Research Council 1966 United States and Canadian table of feed composition. Publication 1684, National Academy of Sciences Wash. D.C.

Burnell, R.H.; Keating, J.; Quaresimo, G.K. 1965 Alpha - Tocopheral content of food, American Journal of Clincal Nutrition 17:1

PRIMATE PANEL DISCUSSION:

Q: THE EVALUATIONS ON THE COMPOSITIONS OF THE DIETS ON A DRY MATTER BASIS, WAS THAT ON AN AS FED BASIS OR WHAT WAS CONSUMED BY THE ANIMAL?

HIGGENBOTTOM: WE MEASURED THE TOTAL AMOUNT OF CONSUMPTION. WE SUBTRACTED THE WASTAGE FROM THE TOTAL AMOUNT GIVEN.

Q: WAS THAT IN A GROUP SITUATION?

HIGGENBOTTOM: YES

Q: IT WASN'T ON AN INDIVIDUAL ANIMAL BASIS?

HIGGENBOTTOM: THE MILK AND PRIMATE DIET WAS GIVEN INDIVIDUALLY, THE VEGETABLE AND FRUIT WERE PRESENTED TO THE GROUP.

Q: WHEN THE GORILLA DIETS WERE ANALYZED AT THE MILWAUKEE ZOO, BASED ON THE NRC RECOMMENDATIONS FOR PRIMATES AND THE HUMAN RECOMMENDATIONS, OUR ANIMALS WERE GETTING LESS CALORIES THAN RECOMMENDED, BUT NONE THE LESS WERE MAINTAINING THEIR WEIGHTS. I WAS WONDERING IF PERHAPS GORILLAS MAY HAVE A HIGHER DIGESTIVE EFFICIENCY?

HIGGENBOTTOM: IF YOU ARE USING THE ENERGY VALUES IN HUMAN FOOD COMPOSITION TABLES FOR THE GORILLA, THOSE TABLES ARE CONSIDERING THE CELL WALL TO BE INDIGESTABLE, AND SO THEY ARE ACTUALLY IN ERROR, PARTICULARLY THE OLDER TABLES. THEY ARE IN ERROR FOR HUMANS ALSO BECAUSE THERE CERTAINLY IS FERMENTATION IN THE LOWER TRACT IN HUMANS. SO THAT THE OLD STORY ABOUT THERE NOT BEING MUCH ENERGY IN AN APPLE IS NOT AS TRUE AS IT USED TO BE. BECAUSE YOU'RE DIGESTING A FAIR AMOUNT OF THE CELL WALL MATERIAL IN AN APPLE AND IT SEEMS POSSIBLE TO ME THAT THIS IS AT LEAST CERTAINLY THE CASE IN THE GORILLA, PERHAPS EVEN MORE SO GIVEN THEIR NATURAL DIETS, BEING VERY HIGH IN LEAFY MATERIAL. THE OTHER POSSIBILITY IS THAT THERE MIGHT BE A DIFFERENCE IN METABOLIC RATE. THERE IS EVIDENCE TO SUGGEST THAT ARBORIAL FOLIVORES HAVE REDUCED METABOLIC RATES RELATIVE TO THE STANDARD MAMMALIAN NORMALS. IT CAN BE VERY PRONOUNDED IN SOME CASES. I DON'T THINK THAT KIND OF WORK HAS EVER BEEN DONE ON GORILLAS.

Q: I USED THAT DATA TOO, I USED THE FORMULA OF BODY WEIGHT X 70 X 2 AND AGAIN OUR GORILLAS WERE NOT GETTING THAT MANY CALORIES.

HIGGENBOTTOM: OK, WHAT I'M SAYING IS THAT VALUE OF BASAL METABOLIC RATE, THAT'S 70 KILOCALORIES PER UNIT METABOLIC BODY SIZE, IS TOO HIGH APPARENTLY IN RELATIONSHIP TO ARBORIAL FOLIVORES. NOW WHETHER THE GORILLAS IS AN ARBORIAL FOLIVORE, IT CERTAINLY CLIMBS IN TREES AND IT CERTAINLY IS FOLIVOROUS. I DON'T THINK ANYONE HAS MEASURED THE ACTUAL RESTING METABOLIC RATES IN GORILLAS OR ORANGUTANS. SO THAT'S THE TROUBLE WITH TRYING TO ESTIMATE THE ENERGY REQUIREMENTS OF ANIMALS. ALSO, ACTIVITY PATTERNS ARE INCLUDED BY DOUBLING THE 70, AND THAT IS DETERMINED IN RELATION TO A CERTAIN ACTIVITY PATTERN OF THE ANIMALS. I THINK OUR ANIMALS IN CAPTIVITY ARE A LOT LESS ACTIVE THAN THEY ARE IN THE WILD, AT LEAST OUR ARE. SO YOU REALLY HAVE TO MONITOR ANIMAL CONDITION. IF THE ANIMALS ARE HOLDING WEIGHT AND APPEAR IN GOOD CONDITION THEN YOU ARE AT ABOUT THE RIGHT ENERGY INTAKE, IF THEY ARE FAT YOU ARE FEEDING THEM TOO MUCH. AND I THINK, THAT AT THIS TIME, WE CAN'T MAKE A VERY ACCURATE PREDICTION OF WHAT TO FEED A LOT OF ZOO ANIMALS FROM AN ENERGETIC POINT OF VIEW UNLESS WE HAVE ACTIVITY BUDGETS AND GOOD METABOLIC RATE DATA.

Q: IT SEEMS TO ME THAT THERE ARE TWO CONCEPTS HERE TODAY THAT ARE BEING RECORDED. ONE, EARLIER BY DR. ULREY, THAT INDICATED THAT APPROXIMATELY 85% OF THE DIET SHOULD BE PREPARED, 10-15% AS TREATS OR MANAGEMENT TOOLS. THE NEXT CONCEPT INDICATES BETTER THAN 50% AS ZOO SALAD. I THINK EVEN THE GORILLA DIETS SHOWED PURINA MONKEY CHOW AS 3% OF THE TOTAL DIET. AND THERE WERE SOME OBESITY PROBLEMS AGAIN AND SO FORTH. MARY INDICATED THAT YOU DILUTE THE PREPARED DIETS DOWN WHEN YOU START ADDING THE ZOO SALAD TO IT, SO YOU ARE NOT GETTING THE FULL EFFECT OF THE PREPARED DIET. I DON'T THINK THAT THE PREPARED DIET IS MEANT TO BE SOLD FOR EXLUSIVE USE PARTICULARLY TO ZOOS BECAUSE THERE ARE BEHAVIORAL AND MANAGEMENT PROBLEMS. WHICH WAY IS THE BEST WAY TO GO?

HIGGENBOTTOM: SERGIO OYARZAN MAY WISH TO SPEAK TO THIS A LITTLE BIT MORE BUT I BELIEVE THAT THE TORONTO ZOO HAD TRIED CUTTING BACK ON THE VEGETABLE/PRODUCE CONTENT OF THE GORILLA'S DIET AND IT MET WITH SOME RESISTANCE FROM THE ANIMALS. THEY DID NOT SEEM TO DO AS WELL OR SEEM AS SATISFIED WITH THEIR DIETS WHEN THE PRODUCE WAS CUT BACK TO A GREAT EXTENT.

OYARZUN: ONE OF THE THINGS WE TRIED TO DO WITH OUR GORILLA DIET WAS TO TRY TO ENCOURAGE THE ANIMALS TO EAT MORE PURINA MONKEY CHOW 5045 PREPARATION (THE 25% PROTEIN MIX). WE RAN INTO PALATABILITY PROBLEMS. WE HAD A GROUP OF 2.5 ADULT GORILLAS, AND I THINK MORE THAN 50% OF THE ANIMALS STARTED TO COMPLETELY REFUSE THE MONKEY CHOW. WE THEN HAD TO SWITCH DIETS TO KEEP THE ANIMALS EATING SOME OF THE COMMERCIAL DIET. WE SWITCHED TO THE 6038 PREPARATION (THE LOW PROTEIN MIX). THOSE ANIMALS WHO HAD REFUSED THE HIGH PROTEIN DIET STARTED TO EAT THE LOW PROTEIN DIET. HOWEVER, THAT LASTED ONLY A COUPLE OF WEEKS, AND THEN AGAIN WE RAN INTO THE PROBLEM. IN ORDER TO KEEP THEM

ON A BALANCED DIET, WE REINSTATED WHAT WE USED IN THE PAST. IT'S A GELATIN DIET (WHAT WE CALL A GORILLA GELATIN DIET, A HIGH FIBER TYPE OF GELLED DIET) WHICH IS VERY PALATABLE TO THESE ANIMALS. ABOUT TWO YEARS AGO DUE TO STOCK SHORTAGES IN THE COMMISSARY AREA WE HAD TO CANCEL THE GORILLA GEL. UNTIL ABOUT 2 MONTHS AGO WE HAD NOT REPEATED IT AGAIN. WE USED TO FEED THE GORILLA GEL ON A CAFETERIA OR FREE CHOICE BASIS. THE ANIMALS PREFERRED THE GEL IN THE FIRST PLACE EVEN TO FRUITS AND VEGETABLES. FRUITS AND VEGETABLES WERE THE SECOND CHOICE. BROWSE WAS MORE OR LESS ON THE SAME LEVEL AS FRUITS AND VEGETABLES, AND IN LAST PLACE WERE THE COMMERCIAL FEEDS. IN ORDER TO REDUCE THE CALORIC CONTENT OF THE DIET WE ARE TRYING TO SWITCH FROM BANANA OR REDUCE THE NUMBER OF BANANAS (A HIGH CALORIC TYPE OF FRUIT) AND INCLUDE MORE LEAFY TYPE OF VEGETABLES LIKE LETTUCE, ETC.

Q: WHAT PROPORTION OF THE DIET NOW WINDS UP BEING THE PREPARED MONKEY BISCUITS TYPE DIET?

OYARZUN: THESE ANIMALS GET ABOUT ROUGHLY 700 GMS OF COMMERCIAL PURINA DIET. THEY ALSO GET ONE KILO OF FRESH VEGETABLES, CELERY, ETC. GELLED DIET, ON A DAILY BASIS, ABOUT 600 GMS. THE REST IS MADE UP OF FRUITS AND VEGETABLES, I CAN'T REMEMBER EXACT PROPORTIONS RIGHT NOW. THE AMOUNT OF COMMERCIAL FEED IS NOT MUCH, ITS ABOUT 700 GMS PER ANIMAL MAXIMUM INTAKE.

Q: SO THE SOLUTION, IN THAT CASE, IS TO GET AWAY FROM THE CAFETERIA PROBLEM, YOU JUST MAKE SOMETHING THAT YOU CAN ALTER THE MAKEUP OF, YET IT'S HIGHLY PLATABLE.

OYARZUN: YES, MAKING UP A GEL DIET COULD BE AN ANSWER BECAUSE OF THE HIGH PALATABILITY. YOU CAN PRODUCE A GET WITH A HIGH FIBER CONTENT, AS HIGH AS YOU WANT, BY INCLUDING RAW PRODUCE. WE USE ALFALFA MEAL, WHEAT BRAN, ETC.

CHAH: I'D LIKE TO ADD A COMMENT TO THIS. SPECIALTY FEEDING IS A UNIQUE PROBLEM. THE BASIC APPROACH FROM A NUTRITION STANDPOINT, BEING IDENTICAL TO WHAT WE'VE FOUND IN BIRDS. IN OTHER WORDS, WE TRY TO CUT DOWN THE CALORIC COMPOSITION OF THE DIET, SO THAT THE ANIMALS WILL PROSPER. BOTH OF THESE DIETS THAT WE HAVE FOR PRIMATES ARE COMPOSED, IN MY OPINION, OF A HIGH CALORIC CONCENTRATION. IN OTHER WORDS, 24-28% OF PURINA MONKEY DIET HAS ABOUT 3800 KCAL OF CALORIC CONCENTRATION. THIS IS PERHAPS KNOWING THE OVERACTIVITIES OF A GORILLA. IT IS ABOUT TWICE AS MUCH CALORIC REQUIREMENTS ON A DAY TO DAY BASIS, ACCORDING TO MY EXPERIENCE. IF YOU HAVE A UNIQUE PROBLEM COMPLETING THAT TYPE OF DIET, YOU COULD PERHAPS CONTACT THE MANUFACTURER TO CUT DOWN ON THE CALORIC CONCENTRATION AND REPLACE THAT WITH SOMETHING ELSE, DIGESTIBLE FIBER OR ANY KIND OF BULKY INGREDIENT TO REPLACE THAT INGREDIENT. YOU CAN STILL FEED A COMPLETE FEED, WITH ALL THE NECESSARY VITAMINS AND MINERALS INCLUDED, AND YET CUT DOWN ON THE CALORIC CONSUMPTION BY HALF. YOU CAN AT LEAST MANAGE YOUR OBESITY PROBLEM BY FEEDING THAT KIND OF FEED.

COMMENT: I JUST WANTED TO SUGGEST THAT THERE IS AN ANSWER IN THE MAKING. THERE IS A NEW PROJECT OF THE AAZK WHICH WILL INVOLVE COLLECTING ALL ZOO ANIMAL DIETS, INCLUDING NOTES ON ACTIVITY PATTERNS AND OVERALL CONDITION OF THE ANIMAL. THIS WON'T BE AN INSTANT ANSWER TO ANYTHING, BUT EVENTUALLY YOU'LL HAVE STATISTICS ON A LARGE VARIETY AND POPULATION OF ANIMALS. BECAUSE WE ARE TALKING ABOUT ALL ANIMALS IN CAPTIVITY, I WOULD SUGGEST THAT IF YOU WANT TO MAKE SUGGESTIONS TO THE COMMITTEE, IT'S THE SOUTH FLORIDA CHAPTER THAT IS GOING TO BE HANDLING THIS NOTEBOOK, AND ENCOURAGE THE KEEPERS AT YOUR INSTITUTION TO PARTICIPATE IN GETTING THE DIETS TOGETHER.

Q: WAS THAT THE DIETS CONSUMED OR THE DIETS THAT WERE OFFERED?

A: I WOULD HOPE THAT IT WOULD BE DONE FROM BOTH POINTS OF VIEW, WHAT IS CONSUMED AND WHAT IS OFFERED. THE STATISTICS, HOW IT WILL BE HANDLED, AND THE FORMAT OF THE NOTEBOOK ARE RIGHT NOW BEING CREATED. I WILL SUGGEST THAT TO THEM.

OFTEDAL: I WOULD JUST LIKE TO POINT OUT SOME OF THE DIFFERENCES IN MEASURING DIETS ON A WET OR DRY WEIGHT BASIS. IF YOU HAVE LETTUCE SITTING OVERNIGHT IT'S LOSING WEIGHT AND IT'S NOT BECAUSE THE ANIMAL IS EATING IT, AND ALSO FOR MOISTURE CHANGES IN YOUR MONKEY CHOW WHICH TEND TO GAIN WEIGHT BECAUSE THEY GET WET IN SOME CASES. SO YOU MAKE THOSE KIND OF CORRECTIONS AND YOU LOOK AT THEIR ACTUAL CONSUMPTIONS, THEY MAY BE QUITE DIFFERENT FROM WHAT YOU'RE OFFERING. WHEN YOU RECALCULATE ON A DRY MATTER BASIS IT'S REALLY DIFFERENT FROM WHAT YOU'RE OFFERING. WE WERE OFFERING ABOUT 2/3'S OF THE WET WEIGHTS OF OUR DIETS AS PRODUCE AND KALE, AND THEY ACCOUNTED FOR ABOUT A QUARTER OF THE DRY MATTER INTAKE.

Q: I WOULD LIKE TO KNOW IF DR. OFTADAL CAN COMMENT ON SOME OF THE ETILOGY OF SOME OF THE GASTRIC BLOAT IN FEEDING LEAF EATING MONKEYS.

OFTEDAL: HOPE EVERYONE WAS IMPRESSED BY DUANE'S PICTURE OF THE FOREGUT OF THE LANGUER, ESPECIALLY THE TREMENDOUS VOLUME OF THAT. OF COURSE, IF YOU ARE GETTING VERY RAPIDLY FERMENTABLE SUBSTRAINTS INTO THAT FORE-STOMACH, IT SITS AND

FERMENTS AND YOU GET AN EXPLOSIVE FERMENTATION. THIS IS PARTICULARLY TRUE WITH SOMETHING LIKE A PRIMATE BISCUIT OR PROCESSED FOOD HIGH IN SUGARS. SOMETHING THAT CAN OCCUR IN PARTICULAR SITUATIONS AND, I DON'T THINK THERE HAS BEEN VERY MUCH WORK DONE ON IT, AS IN THE LEAF EATING MONKEYS THERE IS A LOT OF GAS PRODUCTION. WITH THIS GAS PRODUCTION IF THERE IS NOT A FEASIBLE MEANS FOR GAS ESCAPE (WHICH IS PROBABLY PART OF THE PROBLEM) THEN A BLOATING SITUATION OCCURS. I KNOW THAT BASEL ZOO HAS EXPERIENCED A BLOAT CONDITION IN COLOBUS MONKEYS FED A HIGH LEVEL OF KALE. KALE IS RAPIDLY FERMENTABLE FORM OF PLANT CELL WALL. SOME ZOOS IN EUROPE WON'T USE KALE FOR THEIR LEAF EATING MONKEYS FOR THIS REASON. WE HAVEN'T HAD A PROBLEM. I'M NOT SAYING KALE IS THE RIGHT SORT OF A FIBER SOURCE TO USE FOR A LEAF MONKEY. THE VERDICT ISN'T IN YET. CERTAINLY I DON'T KNOW IF ANYONE WOULD LIKE TO SPEAK TO THE ISSUE. THE NATIONAL ZOO HAD A PROBLEM WITH A PROBOSCUS MONKEY. THEY WERE HAVING TROUBLE INTUBATING THEIR PROBOSCUS MONKEYS WHO HAD GONE OFF FEED, WITH A MONKEY CHOW SLURRY. THE MONKEY WAS BLOATING, AND OF COURSE, THE MONKEY WAS UNDER INTENSIVE OBSERVATION, BUT THEY WERE ABLE TO RELIEVE THAT SITUATION. THE ANIMAL DID NOT LIVE MUCH LONGER. IT WAS A COMPLEX MEDICAL PROBLEM. I THINK ANYTHING THAT IS GOING TO AFFECT GUT MOTILITY, COMBINED WITH THE INTRODUCTION OF HIGHLY FERMENTABLE FOODSTUFFS, AS ARE TYPICAL OF NON LEAF EATING MONKEY DIETS COULD BE A PROBLEM TO CONSIDER. SO WE HAVE TO BE CAUTIOUS OF THE TYPES OF DIETARY MANIPULATIONS WE MAKE. I THINK THAT IN REFERENCE TO THE DATA THAT DR. ULREY PRESENTED ON THE LEAF EATING MONKEYS AT SAN DIEGO, YOU NOTICE THAT THE BROWSE WAS NOT A VERY LARGE PROPORTION OF THE DRY MATTER INTAKE. AGAIN, I THINK THAT RELECTS THE RELUCTANCE OF PEOPLE TO FEED SOMETHING LIKE A DOUC LANGUER WHICH IS A HARD KEEPER (WHICH MOST OF THE LEAF EATERS ARE). THEY'RE RELUCTANT TO TRY ANY SORT OF DRASTIC MODIFICATION OF THE DIET AND A LOT OF THE FEAR IS OF THE BLOATING SYNDROME. I DON'T KNOW IF THERE IS SOMEONE, WHO IS A VET, THAT COULD ADDRESS THIS QUESTION BETTER THAN I COULD WITH REGARD TO LEAF EATING MONKEYS WHO HAS HAD EXPERIENCE WITH BLOATING DIRECTLY.

MEEHAN: MY EXPERIENCE HAS NOT BEEN WITH CLINICAL PROBLEMS WITH BLOAT. HOWEVER, A THING THAT STRUCK ME, IN COMING FROM THE SPECTACLED LANGUERS THAT WE HAD AT ST. LOUIS TO THE ONES WE HAVE HERE, THEY JUST LOOK LIKE THEY HAD A HIGHER VOLUME OF GAS DURING THE DAYTIME. THE ONLY THING I COULD ATTRIBUTE THIS TO IS THE DIFFERENCE IN FEEDING SCHEDULE. THIS GETS BACK TO WHAT DUANE SAID ABOUT THE LOGIC OF FEEDING ANIMALS CERTAIN THINGS AT CERTAIN TIMES OF THE DAY, AND SOMETIMES THIS HAS MORE TO DO WITH MANAGEMENT THAN NUTRITION. HERE AT LINCOLN PARK WE HAVE AN OLDER BUILDING AND PROBLEMS WITH VERMIN IF WE LEAVE FOOD IN THE CAGE OVERNIGHT. WE DIDN'T HAVE THAT AT ST.LOUIS. SO FOR MANAGEMENT REASONS, IN ORDER TO GET THE MONKEY CHOW PROPORTION OF THE DIET TO BE A HIGHER PERCENTAGE OF THE DIET, WE WERE OFFERING DIFFERENT DIETS AT DIFFERENT TIMES OF THE DAY. I THINK DURING THE DAY TIME, THEY HAVE THIS INFLUX OF HIGHLY FERMENTABLE SUBSTRAIT AND DURING THE DAY THEY WERE PRETTY GASY. HERE THEY ARE OFFERED THE SAME FOOD STUFFS AND WILL PICK OUT THE SAME ITEMS DURING THE DAY. THAT'S BEEN MY ONLY EXPERIENCE WITH THE BLOAT IN THE LANGUERS, BUT NOT A CLINICAL PROBLEM.

OFTEDAL: I KNOW YOU WILL GET A SYNDROME OF ACUTE GASTRIC DILITATION IN OTHER PRIMATES BESIDES LEAF EATING ANIMALS. THERE'S DISCUSSIONS ABOUT THE DIETARY CAUSES THAT MIGHT BE RELATED. SOME PEOPLE HAVE SUGGESTED THAT PERHAPS SOY MEAL MIGHT BE INDICATED IN SOME SITUATIONS, AT LEAST IN DOGS.

OGDEN: IT HAS BEEN REPORTED, JUST IN THE CHICAGO AREA, IN THE PAST YEAR, OF ACUTE BLOAT IN RHESUS MONKEYS DUE TO CLOSTRIDIAL CONTAMINATION OF THE MONKEY BLOCKS. IT LOOKED LIKE IT WAS A DOSE RELATED THING, AS IF AN OVERZEALOUS KEEPER HAD PUT IN 3 TIMES AS MANY BLOCKS AS HE SHOULD HAVE. THE ANIMAL CONSUMED THEM ALL, AND WAS DEAD THE NEXT DAY. BUT IT WAS ISOLATED SEVERAL TIMES, BOTH FROM THE GASTRIC CONTENTS OF THE MONKEY AND THE MONKEY BLOCKS THEMSELVES.

Q: WITH RESPECT TO THE WEANING OF LEAF EATING MONKEYS AND THE TRANSITION FROM A DIET OF MATERNAL MILK TO AN ADULT DIET, THERE IS A PROBLEM WITH LEAF EATING MONKEYS AT THIS TIME. WHICH IS MORE IMPORTANT, A HIGH PROTEIN FEED TO MEET THE PROTEIN NEEDS OF THE YOUNG OR THE INTRODUCTION OF A HIGHER FIBER DIET TO HELP INSURE A NORMAL GASTRIC FERMENTATION?

OFTEDAL: THIS PARTICULAR PROBLEM IS ALSO A PROBLEM WITH HAND REARED ANIMALS, IF YOU ARE TRYING TO HAND REAR A LEAF EATING MONKEY AND TRYING TO MAKE A TRANSITION OFF OF BOTTLE FEEDING ONTO AN ADULT DIET. I THINK THE ANSWER IS TO TRY TO FORMULATE A RATION THAT CONTAINS BOTH. OBVIOUSLY, THAT'S VERY HARD TO DO. IF WE COULD FIND A PALATABLE, COMMERCIALLY PRODUCABLE PRODUCT THAT ISN'T OUTRAGEOUSLY EXPENSIVE, THAT SEEMS TO ME TO BE THE WAY TO GO. I HAVE BEEN WORKING WITH JOE CONAPCA AT NIH, CONSIDERING THIS PROBLEM AND ATTEMPTING A FORMULATION OF DIETS. DUANE HAS GONE FURTHER AND HAS BEEN TESTING SOME HIGHER FIBER DIETS AT SAN DIEGO. WHAT I WOULD LIKE TO SEE ARE SOME KIND OF DIETS THAT WERE HIGHER IN PROTEIN THAT WOULD NOT PRESENT SUCH A DANGER TO THE ANIMALS BY HAVING SUCH READILY FERMENTABLE CARBOHYDRATE AND YET DID HAVE PROTEIN LEVELS AT A HIGHER LEVEL.

MEEHAN: I'VE HAD EXPERIENCE WITH THE PROBLEMS OF YOUNG WEANING LEAF MONKEYS AND SOME OF THE OTHER SMALL PRIMATES. IT SEEMS LIKE THEY WILL START PICKING UP THE FRUITS AND VEGETABLES AND YET THEY ARE NOT PICKING UP THE HARD MONKEY BISCUITS. ONE MANAGEMENT TOOL I'VE SEEN IN THIS SITUATION, BUT HAVE BEEN HESITANT TO USE ON LEAF EATERS, WAS A

HIGHLY PALATABLE, HIGH ENERGY PROTEIN SOURCE. THIS WAS JUST MASHING UP ZU-PREEM MONKEY CHOW, PUTTING ENOUGH BANANA WITH IT TO MAKE IT STICK TOGETHER, AND MAKING SMALL PALATABLE SOFT BALLS THAT THE BABIES WOULD TAKE. I'VE BEEN CONCERNED THAT IN LEAF EATERS, THAT IF THE BABIES STARTED EATING THIS AS THEIR FIRST CHOICE AND STAYED AWAY FROM THE ZOO SALAD, THAT YOU MIGHT HAVE SOME PROBLEMS THERE. YET THIS HAS SEEMED TO WORK WELL IN SOME OF THOSE OTHER SITUATIONS, WHERE MOM IS NOT TEACHING THEM, OR HOWEVER IT IS THAT THEY NORMALLY PICK UP THE HABIT OF STARTING ON THE HARD MONKEY BISCUIT, AS MOM STARTS KICKING THEM AWAY. THAT'S PART OF AN ANSWER AND PARTLY QUESTION; WHAT WOULD BE YOUR FEELINGS ON USING THIS AS A CRUDE MANAGEMENT TOOL FOR LEAF EATERS.

OFTEDAL: I SUPPOSE YOU COULD TRY TO FIND SOME WAY. I THINK CERTAINLY TEXTURE IS IMPORTANT. SOFTENING DIETS FOR WEANING, IN LOTS OF DIFFERENT ANIMALS, INCLUDING CARNIVORES WHERE THERE IS A COMMON WEANING PRACTICE TO PROVIDE A HIGHER MOISTURE, SOFTER FOOD. SO I THINK THAT IS A SOUND IDEA. WHETHER BANANA IS THE BEST ROUTE TO GO, IT SURE HAS THE PALATABILITY EFFECT. DR. OGDEN MIGHT BE ABLE TO TELL US ABOUT SOME OF THE PROCEDURES USED WITH SOME OF THE MORE DIFFICULT TO FEED LAB ANIMALS. I KNOW SOME PEOPLE ARE USING APPLE SAUCE AND THINGS LIKE THAT TO TRY TO INDUCE THEM TO EAT COMMERCIAL MONKEY CHOW, NEW WORLD MONKEYS IN PARTICULAR.

OGDEN: BASICALLY THIS IS WHAT WE DO WITH OURS, WE START THEM IN WITH SOMETHING THAT IS QUITE ACCEPTABLE, APPLE SAUCE OR BANANA BABY CEREAL, SOMETHING OF THIS TYPE, AND THE COMMERCIAL MONKEY FOOD. THEN GRADUALLY DECREASE THE AMOUNT OF BABY CEREAL OR THE APPLE SAUCE. WITHIN A PERIOD OF A MONTH THEY AREN'T GETTING ANY OF THAT AT ALL, THEY ARE ON STRICTLY THE COMMERCIAL FOOD.

Q: ARE YOU POWDERING THAT TO MIX IT IN? ARE YOU USING THE ZU-PREEM OR HARD DIET?

OGDEN: BOTH. WE FEED BOTH THE CANNED AND THE HARD BLOCKS. SO WE'LL TAKE THE POWDERED MATERIAL OUT OF THE BOTTOM OF THE BAG THAT NORMALLY YOU WOULD THROW OUT. WE MIX THAT RIGHT IN WITH THE APPLE SAUCE OR BANANA. THE SAME WAY WITH THE CANNED FOOD, WE'LL JUST MIX THAT IN WITH THIS MIXTURE. THEN GRADUALLY DECREASE THE AMOUNT OF THE BANANA OR THE APPLE SAUCE, SO IT BECOMES MUCH MORE OF A NORMAL CONSISTENCY.

OFTEDAL: ONE OTHER PROBLEM THAT ONE HAS TO CONSIDER WOULD BE DOMINANCE RELATIONS AND BEHAVIORAL PROBLEMS IN FEEDING IN A GROUP SITUATION. IF YOU'RE TRYING TO GET A SPECIAL FOOD FOR THE BABY YOU ARE OBVIOUSLY GOING TO HAVE TO MAKE SURE IT GETS TO THE BABY.

CHAH: INTRODUCING THE HARD DIET AND JUST THE ENERGY AND PROTEIN DEFICIENCIES THAT RESULTED FROM THE LACK OF PALATABILITY, IS THAT WHAT LED TO THE WASTING MARMOSET SYNDROME?

OGDEN: THAT'S A DISTINCT POSSIBILITY. AS OF THIS DATE THERE ARE SOME 36 LABORATORIES THAT ARE CORRELATING THEIR FINDINGS AND STILL NOBODY KNOWS EXACTLY WHAT THE CAUSE OF THIS WASTING SYNDROME IS. I THINK IT IS A MULTIPLE THING. I DON'T THINK YOU'RE GOING TO FIND ANY ONE CAUSE. IT MIGHT BE DIETARY, ENVIRONMENTAL OR BEHAVIORAL. SOME I'VE SEEN HAVE RESPONSED JUST TO TREATMENT AS AN IRON DEFICIENCY PROBLEM VERY, VERY WELL. THERE IS A PROBLEM, I THINK WITH A LOT OF THESE COMMERCIAL FOODS, WHEN USING SOY BEAN AS A PROTEIN SOURCE. IT'S ALRIGHT FOR YOUR LEAF EATERS BUT YOU HAVE YOUR OMNIVOROUS ANIMALS WHICH IN THE WILD ARE RELYING ON A MEAT SOURCE, YOU GET INTO A DISTINCT NUTRITIONAL PROBLEM IN THIS RESPECT. WHEN IT GETS INTO THE PHYSIOLOGY WHERE YOU GET A METHEMGLOBIN FORM INSTEAD OF A HEMOGLOBIN FORM YOU HAVE QUITE AN ANEMIA DEVELOP. IN ZOOS, YOU HAVE A DIFFERENT WAY AROUND IT, YOU CAN FEED THEM THE LIVE ANIMALS, BUT WE CAN'T DO THAT IN OUR FACILITY DUE TO OUR VIROLOGICAL STANDING. IF YOU CAN FEED THE NATURAL DIETS IN THE ZOO, THEN THAT'S MUCH BETTER FOR THEM.

VAN HOVEN: DR. OGDEN, IN POST MORTEMS THAT WERE DONE ON MULE DEER IN COLORADO WHICH DIED ALSO OF A WASTING DISEASE, THEY FOUND LITTLE VACUOLES IN THE BRAIN. I WAS WONDERING IF ANY POST MORTEMS ON THESE MARMOSETS INDICATED ANYTHING SIMILAR?

OGDEN: NOT TO MY KNOWLEDGE. BASICALLY, IT'S BEEN A LOSS OF SKELETAL MASS, BODY WEIGHT, UNTHRIFTNESS, LOSS OF PELAGE, THINGS OF THIS TYPE. FREQUENTLY DIARRHEA, 80% OF THE TIME, ANEMIA IS A VERY FREQUENT FINDING ALSO. A LOT OF IT SEEMS TO TIE IN WITH SEVERE MASSIVE LIVER PROBLEMS, BUT WE DON'T KNOW WHAT THE ETIOLOGY OF THAT IS. I THINK MANY TIMES THE DIARRHEA IS DUE TO AN OVERGROWTH OF VIBRIO ORGANISMS, CAMPYLOBACTER. WE'VE FOUND THAT TO BE PART OF THE NORMAL FLORA AT LEAST OF MARMOSETS-LOOKS LIKE IT'S A DOSE RELATED INCIDENT. THE ANIMAL IS HARBORING 10,000 CAMPYLOGACTER WITH NO PROBLEM, IF IT GETS UP TO A MILLION, HERE COMES THE DIARRHEA. SOMETHING TO CONSIDER IF YOU ENCOUNTER THIS IN ANY OF YOUR SPECIES.

Q: ISN'T IT TRUE THAT THERE IS SUBSTANTIAL VARIATION AMONG SPECIES OF THE CALATRUSES IN RELATIONSHIP TO THEIR SUSCEP-

TIBLE.

OGDEN: I HAVE NO KNOWLEDGE OF THE GOLDENS. BUT, I WORK WITH ABOUT 12 DIFFERENT SPECIES AND AT ONE TIME I SAID IT WILL NEVER HAPPEN TO THE MUSTACHES, AND LOW AND BEHOLD THERE IT WAS. THEY DO FINE FOR 8 OR 10 YEARS AND THEN DEVELOP THE SYMPTOMS. I'VE SEEN IT IN AT LEAST 12 DIFFERENT KINDS OF MARMOSETS.

Q: HAS THERE BEEN ANY CORRELATION BETWEEN THE INCIDENCE OF WILD CAUGHT MARMOSETS AND CAPTIVE BORN MARMOSETS IN TERMS OF THE OCCURANCE OF THIS SYNDROME? HAS THE POSSIBILITY BEEN EXPLORED OF A CHANGE OF MICRO-FLORA IN THE GUT IN THESE ANIMALS WHICH HAVE WMS?

OGDEN: I DON'T KNOW THAT ANYONE HAS LOOKED AT THAT ASPECT OF IT. WE'VE SEEN IT IN ANIMALS ANYWHERE FROM SIX MONTHS OF AGE TO 15 YEARS OF AGE. AND IT USUALLY IS A RATHER GRADUAL PROCESS, TAKING A SHARP EYE TO PICK THEM UP, EARLY IN THE STAGE. THEY DON'T GIVE YOU MUCH FOREWARNING, EATING A GRAPE AT 10 O'CLOCK AND DEAD AT 10:20. WE'VE SEEN THEM WITH HEMATOCRITS AS LOW AS 8% AND TREAT THEM PROPERLY AND LOW AND BEHOLD THEY COME RIGHT BACK TO NORMAL. SO YOU SEE THE NEXT ANIMAL LOOKING AS ROTTEN, AND SURE ENOUGH ITS HEMATOCRIT WILL BE 48%. SO IT'S A MULTIPLE ETIOLOGY THING.

Q: IS THERE A POSSIBILITY THAT THERE IS A SUBSPECIES OF BACTERIAL FLORA THAT MAY BE PRODUCING A CERTAIN AGENT THAT IS LACKING, SUCH THAT AS THE TURNOVER OF FLORA, THESE FLORA DIE OR MUTATE TO A DIFFERENT FORM, THEN YOU LOSE THAT PARTICULAR ENTITY WHATEVER THAT IS.

OGDEN: I SEE WHAT YOU MEAN, BUT PART OF THIS PROBLEM IN THIS WASTING SYNDROME AS FAR AS THE ENTERITIS GOES MIGHT WELL BE THIS CAMPYLOBACTER. U NTIL ABOUT 3 YEARS AGO WE DID'T HAVE ANY READILY AVAILABLE METHOD FOR DETECTING THIS, AND NOW WE DO. WE SEE THIS IN A LOT OF THESE ANIMALS, BUT MANY TIMES IT'S ASYMPTOMATIC. THERE IS NO GROSS SIGNS OF DIARRHEA YET THE ANIMAL IS POSITIVE FOR IT. BUT, APPARENTLY IF THAT POPULATION IS ALLOWED TO INCREASE THEN THE DIARRHEA INSUES.

Q: I NOTICED ON YOUR MARMOSET DIET THAT YOU WERE FEEDING LEVELS OF FAT AT 6-15%?

OGDEN: WELL, THAT IS WHERE I BUMPED HEADS WITH ONE PERSON ABOUT IT, HE HAD RECOMMENDED 10% AS HIS IDEAL PERCENTAGE, THAT TO ME IS ABOUT 9.5% TOO HIGH. IF YOU BASE IT ON WHAT THEIR NATURAL DIET IS, IT LOOKS LIKE IT'S A VERY HIGH PROTEIN, HIGH CALORIC, HIGH ROUGHAGE, LOW FAT TYPE OF DIET IN THE WILD.

Q: I'M NOT ACQUAINTED WITH THE MARMOSET IN PARTICULAR, BUT IN OTHER HERBIVOROUS ANIMALS FAT WILL REDUCE INTAKE, WILL INFLUENCE THE GUT MICROFLORA, CAUSES DIARRHEA, AND DIRECTLY AFFECTS LIVER METABOLISM. ALL ARE SOME OF THE SIGNS THAT YOU HAVE INDICATED. I SUGGEST THAT MAYBE YOUR FAT MIGHT BE LOOKED AT.

OGDEN: RIGHT, ONE THING WE'RE WORKING WITH IS TRYING TO ALTER THE LEVELS OF THESE VARIOUS INGREDIENTS. BUT, IT TAKES SUCH A LONG TIME BEFORE YOU GET ANY RESULTS, SIX MONTHS TO A YEAR IN OUR CASE.

Q: I HAVE A QUESTION ABOUT THE DATA DR. ULREY PRESENTED ABOUT THE ETHER EXTRACT IN THE DIFFERENT BROWSES, IN WHICH IT RANGED FROM 10-16%. IS THAT TYPICAL FOR A BROWSE?

OFTEDAL: I'M NOT SURE IF I CAN ANSWER THAT QUESTION, THERE IS TREMENDOUS VARIATION IN THE COMPOSITION OF BROWSE, EVEN WITHIN A SPECIES ACCORDING TO SEASONAL VARIATION, CERTAINLY IN A NORTHERN TEMPERATE CLIMATE. WE SAY WE'RE FEEDING WILLOW OR MAPLE LEAVES AND ACTUALLY DURING DIFFERENT SEASONS WE'RE FEEDING TREMENDOUSLY DIFFERENT DIETS. HOW ACTUALLY ETHER EXTRACT VARY IS NOT CLEAR TO ME. I'M SURE THERE IS DATA ON THAT. I'D LIKE TO MAKE A COMMENT AS THE DISCUSSION GOES ON. I'D LIKE TO MAKE THE POINT THAT THE ANIMALS WE HAVE IN ZOOS ARE THOSE THAT HAVE LIVED. A LOT OF ANIMALS COMING OUT OF THE WILD INTO CAPTIVITY HAVE NOT LIVED. IN REFERENCE TO A POINT THAT ONE GENTLEMAN WAS MAKING, AND ALSO IN THINKING ABOUT OUR COLOBUS MONKEYS AT THE NATIONAL ZOO AND THE DIETS THEY'RE FED, I'M SURE THAT THEIR MICROBIAL POPULATIONS ARE CERTAINLY AFFECTED BY DIET FIRST OF ALL, BUT THERE MAY WELL BE INDIVIDUAL DIFFERENCES. I'M SURE THAT OUR ANIMAL'S MICROBIAL POPULATION IS NOT ANYTHING LIKE WHAT IS SEEN IN THE WILD ANIMAL. IF YOU WERE TO LOOK AT THE MICROBIAL POPULATION OF MOST OF OUR ZOO ANIMALS THEY HAVE LEARNED TO ADAPT TO THOSE KINDS OF POPULATIONS THAT EXIST NOW WITH THE DIETS WE FEED THEM . THEY MAY BE STRESSED BY THESE DIETS, THEY MAYBE AT THE BORDER OF THEIR ADAPTATIONS SUCH THAT SOMETHING ELSE COULD HAPPEN TO THROW THEM OFF. BECAUSE WE HAVE SURVIVORS DOES NOT MEAN THAT WE ARE FEEDING OPTIMAL DIETS. I'M AMAZED AT SOME OF THE DIETS ZOO ANIMALS LIVE ON.

MEEHAN: THAT SOUNDS LIKE A GOOD NOTE TO CLOSE ON.

NUTRITION OF HERBIVOROUS EDENTATES: TWO-TOED AND THREE-TOED SLOTHS, *Choloepus* sp. and *Bradypus* sp.

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The order Edentata contains the anteaters, armadillos and sloths, three unique forms of mammal. The word edentate is indeed a misnomer, for the anteaters are the only members of the order without teeth. The armadillos and sloths each have teeth but these are rootless, peglike and lack enamel; they grow continuously throughout the animals life. While it is often reported that the number of teeth in these mammals are greatly reduced, this is incorrect. Edentates are confined to the New World, with the vast majority of species restricted to Central and South America.

Sloths are members of the family Bradypodidae and are herbivorous as well as arboreal. Sloths have pouched stomachs capable of holding fair quantities of rather bulky food (Grasse, 1955). Of the two living genera of tree sloth, Choleopus and Bradypus, the latter has a more complex stomach and also is more folivorous in its feeding habits.

Bradypus, the Three-toes sloth is rarely exhibited in Zoological Gardens and at the present time there are none exhibited in any North American facility. Choloepus, the Two-toed sloth is exhibited in Zoological Gardens but not commonly. Of the two species of Choloepus, Hoffmann's sloth, C.Hoffmanni is usually exhibited while the so-called Common Two-toed sloth, C.didactylus is infrequently maintained. This is more a reflection of availability than of acclimation to a captive environment and a successful nutritional regimen. Both forms of Two-toed sloth can be acclimated to captive conditions without difficulty while the Three-toed sloth rarely adjusts to captive conditions. The failure of Three-toed sloths to adjust to captive conditions is not only a reflection of inadequate diet but also of inadequacies of environment, as well as the behavioral and physiological uniqueness of the animal itself.

Work on edentates has been pioneered at the Lincoln Park Zoological Gardens. Beginning in 1969 it centered about the nutritional needs of edentates as an order. Initially an assessment of diets in the wild for each form were made then substitute foods were chosen from produce and food products readily available to us. The need for choosing not only comparable food items, but those that were nutritionally sound, acceptable and palatable was important. Careful consideration was also given to those food items which were available on a twelve month basis. Obviously, each of these considerations in itself was important but the latter had the largest impact on the diets per se. Since that time, the edentate research has expanded to include behavior, reproductive biology, development, chromosome analysis, physiology and pathology, among other areas of interest. An integral part of the work has been the comparison of captive data with data collected in nature. This aspect of the research has been ongoing since 1972 on an annual basis (Meritt, 1972 a).

The rationale for the diet offered Two-toed sloths has been previously reported (Meritt, 1970; 1973; 1975 b; 1976a; 1976 b). It is sufficient to say and to again stress the need for variety in the fruits and vegetables offered, and to pay particular attention to the size and shape of the food fed these arboreal mammals (1980 a). The diets developed at the Zoological Gardens for Choloepus have been time tested. The diet is not only adequate for the long term maintenance of these tropical mammals, but is also adequate for reproduction and subsequent development of offspring. Those animals necropsied during the course of this work have shown no nutritional disease nor disease entity related to nutritional disorders or deficiency. Periodic updates continue to be made in the diet offered and the individual food items used (1980 b.).

Three-toed sloths remain an enigma and are a source of frustration to those concerned with attempting to establish captive pairs of small breeding groups. While metabolic and physiological differences clearly exist between two and three-toed sloths, the opportunity for study and detailed research on Bradypus has been limited. McNab (1978) has reported on the energetics of this sloth genus and Parra (1978) has described fermentation in the fore gut of these arboreal foliovores. Montgomery and Sunquist (1978) have discussed the role of solar radiation in energy expenditure by Bradypus. Each of these writers has reaffirmed the unique physiological nature of this sloth and have provided pieces to the puzzle which is yet to be completely solved. The complete puzzle is how to maintain Bradypus in captivity and what to feed it that is an adequate and acceptable substitute diet.

Beebe (1926) was one of the first to point out the difficulties of maintaining Three-toed sloths in semi-captivity, even when fed a natural diet. On the other hand, Tirler (1966) gives an interesting account of his success with these sloths in captivity but under natural environmental conditions and using natural food supplies. His account is perhaps one of the most factual and first hand of any published for Bradypus. Largely due to the influence of both of these authors a portion of the field work undertaken in the Republic of Panama has been devoted to the study of the Three-toed sloth (Meritt, 1977).

Experience with Three-toed sloths beginning in 1970 has demonstrated that these mammals are handleable, nearly tame and not aggressive to their captors within minutes of being removed from the forest. It should be pointed out that every effort was made to capture the sloths with as little physical or psychological trauma as possible and an attempt was made to keep stress to a minimum. The stress factor was a major consideration not only during capture, but also for the first few days in a captive environment.

Three-toed sloths were maintained in the Republic of Panama in large walk-in cages under natural conditions of temperature, including exposure to sun light and access to shade, day length, and weather for Central Panama. They were offered leaves and flowers known to be consumed in nature and an assortment of native fruits and vegetables in appropriate form. Each animal was offered a variety of this food by hand several times each day during day light hours in an effort to stimulate feeding. The sloths behaviorally divided themselves into one of two groups within the first 72 hours of captivity in Panama, those that freely ate and those that refused to eat were taken to their capture locations and released at or near the point of capture. This was done to insure their survival and to keep mortality to a minimum. Those released were monitored and at the end of the study period were all successfully readapted to the natural habitat they had been removed from.

The remaining sloths, those accepting hand feeding or eating on their own, were maintained for varying lengths of time prior to release back to the wild. One dozen adult Three-toed sloths were maintained nearly eighteen months on a mixed diet of fresh native leaves, fruits, and vegetables. Each animal had daily access to freshly picked leaves and/or fruit of Cecropis sp., Ficus sp., carrot greens, chinese lettuce, egg plant, red papaya, banana, green bean, spinach, apple, orange, green pepper, carrot and mango. While no food item was accepted dependably every day, each was acceptable and eaten over time. Three-toed sloths maintained under these near natural environmental conditions, in captivity, in the Republic of Panama, showed a decided preference for diced apple, diced, peeled banana, diced eggplant, whole young Ficus sp. leaves, diced green beans, and spinach leaves.

At the same time these feeding trials were undertaken, selected sloths were monitored daily with an internal temperature probe. Deep core body temperatures were measured at regular intervals beginning at sunrise and ending after sunset. Three-toed sloths took full advantage of the sun, moving into it and orienting themselves for maximum exposure at the earliest opportunity. Body temperature showed an immediate and dramatic rise with expose to the sun. With increased body temperature, came increased activity and food consumption. It was as if the sloths were dependent upon this solar radiation to stimulate activity and with the increased activity, food consumption. Indeed, and significantly, on cloudy or rainy days the deep core body temperature never reached the levels obtained on sunny days. In these instances the sloth were lethargic and rarely even attempted to eat or refused hand feeding. They spent most of their day resting or sleeping in one position or location without moving except for minor positional changes (ie. shifting limbs or looking about). Not only was food refused, but water was not taken and the sloths did not eliminate on these days. With the return of a sunny day and exposure to the sun, activity increased, food was consumed, the sloths defecated and urinated and the core temperature rose significantly. It is clear from the data that there is a critical and minimum temperature in Bradypus below which activity dramatically decreases, food consumption decreases or ceases entirely, and above which these functions/activities return to normal levels. Sloths of both sexes, adult, subadult and juveniles were used in this work and there was no measurable difference in response based on sex, age, body size or weight.

There are further implications of this temperature data. If general activity decreases and food consumption falls off, or ceases entirely, it follows logically that digestion would decrease too. This is reinforced by the absence of elimination when body temperature is low, or more correctly, below the minimum and apparently critical level. It is well known that the organisms responsible for fermentation in other mammals are temperature dependant, not only for function , but for survival, and it follows that these organisms in sloths would respond accordingly to low, as well as high body temperatures. Those bacteria and protozoans responsible for digestive activity in Bradypus are yet to be fully identified. Perhaps when this has been accomplished, the role of temperature on function, both internal and external, can be finitely defined. It is clear that solar radiation, or minimally an external heat source is needed by Three-toed sloths to carry out their normal life processes and insure survival. It must be pointed out that sloths, especially Bradypus are partially poikilothermic and indeed are dependant upon their environment for temperature regulation. In this tropical setting sloths obtain additional energy by using the sun and solar radiation to maximum advantage to increase body temperature.

Preliminary studies have shown that Bradypus can be successfully maintained on substitute food items in a captive environment in nature. It is reasonable to assume that this would also be possible outside of the tropics. However, the environmental needs of this arboreal edentate must be carefully considered and met, if such an effort is to succeed. In addition to temperature, suitable humidity levels, exposure to solar radiation and psychological considerations must be accessed in planning and implimenting such an environment in a zoo setting. With the technology currently available to us in the zoological community, the time is ripe to attempt such an undertaking with the Three-toed sloth, Bradypus sp. This effort is of critical importance because one member of this genus, the Maned sloth, Bradypus torquatus, of Brazil, is critically endangered in the wild. Its ultimate fate and survival may depend upon captive studies with the other members of the genus.

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THE GIANT PANDA-AN HERBIVOROUS CARNIVORE

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INTRODUCTION

Although a member of the order Carnivora the giant panda is herbivorous, feeding predominantly on bamboo in its native montane habitat in central China. Both the skull and forepaw exhibit modifications for bamboo feeding. Large, flat cheek teeth and skull alterations associated with enlargement of the jaw musculature (Davis, 1964; Sicher, 1944) allow a powerful bite and efficient crushing of the hard, coarse bamboo stalks and silicaceous leaves. Elongation of a wrist bone, the radial sesamoid, and rearrangement of muscles normally attached to the first digit gives the panda a mobile, opposable "digit" with which to manipulate bamboo in the process of feeding (Wood-Jones, 1939). Yet the gastrointestinal tract is rather short and simple with no obvious fermentation chambers or other means of retaining bamboo for the digestion of plant fiber, (Davis, 1964). In this respect, the giant panda seems much more similar to other carnivores that do not ingest much fibrous plant material.

In captivity it is not feasible to feed giant pandas exclusively on bamboo. In addition to bamboo (or sometimes a bamboo substitute such as green sugar cane, reeds, tall grasses), giant pandas are often fed a rice gruel containing dairy products (milk, eggs, or powdered cottage cheese), vitamin and mineral supplements, and a sweetener (honey or sugar). Assorted fruits and vegetables are usually offered to provide diversity and treats. In some zoos meat products (canned cat food, chicken, etc.) are given since wild pandas are reported to have a fondness for meat when it is available. In China mutton is considered a good bait for live trapping giant pandas!

GIANT PANDAS AT THE NATIONAL ZOO

Given the persistent problem of a lack of successful reproduction in the giant pandas at the National Zoological Park (NZP), there was considerable interest in evaluating the NZP diet for possible nutritional deficiencies or imbalances. Preliminary intake studies conducted by NZP keepers indicated that about 50% of the bamboo offered was being eaten; portions of the large stalks and smaller stems were left. Unfortunately, there was very limited data available on the composition of bamboo and no data at all on the ability of giant pandas to digest it. By analogy to other grasses and other animals, I (Oftedal) guesstimated that bamboo

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supplied about 0.5 kcal metabolizable energy per gram, and therefore contributed about 40% of the energy in the total diet. The concentrate portion (rice gruel, canned feline diet, dog biscuits) was thought to contribute about one half of total diet energy. On this basis the nutritional composition of the gruel was evaluated and determined to be low in protein, calcium, phosphorus and trace minerals, especially zinc. The diet was revised (table 1) with the inclusion of powdered cottage cheese (a protein supplement) and special mineral and vitamin premixes. The mineral prexim was manufactured to NZP specifications by Zeigler Bros., Inc., Gardners, Pa. The amount of produce fed was reduced although carrots were still useful in enticing the giant pandas onto a scale in the exhibit so weights could be obtained.

The giant pandas continued to play but did not reproduce on their new diets. We realized that better data were needed if more exact diet evaluations were to be possible. In particular research on the composition, consumption and digestion of bamboo by giant pandas was essential since this represents such a large part of both captive and wild diets. A collaborative project was established between the National Zoological Park and Cornell University. One of us (Dierenfeld) tackled this problem as a master's thesis in animal nutrition. Since the procedures and results of the experimental work have been published in detail elsewhere (Dierenfeld, et al, 1982), we will only summarize the findings as they relate to bamboo composition and digestibility by giant pandas.

BAMBOO CONSUMPTION AND COMPOSITION

The amounts of yellow groove bamboo fed over the course of the study varied from 6.8-9.1 kg/day for the male (Hsing hsing) and 2.3-4.5 kg/day for the female (Ling ling). The lower level offered Ling ling reflected her prior level of consumption as well as an attempt to restrict her weight. On a dry matter basis Hsing hsing consumed 5.2 kg bamboo, equivalent to 75% of total diet dry matter, while Ling ling ate 1.8 kg bamboo (54% of diet dry matter). Thus bamboo was the major food component for both animals.

Giant pandas exhibit selectivity in bamboo consumption. At NZP the pandas typically strip off the leaves with their teeth while manipulating the entire stalks with their dexterous forepaws. The largest diameter stems (termed culms for bamboo) are then cracked between the molars and peeled with the teeth to expose the interior which is then consumed. Smaller culms, if eaten, are not peeled.

The bamboo offered to the pandas was composed (by weight) of about 35% leaves, 26% small culms ($<$ 5 mm diameter), 17% intermediate culms (5-25 mm) and 21% large culms ($>$ 25 mm). Both pandas ate most of the leaves, but Hsing hsing ate a greater proportion of the larger culms ($\geq$ 15 mm). Ling ling only peeled culms that were greater than 25 mm in diameter. The residue remaining after feeding was examined for size distribution. For example, Hsing hsing left a residue consisting of 4% leaves, 31% small culms ($<$ 5 mm), 4% intermediate culms (5-15 mm) and 61% shards or strippings from peeled larger culms ($\geq$ 15 mm diameter).

This selectivity in feeding suggested that the leaves, various size culms and exterior ("cuticle")and interior ("pith") of the large culms should be analyzed separately (Table 2). Bamboo leaves were lower in dry matter and cell wall than the various size culms, but higher (on a dry matter basis) in crude protein, hemicellulose and ash. Preference for leaves implied selection of the bamboo parts of greater protein and mineral content. Of the various plant fiber fractions (cellulose, hemicellulose, and lignin) hemicellulose is apt to be most digestible for an animal that does not rely extensively on fiber fermentation by symbiotic gut microorganisms. Leaves also proved to be high in silica, however, which reduces fiber digestibility in most herbivores.

Comparison of the various size culms did not reveal any obvious or consistent differences that could explain selectivity by pandas (Table 2). All culms were very high in cell wall (80-88% of dry matter) and low in protein (2-4%) and thus did not appear to be good sources of digestible energy or protein. The largest culms were fragmented by giant pandas into pith and cuticle fractions with only the former consumed, but by analysis these two fractions were not much different (Table 2). Perhaps mechanical properties, such as abrasiveness or splintering, are important to giant pandas. It is hard to understand why giant pandas go to the trouble of selectively eating the rather low quality pith.

BAMBOO DIGESTIBILITY

Giant pandas process their ingested food quickly: markers incorporated into both the liquid and particulate fractions of panda diets are excreted into feces by 5-14 hours after eating. Fecal production is not only rapid but voluminous: on average Hsing hsing generated 13.5 kg feces/day and Ling ling 7.1 kg/day. Visual examination of feces reveals large paricles and chunks of bamboo leaves and culms suggesting that digestion is quite incomplete.

The extent of bamboo digestion was measured by collection and analysis of food (subtrating uneaten portions) and feces over 3 one-week periods. Hsing hsing digested about 51% of the dry matter and 37% of the gross energy of the total diet while Ling ling digested 68% of the dry matter and 52% of the gross energy of her total intake. This difference can be attributed to the differing proportions of bamboo consumed by the two animals. If corrections are made for the digestibility of the non-bamboo dietary items (Dierenfeld et al 1982), it is possible to calculate bamboo digestibility. Both animals showed remarkably similar digestion coefficients for bamboo constituents. Only 20% of the dry matter and 23% of the gross energy in bamboo was digestible. As expected, hemicellulose was the only plant fiber fraction that was partly digestible (27%) by an animal without extensive microbial fermentation in the gut; digestion coefficients for cellulose (8.0%) and lignin (7.7%) were probably not different from zero. Protein in bamboo was highly digestible (90%), however.

The indigestibility of the fiber fractions of bamboo is in part explicable by the very short residence time of bamboo in the giant panda digestive tract. From a theoretical point of view it was of interest to see if longer time for microbial fermentation would have resulted in markedly improved fiber digestion. Leaves, culm and culm pith were subjected to in vitro fermentation tests using rumen inoculum from a cow fed timothy hay. Samples analyzed after 6, 12, 24 and 48 hours fermentation indicated that about 20% of the dry matter of culm and culm pith had been digested by 6 hours but little further digestion occurred thereafter. This 20% probably represents cellular contents rather than cell wall, i.e. the 80-88% of dry matter consisting of cell wall is largely indigestible even with longer time for fermentation. Bamboo leaf was only somewhat better: nearly 40% of dry matter was digested by 6 hours, but only about 50% by 48 hours. There seems to be little advantage in retaining bamboo leaves or culm for fermentation in the gastrointestinal tract for more than 6 hours. Giant pandas have opted for short retention times that allow the processing of large amounts of bamboo since the extent of potential fiber digestion is limited.

CONCLUSIONS AND APPLICATIONS

Giant pandas digest only about one fourth of the energy and one fifth of the dry matter in bamboo. In the wild they must consume great quantities to compensate for the low digestible energy content of bamboo (about 0.6 kcal/g fresh weight basis or 1.1 kcal/g dry weight basis). In captivity the low digestible energy content of bamboo implies that even though one half to three quarters of diet dry matter is composed of bamboo, the proportion of digestible energy provided by bamboo will be much less. Our digestion trials indicate that about 45% of the total digestible energy intake of Hsing hsing and 26% of the total digestible energy intake of Ling ling come from bamboo. By contrast the concentrate portion (rice gruel, canned feline diet) supplies about 50-60% of digestible energy intake. Our initial diet revision assumed that 50% of metabolizable energy (i.e. digestible energy-urinary energy excretion) was derived from bamboo; this value appears to be essentially correct. We now can have much more confidence in the diet revisions implemented prior to this research.

The digestible energy intakes for Hsing hsing and Ling ling were calculated as 11,900 kcal and 7600 kcal, respectively. If a wild giant panda were to eat sufficient bamboo to match or exceed the digestible energy intake of these captive animals they would need to consume more than 13-20 kg of bamboo daily. This consumption level is a remarkable feat for an animal weighing about 110-120 kg!

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TABLE 1. REVISED GIANT PANDA DIET

1.6 kg	Cooked Rice
100 g	Powdered cottage cheese[1]
50 g	Giant panda mineral premix[2]
20 g	Vitamin Diet Fortification Mixture[3]
1 tbsp.	Soybean Oil
2 tbsp.	Honey
1 liter	Water
.5 can	Canned Feline Diet[4]
430 g	Carrots
340 g	Apples
11 kg	Bamboo

[1]American Nutritional Laboratories, Burlington, N.J.
[2]Ziegler Bros. Inc., Gardners, PA.
[3]ICN Pharmaceuticals Inc., Cleveland, OH.
[4]Zu/Preem, Hill's Division Riviana Foods, Inc., Topeka, KA.

TABLE 2. COMPOSITION OF YELLOWGROOVE BAMBOO (Phyllostachys aureosulcata)

Sample	Dry matter	Ash	Cell wall	Hemi-cellulose	Cellulose	Lignin	Crude protein	Gross energy
	%			% dry matter				kcal/g
Leaf	52.0	7.8	65.6	35.7	21.5	6.2	13.4	4.8
Culm:								
<5 mm	61.7	2.3	79.6	25.2	34.3	9.9	3.8	4.6
5–15 mm	57.1	1.2	88.4	22.8	41.1	7.1	2.2	4.6
15–25 mm	67.2	1.2	81.7	23.4	37.4	7.4	3.5	4.7
>25 mm	59.4	1.1	84.5	23.0	40.0	5.9	2.3	—
Pith	65.6	0.9	82.7	22.5	37.9	7.2	1.9	4.6
Cuticle	78.2	0.7	84.6	18.1	41.9	6.2	2.0	—

from Dierenfeld et al (1982)

GENERAL SESSION: PANEL DISCUSSION

Q: DO YOU THINK THE AMBIENT TEMPERATURE IS AS IMPORTANT IN 2 TOED SLOTHS AS IN 3 TOED SLOTHS.

MERITT: NOT AS CRITICAL. IT CERTAINLY IS BETTER TO KEEP ANIMALS LIKE THAT WARMER, BUT IN TERMS OF THEIR LONG TERM MAINTENANCE, SURVIVAL AND REPRODUCTION IN A CAPTIVE ENVIRONMENT, IT ISN'T AS CRITICAL.

Q: I HAVE A QUESTION ABOUT SLOTHS, DO YOU FEEL THAT INCREASED LEVELS OF VITAMIN K ARE NECESSARY?

MERITT: ONE OF THE SIDE THINGS THAT CAME OUT OF THE NUTRITIONAL WORK WAS THAT EVEN ANIMALS STRAIGHT FROM THE WILD, EDENTATES IN GENERAL, BUT ARMADILLOS IN PARTICULAR, SHOWED A PROPENSITY TO BLEED IF THEY WERE INJURED. IN FACT, SOME OF THE FIRST WILD CAUGHT ANIMALS SLOWLY BLED TO DEATH OVER THE COURSE OF THE FIRST SEVERAL DAYS IN CAPTIVITY AND WE DIDN'T KNOW IT UNTIL WE GOT THEM ON THE NECROPSY TABLE. AT FIRST WE DIEN'T HAVE A READILY AVAILABLE SOURCE OF VITAMIN K, SO WE GROUND UP FISH IN OUR COMMISSARY, AND LET IT ROT FOR A COUPLE OF DAYS AND THEN FED IT TO OUR ANIMALS. THEY THOUGHT IT WAS WONDERFUL STUFF. IT WAS TERRIFIC GOING IN, BUT YOU SHOULD HAVE SMELLED IT COMING OUT. THEN WE GOT ON TO A POULTRY PRODUCT WHICH HAS VITAMIN K ACTIVITY. WE NOW INCORPORATE THIS AS PART OF THE VITAMIN SUPPLEMENT ON A ROUTINE BASIS. WE HAVEN'T HAD ANY PROBLEMS AT ALL WITH HEMORRHAGE IN ANY OF THE ANIMALS.

Q: WHAT KIND OF PROJECTS ARE FEASIBLE OR NOW GOING ON IN REGARDS TO THE NUTRITION OF THE GIANT PANDA?

OFTEDAL: THE THINGS THAT COULD BE DONE IN CAPTIVITY WOULD BE VERY INTERESTING. WE STILL HAVEN'T DONE ANY WORK ON MINERAL ABSORPTION. IN SOME ANIMALS YOU CERTAINLY HAVE HIGH LEVELS OF FIBER PASSING THROUGH THE GUT WHICH MAY BIND CERTAIN MINERALS AND REDUCE THEIR AVAILABILITY. SO IT WOULD BE NICE TO KNOW WHAT KIND OF MINERAL DISAPPEAR-ANCES WE'RE GETTING.

DIERENFELD: WE DO HAVE FAIRLY ACCURATE DATA ON THE DAILY INTAKE OF BAMBOO BY WILD GIANT PANDAS AS WELL AS ACTIVITY PATTERNS AND CAN ESTIMATE ENERGY REQUIREMENTS BASED ON THE WORK FROM THE ZOO AND JUST GENERAL NUTRITIONAL KNOWLEDGE. WE SHOULD BE ABLE TO MANAGE THE PANDAS BETTER IN THE WILD BY HAVING THAT INFORMATION-KNOWING EXACTLY HOW MANY CAN COVER A SPECIFIC AREA.

Q: COULD YOU CORRECT FOR POSSIBLE LOSSES FROM OTHER INHABITANTS OF THE EXHIBIT SUCH AS BIRDS OR MICE?

OFTEDAL: THIS IS THE DISADVANTAGE OF HAVING AN INSIDER IN THE AUDIENCE WHO IS FAMILIAR WITH OUR PANDA HOUSE... ACTUALLY THE PANDAS LEARNED BEFORE I DID THAT IF THEY DIDN'T EAT IT, THE GRUEL IN PARTICULAR, THEN THE MICE WOULD. SO THEY WOULD LAP THAT UP RIGHT AWAY. THE FEMALE WAS THE ONLY ONE WHO, IF SHE DIDN'T EAT IT RIGHT AWAY WOULD LOOSE SOME TO BIRDS AND MICE. I TRIED TO QUANTIFY IT BY USING SOME CONTROL PANS, BUT I DIDN'T GET A REAL GOOD EVIDENCE OF IT.

Q: HOW MANY PANDAS ARE THERE IN THE WILD:

A: BEST ESTIMATES IN THE WILD RANGE BETWEEN 1000 AND 2,000, THAT'S AS GOOD AN ESTIMATE AS THEY CAN GET. THE CHINESE A COUPLE OF YEARS AGO ESTIMATED 200-1,000 ANIMALS. IT SEEMS TO HAVE SHOWN A LITTLE BIT HIGHER POPULATION THAN THAT. A COUPLE OF YEARS AGO THE BAMBOO IN A PARTICULAR RANGE OF PANDAS IN CHINA FLOWERED. AFTER IT FLOWERS IT DIES BACK WHICH IS WHY THIS STUDY GOT SET UP, BECAUSE THE CHINESE WERE SCARED OF LOSING THEIR ENTIRE POPULATION OF PANDAS AND REALLY NEEDED TO KNOW WHAT WAS GOING ON. SINCE THEN THE BAMBOO IS RECOVERING IN THAT SPECIFIC AREA. THAT LIMITED AREA WAS REALLY THE ONLY PLACE THAT PANDAS WERE DYING OUT IN LARGE NUMBERS.

Q: YOU INDICATED TO US THAT THERE ARE 2 PANDAS, THE GREATER AND THE LESSER PANDA. HAS THERE BEEN WORK DONE IN THE

LESSER PANDA?

OFTEDAL: WE DID HAVE A STUDENT WHO DID A LITTLE MEASURING OF INTAKE. WE HAVE SOME INTAKE DATA IN ANIMALS GOING INTO LACTATION FOR EXAMPLE. BUT, ITS NOTHING OF ANY DEPTH. IT'S CERTAINLY WORK THAT COULD BE DONE.

DIERENFELD: I'LL ADD JUST A COMMENT TO THAT. I'VE GOT SOME DATA FROM CHINA, THE COLLECTION OF SOME LESSER PANDA FECES AND FEEDING HABITS. I'M ANALYZING SOME OF THE WILD DATA ON THE LESSER PANDA RIGHT NOW AND I'VE ALSO GOT A TRIAL RUNNING WITH LESSER PANDAS IN AUSTRALIA. SO WE SHOULD HAVE THAT NEXT YEAR.

Q: DOES SILICA ACCUMULATION DIFFER SEASONALLY IN BAMBOO?

DIERENFELD: THERE ARE MANY FACTORS WHICH AFFECT SILICA ACCUMULATION. WE DON'T UNDERSTAND THE MAJORITY OF THEM. THERE ARE ONLY ABOUT 2 OR 3 PLANTS THAT HAVE THE LEVELS OF SILICA THAT WE'RE SEEING IN THE BAMBOO RIGHT NOW. CERTAINLY IN THE WET SEASON SILICATE BECOMES MORE SOLUBLE AND THAT ALSO HAPPENS TO BE THE TIME WHEN THE BAMBOO IS GROWING THE FASTEST. IT GETS TRANSPORTED UP INTO THE LEAVES AT THAT TIME. WHEN THE TRANSPORTATION RATE OF WATER FROM THE LEAVES EXCEEDS DEPOSITION, YOU'LL SEE AN ACCUMULATION BECAUSE THE WATER WILL BE LOST SO SILICA CONCENTRATES IN THE LEAVES. THERE'S A CYCLING IN THE WILD, A SEASONAL PATTERN THAT WE HAVEN'T FIGURED OUT YET. IT DOESN'T FOLLOW RAIN FALL, IT DOESN'T FOLLOW TEMPERATURE, WE DON'T KNOW WHAT IT FOLLOWS.

Q: DO YOU KNOW WHAT THE DIETS ARE THAT HAVE BEEN USED BY THE ZOOS THAT HAVE HAD REPRODUCTIVE SUCCESS WITH GIANT PANDAS?

OFTEDAL: MEXICO FEEDS A CHICKEN TO THEIR PANDAS. THE PEOPLE WHO HAVE DONE THE MOST WORK ON RESEARCH ON THE GIANT PANDA HAVE THE LEAST TO SHOW FOR IT. WE STILL HAVE 2 LIVE ANIMALS AND I SUPPOSE THAT'S SOMETHING. BUT, A TREMENDOUS AMOUNT OF RESEARCH HAS BEEN DONE ON THESE 2 ANIMALS, WITH A TREMENDOUS AMOUNT OF FRUSTRATION. THE CHINESE HAVE MORE THAN 2 ANIMALS AND I THINK THAT IS PERHAPS THE BIGGEST REASON WHY THEY HAVE BEEN ABLE TO BREED THESE ANIMALS IN CAPTIVITY. WHY ARTIFICIAL INSEMINATION TOOK IN SPAIN THIS YEAR WHEN IT DIDN'T TAKE HERE, NO ONE KNOWS. THE ANSWER TO YOUR QUESTION IS NO, THERE IS VERY LITTLE WORK EXCEPT FOR WHAT'S GOING ON RIGHT NOW IN THE WORLD WILDLIFE FUND STUDY IN CHINA. TO MY KNOWLEDGE THERE'S BEEN VERY LITTLE WORK DONE IN SPAIN OR IN MEXICO. IT'S ALSO VERY HARD FOR US TO GET INFORMATION ABOUT WHAT'S GOING ON.

Q: HOW DID YOU KNOW WHAT ADEQUATE LEVELS OF VITAMIN K IN SLOTHS WERE?

MERITT: WE DON'T. BASICALLY, WHAT WE DID WAS ADD VITAMIN K AT A CONVENIENT LEVEL AND AT A LEVEL THAT CORRELATED WITH THE LEVELS YOU WOULD GIVE TO AN ANIMAL THAT WAS HEMORRHAGING AND THEN BACKED OFF OF THAT. WE THEN LOOKED AT IT LONG TERM TO SEE WHAT WAS KIND OF MINIMAL NEED. WE DIDN'T WORRY ABOUT TOXIC LEVELS OF VITAMIN K BECAUSE WE KNEW THAT WE'D HAVE TO FEED A TREMENDOUS AMOUNT TO ATTAIN IT.

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