



Rotterdam Zoo
Veterinary Faculty of Utrecht

First European Zoo Nutrition Meeting
Friday 8th January - Monday 11th January 1999

Rotterdam, The Netherlands

ABSTRACT BOOK



Utrecht University

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Dr. Andrea Fidgett
Wim van der Horst
Rotterdam Zoo
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FOREWORD

Dear congress participants

In order to improve the welfare of zoo animals it is essential to provide a good diet, which fulfils as many aspects of a natural diet as possible. Although a lot of research has already been conducted and more is ongoing, there is still a great need for further research in the field of zoo animal nutrition. Exchange of research results is essential in improving zoo animal diets.

When we started organising the First Zoo Animal Nutrition Meeting, we believed in the statements above, but did the zoo world support them? From the numbers of participants from many different countries, and the number of talks and poster presentations at this conference, it is clear that zoo animal nutrition does play an important role within the zoo world.

The organisers of this conference hope that the meeting furthers our collected knowledge of zoo animal nutrition. It is also hoped, that by bringing interested individuals from zoos, research institutes and food industry together during the course of the next few days, this will lead to more productive co-operation and communication between zoo animal nutrition experts in the future.

This conference could not have happened without the full co-operation of Rotterdam Zoo, the EAZA Research Group and the Large Animal Medicine and Nutrition Department of the Veterinary Faculty of Utrecht. Sponsorship by several companies is also very gratefully acknowledged. In addition to the above-mentioned institutes and companies, I would like to acknowledge the assistance of students, the volunteers of Rotterdam Zoo and the VVV Rotterdam for the hotel bookings. Three people also require special thanks: Dr. Jean-Michel Hatt (University of Zurich), Andrea Fidgett (University of Glasgow) and my voluntary personal secretary Wim van der Horst.

January 1999
Joeke Nijboer

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PRESENTATIONS

THE APPLICATION OF NUTRITIONAL SCIENCE IN THE FEEDING OF ZOO ANIMALS

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Nutritional science applied to zoo animals is a new field. In 1950's, Wackernagel at the Basel Zoological Garden was a pioneer in recognizing the importance of nutrition. Rational diets were made in house for many species using knowledge of the requirements of domestic animals. In the 1930's H.L. Ratcliffe began to formulate complete diets for animals at the Philadelphia Zoo. Few, if any, suitable, nutritionally complete feeds were available commercially.

In the late 1950's a white-tailed deer herd associated with the Department of Natural Resources in Michigan provided the first opportunity to establish nutrient requirements of this ruminant, which resulted in the formulation of complete pelleted feeds that were ultimately marketed for zoo herbivores. Another important outcome was the establishment of known nutrient requirements for white-tailed deer. This model is used when formulating rations for most browsing herbivores. Michigan State University (MSU) formed the Comparative Nutrition Group to foster the education and training of students in this field. Many student projects were conducted at the Detroit and San Diego Zoos and involved nutritional studies with birds, reptiles, amphibians and mammals. Such training at other universities in the US and abroad is increasing. The presence of trained nutritionists in zoos provides yet more opportunity for research. The more rapid advances in this field during the last 30-40 years are attributable to a number of factors; university involvement, opportunities for training and research, and the recognition by zoo administrators that adequate nutritional management is essential to preventive medicine.

Odd habits and beliefs crop up concerning the feeding of zoo animals. Most are harmless but others may involve risk. Most of us welcome the involvement of reputable feed companies, but regulation of products is poor. A well-trained staff nutritionist is not only a safeguard against such practices, but is an important member of the decision making team concerning animal care and well-being.

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THE FORMATION OF A NUTRITION ADVISORY GROUP FOR THE AMERICAN ZOO AND AQUARIUM ASSOCIATION (AZA)

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In 1994 the American Zoo and Aquarium Association (AZA) Nutrition Advisory Group (NAG) was formed. The mission of the Nutrition Advisory Group (NAG) is to promote the welfare of animals in captivity by incorporating the science of nutrition into their husbandry. The goals are to:

- 1) Identify nutritional and dietary problems in zoos and facilitate their resolution.
- 2) Establish a mechanism for the review of nutritional and dietary information provided by AZA committees and subgroups.
- 3) Coordinate acquisition and dissemination of information regarding nutrition.
- 4) Encourage and coordinate nutrition-related investigations among zoos and collaborating institutions.

The purpose of membership in the NAG is to provide service to AZA. The main client of the members is the Zoo. The NAG began with nine members and now has 52 members and affiliates from the zoo community, academia, and industry. There also is an executive committee of nine established. This committee works to represent the NAG, and liaise with other groups and organizations on behalf of the NAG, make decisions concerning the NAG and its activities, coordinate and disseminate information, facilitate the performance of action plans, approve and appoint NAG members and advisors, appoint sub-committees and task forces, review or appoint reviewers of publications.

Nutrition is a science integral to the good management of zoo animals and must be addressed in a scientific and professional manner. The formation of a NAG gave the discipline, and/or practice of nutrition appropriate recognition. It allows for better communication and coordination among nutritionists and those requiring nutrition information (zoos). It helps provide leverage for accomplishing projects, research and or dealing with zoo nutrition and industry problems.

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CURRENT STATUS OF NUTRITION IN EUROPEAN ZOOS

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An investigation of the current status of zoo nutrition in Europe was conducted by means of a questionnaire sent to European zoos, research institutions and food industries in 30 European countries. Almost 50% of the zoo-questionnaires, 11% of the research-questionnaires and 13% of the food industry-questionnaires were returned.

Responses are used to meet the project objectives set, namely:

- Improve Zoo Nutrition in Europe
- Improve communication between zoos, research and food industry

The main results and conclusions are:

Only in ca. 20 % of the European zoos an animal nutritionist is employed.

80 % of the participating zoos remark that more research towards animal nutrition is necessary.

Most food industries didn't respond. Out of the answers of manufactures which did respond no good general conclusions could be made which were useful for this project.

Research institutions, in spite their low response, seem to be a better potential research partner in future.

Recommendations

Not many zoos do employ an animal nutritionist or conduct research towards animal nutrition. It can be wondered if it is realistic to think that this will change soon for the percentages are still more or less the same as 5 years ago. Some options to improve zoo nutrition can be:

Better communication

If nutrition problems occur a zoo should call a colleague of another zoo. For an EEP animal this can be the EEP-coordinator, or in other cases a zoo which is very successful with the species concerned. To improve these contacts a list or Internet site can be made on which these addresses can be found. Internet, newsgroups, synchronised computer programs and regular meetings can improve communication, too.

Contract out research

As zoos are often not able to conduct their own research, they could contract it out. A list with potential research partners can be made.

Fact sheets

Fact sheets can be made for species kept in European zoos. They can form a valuable database, for instance on the Internet, which can be consulted by zoos. These fact sheets can contain all kind of nutritional information.

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THE STRUCTURE OF THE DIGESTIVE SYSTEMS IN FEEDING OF MAMMALS: A COMPARATIVE APPROACH

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Phylogenetic development and structural adaptations determine optimal utilisation of species – or type – specific feeds and of feeding intervals. This basic rule is frequently ignored in zoo nutrition. Economy-based compromises must approach natural conditions again and even consider complex processes of adaptation to plant defence systems and seasonal adaptations/restructuring of the digestive tract.

The relatively simply structured and short carnivore system is robust in comparison to herbivore systems. Hindgut fermentation systems show great phylogenetic diversity (rodents, lagomorphs, hyraxes, perissodactyls, proboscids etc.) but less adaptive plasticity than foregut fermenters (kangaroos, camelids, tragulids, ruminants).

In zoo nutrition underrated and poorly understood is the complex system of salivary glands, which appear to display their multiple function cascades in species browsing on chemically protected ("antinutritiva") plants, not, however, on prefabricated feeds. Similarly, the evolutionary differentiation and co-evolution of ruminants and their main forage plants, as expressed in morpho-physiological variations of several portions of their digestive system, is apparently evened out by standardised feeds with negative long-term results.

The importance of selectivity, seasonal adaptations and limited capabilities to digest cellulose for most larger herbivores (> 3 kg, > 100 kg BW) is emphasised. Metabolic adjustments to photoperiodically induced availability and digestibility of forage plants, regression and atrophy of absorptive structures, cyclic restructuring and hypertrophic response to abundance of freely chosen (selected) nutrients can hardly be simulated under zoo regimes. They must, however, be taken into consideration in order to prevent long-term maladaptation (especially of selective ruminants), breakdown and irreversible destruction of macro – and microstructures of the digestive system, which is originally "designed" for alternating physiological options (e. g. bypass of soluble nutrients).

The widely observed fallacy of generalisations e. g. ignoring feeding type in favour of body mass only which, in turn, is transformed into grossly standardised, prefabricated feeds has been documented frequently as an uncontrolled development from initially compromising nutritional physiology to finally irreversible and fatal pathological processes.

There is sufficient structural evidence that zoo nutrition, by necessity artificial, is a troublesome however rewarding biological art, but can also easily be harmful to captive animals and thus ethically doubtful.

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MINERAL STATUS OF RUMINANTS

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The breeding of rare animals is one of the main goals of zoos. Nutrition is an important component of captive reproduction programs. The assessment of the nutritional and especially of the mineral status of different species of ruminants depends on the knowledge of their normal status. Using the values of mineral concentration in organs which are regarded as the limit values for a sufficient mineral supply in cows and sheep may result in overestimating the incidence of mineral deficiency in wild ruminants. Due to the fact that mineral status is species-specific, organ tissues and hair of different species of ruminants were analysed and compared with domestic ruminants.

Tissues from the liver, kidney, cerebrum, rib, skeletal muscle, heart, lung, aorta, spleen, pancreas, and hair were obtained from ruminants, that were kept in captivity. The animals came from the Zoological Society of San Diego, from the Leipzig Zoo, and from the Zoo Delitzsch, Germany. For comparison, organ tissues from wild living and domestic ruminants were obtained from different locations of Eastern Germany and Northern California.

After dry ashing of samples the Ca, Mg, Fe, Zn, Cu, Mn, and Mo concentration were analysed by atomic absorption spectroscopy (Jarrell Ash 850) or optical emission spectroscopy with inductively coupled plasma (Spectroflame D, Spectro Analytical Instrument).

The mineral status of different ruminants depends on species, age and mineral intake. The results are discussed, and the mineral values limit for a sufficient supply are given in species of wild ruminants.

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COMPARATIVE ANATOMY AND ECOLOGY OF PREGNANCY AND LACTATION IN WILD PIGS

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The nutritional requirements of animals during pregnancy and lactation differ from the requirements of the growing animal, or the non-pregnant adult, as revealed by studies of non-domesticated species. However, relatively little information has been published to indicate the comparable requirements for pregnancy and lactation of most animals in the wild. Similarly, there is surprisingly little information available from the study of animals in zoological collections. Analyses of comparative anatomical and physiological data can contribute to our understanding of the problem. Similarly, behavioural and other data may help to indicate some aspects of the relationship between the pregnant or lactating animal and its environment.

As with many other widespread groups of animals, the nature of the relationships which exist between the various Eurasian, African and Southeast Asian wild pig species and their respective environments during pregnancy and lactation has not attracted specific research attention. This review will firstly seek to gather together what is available, and, on the basis of analyses of this, to seek to establish an investigative framework within which future studies may be undertaken. The anatomical and physiological changes which occur in different parts of the body of the sow during pregnancy and lactation will be described for the different species of pig, and related changes in her behaviour and feeding patterns reviewed.

The other participants in these developments, the fetal and neonatal piglets, will also be presented for investigation. The nature of their nutritional requirements for growth and development will be analysed.

Where data permit, suggestions will be made with respect to conservation management during the pregnancy and lactation of these species.

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STRUCTURAL FLEXIBILITY OF THE INTESTINE OF BURMESE PYTHON (*Python molurus*) IN RESPONSE TO FEEDING. MORPHOMETRY, ULTRASTRUCTURE, AND IMMUNOHISTOCHEMISTRY

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Introduction: Burmese pythons have amazing guts. They consume large meals (up to 100% body mass) after long periods of fasting and adjust the structural and functional parameters of their gut to the actual needs. Within a short time after feeding, they build up an effective and active resorption organ. When the meal is digested the intestine is reduced again to resting state. The adjustment of structure and function of the intestine is rapid, reversible, and is repeated after each meal. Previous studies have shown that the resorptive capacity for various nutrients is upregulated briefly after feeding (Secor and Diamond 1994; *Am J Physiol* 266:G695-705; Secor and Diamond 1997 *Physiol Zool* 70: 202-212), and that dramatic structural changes occur after feeding (Starck and Burann, *Zoology* 101 Supplement 1: 41; Starck and Burann 1998: *Zoology* 101, in press). Within two days after feeding, size of the intestinal mucosa increases to more than 300% of the resting stage. — Immunohistological and morphometric data are presented, that study the cytological mechanism of observed organ size changes.

Methods: Six young Burmese Pythons (*Python molurus*) were purchased from a commercial reptile farm. The animals were kept at 27°C and 50% humidity. Animals were fed live mice every in intervals of 6 weeks. Effects of feeding on intestinal morphology were studied by transcutaneous ultrasonography. For the comparison of effects of feeding on epithelial morphometry, and cellstructure, 3 fed animals were compared to 3 fasting animals. Animals were sacrificed by an overdosis pentobarbital, and tissues were immediately preserved in 5% paraformaldehyde in 0.1m phosphatebuffer for processing for lightmicroscopy and 2.5% glutardialdehyde for eletronmicroscopy, respectively.

Results: Transcutaneous ultrasonography revealed a significant increase of the size of the small intestine and the liver. The size increase reached a maximum within two to three days after feeding. An significant increase of the thickness of the muscle layer could not be detected by ultrasonography, however, morphometry using histological sections revealed a strong increase in muscle layer too. Epithelial morphometry (i.e., size of the resorption surface), enterocyte cell size, and the number of mitochondria increase within two days after feeding to levels highly significant above resting stage. Enterocyte brush border length (microvilli length) and membrane bound alkaline phosphatase activity also increase within short time after feeding. Ongoing studies investigate changes of cell proliferation rates in the mucosal crypts and changes of rates of apoptosis at the tip of the villi as mechanisms that support structural flexibility.

Discussion: Responses of the python's intestine reveal a high structural flexibility that allows the structure and function of the intestine to adjust to the actual needs. Preliminary data show that differential changes of cell proliferation activity drives the up- and down regulation of organ size.

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EXAMINATION OF THE DIGESTIBILITY OF CALCIUM, MAGNESIUM, AND PHOSPHORUS IN CAPTIVE BORN JUVENILE GALAPAGOS GIANT TORTOISES (*Geochelone (elephantopus) nigra*)

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The growth of animals is characterised by high variability and depends largely on food, climate, and environmental conditions. Many diets of zoo animals are low in calcium or have a poor calcium:phosphorus ratio. To achieve an optimal growth, including a healthy skeleton and a powerful shield, a well-balanced supply with calcium and phosphorus is important. The knowledge of the digestibility of the minerals is the basis for a correct supplementation.

Four captive born Galapagos giant tortoises (2 x 1995 / 2 x 1996) of Zurich Zoo were used. The animals had an average weight of 2123 g. They were housed inside at a mean temperature of 23°C, at 65 % humidity, and were exposed to a 12h light:12 h dark day including exposition to UV light. To get an idea of the transit time of digesta, carmin red (approximately 66 mg per kg BW) was given into the food once. After transit time was estimated (8-18 days), the animals were fed the same diet which consisted of vegetables, herbs, and a mixture of different Ca sources (commercially available lime mixture, cuttle bones, egg shells, shell lime). Daily mixed faeces samples of all tortoises were collected from day 8 to day 18. A Weender analysis was performed and the HCL-insoluble ash was used as an endogen indicator for the determination of the digestibility.

The energy content of the mixed feedstuffs was 15.23 MJ/kg dry matter, the crude fibre content was 131 g/kg dry matter, and the protein content was 194 g/kg dry matter. The Ca content of the above described feedstuffs was 5.72 % dry matter and the Ca:P ratio was 14:1. The digestibility of Ca was 61 % ±0.7 (SE). The two other examined minerals, Mg and P, had a digestibility of 62 % and 79 %, respectively.

Other previous studies described, that Ca and P play an important role in the nutrition of reptiles, especially tortoises. During growth, it is even more important to have enough Ca. From these results, the digestibility of Ca, Mg, and P was very good in comparison with other animals.

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WHAT CAN THE NUTRITIONIST DO WITH THE RESULTS FROM THE PATHOLOGIST?

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There is abundant evidence that diet and health are intimately connected (Ullrey and Allen, 1993). A disease may be a primary consequence of nutrient deficiencies or excesses, or it may be complicated by opportunistic microbial invaders that take advantage of the host's decreased resistance.

Disease in many cases will lead to mortality, all animals will die. It is an essential part of zoo management to have a necropsy done on every animal that dies. The main reason is obvious. Zoo management, including the veterinarian, need to know why the animal died. There is, however, much more information to be collected from a dead animal. Every death animal is a sample from a collection and will provide information about the quality of preventive medicine (e.g. parasites), about the presence of carrier status of certain infectious diseases (e.g. mycobacteriose, salmonellose, campylobacteriose, chlamydiöse), but also about possible nutritional problems (e.g. hypovitaminosis A, D3, E; hypervitaminosis A, D3 or Se, Ca deficiency, iron/copper storage, arteriosclerosis, fatty liver).

All these nutritional problems lead to pathological changes of tissues recognisable by the pathologist. The result of these findings will be that the nutritionist will check the diet or to confirm such a diagnosis an analysis of organs can be performed.

However, not always are nutritional problems directly reflected in pathological changes.

Certain postmortem findings (e.g. chronic aspergillosis, candidiasis) are often correlated to a chronically deficient diet resulting in an impaired immune system.

It is even more difficult when a specific disease patterns, all including wasting, are initiated by an inadequate diet, or related to insufficient energy or inadequate protein intake. It is more easy when an animal keeps eating till it dies than when an animal stops eating and dies subsequently. We have seen actually animals dying of starvation, because it was not obvious which shift of keepers was supposed to feed the animals!

In the presentation, examples will be shown to explain the different types of information the nutritionist can "read" from necropsy reports. These examples will be illustrated with some typical cases as regularly seen in our necropsy room.

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IRON IN THE LIVER OF ANIMALS IN THE ZOO; A PATHOLOGIST'S POINT OF VIEW

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The demonstration of iron in organs, especially liver and spleen, is a common finding in the histological evaluation of (zoo) animals. Iron is easy to demonstrate with the Prussian blue stain. There is also an abundance of reference literature about the possible causes and meaning of iron storage (hemosiderosis and hemochromatosis), especially in mynahs, starlings, toucans and birds of paradise.

In combination with additional information like animal's species, diet and disease history the pathologist can say much more on the meaning of these findings. Also the location of the iron in the hepatocytes and/or macrophages (including Kupffer-cells) is essential for evaluating the background of this "storage". In some situations, especially in birds, the spleen can be used to differentiate between a dietary overload or excessive hemolysis.

Etiologically there are several possible backgrounds for iron in the liver: oral intake of iron, infectious diseases, and excessive hemolysis. It is essential to differentiate between the different possible causes, because some involve diet management, others do not.

In a study we re-evaluated the livers of 945 birds (13 orders), 179 New world monkeys (11 families) and 136 artiodactyla (6 families, 32 genera) using Prussian blue, scoring from 0 to 4 for the staining intensity. We also differentiated for localisation: hepatocytes, macrophages or both. The results indicate different sensitivity to iron-storage in different species or groups of animals. There was in some species a remarkable difference in iron load between two larger zoos indicating differences in iron diet contents. In many species iron was only restricted to the reticulo-endothelial-system, which might be related to specific iron absorption by macrophages. This information indicated the need for more research, but above all communication between the nutritionist and the pathologist about the diet in relation to the finding of iron in the liver. In the necropsy reports "iron" should be differentiated in "iron in macrophages" and "iron in hepatocytes". It is also essential in this study that all material is collected from animals that died spontaneously for some pathological reason. It is the opinion of the authors that iron in the hepatocytes is always directly related to iron intake via the gastrointestinal tract unless iron injections were used for therapeutical reasons.

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DIGESTIVE STRATEGIES IN MEAT AND FISH EATING BIRDS

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Birds of prey and fish-eating birds show inter-specific variation in the efficiency with which they digest their food. This variation is associated with differences in gut morphology and digestion rate. We have carried out feeding trials and post-mortem studies of gross gut morphology. These suggest that in both groups there is an apparent trade-off between digestion rate and digestion efficiency; species with rapid digestion tend to show rather inefficient digestion. In raptors there is also a negative correlation between gut size and digestive efficiency. Such a trend is not evident in piscivorous birds, probably due to an overriding link between metabolic rate and gut size. We consider the factors which determine the digestion strategy adopted by a bird species. Fast but inefficient digestion may be selected if the consequent rapid weight loss following a meal results in improved foraging success, giving a greater overall rate of energy gain. This might occur in pursuit foraging birds, which rely on rapid acceleration and agility to catch prey. Finally we consider the implications of variation in digestion strategy for prey selection.

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CAROTENOID METABOLISM IN ORNAMENTAL FISH

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Carotenoids are one of the most widespread groups of natural pigments in nature, with over five hundred identified. The primary source of carotenoids in the food chain is from photosynthetic plant tissue such as algae. Consequently, the vibrant red, orange and yellow pigments in the flesh, skin and exoskeleton of animals such as flamingos, koi, salmon and shrimp are a result of carotenoid ingestion and metabolism. Fish, like other animals, are incapable of synthesising carotenoids *de novo* and therefore acquire them from dietary sources such as plants and crustacea. There is a general tendency amongst aquatic animals to preferentially accumulate xanthophylls rather than carotene pigments. Xanthophylls are a classification of carotenoids which include; Astaxanthin (red), Canthaxanthin (pink), Zeaxanthin (orange) and Lutein (yellow). Carotenes include β -carotene and γ -carotene. The main bank of carotenoids in fish is the integument, within highly specialised cells called chromatophores. Chromatophores are classified according to the colour of pigment that they contain. Erythrophores stock red or orange carotenoids and xanthophores primarily store yellow carotenoids.

Research has been conducted to investigate the pigmentation dynamics of goldfish (*Carassius auratus*). Goldfish belong to the Cyprinidae family, which are able to biosynthesise astaxanthin (red) from lutein sources (yellow). Goldfish with uniform skin pigmentation (n=280) were selected from quarantined stock. Experimental diets which were iso-caloric were formulated with different carotenoid sources. These included sources of lutein, astaxanthin, capsanthin and capsorubin. Combinations and differing levels of carotenoid sources were also used so that eight experimental diets were fed in total. The performance of these diets were compared against a control base diet, devoid in carotenoids. Twenty fish were maintained on each experimental diet during the course of the 12 week trial. Fish were fed at 2% bodyweight per day, in three feeds a day, five days a week. A panel of trained assessors were used to colour assess the fish at weeks 0, 3, 6, 9 and 12. Each fish was scored under uniform fluorescent light against an 8 graded colour chart ranging from pale yellow "1" to deep red "8". In addition to this, groups of fish were also ranked relative to others, thus resulting in a hierarchy of perceived intensity of colour.

Results were analysed using multiple ANOVA. At week 0, all the fish fell between the scores 1 to 3 (pale yellow to yellow). By the end of the 12 week trial, six of the eight diets tested had resulted in significant increases in the colour score of fish. These were lutein sources fed at both 3% and 0.5% inclusion in the diet, the capsanthin source fed at 3% and 0.5%, and a combination of a lutein and a capsanthin source fed at 3%. All colour and ranking scores correlated. The rate of colour change was generally fastest during the first three weeks of the trial. Of all the diets tested, a source of lutein fed at a level of 3% in the diet resulted in the fastest and most significant colour change. No significant decreases in colour were observed 23 weeks following the cessation of supplementation.

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NUTRITIONAL MANAGEMENT OF UNGULATES IN CAPTIVITY - SHOULD WE LEARN FROM NATURAL SEASONALITY OF THE VEGETATION?

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The aim to ensure an adequate nutritional basis for wild herbivores in captivity is difficult to realize in many cases, mainly because of insufficient data on the particular needs of the species. The natural diet is usually impossible to offer, in particular for selective herbivores and for animal species away from their natural climatic zone. To adapt commercial dietary components designed for domestic livestock may be the only alternative in most cases.

However, in temperate climatic zones and close to the polar regions, seasonal variations of the biomass available for consumption of wild ungulates varies several orders of magnitude, both in respect to quantity and to quality. This is mainly a result of the short vegetation period. Wild ungulates in the polar region (but also in temperate zones) consequently are strictly seasonal. Reproductive functions with the highest nutritional demand (late pregnancy and lactation in particular) must be synchronized with the vegetation period. However nutritional strategies are often very different between species. Examples for different ungulate species and feeding types will be discussed. Energy expenditure is greatly reduced in winter in many northern cervids, energy balance is negative in winter and body fat reserves may contribute substantially to winter energy expenditure. Voluntary feed intake and the extent to which body reserves are accumulated during the vegetation period are not only a matter of feed quality and quantity offered, but depend on day length and season. Seasonality of feeding behavior changes seem to be inherited and thus remain present in captivity, even if continuous feed supply is guaranteed since many generations. As a consequence for practical management, northern cervids in particular may need to be fed below voluntary consumption in autumn to avoid the accumulation of body reserves which are not utilized during winter in captivity. A second possible management strategy may use the natural seasonal rhythm. To simulate winter conditions animals may be fed below maintenance and may thereby reduce excess body reserves accumulated previously.

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Regulation of food intake

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Adult individuals are usually characterized by a balance between energy intake and energy expenditure. Food intake is controlled by various feed back loops. Short-term and long-term regulatory systems can be differentiated. The feed back signals are integrated in the central nervous system (CNS) and translated into an appropriate feeding response.

Short-term regulation of food intake mainly involves feed back signals originating in the gastrointestinal (GI) tract. They may be positive (e.g. from the oral cavity) or negative in nature. Distension of the stomach (or the forestomachs in ruminants) leads to the activation of vagal afferents projecting to the nucleus of the solitary tract (NTS) in the hindbrain being connected with the hypothalamus. The presence of nutrients in the small intestine (or rumen in ruminants) is sensed and the information transmitted via vagal afferents or via the release of GI hormones, e.g. cholecystokinin (CCK). Besides CCK, other hormones (e.g. gastrin-releasing peptide and the pancreatic hormones amylin, glucagon and insulin) also play an important role in the regulation of food intake. These satiety hormones act partly via receptors on vagal or splanchnic afferent nerves (CCK) whereas amylin and insulin appear to act directly in the CNS. Feed back signals from the hepatoportal area are postabsorptive in nature. The availability of glucose (propionate in ruminants), the oxidation of fatty acids and the energy status in general appear to be sensed in the hepatoportal area with the signals being transmitted mainly via hepatic vagal afferents.

The lipostatic theory of the long term regulation of food intake and body weight postulates the presence of humoral factors whose concentration depends on the size of the adipose tissue. The most important signals are leptin and insulin whose plasma concentrations increase with the degree of obesity. Both constitute negative feed back signals acting directly on the brain, their main target organ being the hypothalamus, the main integrating center for the control of food intake.

Within the CNS, a plethora of substances interact in a complex system to control food intake. Among them are the neurotransmitters serotonin, histamine, norepinephrine and dopamine and the neuropeptides corticotropin releasing factor (CRF)/melanocortin (MC) and neuropeptide Y (NPY). The anorectic effects of leptin and insulin, e.g., also appear to be mediated via the NPY and CRF/MC systems.

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VARIATION IN ENERGY INTAKE IN EURASIAN OTTERS (*Lutra lutra*): EFFECTS OF LACTATION AND SEASONAL CHANGES

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As Eurasian otters are kept in many countries in Europe, with very different climatological circumstances during the year, it is difficult to advise on food quantities that have to be given to an individual. In this report temperature related energy intake data are presented as a guideline.

Otters are large consumers, daily food intake can mount up to 15% bodyweight in wintertime, or up to 20% bodyweight during lactation. In order to investigate variation in energy intake related to changing seasons and lactation the food intake of 4 otters kept at the Otterpark AQUALUTRA was monitored. All animals were fed an identical diet, consisting on 2/3 of gross energy intake provided by mackerel and 1/3 of gross energy intake from one day old chickens. During the test period all animals appeared healthy and were behaving normally.

Two adult, non pregnant or lactating animals (1.1) of average bodyweight housed in the public accessible enclosures were followed during one year. The animals were fed three times daily ad lib to the point they would not appear from their nestboxes for their last feeding time, then the daily quantity of food given was reduced. When the animals became too aggressive to the keepers because of hunger, the quantity of food offered was increased.

Together with this data on average temperature during the test period were collected, in order to be able to give more specific advise on gross energy intake related to average environment temperature.

Furthermore the effects of lactation on energy intake were studied in two females otters. They were housed in the breeding centre and fed the same diet, the quantities of food offered being determined by the animals in the public enclosures. The animals were fed once daily at the end of the day, the amount was titrated by the aggressiveness of the animals during feeding time and the amount of food not eaten the next morning. Both females were housed under comparable conditions in adjacent enclosures, and were monitored over a period of six months.

One of the females was mated, became pregnant and raised three cubs successfully. The other female, of approximately the same bodyweight, remained unmated and was used as reference animal to eliminate climatological effects.

Results indicate that in winter the amount of food offered should be monitored carefully (weighing the amount given and the amount not-eaten daily!) and increased in our case up to almost 200% compared to the lowest summer averaged week intake. For lactating females the amount increases even more (up to almost 300%). Regarding the fact that an important component of otter diets (fish) is very perishable, husbandry measures are necessary in order to provide the animals a sufficient amount of proper food.

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DIET SELECTION AND FORAGING ECOLOGY IN MACROPODIDAE (KANGAROOS, WALLABIES, AND RAT-KANGAROOS)

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Macropodoids possess morpho-physiological as well as ecological adaptations similar to herbivorous placental e.g. ungulates. Both from the morphology of dentition and jaw mechanics and from morpho-physiology of stomach and gut function, at least three types of macropodids can be distinguished: browsers, intermediate feeders, and grazers. Within the potoroids (rat-kangaroos), a fourth group, the frugivores and subterranean bulb-feeders, can be found.

Kangaroos and their relatives are ideally suited for studies of sex and size differences in feeding ecology, and possible influences of behavioural as well as morphological constraints acting on them. One reason for this is that most of the medium to large-sized species are heavily sexually dimorphic in size, with males growing throughout their lives. This allows an intraspecific comparison of food selection, habitat choice and foraging behaviour not only between sexes but also between age classes and, in case of females (pouch size as an indicator!), reproductive conditions.

Influences of food quality and food availability on selectivity and time budgets were studied for several species of macropods, and possible consequences on social as well as reproductive behaviour will be discussed and related to captive management.

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A REVIEW OF FORAGING NICHES IN RODENTS AND THEIR IMPLICATIONS FOR CAPTIVE MANAGEMENT

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Of all the Mammalian Orders, the Order Rodentia contains the largest number of mammal species. The Rodents comprise a total of 2021 species, which represents 43.7% of all mammals.

They occupy all six zoogeographical regions of the world, and in each region different species have evolved to occupy a massive diversity of ecological niches. This ranges from commensal species such as the Western House Mouse (*Mus domesticus*) to tropical arboreal species such as Prevost's Squirrel (*Callosciurus prevosti*).

In behaviour the rodents are again incredibly diverse and species exist that can provide examples of many different strategies across a wide range of habitats. Rodents show a wide variety of foraging specialisations, since by developing such specialist foraging behaviours each species fully exploits its habitat and reduces competition with other inhabitants of the same area.

However, within a large number of zoological collections the diversity of rodents is poorly known and even more poorly displayed. Despite the large variety in natural diets and foraging ecology amongst rodents, most species are still fed in captivity with exactly the same diet and food presentation techniques irrespective of their wild ecology. For the majority of rodents this consists of a seed mixture fed in a static food bowl. Rodents have the potential to be more effectively displayed if their natural foraging behaviours are utilised, as well as enhancing the welfare of the individuals themselves through providing environmental enrichment. An example of this is the Fat-tailed Duprasi (*Pachyuromys duprasi*). In the wild this animal is a voracious hunter, and given a regular supply of live insects and molluscs can display active hunting behaviour. Zoos must therefore look to what happens in the wild in order to enhance their displays and improve welfare - and rodents should not be exempt from this rule.

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NUTRITION RESEARCH IN ZOO ANIMALS

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The diet of a zoo animal is rarely the same as the species would eat in its natural habitat. Generally a substitute diet has to be designed. Presently in most cases these diets are based on tradition. On these diets many animals survive, and in many cases may even reproduce. However, diet related diseases still occur frequently in zoo animals. The improvement of substitutional diets for better health and longevity depends on a more detailed knowledge of the requirements of the species. Such knowledge may be gained by „trial and error“-studies or through systematic scientific studies on the digestive strategies and physiology of the species. The increasing importance for research on the nutrition of zoo animals is supported by the increasing involvement of zoos in conservation issues. The limits of extrapolation of nutrient requirements derived from domestic animals, for the design of zoo animal diets, are becoming more and more obvious. However, studies with zoo animals are often perceived as not being "good science". One reason for this is the fact that trained scientists are rare to be employed by zoos. Another reason is that the study subjects are not laboratory animals. The number of study animals is generally small, they have a high variability and the environment is difficult to control. Therefore, a major problem is a low degree of standardisation and a high degree of variability.

This paper describes possibilities for the design of nutrition research. Practical examples, with special emphasis on ruminants, are given. The following aspects of research are discussed in relation to nutrition studies: Formulating a problem, developing a research design, setting out alternative hypotheses, appropriate sampling and data collection techniques, and data analysis.

As a conclusion there is an encouragement for rigorously designed scientific projects, with a multidisciplinary approach, that have the involvement of universities. Finally, the need to publish of results of nutrition studies in scientific journals is emphasised.

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STARTING A ZOO NUTRITION SERVICE

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Captive exotic animal management has always included nutrition, but in the last 20 years, several zoos have built nutrition services and developed those that already existed. This paper will briefly discuss some of the issues involved in building a nutrition services and will include information from surveys of the nutritionists currently working in zoos in Europe and North America and their beginnings.

Although zoo nutrition is a relatively new field, its importance is growing quickly among the zoo's community. Nutrition represents one of the many inter-related parts that determine the well being of an animal. If any of the parts fail, animal health may be compromised, and, with it, our ability to conserve endangered species and educate the public.

When starting to work on nutrition at a zoo, a foundation and structure must be created first, upon which to build a nutrition service. That foundation can begin by demonstrating the need for that service. Institution-wide support of a nutrition service is imperative to its success.

The advantages of a nutrition service materialize over the long term, as nutrition problems are not always detected in a timely fashion. Thus, the evaluation of the benefits of a nutrition service may be based on decreased veterinary costs and/or decreased incidence of health problems. Therefore, the best initial approach may be to begin concentrating on the financial aspects.

Zoos are not always ready to support a nutritionist, and therefore it is important to get external support. However, there are a few prerequisites to develop a nutrition service, and the nutritionist can begin working part time on nutrition issues while filling another role at the zoo. This is a good start and may allow the person to develop good working relationships with the curatorial and keeper staff and become familiar with the institution's policies, prior to working intensively with nutrition.

Every institution is different, but there may be some common problems that arise. The staff understanding of the importance of adequate nutrition for the animals is crucial for the success of the nutrition service. If the basic skills are lacking, it is worthless to design great diets because they will not be utilized. It is more important to concentrate on the basic first steps and develop a framework upon which to build later. Building a successful nutrition service takes a period of years, even decades. If the foundation is firm and development takes place in a stepwise fashion, an effective nutrition service can be developed and flourish.

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ZOOTRITION©: WINDOWS®-COMPATIBLE DIETARY MANAGEMENT SOFTWARE

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Zootrition© software is designed as relational databases which will assist in recording and evaluating diets for zoo species in standardized, intuitive formats. This program is designed to incorporate user feedback from a workshop held at the Nutrition Advisory Group meeting in Toronto, Canada (1995). Input at that time indicated a need for a comprehensive system that is user-friendly; able to calculate chemical composition of diets, with appropriate units of measurement; includes a broad nutrient database of feedstuffs (centralized for updating and maintaining accuracy); has the ability to print diet cards and relevant reports; and can link individual animal reproductive and medical information with diet records. Zootrition© has been tested initially by several zoos in the United States and Europe for functionality and usability. Animal information can be entered into Zootrition© by the user, and individual diets can be linked to individuals, enclosures, or other relevant groupings. Animal-level linkages are designed to eventually upload data directly from existing records-keeping systems such as the International Species Information System (ISIS)©, ARKS©, and MedARKS©. Other functions of this software include (but are not limited to): databases with maximal record storage capacity for chemical composition of feeds, diets and species requirements; global and local feedstuff directories that allow for data updates without overwriting the user's locally entered feedstuffs; flexible measurement units; customizable nutrient screens; printout options on most screens; and the ability to save a diet as a feedstuff ("in-house mix") with the original ingredients intact. Feeding tools allow the user to summarize diets into groups from which specialized reports total ingredient amounts for all diets in the group, along with costs, for designated time periods, to provide readily-available ordering, delivery, and economic summaries.

The system requirements for Zootrition© are: Windows® 95 operating environment or better, at least a 486 processor, VGA or better monitor, 16 MB of RAM, and at least 15 MB of available hard-disk space.

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MODERN INFORMATION SOURCES FOR THE ZOO ANIMAL NUTRITIONIST

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The Internet is becoming a very important information source.

Different methods of obtaining zoo animal nutrition information will be explained:

1 Search engines.

A lot of (free) information can be found using search engines. It is estimated that there are currently approx. 2,100 different search engines. This presentation will provide an explanation of how search engines work, how they get their information and how to use them to access specific zoo animal nutrition literature.

2 Alternative search strategies.

Other free sources of information are available on the Internet. For example: Scientific library catalogues and other freely accessible databases.

3 Newsgroups and discussion groups.

Demonstrations explaining where to find news and discussion groups specific to zoo animal nutrition will be given.

4 Stand-alone databases.

The Internet is not the only digital information source. Stand-alone databases are sometimes easier and faster to use.

The pro and contra of all four categories will be discussed. A list with names of relevant sites and databases will be distributed to the participants.

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ANIMAL NUTRITION IN THE NOORDER DIERENPARK ZOO EMMEN

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Organisation

Food management in the Noorder Dierenpark ZOO Emmen is based on a centralised system, in preparation, handling and distribution. All this takes place in the central food centre. There is a team of four people of which three are working full time and one part-timer. This team consists of a part-time nutritionist, a section-head and two assistants. These people are strictly related to the food-centre.

Hygiene

One of the major disadvantages of the system is the risk of contamination through the zoo. This is the reason for having hygiene as a top priority. This is being carried out by maintaining a strict separation of vegetarian and non-vegetarian products in preparing the diets, by strict instructions in handling, storage and routines and of course by thorough cleaning methods.

Logistics

One of the advantages of the system is to be able to manage and control all needs and deliveries. After preparation, the diets are being distributed with a electric van to all sections in the zoo and at the same time dirty trays are being collected. These are cleaned with a dishwasher.

Administration

All records of diets and recipes are processed by a computer and put on screens in the food centre. Any changes in diets can only be carried out after permission of the nutritionist. Recipes are changed according to information written by the (head)keepers, veterinary and zoological staff. The recipes contain information about the quantity and handling of food, the number of animals involved, the products being used and where etc.

Analysis and dietetics

All analyses are carried out with the help of the software programme Animal Nutritionist. Specific health problems related to nutrition can only be sufficiently investigated with a sound administration. In most zoos, this is a major issue, as a lot of information on diets and their consumption is not sufficiently recorded. A professional approach of all the diets is very important because the first thing looked at in case an animal is suffering health problems is nutrition. To be more efficient all zoos should carry out research in close cooperation.

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FOOD SAFETY AND QUALITY ASSURANCE IN THE ZOO

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Quality assurance in general, and in particular veterinary and zotechnical care, are nowadays an integral part of the policy of zoos. Modernization and renovation of zoos is taking place rapidly. Nevertheless, unfortunately the importance of production and preparation of safe food with regard to the health of the animals, as well as establishing a hygienic image through food quality assurance, is underestimated by many.

In cooperation with the Faculty of Veterinary Medicine of Utrecht, two manuals have been produced with the purpose of providing an analytical framework, suitable for implementing basic food safety and food quality control. These contain priorities and protocols regarding purchase of safe food, prevention of contamination, decontamination of products and equipment, and the change of attitudes required to reach high hygiene standards.

The project has been set up based mainly on three concepts:

- International organization for standardization norms for the setting up of systems for quality control (NEN-ISO 9000 series)
- Good Hygienic Practices
- The Hazard Analysis Critical Control Point concept (HACCP)

It can be concluded that when working with these concepts and protocols zoo personnel are able to change attitudes towards better hygiene standards, resulting in lower risks of possible contaminations of animals, personnel and public.

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INTENSIVE CULTURE OF ARTEMIA AS FOOD FOR AQUARIUM FISH AND SHRIMP

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Over the past few decades aquaculture has evolved from a traditional and risky occupation to a mature bio-industry. Initially focussing on a few promising species such as salmon and penaeid shrimp, it has strengthened its viability through systematically solving each bottleneck that occurred as the sophistication of the industry increased.

First, purely biological questions needed to be addressed: what are the animal's zootechnical requirements (temperatures range, light regimes, water quality parameter etc.); what does the animal feed on? Later, with increasing intensification, factors such as hygiene and broodstock management became important. Nowadays, cutting-edge aquaculture-ventures can only survive competition through rigid business management and care for environmental sustainability.

Since zoo biology or aquariophily mainly deals with rare or non-commercial species they could be faced with similar problems as early aquaculture trials. In that respect larval nutrition will surely be one of the first obstacles to be encountered. Due to obvious biological similarities, aquarium holders can learn a lot from aquaculturists' experience.

The purpose of this presentation is to summarise the advantages, the use and production techniques of cultured Artemia as larval food for fish and shrimp larvae.

First it is argued why, or better, under what circumstances it is advantageous to use adult Artemia, and why to culture Artemia rather than to use frozen Artemia biomass. Then, an overview of culture requirements and techniques is discussed, including methods for improving nutritional quality (enrichment) and harvest and storage techniques.

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WHAT MAKES A GOOD EGG? NUTRITIONAL CONSTRAINTS ON EGG PRODUCTION

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Egg production is a demanding process for many birds. Many field studies suggest that the weight of the clutch laid relates to the local food supply, which suggests that food availability might limit egg production; some experimental evidence from supplementary feeding trials support this. Most supplementary feeding trials assume energy is limiting, but field trials with gulls and tits in which the diet quality was varied, have shown that availability of certain nutrients may also limit egg production. Protein quality could, for some species, be important because of the unusual amino acid balance of eggs. Birds might also use body stores of protein to assist with egg production, especially in the supply of limiting amino acids. As feeding trials with zebra finches *Taeniopygia guttata* and gulls suggest, the muscle condition that a female has established before the start of breeding can be an important factor in determining egg production.

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PRIMATE NUTRITION. TOWARDS AN INTEGRATED APPROACH

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"Primate nutrition" on an applied level in Europe refers to more than 20000 primates in about 200 species and subspecies kept in more than 600 institutions. About 85% of the primates are kept in zoos, 15% in research institutions. The latter tend to keep a small spectrum of species only and to feed a more or less standardised diet, which mostly includes a large proportion of commercially available pellets. Contrary to this, zoos rely on fruits, vegetables, insects, various gruels, etc. The diets they feed usually are designed according to local know-how.

The results of an evaluation of about 200 diets fed in 25 zoos and referring to 50 primate species indicate that within a zoo diets tend to be similar for all species. Between the zoos however diets differ considerably even within species in particular with reference to supplements like vitamins and minerals. The sample of diets analysed suggests, that they are not based on generally accepted standards or recommendations and that in a few cases only the feeding ecology of the corresponding species seems to be considered consequently.

This situation possibly reflects that knowledge about nutritional requirements of primates is still poor and must be developed.

The fact that most primates live and have to be kept in social units in which the members compete for access to food leads to feeding schedules which try to avoid social conflicts by offering large amounts of food. Individual food intake thus is neither known nor controllable. The long term effects of this need to be considered. Obesity problems and a tendency to early reproduction in some of the larger populations point to possible negative effects.

Feeding schedules increasingly are used to provide "enrichment" and to stimulate more of a species behavioural repertoire. This adds another aspect to primate nutrition which needs to be integrated.

In order to deal with these and other implications of primate nutrition a complex approach is required which fits with the conservation oriented goals of captive propagation. It is suggested to work out a "feeding ecology" of captive primates, which integrates physiological, behavioural and environmental aspects.

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FEEDING FUSSY FOLIVORES: NUTRITION OF GENTLE LEMURS

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The genus *Hapalemur* comprises five currently-recognised taxa, three of which are critically endangered. They range in size from 700-2300 g, but most weigh less than 1500 g. All members of this genus are specialist feeders on the monocot family Poaceae. The forest lemurs *Hapalemur g. griseus*, *H. g. occidentalis*, *H. aureus* and *H. simus* all spend >85% of their feeding time on bamboos, whereas the marsh dweller *H.g. alaotrensis* spends >95% of feeding time on papyrus, reeds and surface grasses. All are highly selective, choosing shoots, leaf bases, growing tips and pith. These lemurs can thus be classed as highly selective and almost exclusively folivorous. All the *Hapalemur* species are represented in captivity, although most (cf. *H. g. alaotrensis*) only in small numbers. However, folivores are generally difficult to maintain in captivity, because plant material is extremely variable in its nutritional composition, and regular quantities of appropriate forage may be difficult to obtain. Studies of nutrition in both wild and captive *Hapalemur* indicate that these lemurs have a typically folivorous diet containing high protein and fibre and relatively low energy. It is unclear how these small lemurs can sustain themselves on a completely folivorous diet. Constraints of low energy and low fibre digestibility could theoretically be met by: reduction in BMR, specialisations of the digestive tract, and behavioural adaptation. The existence of these strategies in *Hapalemur* is reviewed and recent work from field studies on *H. g. alaotrensis* suggests several implications for captive management: e. g., the diet should be high in fibre to maintain gut function; pelleted diet should be leaf-eater/folivore rather than a primate pellet; large amounts of forage should be provided to allow the lemurs to be selective; and sufficient quantities of fibrous food should be given to allow for nighttime feeding.

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FEEDING BEHAVIOUR IN TWO GROUPS OF BLACK-AND-WHITE RUFFED LEMURS (*Varecia v. variegata*, KERR 1792)

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Obesity is supposed to be a problem in many captive Black-and-white Ruffed lemur colonies. Furthermore, an increase in the number of infants per litter in captive females is reported. Both phenomena are assumed to be nutrition-related.

This study intends to investigate the feeding behaviour of captive Black-and-white Ruffed lemurs in order to provide basic data which can be used in further studies on obesity.

The feeding behaviour as well as the amount and composition of food consumed by 12 Black-and-white Ruffed lemurs kept in two groups of six animals each at the Cologne Zoo was examined non-experimentally over a period of four months. Interactive behaviour was recorded additionally during feeding and non-feeding sessions. Data refer to a total of 220 hours of focal animal sampling. For nutritional analysis, the computer program „The Animal Nutritionist“ (Version 2.5; N-Squared Inc. & Durango Software) was used. The results were compared to recommendations provided by the program as for old-world monkeys and to values from a study by Ganzhorn (1988). The latter refer to nutritional analysis of plants consumed by free-ranging Brown lemurs (*Eulemur fulvus*) and other lemur species which share their habitat with Ruffed lemurs.

In a second, „pilot“-part of the study, the transit times through the gastrointestinal tract for eight different feedstuffs were measured once each in three Black-and-white Ruffed lemurs.

In addition, commercial apples mash, enriched with sucrose (358 % of the original concentration) as well as non-enriched, was offered to two Ruffed lemurs in order to assess preferences.

Data analysis is ongoing. Preliminary results show that the animals consumed a diet that was 50 % to 64 % higher in energy-concentration (Kcal / g DM) than recommended by „The Animal Nutritionist“. With reference to the major constituents, the concentration of crude protein (% DM) in the diets for the two different lemur-groups varied from a low of 39 % to 86 % of the recommendations. Recommended values for fat, carbohydrate and crude fiber were not available. Referring to vitamins, ascorbate (vitamin C) seems to be highly overdosed (642 % - 774 %).

Transit times for the eight feedstuffs tested ranged from 70 min. (apple) to 283 min. (pear). The transit times seem to be higher than those found by Overdorff (1988) for *Eulemur rubriventer*, but seem to be much lower (as seems to be characteristic for small frugivores) than those of the folivorous *Haplemur* species (Santini, 1992) and of the South American *Alouatta* species (Milton, 1981).

A preference for fruits in general and for feedstuffs with high sucrose-concentration was evident.

The preliminary results of this study are compatible with the assumption that obesity problems in captive Ruffed lemurs might be nutrition-related.

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DIET COMPOSITION AND DIGESTIBILITY IN CAPTIVE BLACK AND WHITE RUFFED LEMURS (*Varecia variegata variegata*)

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The composition of the food consumed by two black and white ruffed lemurs in Blijdorp Zoo (Rotterdam, The Netherlands) was studied. The macronutrient and mineral composition of the diet consumed was chemically analysed. The composition was compared with that of diets used in other zoos. The apparent digestibility coefficients of crude protein, carbohydrates, fat and fiber were found to be low. The observed digestibilities will be discussed in the light of the persistent diarrhoea in the lemurs.

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**DIET COMPOSITION AND DIGESTIBILITY IN CAPTIVE EMPEROR TAMARINS
(*Saguinus imperator subgrisescens*)**

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The composition of food consumed by two emperor tamarins in Artis Zoo (Amsterdam, The Netherlands) was studied. The macronutrient composition was chemically analysed and the micronutrient composition was calculated on the basis of product information and food tables. The composition was compared with the nutrient requirements and a commercial diet for New-World monkeys.

The diet consumed contained 14.9% protein when expressed for a dry matter content of 90%. The levels of vitamins A and D₃ in the food consumed were very high and the calcium concentration was low. The apparent digestibility coefficients for the macronutrients were found to be high. The diet contained almost no lignin and the apparent digestibility of the crude fiber fraction was as high as 60%.

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EFFECTS OF WHEAT IN CALLITRICHID DIET

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Captive callitrichids are prone to developing intestinal problems. Captive and natural callitrichid diets differ enormously and diet has been suggested to play a major role in Wasting Marmoset Syndrome. Proteins in wheat, soy and milk are included in callitrichid diets of most colonies given in the literature. These proteins, however, have been suggested to cause an immune reaction in *Saguinus oedipus* and *Callithrix jacchus*. A similar finding relates to coeliac disease in humans. To investigate this observation under controlled conditions, wheat was chosen as a test protein. Twenty-three males and females of the two species were included in the study. All animals were fed the same diet, with the exception that one group had wheat and the other had rice in their diet. The two groups were balanced for species and sex. Soy and milk products were excluded from both diets. Health checks were made continuously throughout the 6 month pilot project. Blood samples and microscopic biopsies from the colon were taken at the beginning, at 3 and at 6 month intervals. Both diets were readily ingested and health status was maintained throughout the study. Results showed changes in the colon and an immune reaction to gliadin, a wheat protein. A further immune reaction was also observed. The results suggest that the diet of captive callitrichids must be reconsidered.

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EFFECTS OF DIETARY CHANGES ON THE BEHAVIOUR AND FAECAL CONSISTENCY OF THREE CAPTIVE EASTERN LOWLAND GORILLAS (*Gorilla gorilla graueri*) AT THE ROYAL ZOOLOGICAL SOCIETY OF ANTWERP

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An important problem with the eastern lowland gorillas (*Gorilla gorilla graueri*) at the Royal Zoological Society of Antwerp was regular re-occurrence of soft faeces. Examination of fresh stool samples often revealed the presence of protozoans. Because medical treatment was not always successful, the hypothesis was tested that this problem might in part be attributed to the animals' diet.

The goal of the study was to evaluate the possible relationships between the current diet, as well as a new improved diet, and the occurrence of soft faeces and the activity pattern of the animals. A series of baseline behavioural observations (2 hours per day (random spread) per animal during 12 days) was started which also allowed more precise quantification of the daily intake of food per animal. For each animal the daily consumed diet was then analysed using the Animal Nutritionist program, and was compared with the diet of wild lowland gorillas and the SSP recommendations for captive animals. A new diet, containing less fruits and concentrates and more green leafy vegetables, other vegetables, leaves and branches than the old diet was proposed and introduced. In comparison with the baseline observations, observations of the situation with the new diet revealed an absence of soft faeces in the 30 year old female and the 41 year old male, combined with a significant increase in food searching behaviour for the female and eating for the male. In contrast, the younger animal (a female of 8 years) showed only a slight reduction in the occurrence of soft faeces and no significant changes in behaviour. It can not be excluded that for this animal the occurrence of soft faeces is related to other factors in addition to diet.

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DIET ASSIMILATION AND PLASMA NUTRIENT CONCENTRATIONS IN THREE SPECIES OF CAPTIVE PTEROPID BATS

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Intake, digestion, and circulating fat-soluble vitamin and mineral concentrations were compared in females of 3 species of captive fruit bats (*Pteropus vampyrus*, *P. hypomelanus*, and *P. pumilus*) fed the same diet. Daily total food intake averaged 28% of body mass on an as-fed basis, or 7% on a dry matter basis. Dietary leftovers contained higher concentrations of protein, fat, P, Mg, and Zn than the diet offered, and lower levels of soluble carbohydrates (CHO), suggesting some nutrient selectivity even in an apparently homogenous diet. Digestibility of dry matter (89 to 94%), protein (76 to 91%), crude fat (51 to 58%), and water-soluble CHO (95 to 98%) did not vary among species. Plasma concentrations of vitamin A (0.02 to 0.05 µg/ml retinol), vitamin D (1.50 ng/ml 25-OH D₃; 93 to 108 pg/ml 1,25 diOH D₃), and vitamin E (0.49 to 1.05 µg/ml α-tocopherol) were lower than in other herbivorous mammals, whereas plasma mineral concentrations were within ranges of other mammals. Body size had no consistent effect on the digestive physiology of these bats. Results indicate that *Pteropus hypomelanus* may provide a suitable physiological model for nutrition studies of other, more endangered, fruit bats.

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NUTRIENT INTAKE OF 1-4 WEEK OLD SUCKLING KITTENS (*Felis catus*): A MODEL FOR ARTIFICIAL REARING OF YOUNG FELIDAE¹

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This study presents data on the daily milk and nutrient intake of the suckling young cat and estimates of the essential nutrient intake for normal growth and development based on the daily intake of metabolizable energy. The values reported may serve as a useful guide for artificial rearing of the offspring of small and large Felidae and for the manufacture of high-quality milk replacer.

Table 1. Body weight and energy intake of lactating queens and their offspring during a 4-week study

Fout! Bladwijzer niet gedefinieerd.	Postnatal week			
	1	2	3	4
Queens (n=3)				
Body weight (kg)	3.29 ± 0.220 ^a	3.09 ± 0.206	2.93 ± 0.165	2.71 ± 0.195
ME ^b intake (kJ/kg/d)	371 ± 31.1	493 ± 19.0	567 ± 31.5	580 ± 24.3
Kittens (n=11)				
Body weight ^c (g)	215 ± 4.5	287 ± 7.5	356 ± 19.4	410 ± 12.6
Body weight gain (g/d)	13.4 ± 0.32	10.3 ± 0.72	10.0 ± 0.77	7.6 ± 0.84
Milk intake (g/d)	47 ± 1.2	44 ± 2.0	49 ± 2.0	44 ± 2.6
Milk ME intake (kJ/d)	206 ± 5.3	191 ± 8.8	216 ± 9.0	193 ± 17.6

^aValues are mean ± SEM.

^bME = metabolizable energy, calculated as: protein × 17.1, lipid × 37.7, carbohydrate × 17.6 (kJ/g).

^cWeight on the last day of the week.

Table 2. Daily milk yield of queens (% of queen's body weight)

Reference	Litter size	Week 1 ^a	Week 2-4	Week 5-9
Zottmann et al. (1998)	3-4	2.74 ± 1.03 ^b	3.87 ± 0.27	2.58 ± 0.62
Present study	3-4	5.01 ± 0.61	5.54 ± 0.33	n.d. ^c

^aWeek post partum.

^bValues are mean ± SEM.

^cn.d. = not determined.

Table 3. Average gross composition of the milk of some species of Felidae^a

	Solids g/100 g milk	Crude protein g/100 g DM ^b	Lipid g/100 g DM	Carbohydrate g/100 g DM
Leopard (<i>P. pardus</i>)	22.6	49.1	28.8	18.6
Lion (<i>P. leo</i>)	30.2	30.8	57.9	11.3
Cheetah (<i>A. jubatus</i>)	23.7	39.7	40.1	14.8
Cougar (<i>F. concolor</i>)	35.5	33.8	52.4	11.0
Lynx (<i>F. lynx</i>)	21.7	47.0	28.6	20.7
Cat (<i>F. catus</i>)	20.1	40.3	26.5	13.6

^aData compiled from Fowler (1986) and Table 4 (present study).

^bDM = dry matter.

Table 4. Cat milk composition, daily nutrient intake and estimated daily nutrient intake of suckling kittens (*Felis catus*) for maintenance and growth

	Milk		Estimated daily intake	
	composition ^a	intake ^b	Maintenance	gain
	g/100 g	g/day	g/kg ^{0.75}	g/100 g ^c
Dry matter	20.1	9.2 ± 0.21 ^d	12.8	38.3
	kJ/100 g	kJ/day	kJ/kg ^{0.75}	kJ/100g
Metabolizable				
Energy ^e	444	203 ± 4.7	282	847
	g/100g DM ^f	g/day	g/kg ^{0.75}	g/100g
Crude protein	40.3	3.7 ± 0.09	5.1	15.5
Lipid	26.5	2.4 ± 0.06	3.4	10.2
Lactose	13.6	1.2 ± 0.03	1.7	5.2
Ash	3.5	0.3 ± 0.01	0.4	1.3
	mg/100 g DM	mg/day	mg/kg ^{0.75}	mg/100g
Sodium	810	74 ± 1.7	103	311
Calcium	800	74 ± 1.7	102	307
Phosphorus	640	59 ± 1.4	82	245
Potassium	48	4.4 ± 0.10	6.1	18.4
Magnesium	47	4.3 ± 0.10	6.0	18.0
	µg/100g DM	µg/day	µg/kg ^{0.75}	mg/100g
Iron	3600	331 ± 7.7	459	1.38
Zinc	3600	331 ± 7.7	459	1.38
Copper	400	37 ± 0.9	51	0.15

^aReferences: Kienzle & Kamphues (1991), Baines (1981), Remillard et al. (1993) and Zottmann et al. (1998).

^bMean values (36 observations on 9 kittens) during weeks 1-4 post partum.

^cUnit: g per 100 g weight gained, cf. p. 3.

^dValues are mean ± SEM.

^eCalculated using the factors given in Table 1.

^fDM = dry matter.

¹This study was supported by the Danish Agricultural and Veterinary Research Council and the Heinz-Wattie's Companion Animal Nutrition Research Unit, Massey University, New Zealand

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OKAPI FEEDING (*Okapia johnstoni*) IN EIGHT EUROPEAN ZOOS

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By comparison of diets fed to okapis in captivity with their natural diet more information can be obtained about how to feed okapis in captivity. In nature they feed mostly on fresh leaves; in zoos they are fed concentrates, roughage (lucerne and browse) and fruit and vegetables.

For one week, all amounts of food consumed as well as the amounts of faeces produced by eight okapis were measured in eight different European zoos. Samples of foodstuff and faeces of okapi were collected and analysed. Average dry matter, crude protein, NDF, ADF and lignin intake were analysed for each okapi. In addition digestion coefficient were calculated for each okapi.

Average dry matter intake in grams/day/okapi for vegetables and fruits was 431 ± 246 , for concentrates $1,737 \pm 392$, for roughage $1,983 \pm 883$ and the total food intake was $4,151 \pm 782$.

Although vegetables and fruits are consumed a lot, they essentially contribute little to the nutrient value of an okapi diet in comparison to concentrates and roughage. Browse intake is poor in winter.

The total food intake is higher in Europe (8,320 gr.) than in North America (8,120 gr.) Roughage is consumed twice as much in North America (4,320 gr.) than in Europe (2,450 gr.). Concentrates are being consumed more in North America (2,520 gr.) than in Europe (1,940 gr.). The intake of vegetables and fruits is higher in Europe (3,930 gr.) than in North America (1,280 gr.). The calculated digestion coefficient for the DM is $71\% \pm 7$, the average Crude Protein digestion coefficient is $78\% \pm 4$, for NDF it is $58\% \pm 9$, ADF $52\% \pm 10$ and the average digestion coefficient for lignin is $34\% \pm 14$.

With the help of this project a nutrition guideline will be set up for the SSP and EEP okapi population.

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RECOMMENDATION FOR FEEDING OKAPI FOR THE EEP AND SSP

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Based on the data collected in eight European zoos and four North American zoos and from the wild, to support optimal reproduction and longevity of okapi, diet changes must be initiated. The comparison of diet intake as consumed indicates that European okapi consumed more food than the North American okapi. However, on a dry matter basis, the North American okapi consume more.

Table 1: Comparison of diet intake as consumed and dry matter intake (grams).

	N. America	Europe	Epulu (Hart, 1989)
Range intake/day			
Produce	0-6,000	1,500-8,800	
Mean	2,500	3,900	23,500 (leaves)
Concentrates	1,200-4000	1300-2,600	
Mean	2,000	1,900	
Roughage	2,200-15,000	800-4,200	
Total, Mean	7,500 +/-1,600	8,200 +/-2,100	
Range DMI/day			
Produce	106-171	190-933	
Mean	126	430	
Concentrates	1,600-3,700	11,300-2,300	
Mean	2500	1,740	
Roughage	2,200-4,100	690-3,450	
Mean	3,000	1,980	
Total Mean	5,500 +/-1,400	4,150 +/-780	4,100

Table 2: Diet analysis (%DMB)

	N. America		Europe		Epulu	
	Range	mean	Range	mean	Range	Mean
CP	17.7-19.6	18.4	15.1-20.5	18.7	12.0-12.9*	12.4*
Fat	1.5-2.01	1.1	2.9-4.5 3.7			
NDF	20.1-38.4	32.3	31.2-50.2	44.2	34.2-51.1	44.7
ADF	14.3-36.9	24.1	17.9-33.8	28.8	23.4-41.1	34.8

*=available protein

As an example of full cooperation, after discussion and review of data, the following are general recommendation to the SSP and EEP for feeding okapis.

- Of the total diet:
- 50% should include a good quality of alfalfa
- 25% must be a nutritionally complete concentrate
- 25% should be produce
- The daily diet intake on a dry matter basis should be 2% of the body weight/day

Browse used for behavioral considerations and in substitution for alfalfa is good if the quality and palatability are poor. Care must be taken to offer approved browse high in protein and adequate digestibility.

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SUPPLEMENTING THE DIET OF CAPTIVE GIRAFFE (*Giraffa camelopardis*) WITH LINSEED EXTRACTION CHIPS

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Captive giraffe (*Giraffa camelopardis*) are known to be, in comparison with free-ranging individuals, deficient in linolenic acid. There is no clear evidence whether this reflects merely a different diet, or whether it will also impair body functions.

However, large numbers of captive giraffe have died with no obvious necropsy results except for serous atrophy of body fat (peracute mortality syndrome of giraffe). A deficiency in linolenic acid could, in theory, make animals more susceptible to factors triggering fat mobilisation, and worsen its effects. Therefore, supplementation with linolenic acid could be understood as part of a prophylactic program against the peracute mortality syndrome.

As linseed contains significant amounts of linolenic acid, the feeding of linseed extraction chips might be a practical way of supplementation.

Captive giraffe with low linolenic acid status in their blood lipids were introduced to a diet that included linseed extraction chips. Blood lipids of animals from which samples were available after the change in dietary regime (n=2), showed an increase in linolenic acid content. One of the animals had a history of skin lesions resistant to treatment. The skin lesions improved markedly during the course of linseed supplementation.

While the long-term effects of either linolenic acid deficiency and linolenic acid supplementation in giraffe remain to be demonstrated, these results suggest that giraffe might benefit from the addition of linseed extraction chips to their diet.

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FEEDING BABIRUSA (*Babyrousa babyrussa*) IN CAPTIVITY

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This paper reviews the available information on stomach anatomy, digestion, foraging behaviour and diet of wild and captive babirusa, in order to formulate a recommended diet for babirusa in zoological gardens.

Although unilocular, the babirusa stomach contains an enlarged area of mucus-producing cardiac glands (>70% of internal surface area *v.* 30% in *Sus scrofa*) with a near-neutral pH and populations of micro-organisms. The true gastric glands are confined to a small gastric unit. Results from two independent digestibility studies on captive babirusa were in concordance with the general characteristics of non-ruminant forestomach fermenting frugivore/concentrate selectors specialised in the fermentation of more easily digestible plant components. Passage time experiments suggested that no part of the digestive tract selectively held digesta longer than any other part and that caeco-colic fermentation may be less important in the babirusa than in the Eurasian wild pig. Behavioural observations on wild and captive babirusa indicated that they usually practise surface foraging, that rooting only takes place in loose soil, that they stand on their hind legs to reach food in higher places and that males tend to monopolise food when animals are fed together.

Published information as well as a recent field study suggest that wild babirusa show a marked preference for fruit and also consume a fair amount of animal material as well as mineral-rich soil and water. Analyses of the dietary habits of babirusa in 25 zoos world-wide revealed food preferences similar to those of wild animals. However, calculation of the nutritional composition of the captive diets revealed a spread in values so large that it is impossible for all of these diets to answer to the nutritional requirements of the species. Using the above information, adapted prediction equations and the animal nutritionist program a recommended diet for babirusa in captivity will be formulated.

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SOME DIET RELATED PROBLEMS SEEN IN BIRDS

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Tracing and correcting diet related problems in (companion) birds is one of the major tasks of an avian veterinarian. Diseases that, in part, are due to an excess or deficiency of one nutrient are: hypovitaminosis A, hypocalcaemia in African grey parrots (*Psittacus erithacus*), goitre in budgerigars and iron storage disease in mynah birds and toucans. Hypovitaminosis A will lead to a metaplasia of the mucus membranes which can lead to chronic rhinitis and respiratory fungal infections.

Seed-based diets are deficient in up to 20 nutrients. Calcium is one of those nutrients and if a seed-based diet is not supplemented with a calcium source like grit this will lead to a secondary nutritional hyperparathyroidism. In African grey and timneh parrots a specific syndrome is known to cause tetanic convulsions due to a severe hypocalcaemia. Oversupplementation of the diet with vitamin D can cause an intoxication of which the initial symptoms are polyuria and polydipsia.

The precise aetiology of iron storage disease in mynah birds and toucans is not fully understood. A low iron and low vitamin C diet are recommended for treatment.

An iodine deficiency, leading to goitre, is most commonly seen in budgerigars that are fed an all-seed diet containing a lot of millet seeds.

Conditions that can be caused by a multi-deficient and / or poorly balanced diet are reproductive disorders, poor feather quality and decreased immunity leading to secondary infections. Besides treating the underlying infection these patients should be switch over to a commercial, extruded avian diet.

Although obesity is not considered a disease by many people it must be considered a problem. Galahs, amazon parrots and budgerigars are especially prone to obesity which can lead to hepatolipidosis and lipoma. Therefore, it is advised to let these birds gradually loose weight.

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NUTRITION OF CROWNED PIGEONS IN CAPTIVITY AND IN THE WILD

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Crowned pigeons (*Goura* sp.) suffer from a negative natural growth of the population in captivity. One of the explanations might be a difference between nutrition of crowned pigeons in captivity and in the wild. In 1995 a questionnaire was sent out to all participants in the European Endangered Species Program for crowned pigeons. An average in nutrients of the five institutions with the best reproductive results was calculated. In 1997 the crop and stomach contents of four crowned pigeons who were shot in Papua New Guinea could be analysed at Research Institute 'De Schothorst' at Lelystad, the Netherlands. In table 1 the results of both investigations are summarised.

Table 1. Comparison between crowned pigeon food in the wild and in captivity

	Zoo-diet (g/kg dry matter) n=5 institutions	Wild-diet * (g/kg dry matter) n=4 pigeons
Crude protein	150 ± 38	96 ± 12
Crude fat	110 ± 16	102 ± 24
Crude fibre	110 ± 21	449 ± 73
Crude ash	120 ± 30	
Phosphorus	2.0 ± 0.8	1.1 ± 0.2
Calcium	4.0 ± 1.7	2.9 ± 0.7

*values from samples taken from the crop

In captivity sometimes the *ad libitum* available mineral stones could have been omitted, there might be other animals in the enclosure as well and seasonal changes in the diet have been omitted. In the data from the crowned pigeons collected from the wild it is also not possible to see seasonal influences, and there were only very few data available.

The most remarkable difference between the diets is the ratio of crude fibre, which is four times as high in the wild as in captivity. The crop and stomach of crowned pigeons in the wild contained a lot of large seeds up to 6 cm long, while in captivity they are only being fed small foodparts. It should be considered to supply the crowned pigeons with larger foodparts. Almost nothing is known about the gastro-intestinal tract of crowned pigeons and it might be useful to conduct research into this topic to determine their nutritional needs. The variation in the diets of the different institutions seem not to have any visible effect on the birds. Of course there are more factors who can influence reproductive results, like zootechnic factors, behaviour and stress.

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EXPERIENCE WITH HAND FEEDING OF PHEASANT PIGEON (*Otidiphaps nobilis nobilis*) SQUABS AT THE PRAGUE ZOO

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In summer 1997 it became necessary to hand-raise four pheasant pigeons (*Otidiphaps nobilis nobilis*) squabs. In all cases the breeding pair left the nest. The eggs were artificially incubated. Length of the incubation was 35, 31, and in two cases 29 days.

There was no opportunity to obtain a commercial squab diet. Therefore we had to create a diet with basic nutrient content similar to the pigeon crop milk (PCM). Based on literature we estimated that PCM contains approximately 74-77% water, 11-13% protein, 5-9% lipids, and 1,2-1,8% carbohydrates. The main problem was to keep a relatively low level of carbohydrates. We therefore prepared three different formulas:

1) Egg yolk (fresh or boiled) and fat free-cottage cheese 1:1, calcium and vitamin B supplement. Content: 65-66% water, 15-20% protein, 13-16% lipids, 2,2-2,5% carbohydrates, and 300-350 mg Ca/ 100g.

2) Egg yolk (fresh or boiled), Canine Milk Substitution Instant« (Waltham Veterinary Services, United Kingdom), Feline Concentration Instant Diet« (Waltham Veterinary Services, United Kingdom) and water 4:1:1:2, calcium and vitamin B supplement, unsaturated fatty acid supplement (Sangrim AV sol. ®), and probiotics (Avibion plv. ad us. vet. ®, Bioveta, Ivanovice na Hane, CR) Content: 54.4% water, 17.5% protein, 23% lipids, 4,5% carbohydrates, and 300-350 mg Ca/100 g.

3) Egg yolk (fresh or boiled), Canine Milk Substitution Instant« (Waltham Veterinary Services, United Kingdom), Feline Concentration Instant Diet« (Waltham Veterinary services, United Kingdom), water, fat free cottage-cheese and row egg white 4:1:1:2:2:2, calcium and vitamin B supplement, unsaturated fatty acid supplement (Sangrim®), and probiotics (Avibion plv. ad us. vet. ®, Bioveta, Ivanovice na Hane, CR) Content: 68-71% water, 16-18% protein, 12-13% lipids, 1% carbohydrates, and 300-350 mg Ca/ 100 g.

The first squab was fed formula No.1. This diet was higher in dry matter than the PCM, however, the ratio of nutrients was correct. Dilution with water made the diet too fluid and difficult to handle. The squab died on day 10 because of *Pseudomonas aeruginosa* infection. It showed good viability and crop emptying but low weight gain. The second squab was fed formula No.2, diluted with water depending on the clinical status of the bird. The bird died on day 4, after a recurrent gas dilatation of the crop. No yeast was found at laboratory examination; the cause of death was dysbacteriosis. The third squab, fed formula No. 3, died at 5 days of age and showed the same symptoms as the previous one. In this bird, moreover, bacterial pneumonia was diagnosed. The last, fourth, squab was fed formula 2 on day 1, and formula No. 1 on days 2 and 3. It had problems with gas dilatation of the crop from the first day. Dysbacteriosis and consequent overgrowth of toxinogenic bacteria was shown in the GIT. This squab died at the age of three days.

Four problems are pointed out:

- 1) ability to digest the mammalian milk protein by squabs
- 2) possibility to add enzymes, IgA and essential fatty acids into the diet
- 3) alternative source for preparation of hand-feeding formulas for squabs
- 4) efficiency versus harmfulness of probiotics

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THE INFLUENCE OF THE HANDFEEDING FORMULA ON THE OCCURENCE OF HEALTH PROBLEMS IN BABY PARROTS

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Handfeeding of baby parrots is becoming a widely used method to increase breeding results and to obtain tame domestic birds. Baby parrots are very susceptible to health problems due to their infant immunity system. Disorders and infections of the digestive tract are very common. Signs indicating health problems are: regurgitation, vomiting, retarded crop emptying, weightloss, retarded growth, listlessness or development problems. Besides micro-organisms (candida, coli, klebsiella) and environmental factors, also the feeding method (temperature of the food, feeding frequency, amount of food, feeding implements) and the composition of the handfeeding formula play an important role. For the handfeeding formula, not only the nutrient composition (e.g., optimal levels of protein, fat, minerals, vitamins) is determining. This paper reviews some less documented, not-nutrient-related properties of the handrearing formula which may influence the condition of the chicks.

It is evident that the handrearing food needs to be of good microbiological quality: absence of mycotoxins (aflatoxins, ochratoxin, zearalenon, vomitoxin), low bacterial counts, low fungal counts. However, microbial infections are seldom apported by the ingredients. During microscopical examination (Gram's staining) of the food, one should not confuse brewers yeast or bakery yeast with candida. Supplementing with lactobacillus has been discussed as a method to induce a natural competitive inhibition of gram-negative and other pathogenic bacteria. Since the added lactobacilli are not autochtonous and therefore do not colonise as well, they should be given daily in order to favor colonisation of autochtonous microorganisms.

The supplementation of acids, seems to be an interesting approach in the control of microbial growth. Also in normal physiological conditions, the production of lactic acid by the autochtonous crop flora is a mechanism to inhibit pathogenic bacteria.

Especially some organic acids (e.g., lactic acid) are useful: besides the production of a low pH environment, they have a specific action on the microbial cell (pass across the cell membrane in their undissociated form). Wood demonstrated satisfactory prophylaxis against candida by adding formic acid to the food.

The consistency of the formula is very important and has to be in function of the age of the chick, feeding frequency, feeding instrument and environmental temperature. Besides the water content, other factors such as the gelatinisation of the starch and the content of soluble fibers (e.g. gums, pectins) influence the consistency. Controlling the consistency only by changing the water content is nutritionally not correct. Formulas which are too thick (often used to reduce the number of feedings) have been revealed to be especially dangerous because they slow down digestion and increase the risk of deshydration.

Attention should also be paid to the taste of the formula: a strong sour or bitter taste can cause regurgitation and vomiting, even with syringe feeding. Furthermore, heat treatment and the addition of digestive enzymes can increase digestibility of the food.

More and more breeders replace their home-made formulas with commercial, prepared handrearing formulas. This tendency opens the way to investigate and optimize all these factors in order to obtain formulas which not only provide optimal nutrition but also help to prevent disease.

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TRANSFERRING BIRDS TO PELLET FEEDING : SUCCESSFUL METHODS FOR DIFFERENT SPECIES

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In the last ten years various companies in Europe as well as in the United States have formulated and produced bird foods in the form of extruded pellets. Conversion difficulties are an important barrier for using pellets by the bird owners.

1. Requirements for a successful food conversion

The breeder will need to receive professional advice from the veterinarian, other bird owners and breeders and the retail shop. Successfully converting a bird will mostly depend on the motivation of the bird owner. The perseverance of the bird owner will in fact determine the success of conversion.

2. The various conversion methods

There are various conversion methods from which the bird keeper can choose, depending on the kind of bird, the habitat, etc. However there are a few general rules which must be obeyed. Convert only healthy birds. Convert the birds individually or per couple, never in a group. Watch the constitution of the droppings. Young birds and birds having been fed with a varied diet will adapt more easily. Freshly bought birds must first get accustomed to their new cage and surroundings.

2.1 The Portions Method : The portions method is fast and safe for the conversion of all healthy birds, especially in the case of larger species. The pellets are mixed with the current diet. The total quantity of food is limited to the normal daily ration. The percentage of pellets will be gradually increased.

2.2 The Combination Method : This method is very suitable to safely convert smaller bird species in a period of 5 to 6 weeks, but is also useful for all birds with converting difficulties. Because smaller species eat only a few grams per day, it is practically impossible to weight out an exact portion for 1 day. This method gives a solution by feeding a portion for 2 or 3 days. Full up a box with a quantity of seed/pellet mix for about 1 month. This mixing box is replenished with pure pellets after each feeding.

2.3 The Free Choice Method : The free choice method is the simplest, yet it takes the longest time. Can be used during the breeding season.

3. A few practical examples

From tests in practical conditions we can draw some important conclusions. There is a great individual difference in the conversion time between different species and between the birds of the same species. It is very possible to convert a parrot within 14 days. This is also possible for smaller birds, but not recommendable, considering the loss of condition.

4. Supplementary tips for a smooth food conversion

If you intend to use sweetening agents to make the conversion easier, first accustom the bird to the taste before using them on the pellets. Install an eating tray filled with pellets close to their favourite sitting place. Use new or uncomfortable eating dishes for the seedmix, use the old familiar or shallow dish for the pellets. Offer the pellets throughout the day and the seedmix only for a few hours. Room birds can be made jealous by showing them that you enjoy the pellets. At the weaning age, young birds will gladly eat the pellets to satisfy their hunger in an easy way (no peeling). It is good to set an example by a bird which already eats pellets. Experience

has taught us that the use of one of the suggested tips can be sufficient to help conversion to a good end.

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ASPECTS OF FEEDING REPTILES IN ZOOS

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Due to the larger number of species-specific adaptations and specialisation, the feeding of reptiles in zoos is a difficult task. We recognise Herbivorous -, Omnivorous -, Insectivorous -, and Carnivorous reptiles. Water supply needs special attention. The main problems are: providing adequate energy, calcium, vitamin A, and iodine.

Piscivorous animals may suffer from thiamin deficiency. Energy provision needs attention and should be related to the physiological status of an animal. Calcium is a key element in the feeding of reptiles. In many reptiles calcium supplementation is a major problem. In the food, the ratio of Ca : P is of importance. Deficiency in calcium leads to a variety of problems such as: insufficient calcification of the skeleton; osteodystrophia fibrosa; osteoporosis; insufficient transfer of calcium to the eggs and the embryo. A drain of calcium occurs in species which produce extraordinary large clutches of eggs. Prevention and therapy are in providing sufficient food of good quality, containing 1 % calcium and a Ca : P - Ratio of 1,2 : 1.

Vitamin D3 deficiency: Signs of rickets occur incidentally in young insectivorous lizards. Prevention is by adding 10.000 IU Vitamin D3 aquosum + 4 g Calcium lactate per litre water.

Hypervitaminosis D3 leads to calcification of soft tissues. There is no known therapy.

Vitamin A deficiency occurs when plain meat is fed. Dosing vitamin A is highly effective.

Hypervitaminosis A occurs in tortoises such as the Hermann's tortoise when dosing 100.000 IU vitamin A or more per kg BW. For therapy food containing Vitamin A or carotene should be avoided. Vitamin B1 deficiency occurs when raw fish meat containing thiaminase is fed. Prevention: heating 5 min. at 80°C or in providing fish free of thiaminase.

Vitamin C deficiency occurs in snakes after non-eating during 6 - 12 months.

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THE CLINICAL EXPERIENCE WITH SALMON CALCITONIN IN THE TREATMENT OF FIBROUS OSTEODYSTROPHY IN A GREEN IGUANA

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A persistent problem in zoo animal nutrition is calcium metabolism. We face almost daily cases of metabolic bone diseases caused by unbalanced mineral-vitamin intake and environmental factors.

In this report a clinical case of fibrous osteodystrophy in a green iguana (*Iguana iguana*) and its treatment with calcitonin is described. A two-year-old female green iguana was presented after the onset of locomotor difficulties, anorexia and intermittent finger twitching. The clinical examination revealed swelling of both femurs and right radius, and renomegaly. X-ray revealed decreased bone density, normal bone marrow cavity along with greatly increased cortical widening of the long bones, as well as early yolk balls. At the time of first biochemistry examination the animal was not hypocalcemic, however, the Ca:P ratio was inverted (Ca - 2.8 mmol/l: P - 2.82 mmol/l).

The treatment was started with an oral calcium and vitamin D supplementation. We used a complex vitamin and mineral product for reptiles (Vitamix Rep®, Biofaktory Praha, s.r.o., CR). Oral calcium (Calcium-Slovakofarma®, Slovakofarma, Hlohovec, SR) and vitamin AD3 drops (Combinat AD3®, Galena s.p., Opava, CR) was added. One month later, when the Ca:P ratio had improved (Ca - 2.8 mmol/l: P - 1.63 mmol/l), the vitamin D product was withheld and calcitonin therapy was initiated. Calcitonin (Miacalcic®, Sandoz) in the dose of 50 U.I. pro toto (1,5 kg BW) was given five times in one-week intervals. During this period the patient still received extra oral calcium and the treatment was done under an UV light source.

The treatment resulted in an alleviation of clinical symptoms accompanying this metabolic disease. The Ca:P ratio (Ca - 2.7 mmol/l: P - 1.79 mmol/l) was corrected and no signs of metastatic calcification were noted.

This is to document our positive experience with salmon calcitonin, which has not yet been widely used for reptile treatment in Europe. We therefore wish to help zoo nutritionists and Zoo veterinarians to understand the processes underlying the clinical symptoms.

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DIETARY HUSBANDRY OF COMMONLY EXHIBITED TERRESTRIAL INVERTEBRATES

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Invertebrates comprise the majority of animal life on this planet (95 to 99% of all recognized species), and have been exhibited in zoos for more than 100 years. Despite their diversity and recognized global importance, invertebrates have traditionally been a relatively neglected group in most zoo collections. However, butterflies and insects are becoming increasingly popular and important exhibit species emphasized not only in zoos, but also botanical gardens, museums, stand-alone facilities, education programs, popular press, and for conservation efforts. This paper will examine the role of nutrition in the exhibition, maintenance, and conservation of terrestrial invertebrates commonly displayed in captivity.

The determination of feeding requirements for invertebrates in captivity, and successful methods for meeting them, is based on a knowledge of the animal's natural history, mouth parts, and gut structure. While artificial diets have been used for decades for mass rearing of insects required in the study of physiology, ecology, genetics, and developing insect control techniques, targeted development of artificial diets for exhibit species or those species in conservation programs has rarely been investigated. Furthermore, studies of interactions of feeding regimes (amounts and frequencies) with environmental factors necessary for proper growth and development have only been sporadically documented for the species of interest. "Natural diets" are thus most commonly employed for captive populations.

Invertebrate (especially arthropod) diets encompass a wide assortment of ingredients including plants, blood, carrion, wood, seeds, nectar, pollen, and other invertebrates. Feeding strategies can be divided into five major categories, with examples and nutrient considerations from each to be highlighted: 1) solid carnivory (mantids, dragonflies, scorpions, and burying beetles), 2) liquid carnivory (spiders and assassin bugs), 3) omnivory (cockroaches), 4) solid herbivory (stick insects, caterpillars, grasshoppers, and snails), and 5) liquid herbivory (aphids and butterflies).

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POSTERS

SOME ASPECTS OF COMPULSORY FEEDING OF REPTILES

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For maintenance and breeding of reptiles in artificial conditions, especially for bringing up hatchlings and supporting of vital functions of weakened individuals, the compulsory feeding is very important. In many cases, the compulsory feeding is necessary for preserving of animal's life. This measure should be used in exhausted animals, during illness and the first period of recovery, when the animal does not begin to eat well without assistance; and also in the cases of giving up of independent feeding at young reptiles in the first months of their life.

Since 1989, Odessa Zoo carries out investigations of optimum kinds of diet and diet combinations, and also of methods of feeding of various groups of reptiles. We investigate not only positive, but also negative consequences of compulsory feeding at reptiles, and the ways of their prevention.

The compulsory feeding at Odessa Zoo brings good results in species such as:

Monitor lizard (*Varanus salvator*), Tegu lizard (*Tupinambis teguixin*), Wood snake (*Coluber jugularis*), Wood snake (*Coluber ravergieri*), Banded chicken snake (*Elaphe quatuorlineata*), Aesculapian snake (*Elaphe longissima*), *Elaphe schrencki*, Grass snake (*Rhabdophis tigrina*), *Vipera ursini*, Common viper (*Vipera berus*), *Vipera libetina*, Cobra (*Naja oxiana*), Anaconda (*Eunectes notaeus*), Boa constrictor (*Boa constrictor*), *Epicrates cenchris*, Python (*Python molurus*), Reticulated python (*Python reticulatus*), Royal python (*Python regius*), Chinese alligator (*Alligator sinensis*), Cayman (*Caiman crocodilus*), American crocodile (*Crocodylus acutus*), Cuba crocodile (*Crocodylus rhombifer*).

For compulsory feeding of big crocodiles we have designed and constructed a special device for fixation of an animal. The foodstuffs and their combinations which are the best for compulsory feeding of reptiles include:

- meat of a rat
- meat of a hen
- meat of a frog
- heart of a rat
- fragments of a rat's tail
- new-born mice
- new-born rats
- young rats of different ages and weight
- dried Gammarus as a source of chitin.

In some cases it is advisable to use liquid and semi-liquid medleys by probe. The best components for such medleys are (in various combinations):

- hen's egg
- female quail's egg
- meat of a rat
- meat of a horse
- cow's liver
- solution of glucose

For the right choice of foodstuff and of methods of feeding, it is strictly necessary to take into account the peculiarities of common feeding of the species, the age of the animal and its physiological state. This consideration not only helps to reach the best results, but also to prevent possible negative consequences of compulsory feeding applied to reptiles without previous correct estimation of all the aforesaid factors. Particularly important at the compulsory feeding of reptiles is the correct choice of temperature conditions for maintenance of the animal.

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THE USE OF LACTOBACILLI FROM THE CROP IN HAND-REARING OF PIGEONS

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Introduction

Hand rearing of pigeons has not been particularly successful. This is mainly due to the specific composition of cropmilk, which is fed almost exclusively to squabs by parent pigeons throughout the first days. Most squabs died by maldigestion and/or septicaemia.

Material and Methods

In the summer of 1995 two experiments were carried out. Eight strains of lactobacilli were isolated from cropmilk (Buhrows et al.1993). In each experiment two groups of squabs were formed. One group was fed with food fermented by lactobacilli and the other with non-fermented food of the same formula. Protocols were set up for hatching of the eggs, fermentation and preparation of the food, personnel and environmental hygiene, handling and feeding of the squabs, climate and behaviour of the squabs. Bacteriological examination of food, the environment and the gastro-intestinal content of the squabs were performed. Died squabs were sent to the department of pathology for necropsy.

Results and Discussion

Experiment 1. Although the squabs grow very well in the first days all squabs died after one week. The squabs showed signs of cropstasis and septicaemia. From the unfermented food, the environment and the intestines of two squab's *Enterobacter cloacae* were isolated. Based on these figures the hygiene, diet and handling were improved for the next experiment.

Experiment 2. All the squabs survived and showed suboptimal grow figures. After 3 weeks the average weight was approx., 220 gram. All squabs were in health condition. Lactobacilli were isolated in high numbers in the intestinal tract of both experimental groups. Exclusively in the group fed with non-fermented food Enterobacteriaceae were isolated from the crop, It can be concluded that handrearing of pigeons gives good perspectives by implanting the protocols.

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EFFECT OF THE DIETARY CALCIUM AND PHOSPHORUS LEVELS ON THE METABOLIC BALANCE OF SOME MICRO- AND SOME MACRO- ELEMENTS IN ONE-HUMPED CAMELS (*Camelus dromedarius*)

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Introduction

The dromedary camel (*Camelus dromedarius*) is vital to the production system of desert and semi-desert areas. Except for fragmentary results from camels in zoos, there is no reliable information about the health status, feeding system and mineral metabolism of camels in temperate conditions. This experiment was designed to study the effects of dietary calcium (Ca) and phosphorus (P) on the metabolism balance of micro- and macro- elements in camels.

Mineral elements are dietary essentials and influence the efficiency of livestock production.

We struck the balance regarding Ca, P, Mg, Na, K, Zn, Fe, Mn, Cu. The goal of this experiments was to calculate recommendations for some of the tested elements.

Material and Methods

A mineral balance (Ca, P, Mg, Na and K) and the metabolic balance of micro-elements (Zn, Fe, Mn and Cu) were examined in three non-pregnant, non-lactating adult female camels, through four serial metabolism trials. Each trial was continued for about 21 days as an adaptation period followed by 6 days collection period, with about 21 days as the interval. In the first trial camels were fed ration which contained 0.56 % Ca and 0.34 % P through addition of 1% of bonemeal, while in the second and third trials, animals fed on rations containing 1.77, 1.72 % for Ca and 0.91, 0.33 % for P in adding of limestone and/or bonemeal. Camels fed in the fourth trial were supplied 0.24 % Ca and 0.18 % P. All the rations were formulated to contain recommended amounts of digestible energy, crude protein and other minerals and vitamins according to the tables of *NRC, 1988*, for dairy cattle. Ca, Mg, Na, K and the micro-elements (Zn, Fe, Mn and Cu) in feeds, rations and feces were determined by atomic absorption spectrometry, while P was measured by using a spectrophotometric method. Out of the analyses logarithmic trend calculations for the maintenance requirements were performed.

Results

Increasing dietary Ca and P resulted in improved apparent absorption of Ca, P and Mg, while an increased dietary Ca with normal P reduced the apparent absorption of Ca, P and Mg, whereas there was no change in Na and K. Fecal excretion of Ca, P and Mg were increased by lowering dietary Ca and P levels. No significant difference was observed in serum levels of all minerals by increasing or decreasing dietary Ca and/or P in all trials. Apparent absorption of Zn decreased in the second and third trial, and was not affected in the fourth trial. The absorption of Fe decreased in the second and third trial and this may be due to an increase in the fecal excretion of Fe, whereas the absorption of Fe increased in the fourth trial. All increases or decreases of dietary Ca and P altered the absorption of Mn and Cu.

Calculated recommendations can be given for some elements and in case of Ca and P there is evidence that rations with 0,56 % Ca and 0,34 % P are meeting the maintenance requirement for adult female camels.

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**THE NUTRITION OF OLD WORLD FRUIT BATS (Megachiroptera) IN CAPTIVITY:
DIETARY STUDIES OF LIVINGSTONE'S FRUIT BAT *Pteropus livingstonii***

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Relatively little is known about the adequacy of diets for captive megachiropterans. The combination of reduced exercise and a plentiful food supply results in captive bats being generally heavier than their wild counterparts. The nutrition and feeding habits of captive Livingstone's fruit bats *Pteropus livingstonii* were studied at Jersey Wildlife Preservation Trust, with the aim of improving their feeding regime. Firstly, feeding behaviour was examined to try and explain why some bats were much heavier than others. Significant variation in time spent feeding and the utilisation of feeding sites was revealed. The bats' daily diet was then evaluated, by weighing the different foods presented. The amount and the number of different food types were found to vary considerably from day to day. Nutritional breakdowns of food items were obtained, and the available literature on fruit bat nutrition was used to compare known nutrient and energy requirements with the levels presented. Recommended improvements to the dietary regime of the bats were made to try and minimise the effect of individual preferences and social status on nutrition. A new diet was proposed, with a reduced daily diversity of food items. The diet was balanced over a weekly period and made nutritionally comparable to the former one, as no health problems, other than possibly obesity, had so far been linked to nutrition. Trials of the modified diet were carried out by presenting known quantities of food items, collecting the leftovers and determining the proportions remaining. This also gave an indication of dietary preferences: for example, acid fruits were found to be the least preferred foods. The diet was then altered to take into account these preferences, distributing the most preferred and disliked items more evenly throughout the week.

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FEEDING ENRICHMENT: A WAY OF STIMULATING NATURAL BEHAVIOUR OF CAPTIVE BEARS

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In Ouwehands Zoo in Rhenen, the Netherlands, a forested bear enclosure of 2 hectares has been established. This enclosure houses 13 European brown bears (*Ursus arctos*) and 8 wolves (*Canis lupus*). The bears are former zoo bears, dancing bears, circus bears and war victims.

This enclosure provides them with a broad range of stimuli encouraging natural behavioural patterns in brown bears. Although most bears show a normal behavioural repertoire, some bears show disturbed activity patterns, stereotypic behaviour and obesity. This can be an indication of reduced welfare, most likely caused by a lack of stimuli in the feeding and foraging ecology of these bears.

It is generally recognised that natural, functional behaviours can be encouraged in captive animals by increasing the physical complexity of their environments. This can be achieved by using species-appropriate furnishings, and by applying methods of feeding that encourage complex (natural) feeding behaviour (Forthman *et al.*, 1992; Forthman Quick, 1984; Hancocks, 1980; Hediger, 1950, 1966; Hutchins *et al.*, 1984: in Carlstead *et al.*, 1991; van Keulen-Kromhout, 1978; Markowitz, 1978; Mettke, 1995 in: Gansloßer *et al.*, 1995; Morris, 1962, 1964).

Feeding enrichment has proved to have significant effects on the behaviour of captive animals exhibited in traditional zoo enclosures (Carlstead *et al.*, 1991; Forthman *et al.*, 1992; Markowitz, 1978; Mettke, 1995 in: Gansloßer *et al.*, 1995). Feeding enrichment seems to be of particular value because it can be relatively cheap, it stimulates all the animals senses promoting exploration and manipulation, and challenges them from a cognitive point of view (Carlstead *et al.*, 1991; Fersen, 1995, in: Gansloßer *et al.*, 1995; Forthman *et al.*, 1992). However, a recurrent problem with feeding enrichment programs for captive bears is that it is not very clear which feeding techniques (in terms of quantity, quality, diversity etc.) ensure long term positive effects on the welfare and behaviour of captive brown bears.

It is speculated that the provision of diets which resemble natural diets in terms of timing, diversity, quantity, quality, seasonal variation and accessibility may constitute an important environmental enrichment for the bears in Ouwehands Zoo. We consider timing, diversity, quantity, quality, seasonal variation, and accessibility as important variables of a feeding enrichment programme.

A study will be conducted, starting January 1999, to gain a better insight into the effects of these variables on the behaviour and welfare of captive brown bears. The purpose of this presentation is to start a discussion on this subject and to obtain valuable input for this feeding enrichment programme.

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ASPECTS OF THE FEEDING ECOLOGY OF WILD TAMARINS: IS THERE SOMETHING TO LEARN FOR NUTRITION IN CAPTIVITY?

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Callitrichines are widely used as laboratory, zoo and pet animals. Despite considerable improvements in the composition of diets, gastro-intestinal diseases remain a major health problem in captive callitrichines. Apart from the chemical and energetic composition of diets, other factors that have received less attention may play an important role for the nutrition of callitrichines, too, e.g. temporal patterns of feeding or the ingestion of whole seeds.

During several field studies of moustached tamarins (*Saguinus mystax*) in north-eastern Peruvian Amazonia, different aspects of their feeding ecology were investigated. Two aspects may be of particular relevance for the nutrition of callitrichines in captivity: temporal feeding patterns and the almost constant ingestion of whole seeds.

Moustached tamarins use gums (mainly from trees of the genus *Parkia* [Mimosaceae]) throughout the year, but especially during periods of reduced fruit availability. The consumption of gums is not evenly distributed throughout the day but takes place mainly in the afternoon. This is considered as an adaptation to the longer period required for the digestion of the long-chained carbohydrates of gums. In contrast, fruits with their readily accessible carbohydrates are mainly consumed in the morning.

Moustached tamarins swallow the seeds of more than 50% of fruit species they consume and void them undigested with their faeces. Dimensions of seeds range from < 1 mm to 2.5 cm length, and most are 1.2-1.8 cm long. More than 90% of all faecal samples include seeds. Thus, the gastrointestinal tract of the tamarins is constantly faced with indigestible, bulky material resulting in a constant mechanical stimulation.

It is suggested that in the captive nutrition of callitrichines aspects like the temporal patterning of feeding and the uptake of indigestible bulky material receive more attention. This could alleviate health problems that persist despite the considerable efforts of optimising the diet of captive callitrichines.

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WHY DO ELEPHANTS EAT SOIL?

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Analysis of soil eaten by elephants from a montaine site at Ngorongoro, northern Tanzania, showed it to consist mainly of clay containing poorly crystallised kaolin. The soil was tested for its ability to adsorb secondary plant compounds, and found to be close to that of pure kaolin. It is suggested that, as well as deriving minerals from the ingestion of soil, elephants also select soil with good cation exchange capacity because this assists them in the detoxification of forest vegetation.

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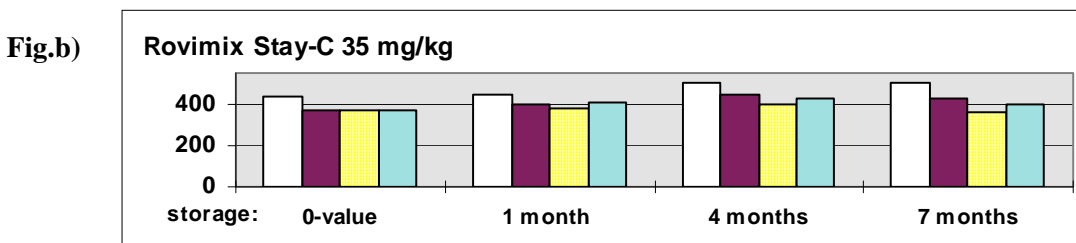
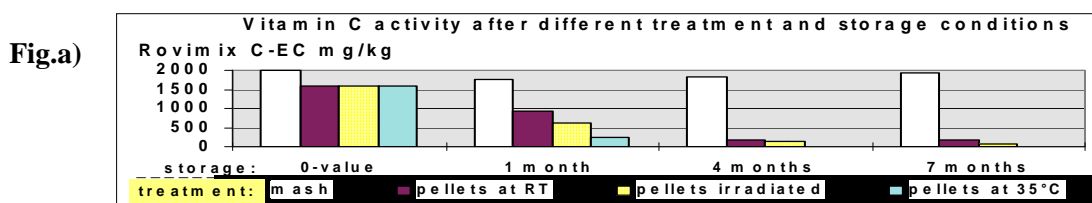
VITAMIN C-ACTIVITY IN GUINEA PIG FEED (KLIBA NO. 3420) COMPARISON OF COATED ASCORBIC ACID (ROVIMIX C-EC) WITH ASCORBYL-MONOPHOSPHATE (ROVIMIX STAY C-35)

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Method: Two lots of guinea pig diet (KLIBA Art. No. 3420) were fabricated with the KLIBA standard procedure (conditioning temperature >90°C) on the same day: lot 1, contained vitamin C in a coated form (Rovimix C-EC) at a dose of 2g/kg; lot 2, contained vitamin C as ascorbyl-monophosphate 35% (Rovimix Stay-C 35) at a dose of 440ppm ascorbic acid equivalents. Samples of each lot were taken before (mash) and after pelleting. Both, mash and pellets of each lot were then divided into two groups, one of which was stored at room temperature (RT) the other was stored at 35°C (stress storage). In addition, pellets of each lot were vacuum sealed, irradiated (minimal dose: 25kGy) and then stored at room temperature. Vitamin C measurements were performed by F. Hoffmann-La Roche Ltd. (standard determination) on the day of production (0-values) and 1 month, 4 months and 7 months after the fabrication day.

Results:



- In the mash, retention of vitamin C activity was retained irrespective of the galenic formulation and storage treatment over 7 months (empty columns, fig. a and b).
- The pelleting procedure (0-values) reduced Vitamin C activity by about 20% in the feed lot with Rovimix C-EC (fig a) and by 15% in that containing Stay-C 35 (fig. B).
- In the pellets with Rovimix C-EC, vitamin C activity decreased however dramatically with time (fig a); after one month, activity was about half of the initial value in the pellets stored at RT and only 15% in pellets stored at 35°C. After 4 months, only 7% of the initial activity remained in the pellets stored at room temperature and was below detection in pellets stored at 35°C.
- Sensitivity of Rovimix C-EC on radiation was difficult to judge from the present data since potentially deteriorating processes during extra handling (sealing, transport temperatures etc.) may have aggravated the time dependent decrease (fig a).
- In contrast, the pellets with Rovimix Stay-C 35 were resistant to radiation as well as to a time dependent decay even after stress storage for 7 months (fig b).

Conclusion: In guinea pig feed (Kliba Art. 3420), the use of vitamin C in form of Rovimix Stay-C 35 guarantees stable Vitamin C activity over 7 months. This activity remains essentially the same after irradiation with >25kGy and during storage even at high temperature.

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AN APPROACH TOWARDS MORE SPECIFIC DIETS FOR TROPICAL BEAR SPECIES - A PUZZLE WITH A LOT OF MISSING ELEMENTS

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Based on the assumption that species are adapted to the seasonally varying diets available in their natural habitat, these diets should meet the specific requirements best. In order to improve the rather vague and crude feeding recommendations within the Ursid husbandry guidelines a project was initiated, to compile in detail the literature data on diet composition of Andean bears, Malayan sun bears and Asiatic black bears in the wild. Simultaneously a survey was done on the composition and amount of diets offered to these bear species in selected zoos. The nutrient composition of the zoo diets was estimated by using currently available compendiums. The same approach was used for the natural food. In cases data were not available for the listed wild food items, values of similar or related known food species were taken.

Even the few studies published revealed, that the bears take a wide variety of mainly vegetarian food. For sun bears insects are important diet components. For some of the naturally taken and for many similar food items nutrient composition could be estimated. Because the amount of each diet component selected by the bears during a certain season is unknown, total nutrient intake in the wild could not be calculated and used for comparison with the zoo diet. Instead the nutrient composition of the zoo diets offered was compared with two standards. The data varied between zoos. The values of several nutrients deviated considerably from the standards. The results are discussed with regard to further research necessary to close the gaps.

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FEED INTAKE AND DIET DIGESTIBILITY OF CAPTIVE RED PANDAS (*Ailurus fulgens*) AT THE TORONTO ZOO

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Red pandas (*Ailurus fulgens*) are unique animals from a dietary point of view. Approximately 95 - 99% of the red pandas' natural diet consists of bamboo, yet these animals possess a gut typical of a mammalian carnivore, completely lacking any type of fermentation site such as a cecum. In captivity however, red pandas are rarely fed a diet solely consisting of bamboo. Red pandas held in North American zoological collections are fed a diet according to the Species Survival Plan (SSP). The focus of this study was to determine how the red panda utilizes the dietary components of the modified SSP diet at the Toronto Zoo. Four dietary treatments were evaluated for feed intake and digestibility: Toronto Zoo Primate Chow and fruits (A), Toronto Zoo Primate Chow alone (B), Mazuri Leaf Eater Primate Biscuit and fruits (C) and Mazuri Leaf Eater Primate Biscuit alone (D). Four red pandas (*Ailurus fulgens styani*) were used in the study in cooperation with the Toronto Zoo. Feed and fecal samples were analysed for dry matter (DM), gross energy (GE), crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF) and ash. Daily DM consumption by red pandas, expressed as a percentage of body weight, was greater than reported for other carnivores, ranging from 1.59 - 2.03% in the present study. The Mazuri Leaf Eater Primate Biscuit had a higher CP content (24.7% vs. 17.4%), a higher ADF content (17.2% vs. 11.8%) and a higher NDF content (29.9% vs. 21.9%) than the Toronto Zoo Primate Chow. However, this higher fibre content in turn affected the digestibility of other components. Diets A and B had a higher dry matter, ADF and gross energy digestibility than diets C and D. Trials A and B resulted in digestibility coefficients of 76.8% and 70.0% for DM, 52.9% and 42.6% for ADF and 74.3% and 74.3% for GE, whereas in trials C and D digestibility coefficients of 65.9% and 62.2% for DM, 35.6% and 34.7% for ADF and 66.3% and 69.2% for GE were obtained. Crude protein and NDF digestibility coefficients were relatively consistent throughout all dietary treatments, ranging from 78.2 - 80.9% and 45.1 - 54.4% respectively. The trend toward higher digestibility coefficients found with the Toronto Zoo Primate Chow diets implies that the chow is utilized to a greater extent than the Mazuri Leaf Eater Primate Biscuit by red pandas. The Toronto Zoo Primate Chow compares well in nutritional composition with the red panda's natural diet, bamboo. Red pandas digest fibre only partially, and protein and gross energy more efficiently. Red pandas at the Toronto Zoo were observed to consume grass in the enclosure, indicating that these animals possibly seek a fibre substitute when bamboo is not available.

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NUTRITION RESEARCH ON NEW WORLD MONKEYS AT JERSEY ZOO

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Problems potentially related to nutrition that have arisen in the collection of New World primates at Jersey Zoo are described. A study of the nutrition of Geoffroy's marmosets (*Callithrix geoffroyi*), initiated because of health problems and high infant mortality, suggested that the diet may have been low in calcium and protein. Alterations were accordingly made to the diet: gum arabic is now provided on a daily basis for all *Callithrix* in the collection, and the proportion of insects in the diet has been increased. Palatability of different concentrations of gum has been investigated to assess the most cost-effective way of maximising gum intake. The diet of pied tamarins (*Saguinus bicolor*) in the collection has also been modified because of several health and related problems: chronic diarrhoea and "wasting"; frequent observations of coprophagy; the relatively common occurrence of premature and stillbirths; and locomotor problems in young pied tamarins that have had to be confined indoors despite dietary supplementation. These problems suggested that this species has high protein and vitamin D3 requirements. Citrus fruits and other potential irritants have been eliminated from their diet, they are supplied with extra insects daily, and gum arabic is given regularly. Increasing protein is difficult, as a study on the palatability of several types of primate pellet showed that the pellets designed specifically for New World primates are not the most palatable. Approaches to increasing palatability and intake are described, included the use of different flavourings, and the effect of reducing the amount of fruit presented on pellet intake. Finally, food preferences in several species have been investigated, with an emphasis on the effects of reproductive status on preferences, and the results are presented.

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GROSS ENERGY AND APPARENT METABOLIZABLE ENERGY INTAKE OF CAPTIVE FELIDS ON A RAW MEAT-BASED DIET AND A CANNED DIET

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Energy requirements previously have been examined for domestic cats and some non-domestic species. This study compared gross energy (GE) intake and apparent metabolizable energy (AME) intake based on metabolic body size (MBS) for a raw meat-based diet (raw) and a canned meat-based diet (canned) for six felid species including *Felis viverrinus*, (n=1), *Felis rufus*, (n=1), *Felis caracal*, (n=1), *Neofelis nebulosa*, (n=1), *Panthera pardus orientalis*, (n=1) and *Panthera leo*, (n=2). Cats were fed their usual amount of raw diet for four weeks (Trial 1). Canned diet was offered for a varying number of days depending on acceptability and stool quality (Trial 2). Quantity of diet offered in Trial 2 was based on mean GE intake for each cat during Trial 1. AME was calculated based on the following formula for domestic cats consuming meat diets: $AME = (3.9 \times \text{protein} + 7.7 \times \text{fat} + 3 \times \text{carbohydrate}) - 5$. GE intake/MBS/d was similar between the canned and raw diet for each cat, but was slightly increased overall with the canned diet. AME intake/MBS/d was slightly lower with the canned diet than the raw diet. P. leo and P.p. orientalis had the most noticeable reductions (15.7 and 14.9 kcal, respectively). This apparent decrease in AME intake may be due to the differences in the proportion of AME:GE in the diets. AME was a larger portion of GE in the raw diets (70-75%) than in the canned diet (65%). Large cats appeared to have greater changes in estimated AME intake/MBS/d between diets than smaller cats. This may indicate that felids of differing body sizes may utilize dietary energy differently. AME intakes for both the canned and raw diets were plotted against body weight. Although data points were limited, an allometric relationship between energy intake and body size was indicated.

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GROWTH OF CAPTIVE HARBOUR SEAL (*Phoca vitulina*) PUPS IN RELATION TO THE FAT CONTENT OF THE MILKFOOT! BLADWIJZER NIET GEDEFINIEERD.

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The milk of pinnepeds contains the highest fat content observed among mammals. The fat content of the mother's milk of the harbour seal (*Phoca vitulina*) is approximately 45%. During a relatively short lactation period, this high fat content enables a high growth rate of the pup (about 0.5 kg/day). Under natural conditions, early weaning is supposed to be advantageous because of the risk that a pup loses its mother during the lactation period which may lead to undernutrition or subsequent death of the pup. Still, each summer about 30 abandoned pups are brought to the SRRC which are often severely undernourished and dehydrated. Upon arrival until 15 days thereafter, seal pups have been fed with Multi-Milk, the only artificial milk product available with a high fat concentration (12% fat). Although pup survival was very high (95% or higher), growth rates were too low (0.1 kg/day), possibly due to a low intake level of energy and fatty acids. In this study, performed during the summer of 1998, we compared the growth performance of seal pups fed on Multi-Milk (control group, n = 25) with those fed on Multi-Milk plus an oil supplement (experimental group, n = 7). The oil supplement has a fatty acid composition which comes close to that of the milk of the harbour seal. The Multi-Milk was added with oil up to 22% fat, the highest fat concentration pups accepted without adverse reaction. We measured the body mass, axillary girth, fat layer thickness, and the amount of body water and body fat (with the ²H dilution method). The first results indicate that during the first 14 days, body mass increase was considerably higher in pups of the experimental group (0.24 kg/day) than those of the control group (0.13 kg/day). In addition, in pups of the experimental group axillary girth increased by 0.7 cm/day, compared to 0.2 cm/day for the control group. In conclusion, the oil supplement had a considerable effect on the early growth performance of the pups, but their growth rates are still lower than observed in free-living animals.

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DIGESTIBILITY STUDIES WITH CAPTIVE AFRICAN ELEPHANTS (*Loxodonta africana*)

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By conducting diet evaluations and digestibility trials on captive African elephants (*Loxodonta africana*), valuable insight into their nutrient utilization and husbandry needs can be gained. The purpose of this study was to examine the digestibility of a diet consisting of equal parts timothy hay (7.6% crude protein (CP), 3.76 kcal/g gross energy (GE), 18.2% acid detergent fibre (ADF) and 29.8% neutral detergent fibre (NDF) on a dry matter (DM) basis) and Toronto Zoo Fibre Plus Herbivore diet (12.7% CP, 3.72 kcal/g GE, 8.6% ADF and 15.2% NDF on a DM basis). Digestibility variation between animals as well as between days was examined. The collection protocol also allowed for evaluation of the effect of length of fecal collection on estimated digestibility. The Toronto Zoo's seven female African elephants participating in this study were housed in indoor pens but were allowed to follow normal daily activity patterns, including exercise in an adjacent outdoor paddock when weather permitted.

Total fresh weight feed intake averaged 370.6kg per day, or 52.9kg fresh weight per animal per day. In comparison, the total fresh weight fecal output averaged 850.0kg per day for all seven elephants, or 121.4kg per animal per day. Mean total dry matter intake and output were 333.7kg and 181.0kg per day respectively, equivalent to a dry matter intake of 47.7kg per elephant per day and output of 25.8kg per elephant per day.

Mean DM digestibility was 45.9%, with mean apparent digestibilities for ADF and NDF of 9.2% and 23.8% respectively. Average organic matter, cell solubles, and hemicellulose digestibilities were 49.2%, 30.8% and 45.6%, respectively while the mean CP digestibility was 42.8%. Average energy digestibility was 44.3%, giving a digestible energy of 1.66kcal/g DM for the combined diet.

An apparent average ash digestibility of -59.1%, with values ranging from 22.1% to -163.1%, was attributed to the environmental conditions, which caused a variation in ash ingestion from day to day. Specifically, on days in which the elephants spent time exercising in the outdoor paddock, extraneous ash ingestion was higher due to activities such as dust bathing. In turn, this high ash content influenced other components of the feces. Protein and other measured organic constituents were inversely related to ash ingestion, presumably due to a dilution effect. Sequential analysis of the apparent digestibilities of dietary components after the 1st, 2nd, 3rd, and 4th day of fecal collection showed a constant trend in the data after 3 to 4 days indicating that this is the minimum period appropriate for a digestibility trial carried out with this species.

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CALCIUM BALANCE AT VARIOUS CALCIUM INTAKES IN THE DRAKENSBERG CRAG LIZARD, *Pseudocordylus melanotus melanotus* (Cordylidae)

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In order to assess the calcium requirement of the Drakensberg lizard (*Pseudocordylus melanotus melanotus*), these lizards were fed different calcium levels and a restricted diet of mealworms. There were four groups, two non-reproductive females in each. The various calcium intakes were realized by oral administration of calcium carbonate containing capsules. Excreta were collected and analyzed for calcium and uric acid. By collecting pure urinary crystals and assuming that the calcium:uric acid ratio present in mixed excreta equals that in urinary crystals, the amount of calcium in the feces could be calculated. The lizards appeared to be able to maintain calcium balance at calcium intakes equivalent to a range of 1.4 and 5.8% calcium in the dry matter of feed. Calcium balance was maintained by adapting intestinal calcium absorption.

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DIET COMPOSITION OF A CAPTIVE COLONY OF WOOLLY MONKEYS (*Lagothrix lagotricha*)

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The world's largest captive colony of woolly monkeys (*Lagothrix lagotricha*) lives at Apenheul. During the day, the female animals and their infants roam freely and mingle with the visitors. The adult males are kept on an island, but during the night all animals are housed in the same enclosure. The major causes of death are renal and liver failure associated with malignant hypertension. The objective of our study was to describe the diet composition of the monkeys. The various foodstuffs provided were recorded and the nutrient composition of the complete diet was assessed using the Dutch food table. In addition, a sample reflecting the whole diet composition was chemically analysed. In an attempt to qualify the nutrient composition of the diet provided, we compared it with the nutrient requirements of New-World monkeys as set by the National Research Council. For further comparison, we also used the composition of four commercial, complete diets for New-World monkeys. The possible relation between the diet provided and the causes of death in the monkeys will be discussed.

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