

Thursday 24th January ~ Chester Zoo

18:00 REGISTRATION & ICEBREAKER (until 20:00)

Friday 25th January ~ Queen Hotel

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Conservation Nutrition: collaborative efforts between nutritionists and field biologists

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A specialty scientific discipline such as nutrition is often viewed by field staff in terms of technical services that can be provided – for example, recommendations for hand-rearing, dietary protocols, or emergency provisioning of wildlife species under given circumstances. While applied feeding information is clearly important in certain, but generally limited, situations, nutritionists can also offer broad perspectives and critical analytical insights that help clarify wildlife interactions with their nutritional resources and environments. Integrative efforts between facilities-based comparative nutritionists and field-based scientists have resulted in development, modification, and applications of techniques and methods for sample preparation, stabilization, and analysis of nutrients that previously could not be evaluated in many field sites due to basic logistical, environmental, or technological constraints. A number of these advances are highlighted. Providing analytical support to field biologists can encompass advising/training in appropriate sample acquisition and storage, to recommending specific chemical assays that are applicable to the sample set, to actually conducting the analyses and assisting with data interpretation/dissemination – all aspects that contribute to solid collaborations. For the zoo biologist, feeding ecology and chemical composition information obtained in the field, if appropriate, can be applied to captive feeding programs. Conversely, nutritional information obtained ex situ, in controlled environments, provides detail that may not be obtainable in the field. Thus combining data, personnel, and skill sets may prove most comprehensive. Nutritional components are increasingly included in health assessments by wildlife veterinarians, and play a significant, but as yet underappreciated, role in reproductive and disease dynamics that affect populations. Databases that compile information on food composition and physiologic assessment of nutritional status of wildlife would serve as metadata analysis tools to better understand and manage species and habitat interactions.

KEYWORDS: Nutritional resources, chemical analysis, field assessment

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Nutritional ecology of the blue-eyed black lemur (*Eulemur flavifrons*): Integrating *in situ* and *ex situ* research to assist the conservation of a critically endangered species

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The blue-eyed black lemur (*Eulemur flavifrons*) is a highly endangered medium-sized lemur from the Sahamalaza region of north-west Madagascar with a mean body weight of 1.8-1.9 kg and a mean body length of about 39-45 cm. It inhabits semi-humid forests within a transition zone between the Sambirano region in the north and the western dry deciduous forest region in the south. The nutritional ecology of blue-eyed black lemurs in the wild has not been studied so far; usually *Eulemur flavifrons* is classified as a generalist frugivore. In zoos, blue-eyed black lemurs are highly susceptible to obesity, which is reported to negatively affect their reproductive output. This study investigated aspects of the feeding ecology of the blue-eyed black lemur, using data obtained from individuals kept at different European zoos as well as from wild *E. flavifrons*. Our aims were to optimize the species' diet in captivity to prevent individuals becoming obese, and to gain a better understanding of the ecological and nutritional needs of *E. flavifrons* in order to assist planned conservation measures such as forest restoration. The captive part of the study was conducted in two European zoos. We carried out a long-term study with one group of blue-eyed black lemurs (1 male, 3 females) from June 2004 until June 2005. All food offered and leftovers were weighed daily. Fourteen-day digestibility trials were conducted quarterly. All animals were weighed at least once monthly. Samples of feeds and feces were analyzed using Weende analysis and detergent analysis. In addition, we conducted digestibility trials with three groups of blue-eyed black lemurs (1,1; 1,1; 2,1) during May and June 2006, using the same methods as described above. In Madagascar, four groups of *E. flavifrons* in two forest fragments with different degrees of degradation were followed for 24h mo⁻¹ over a 7 month period between July 2004 and July 2005. Samples of plants utilized by free-ranging blue-eyed black lemurs were collected. They were botanically classified and analyzed as described above. Comparing the diet of free-ranging blue-eyed black lemurs to the captive diet, considerable differences were found with respect to NDF, ADF and ADL (NDF: 182 ± 95 g/kg DM in captivity versus 553 ± 150 g/kg DM in the wild; ADF: 88 ± 57 versus 415 ± 130 g/kg DM; ADL: 34 ± 30 versus 217 ± 87 g/kg DM) and crude protein (CP) content (161 ± 93 versus 103 ± 48 g/kg DM), whereas ash and crude lipid content varied only slightly. The NFC and energy contents in the zoo diet were almost twice as high as in the diet of free-ranging blue-eyed black lemurs (NFC: 566 ± 177 g/kg DM in captivity versus 283 ± 160 g/kg DM in the wild; ME: 13.9 ± 2.2 versus 7.7 ± 3.1 MJ/kg). The high NFC, CP and ME content and low NDF/ADF content of the zoo diet as compared to the wild diet, paired with a relatively high apparent digestibility, clearly contributes to the obesity problem of captive *E. flavifrons*. We therefore suggest systematically reassessing the zoo diet for this species, increasing fibre content and decreasing energy density.

KEYWORDS: Blue-eyed black lemur, nutritional ecology

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Mineral requirements as potential reason for insectivory by chimpanzees and gorillas in Southeast Cameroon

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The reasons why and when chimpanzees and especially gorillas show insectivory in the wild remain largely unclear. Yet, the amounts ingested are not always negligible, and a study in southeast Cameroon demonstrated that the lack of tool use by gorillas could not be the main reason for selecting other ant and termite species than chimpanzees. Hence, matching specific requirements through insect's nutritional value might be an explanation. This part focuses on the possible importance of minerals as a criterium for insect selection. At the site "La Belgique" in southeast Cameroon, a study was conducted on the insectivorous behaviour of chimpanzees and gorillas. Part of this study was the collection of ants and termites that were preferably ingested by chimpanzees and gorillas, and some ants and termites that were not eaten deliberately, but were readily available to the apes. The gathered insects (7 ant species and 12 termite species with in some cases workers, soldiers and larvae separate) were analysed for several nutrients, including crude ash and these minerals: Ca, P, Mg, Na, K, S, Cu, Fe, Mn and Zn. Vast differences in crude ash content were observed between, on the one hand, ants and termites feeding on fungi and other vegetal material (range 2-13% ash), and on the other hand, soldiers and workers of soil-eating termites (range 19-68% ash). Many significant overall correlations were observed between minerals, but crude ash was not always correlated with separate minerals, meaning that the extent of soil-eating was not the only cause of specific mineral contents. For instance, Zn was extremely well correlated with Na ($r = 0.999$). Both minerals were very high in termite larvae, but soil-eating termites had in general higher levels: most likely the type of soil (clay) eaten was both rich in Na and Zn. Although comparison of estimated insect intake with estimated requirements did not reveal clearcut reasons for insectivory, the apes seemed to select ants and termites rich in specific nutrients. Although both apes showed a significant preference for ants and termites rich in Zn, only one ant species was eaten by both gorillas and chimpanzees. Gorillas also selected more than chimpanzees for Fe, whereas chimpanzees also selected for Mn (and eventually Ca:P) (next to protein). In conclusion, insectivory in apes deserves more attention, as the dietary contribution of specific minerals through insectivory might be underestimated: mineral-specific selection seems to occur in the wild, and might be related to requirements that cannot be adequately covered by other diet items.

KEYWORDS: *Ants, termites, nutrient composition*

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Nutrient digestibility and consumption evaluation of a diet established for a group of *Saguinus leucopus* (GÜNTER, 1876) including a behavioral nutritional study at Santacruz Zoological Foundation (Colombia)

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The *Saguinus leucopus* is an endemic Colombian species. This species is categorized as Endangered in their natural habitat due to human activities including illegal commercial logging leading to habitat loss. It is important for the conservation of the species to study important issues currently unknown, such as behavioural, nutritional and reproductive ecology. This information will be important when creating a husbandry protocol for Colombian zoological institutions which may hold captive colonies, and help decrease the high mortality currently present. A nutritional study was conducted to inform management decisions. A diet was formulated using the software Zootrition and published data about natural nutritional habits. The diet was used for 6 individuals of *Saguinus leucopus* located in pairs. During the study faecal samples were collected for each enclosure, for periods of 24 hours. Thirty samples were analyzed for their nutritional content, including crude protein, fat, fibre, ash, calcium and phosphorus, and the data were used to calculate apparent digestibility. Video cameras recorded feeding behaviour and this observation, plus analysis of the food remains helped define consumption habits. The diet was composed by 65% of fruits, 4.1% of vegetables, 13.2% of animal protein, and 17.7% of supplements. The diet was offered two times a day (morning-afternoon). Nutritional content found dry matter 32.4%. Crude protein 15.7%, fat 3.9%, fibre 5.9%, ash 2.94%, calcium 0.32%, Phosphorus 0.35%. The quantity of dry matter consumed was: for the Group 1 = 53 g/DM/day, Group 2 = 57.9 g/DM/day, Group 3 = 67 g/DM/day. The average of digestibility coefficient presents minimal variation between the groups, comparing results as: Dry Matter: Group 1 = 94.4%, Group 2 = 93.3%, Group 3 = 91.2%. Consumption of the ingredients by the animals was variable and the quantities were different. The nutritional content of the ingredients consumed present a similar composition for each group, suggesting that the animals make selections in order to supply their nutritional requirements. The digestibility average found could suggest that *Saguinus leucopus* are an efficient species in terms of digestive capacity, this can explain why colonies of this Callitrichidae are been found in tropical dry forest with low food resources.

KEYWORDS: *Coefficient of apparent digestibility, Primate Nutrition, Saguinus leucopus*

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Nutritional ecology of free ranging black rhinoceros: field solution for optimising zoo diets

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Nutritional ecology of the black rhinoceros has been studied in five different ecosystems across Southern Africa. The aim of the research is to document seasonal variations in the chemical composition of the diet of free ranging rhino populations in these different ecosystems, and compare with contrasting reproductive performances. This could be key to understanding if nutritional limiting factors are responsible for the differences in reproductive success between black rhino populations. Several disease syndromes, such as acute hemolytic anemia and superficial necrolytic dermatopathy, as well as reproduction issues in captive black rhinoceroses have been linked to an inadequate diet, and this research may also provide a field solution for optimizing zoo diet. Preliminary results of the seasonal variations of the chemical composition of the diet (fibers, tannins, crude protein, minerals) of free ranging rhinos in three different ecosystems will be presented in relation to recommended values for captive rhino diets.

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Dental wear patterns in captive wild ruminant species differ from those of free-ranging conspecifics

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Ruminants are classified into grazers, browsers, or intermediate feeders. As adaptation to the presence of silicacious phytoliths in grasses and/or a higher amount of dust and grit adhering to grasses, grazers have evolved high-crowned (hypsodont) teeth, and their dental wear pattern in the wild, assessed by the mesowear method, is characterised by a high degree of abrasion (tooth-to-food-contact). The natural diet of browsers contains less phytoliths and grit, they have low-crowned teeth, and attrition-dominated dental wear patterns (tooth-to-tooth-contact). As captive browsers are rarely fed feeds corresponding to their natural forages, we hypothesized that dental wear patterns in captive browsers deviate from free-ranging conspecifics. Therefore, we investigated the dental mesowear pattern in 235 individuals of 27 captive ruminant species (using skull collections in natural history museums) and compared the results to data on free-ranging specimens. Compared to free-ranging populations, captive browsers show a much more abrasion-dominated tooth wear signal; based on the mesowear signal of captive populations, these species would have to be classified as grazers/intermediate feeders. In contrast, grazers tend to show a slightly less abrasion-dominated wear in captivity as compared to the wild. In intermediate feeders, differences between populations were not pronounced. Across feeding types, the dental wear pattern is thus much more homogenous in captivity than in the wild. The results imply that diets in captivity are undifferentiated, and of “medium high” abrasiveness, most likely due to the use of grass hay and phytolith-containing products in pelleted diets. If dental wear is a major factor limiting longevity, then captive grazers should achieve longer lifespans than captive browsers and free-ranging grazers, and the longevity of captive browsers should be particularly compromised. The use of diets that result in non-natural tooth wear patterns might also influence the potential survival of individuals of browser species that are released into the wild in re-stocking programs.

KEYWORDS: browser, grazer, tooth wear

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Differences in food comminution in grazing and browsing herbivores – implications for captive diets

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Besides a fermentation chamber harbouring gut microbes, the evolution of extensive teeth batteries for comminution of forage is a key adaptation of herbivorous mammals. Differences between the feeding types in the morphology of their teeth have been described, like in the arrangement of the enamel crests and dentin basins on tooth surface. To investigate potential differences in their capacity to chew down forage, we quantified fecal particle size in grazing and browsing ruminants (auroxen *Bos primigenius taurus*; giraffe *Giraffa camelopardalis*) and hindgut fermenters (Przewalski horse *Equus ferus przewalski*; lowland tapir *Tapirus terrestris*). Samples came from free-ranging and captive specimens. Faecal particle size was quantified via the wet sieving technique with 9 sieves in a range of 16 to 0.063 mm. Mean particle size (MPS) of each sample was calculated. In all animals, faecal particle size in captive specimens differed significantly from that of their free-ranging counterparts. However, while in grazers a small decrease in particle size was found between the free-ranging and captive conditions (auroxen: 0.42 ± 0.04 vs. 0.26 ± 0.02 mm; Przewalski horse: 0.79 ± 0.14 vs. 0.53 ± 0.08 mm), faecal particle size was considerably larger in captive than in free-ranging browsers (Giraffe: 0.34 ± 0.03 vs. 0.74 ± 0.32 mm; Tapir 1.40 ± 0.28 vs. 2.97 ± 1.33 mm). A lower MPS in captive animals as found in grazers can be expected from the fact that their diet contains some amount of food of small particle size (e. g. pelleted compounds) and that their feed intake may be lower than in their wild counterparts, due to lower energy requirements in captivity. Rather unexpected was the result in browsers, because irrespective of the digestive system, the captive representatives showed a larger faecal particle size than the free-ranging animals. The results indicate that while the (typically grass-based) forages fed to grazing herbivores have comparable characteristics like the plants they feed on in the wild, this does not seem to be the case in browsers. Our results raise the question on the physical or structural suitability of captive diets for browsing herbivores. This topic is directly linked to the apparent and often discussed difficulty in finding the optimal forage for browsing species, and to their reluctance to accept certain types of forages.

KEYWORDS: Chewing efficiency, grazer, browser

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Intestinal calcium absorption capacity is dependent on dietary calcium content in rabbits

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The calcium (Ca) metabolism of rabbits differs from that of most other domestic animals as Ca is absorbed in large quantities from the gut, dietary Ca levels are reflected in blood levels, and excess Ca is excreted in the urine. In this respect, the rabbit resembles other hindgut-fermenters such as horses and many wild herbivores. Factors determining the scope of intestinal Ca absorption have not been elucidated to date and could include dietary Ca level, dietary Ca to phosphorus (P) ratio or unidentified feedback mechanisms. As P is essential for microbial fermentation, and Ca is suspected to form insoluble complexes with P in the intestinal tract, it can be speculated that excessive intestinal Ca absorption is a mechanism that guarantees sufficient levels of available P in the hindgut. In the present study, Ca fluxes were measured, to get more information on possible changes of transport properties (absorption and secretion) of the duodenum and caecum in rabbits after feeding different diets of increasing Ca contents. Twenty-eight rabbits (newsealand hybrids) (age: 5 to 6 weeks at beginning) were kept on woodchips. Four different diets were fed to 7 rabbits each for 5 months in a pelleted form. The different diets were lucerne meal (L) (Ca content 22.2 g/kg dry matter (DM); Ca:P ratio: 8.00:1), lucerne meal with grain (LG) (Ca content 13.6 g/kg DM; Ca:P ratio: 3.82), grass meal (G) (Ca content 10.4 g/kg DM, Ca:P ratio: 1.91) and grass meal with grains (Ca content 8.3 g/kg DM; Ca:P ratio: 1.79). Immediately after slaughter, the duodenum and caecum were mounted in conventional Ussing-chambers. Electrical parameters like resistance and short circuit current were continuously recorded. Unidirectional flux rates of Ca²⁺ across gastrointestinal tissues were measured. Mucosal to serosal Ca²⁺ flux rates (J_{ms}) exceeded respective flux rates in the opposite direction (J_{sm}) in both segments. This resulted in net Ca²⁺ flux rates (J_{net} = J_{ms}-J_{sm}) ranging between +6.1-12.9 nmol*cm⁻²*h⁻¹ in duodenum and +61.6-110.8 nmol*cm⁻²*h⁻¹ in cecum. The highest fluxes in duodenum were observed in the group which were fed the LG pellets, whereas the highest fluxes in cecum were observed in the L group. Since the experiments were carried out in the absence of an electrochemical gradient, significant net Ca²⁺ absorption may indicate the presence of active mechanisms for Ca²⁺ transport. Increasing dietary Ca content increased Ca fluxes in the cecum, but interestingly the relatively high Ca contents in the LG group with a high Ca:P ratio induced high Ca fluxes in the duodenum. In conclusion, there is clear evidence for the cecum as a main site for Ca²⁺ absorption in rabbits. Stimulation of Ca²⁺ absorption by increased dietary Ca levels is different to other mammals, but in accordance to other hindgut fermenters.

KEYWORDS: Calcium, Diet, Absorption, Rabbit

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Frothy bloat and serous fat atrophy associated with insufficient fibre intake in a giraffe (*Giraffa camelopardalis*)

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Malnutrition is a common cause of morbidity and mortality in captive giraffe (*Giraffa camelopardalis*): 48 % of giraffe that died in EEP collections from 1962 to 2003 were emaciated or in poor body condition. Serous fat atrophy, indicative of emaciation, was identified in the majority of these cases. Frothy bloat is a common nutrition-related disease of domestic ruminants that has not previously been reported to cause death in giraffe. A 10-year-old female reticulated giraffe (*G. c. reticulata*), of estimated bodyweight 550 kg, was fed a daily diet of ad lib lucerne (alfalfa) hay, ad lib browser pellets, 750 g linseed lozenges, and, in summer months, limited browse. From June 2006 to October 2006, following a two-month period of reduced food intake and loss of body condition, extra browse was fed and fresh lucerne was offered in addition to lucerne hay. Ad lib grazer pellets were also added to the diet, indefinitely, from June 2006. From July 2006 body condition started to improve significantly. However, food intake and body condition began to decline again in January 2007 and the animal died in February 2007. Multiple nutrition-related abnormalities were observed at post mortem. Frothy bloat appeared to have caused death: the rumen was grossly distended with frothy liquid ingesta and the oesophageal serosa was markedly congested. No fibrous material was present in the reticulum, rumen or omasum and rumen contents were mildly acidotic (pH 6.5). The animal was also emaciated: there was generalised, marked muscle wastage and serous atrophy of multiple fat deposits. Chronic-active interstitial pneumonia was diagnosed on histopathology. Low (structured) fibre intake was associated with the ad libitum availability of pelleted compound feeds and the provision of lucerne hay that had appeared unpalatable (related to the method by which it had been harvested). Frothy bloat and ruminal acidosis were likely to have developed due to insufficient fibre intake, and may have been the cause of insufficient overall food intake. Emaciation indicated that the giraffe's total energy intake had been inadequate: increased energy demands – chronic respiratory illness and cold winter temperatures – may have contributed to this deficit, in addition to inadequate food intake. Deaths of five other giraffe in this collection have been associated with serous fat atrophy since 1980: poor quality lucerne hay and increased energy demands (respiratory disease, lactation and stress) were, similarly, identified as causal factors in these cases. A recent review of other giraffe in this herd indicated that roughage intake and total energy intake were inadequate; the ad libitum feeding of concentrates and poor palatability of lucerne hay appeared to be the key factors limiting roughage intake. Zoos should endeavour to find methods of feeding ad lib browse, the 'gold standard' roughage, to giraffe. Sufficient fibre intake must be assured by restricting concentrate provision and by feeding high quality, palatable roughage subject to regular quality control. The energy intake and body condition scores of individual giraffe should also be estimated regularly.

KEYWORDS: Giraffe, frothy bloat, serous fat atrophy

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Diet transition affects serum calcium, phosphorus and fatty acids in captive giraffe

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Pathology in captive giraffe is relatively common and has often been attributed to nutritional causes. It was hypothesized that a diet transition including reduction of dietary starch and P, and increasing polyunsaturated omega-3 fatty acids would change serum parameters to be more in line with typical mammalian values. Captive giraffe (n=6, Henry Doorly Zoo, Omaha NE), previously fed a commercially available diet, were transitioned to a reduced starch diet for one year (2005). Following the Giraffe Nutrition Workshop recommendations, another diet transition was made (2006). Blood samples were collected every 6 months, and were analyzed for Ca and P and fatty acids. Data were analyzed by repeated measures ANOVA for effects of diet and season. When main effects were significant ($p < 0.05$), students t-test was used to assess differences. There was no difference in serum parameters between 2005 and 2006 diets ($p > 0.20$). Serum Ca was not affected by season or diet ($p > 0.20$, mean = 9.04 ± 0.10 mg/dl), and serum P was not affected by season ($p > 0.20$). Serum P was reduced by the 2005 and 2006 diets as compared to the 2004 diet ($p < 0.05$; 7.35 vs. 9.58 ± 0.28 mg/dl respectively). Therefore, the Ca:P ratio was increased by the 2005 and 2006 diet compared to the 2004 diet ($p = 0.006$; 1.26 vs. 0.98 ± 0.04 , respectively). Given that 2004 Ca:P values were below a 1:1 ratio, the changes noted in this trial would be considered beneficial. Fatty acids also changed in response to diet; total fatty acids, omega-9, omega-6 and omega-3 fatty acids were increased by diet transition ($p < 0.05$). Specifically, diet transition was associated with increases in nervonic acid (24:1 n9), linoleic and arachidonic acids (18:2 and 20:3 n6), and docosahexanoic acid (22:6 n3) compared to the original diet ($p < 0.05$ for each). These changes demonstrate that diet transition can affect blood fatty acid parameters in giraffe, and that the diet transition in this trial resulted in more diverse fatty acid profiles as compared to the original diet.

KEYWORDS: Giraffe, diet transition, mineral metabolism

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Giants with Hiccups?

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Emmen Zoo carried out a research to find out more about a phenomenon in their elephants that can best be described as 'convulsions' or 'hiccups'. Sixteen Asian Elephants were observed of which seven showed the symptoms. For this investigation, the following problem definition was formulated: Which (dietary) factors may have been of influence with the appearance of 'convulsions' in several Asian elephants in Emmen Zoo after the transition to the winter diet? To answer the defined problem, research included a range of all possible factors that could influence:

- Literature investigation. In books and articles, no direct links were found between nutrition related diseases and the 'convulsions'.
- Study of the daily reports of the elephant keepers. Daily reports from 2004-06 were studied to obtain detailed information about the history concerning the elephants, and when and which elephants showed signs of 'convulsions'. The first 'convulsing' symptoms appeared in the eldest female elephant in December 2004.
- Conversations / interviews with the elephant keepers and the veterinarian. It became clear that different terms and definitions were being used for the phenomenon. The veterinarian had undertaken different actions to examine the 'symptoms'. There was nothing unusual that could be connected with the symptoms.
- A questionnaire for other Dutch Zoos that keep elephants. An attempt was made to see if there were differences in (winter) diets between the Dutch Zoos. The only findings were that Emmen Zoo and Natura Artis Magistra fed fodderbeets in wintertime, and the only other Dutch Zoo besides Emmen that fed grass in summer was Ouwehands Dierenpark.
- Observation of the elephant herd. It was apparent that the affected elephants were nervous before and during the 'convulsions'.
- Temperature recordings. Over several weeks, the temperature of the drinking water and the temperature of the inside and outside enclosures from the elephants were recorded. There seemed to be no clear correlation between temperature and the 'convulsions'.
- Laboratory analysis. Analyses of grass, hay, fodderbeets and elephant dung were taken. Comparing the analyses of grass and hay with each other, it became clear that the elephants, after the transition from grass to hay, got much less sodium and phosphorus. The results of two dung analyses (before and after transition on the winter menu) were compared with each other. This showed that the contents of rough ash, phosphorus and sodium in the faeces which contained hay declined by 50%.
- Diet comparison through the years. Winter diets for the year 2004-05 and the year 2006-07 were compared with the recommended daily quantities of nutrients of elephants. Compared with the recommendations, there were no deficiencies or overdoses of nutrients found in the winter diets that could immediately be related to the phenomenon.
- The most important conclusions/ outcomes of the research are:
 - temperature doesn't seem to be an influencing factor to the onset of 'convulsions'.

- there seems to be no clear correlation between the diet and the phenomenon, although comparing the winter diets to the recommendations, deficiencies as well as overdoses of nutrients are present, so more research has to be done.

KEYWORDS: Elephants, convulsions, (winter-)menu

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Speculations on pathogenesis of Metabolic Bone Disease in captive polar bears (*Ursus maritimus*) with links to taurine status

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A calcium and/or Vitamin D3 deficiency can lead to metabolic bone disease. There has been evidence in human pediatric medicine that the amino acid taurine (TAU) might enhance the absorption of vitamin D. Metabolic bone disease in captive polar bears has been historically problematic, and we speculate may be linked to TAU status. Whole blood and plasma TAU content was measured in wild caught (est. 4-5 mo of age; n=2) and captive (1.3-35 yr; n=10 individuals from 4 North American zoos) polar bears to determine if dietary differences influenced the concentrations of TAU available for its biologic activities. Plasma TAU (n=9) in captive bears was significantly lower (99±16 nmol/ml) than measured from the free-ranging bear cubs (237±10 nmol/ml); (t-test; p<0.02). Whole blood TAU concentrations also differed significantly (p<0.05), (253±37 nmol/ml in captive vs. 453±8 nmol/ml (n=2) for free-ranging bears, respectively. No significant differences in plasma or whole blood TAU concentrations were found with regard to sex or age of the captive animals. TAU concentrations in the wild-caught cubs were monitored over 4 yr in a captive environment, and decreased to levels similar to those reported for other captive polar bears (102±18 and 258±32 nmol/ml for plasma (n=5) and whole blood (n=9, respectively). These preliminary results indicate that circulating plasma and whole blood TAU concentrations from wild caught polar bear cubs are higher than considered normal plasma TAU values in domestic carnivores (cats 80-120 nmol/ml, dogs 60-120 nmol/ml), humans (40-100 nmol/ml), or rats (50-95 nmol/ml), and, likely reflect the impact of maritime diets (known to be high in TAU) of free-ranging polar bears, thus likely higher TAU concentrations transferred through maternal milk, that may be altered on a captive diet.

KEYWORDS: amino acid, Ursidae, nutrition, protein

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Current feeding practices for captive okapi *Okapia johnstoni*; how are guidelines used?

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In 1998, a joint European and North American project was carried out aimed at establishing feeding guidelines for okapi. The nutrition guidelines in the okapi husbandry manual, which were published in 2001, are a result of this project. In this guideline, the recommendation for ingredient composition is a maximum amount of 25 % browse, fruits and vegetables, a minimum of 50 % alfalfa hay, and a minimum of 25 % concentrate (all on a as fed basis). The recommendation for nutrient composition (in dry matter) is Crude Protein 17 – 20 %, NDF 20 -35 % and ADF 13 – 18 %. To evaluate current okapi nutrition practices and in European zoos, a questionnaire was sent to the 18 European zoos with okapis in their collection. Twelve zoos with 42 okapis in total responded. From the 12 participating zoos, eight were satisfied with the 2001 guidelines. However, only four stated that they made use of the guidelines. Ten zoos fed more than the recommended 25 % fruit, vegetables and browse. In 9 zoos, more fruit and vegetables than browse was fed. Five zoos offered more than 25 % fruit and vegetables in their diet (as fed basis). Nine zoos fed less alfalfa hay than recommended. Five zoos fed the recommended amount, a minimum of 25%, of concentrates. The ingredient composition of the diet was in only one zoo in accordance with the recommendation. The nutritional composition of all diets was also calculated with Zootrition 2.6™ and the tables from Jansen en Nijboer (2003). In the guidelines, a DM intake of 1.8 % of the body weight is recommended. DM offered in participating zoos varied from 1% to 4.3 % (average 2.3 %). The energy content of the diets offered was higher than recommended in 10 zoos. In 5 cases, it was at least twice the calculated maintenance requirement. Average CP content of the diets was 16.5 %. In 6 zoos, dietary CP content was below the recommendation. NDF content was in the majority of zoos within the recommended range or slightly above it. ADF content was in most cases slightly above the guideline value. The few available data on the composition of the in situ diet indicate that the natural okapi diet is much higher in NDF and ADF and lower in NFE than the values given in the 2001 guideline. In all participating zoos, NDF and ADF values were also lower and NFE values higher than values in the in situ diet. This could contribute to present and potential health problems in okapi, specifically rumen disorders and hoof problems (laminitis). Seven participating zoos reported hoof problems without specifying the nature of the problems. Zoos experiencing hoof problems fed more fruit and vegetables than zoos not experiencing these problems (average daily amount 2.9 kg against 2.0 kg as fed. A similar difference was seen in concentrate use (average 2.2 kg against 1.7 kg). However okapis with hoof problems were on average 4 year older than okapis without hoof problems.

The research shows that guidelines should be unequivocal. Putting browse, vegetables and fruit in the same ingredient class suggested that these dietary items were similar. This idea could have contributed to high amount of NFE rich fruits, which pose a potential health risk for ruminants like okapi. The results of this project show clearly that the art of selling the nutritional message is equally important as designing proper scientifically based nutrition guidelines.

KEYWORDS: Nutrition guidelines, Okapia johnstoni

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EAZA Penguin TAG nutrition survey evaluation

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The Penguin Taxon Advisory Group (TAG) sent a nutrition questionnaire all EAZA institutions holding penguins in 2004. Analysis of responses to this questionnaire in 2006 was the starting point to determine how a Nutrition Advisor could assist the Penguin TAG. A total of 78 questionnaires (one for each species kept at the institution) were received from 58 different institutions, from which 74 (from 55 institutions) were processed; the remaining 4 contained insufficient information to be processed. Based on the questionnaires sent, a total of 9 different species were recorded. The most common species held in EAZA institutions were *Spheniscus humboldti* kept in 32 institutions and *S. demersus* kept in 16 institutions. The least represented species were *Eudyptes chrysocome* and *Aptenodytes patagonicus* both kept by only 2 institutions. According with the estimated data obtained from the Penguin TAG chair, there are 10 different species of penguins held by EAZA institutions and a total of 4250 individuals, being the *S. humboldti* and *S. demersus* the most abundant and *Pygoscelis antarctica*, *P. adeliae* and *Eudyptula minor* the least common. This last species is the only one that has not been represented in the questionnaires. The survey contemplated questions such as the types of fish and amount fed, diet variation, how the fish is offered to the animals, type of supplements used and dosage, thawing methods. The results show that there was not a consistent method for thawing fish used by institutions. Only 21% of the institutions thawed the fish in the refrigerator. Whereas 23.7% used running water (mostly fresh water), 13.2% thawed the fish at room temperature and 38% of the institutions used various methods. Regarding the feeding methods used, 28.4% of the species were hand fed, 9.5% were scatter fed and 3% (2/74) were fed using trays. However, 60% of the species were fed using a combination of methods. Most institutions 82% had set amounts of fish offered to the animals, while 17.6% fed the penguins ad libitum. Penguins were fed from 1 and up to 9 different species of fish, being the mean 3 species of fish. Fish species most frequently used were herring (70%), sprat (69%), mackerel (30%), capelin (26%), squid (20%) and krill (15%). Other food items used in a minor frequency (<10% of diet) included shrimp, anchovy, sardine, whiting, smelt, and mussels. However, these results vary greatly when were calculated by species. All institutions except one used one or more types of supplements. All institutions (98%) supplemented with multivitamins and 44% of these also included a mineral supplement. Only 30% of the institutions used a salt supplement, and most of them (near 80%) housed the penguins in fresh water. Although the survey was difficult to evaluate, these results show that there is no consistency in penguin dietary husbandry. Based on these results, the nutrition advisory of the EAZA Penguin TAG should focus to establish and standardize general feeding practices for the group and give species-specific recommendations when necessary.

KEYWORDS: *penguin, captive diet, fish handling*

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The Development of a Dietary Review Team at Marwell Zoological Park

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Captive animal nutrition is an area which is becoming ever more important in the management of captive wild animal populations. The development of a team of zoo keepers, headed by an individual with a keen interest in nutrition, in addition to some form of nutritional background, is one way in which collections can effectively begin to review the diets of all species within their collection. This method has been successfully implemented at Marwell Zoological Park. In 2006, Marwell's Dietary Review Team was established. Currently consisting of nine keepers and section managers across all sections, each member was chosen for their specific interest in animal nutrition. The primary and most important task was the accurate documentation of the diets of all animal species within the park. A previously formed diet sheet was updated and members were responsible for weighing out the diets of all animals on their sections. This information was documented on the diet sheets and over the period of several months, all diet sheets were collected and filed. In order to establish an estimation of the nutrient levels within each diet, they were individually entered into the Zootrition database and consequently analysed. Where possible, an average of the nutrient levels available to each individual was obtained, on the basis that each animal consumed equal amounts of the diet. The inaccuracies of this method were taken into careful consideration, however all measures were taken to ensure as accurate representation of the nutrient levels within the diets as possible. This process provided an excellent basis for carrying out further dietary work. As a result, certain diets have since been highlighted as requiring attention, such as the diet of Marwell's Giant Anteater. The diet of this species has now become a project in itself, with laboratory analysis having been carried out on the diet and plans for a potentially improved diet underway. Each member of the Dietary Review Team is now focusing on the diet of a species which is of interest to them nutritionally, as well as being highlighted as having potential dietary inaccuracies. Members of the Dietary Review Team meet up every few months to discuss any progress made and any issues of nutritional importance that need addressing. With the implementation of Zootrition and a dedicated team of keepers, such a technique can be employed by any collection to document and analyse the diets of their animals; and to highlight dietary problems which maybe undetected. The basis of this dietary work has since lead to a whole spiral of dietary information, identification of previously unaddressed nutritional issues and communication with nutritional experts across the world. It has proved to be an excellent starting point for carrying forward the increasingly expanding area of captive animal nutrition.

KEYWORDS: *Dietary Review Team, Diet Sheet, Zootrition*

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Review and comparing of analysis of animal products

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Some summarizing data considering the composition of animal products fed to zoo animals can be found in literature. However, these are not complete. Much information about the composition of animal products can also be found in anecdotal literature. This presentation is divided into two parts. The first part summarizes both anecdotal literature and official literature on analyses of animal products. According to the authors the animal products fed can be divided into insects, mammals, chicken and other bird products, reptiles and sea products. Most of the components are characterized by low amounts of dry matter compared to dry food, high amounts of protein and, depending on the products, high amounts of fat. Data show also that there is a great variation in macro and micro minerals among these products. For example crickets fed in zoos are characterized by an imbalanced Ca:P ratio with a relatively low amount of calcium and a high amount of phosphorus (per kg dry matter: Ca 200 mg, P 900 mg). This is contrary to data obtained from the natural environment in Nigeria which shows low amounts of minerals, however more balanced. In the second part of this presentation analyses are presented from animal products fed in Rotterdam Zoo. If possible, analysis were performed on dry matter, crude fat, crude fibre, crude ash, Ca, P, Mg, Na, K, Cu, Zn, Fe and Mn. Analyses were performed according the standard analysis methods used at the Institute für Tierernährung of the Stiftung Tierärztliche Hochschule Hannover, Germany. Ten whole fish samples commonly used at the zoo were analysed. Samples were taken from regular fed fish like capelin, mackerel and herring but also from mussels, krill, mysis and oysters. In the literature limited data are available on the composition of one-day-chicken. In the Netherlands laying hens are fed according the nutrition guidelines for chickens. Data showed that there is some difference in the analyses of the samples of one-day-chickens from four different breeders. For example dry matter varies from 22,9 – 24,9%, in the dm crude protein 67,3 - 73,6 %, crude fat 16,8 - 26,2 ash 7,2 - 7,7% and Ca 1,4 - 1,7%. A greater variation can be found between the analysis of the different samples young and adult mice and rats. Samples were collected from French, Dutch, German and Tsjech breeders. No information could be obtained from the breeders about the diet which has been fed. Dm varies in 2 batches of baby rats from 20,1 - 21,4%, in the DM cp 62,9 - 67,1, cf 18,1 - 23,7%, ash 8,2 - 10,9%, In baby mice dm 20,1 - 21,4%, cp 67,4 – 70,0%, ash 9,8 - 10,1%. In four batches of adult mice the dm varies from 37,5 - 42,9%, cp 49,7 - 60,2%, cf 24,6 - 35,8% and ash 8,6 - 11,4%. When calculating a diet it must be considered that the analyses of rats, mice and one-day-chicken can vary considerably.

KEYWORDS: mice rat one-day old chicken

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Primate feeding solutions at Mulhouse Zoo

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Mulhouse Zoo (Parc Zoologique et Botanique de Mulhouse, France) holds an extremely diverse range of primates species, including 10 Lemuridae sp., 2 Cebidae sp., 5 Cercopithecidae sp., 1 Macaca sp., 4 Hylobatidae sp. one species of Callimiconidae (*Callimico goeldii*) and seven species of Callitrichidae. Populations are generally healthy and regularly breed and this is attributed to several customised feeds, including a pellet and home-made gruel. The feeding programs of all species present in Mulhouse Zoo were gathered in 2002 and have been compiled as a Diet Manual for the zoo. Mean body weights, feeding times, food items, mean quantity of food per day and special remarks per species were noted. If present, seasonal differences were also noted. Intake studies comprising of several observation periods have been conducted with January 2002 and October 2006. A pellet for primates called "Simial" was formulated in 1989 at Mulhouse Zoo (Parc Zoologique et Botanique de Mulhouse, France) as a complement for fruit and vegetable based diets. Since then, this pellet is successfully used in all Old World and some New World Monkeys diets. Since 1986, a special "tamarin gruel" (semi-liquid mixture) has also been in use and this paper will describe, with examples, data collected to demonstrate their efficacy

KEYWORDS: Primate diets, intake, home-made ingredients

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Fruits as Foods – common misconceptions about frugivory

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Many vertebrate species rely on fruits as a dominant part of their diets, either seasonally or year-round. Due to their arboreal nature, the primate order is particularly rich in species exhibiting a predominantly frugivorous nutritional strategy, with an overview by Clutton-Brock & Harvey (1977) listing 30 out of 48 studied species (62.5%) for which fruits accounted for a larger proportion of their diets than any other group of foods did. Primate species known or thought to be mainly or partly frugivorous in the wild are usually provided with a fruit-based diet in captivity. However, domesticated fruits as available on European markets are grown for human consumption and have been selectively bred for a high sugar and low fibre content. They may thus not be representative of wild fruits. In the paper at hand we compared the nutritional characteristics of fruits consumed by primates in the wild to those of such fruits that are commonly used in diets for captive primates in European zoos. We collected fruit samples from 48 plant species that were utilized as food resources by blue-eyed black lemurs (*Eulemur flavifrons*) in northwest Madagascar as well as from 10 species growing in the lemurs' habitat that were not utilized. Samples were dried in a solar drying oven at 60-80°C and analyzed using Weende analysis and detergent analysis. Additional data on nutrient and energy content of wild fruits from different primate habitats in the Neotropics, Africa, Asia and other parts of Madagascar were compiled from the literature. Nutrient and energy values of fruits fed to captive primates were taken from Zootrition®. Wild fruits had a considerably higher content of NDF, ADF and ADL than fruits fed in European zoos and were also higher in protein and NFC as well as in metabolizable energy content. Wild and zoo-fed fruits moreover differed in sugar composition, with the domesticated fruits being higher in sucrose and the wild fruits higher in glucose and fructose content. Overall, fruits consumed by wild primates are more comparable in their nutrient composition to vegetables used in zoo diets. We therefore recommend not to simply translate a frugivorous nutritional strategy of a species in the wild to a captive diet for that species that mainly consists of fleshy fruits, but to look at nutrient composition and try to mimic this as closely as possible in order to avoid diet-related problems such as obesity.

KEYWORDS: Eulemur flavifrons, Obesity, Frugivory

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Should zoo food be chopped?

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The food provided for many zoo animals is chopped into small pieces even if the animals are capable of processing much larger items. Chopping food takes time and the chopped edges increase the risk of bacterial contamination and food spoilage; whereas leaving food whole may allow the animals to express more natural feeding behaviour and increase their food processing time. So why do keepers chop food? Reasons offered are:

1. It enables all individuals in a group to obtain enough of each food type
2. It prevents wastage caused by animals taking one bite and discarding the rest of a large item
3. It enables a wider scatter feed to encourage foraging behaviour and prevent aggression during feeding.

We investigated these anecdotal explanations in two species, Sulawesi crested black macaque (*Macaca nigra*) and Brazilian tapir (*Tapiris terrestris*). *M. nigra* (3.5.3) were studied at Paignton Zoo by observations of three adult female study subjects selected on the basis of their known dominance status: the most dominant, the most subordinate and a female of intermediate status. Eight *T. terrestris* subjects were observed at Paignton Zoo (1.2), Newquay Zoo (1.1) and Bristol Zoo (1.2). The usual fruit and vegetable feed provided to each group was offered in four conditions: chopped/clumped, chopped/scattered, whole/clumped and whole/scattered, such that the total amount of food was the same on each day. The average piece size and total weight of each produce type was recorded each day and any food uneaten each day was weighed. Each study subject was observed individually during feeding time and the number and type of each food item eaten recorded, along with any aggression and their total time spent feeding. Each subject was also observed for two 30 minute sessions at other times throughout the day and their behaviour recorded using instantaneous sampling every minute. The data were analysed using randomisation tests equivalent to two-way ANOVAs to determine the effects of food item size and presentation method on total weight of food consumed, diversity of food items consumed, total feeding time, aggression during feeding, behaviour throughout the day and total food wasted. These results indicate that the supposed advantages of chopping food are not actually evident. For the macaques food size and presentation did not significantly affect any of the variables measured when considering all subjects. However the most subordinate individual was able to obtain significantly more food (randomisation test, $P = 0.008$) when food was left whole rather than chopped (scattering or clumping the food made no difference). For the tapirs the only statistically significant effect was found at Paignton Zoo where the chopped/clumped condition resulted in significantly less foraging behaviour throughout the day than the whole/clumped condition (randomisation test, $P = 0.013$). Therefore chopping food does not seem to have any of the advantages keepers suggest and we recommend that if animals are capable of processing it food should be provided whole to avoid the increased risk of contamination and nutrient loss and save keeper time.

KEYWORDS: Food preparation, food size, behaviour

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Plants are not all the same nutrition-wise

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Here I present a botanists view, starting off by arguing that plants have not evolved to play a major role in supporting animals! Thereafter, I consider the role of soil factors in structuring vegetation and the importance that this has for animal feeders, in terms of growth strategy and nutrient concentrations. I then go on to consider how man has altered the quality of feedstuffs, hay and silage etc, using both a theoretical approach, data from long-term experiments and a discussion of essentiality with respect to plant nutrients. Finally I consider some aspects of plant poisoning from both inorganic and organic sources.

KEYWORDS: plant nutrients, macrominerals, microminerals

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Comparison of two differing diets on digestion in captive red-flanked duikers

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Ruminant frugivores can become especially challenging to maintain simply due to misunderstandings of their natural diet's composition, feeding ecology, and requirements. As animals that rely heavily on 'fruit' as the major components of their diet, duikers fall into this group. They have a history of medical and dietary issues in captivity, including, but not limited to, copper deficiency and ruminitis. However, recent research is not only changing how we feed duikers in captivity, but is also challenging our perception of small ruminants. The goal of this study was to determine if a minor change in diet would affect digestibility of the over-all diet by captive duikers. Nine red-flanked duikers from the Los Angeles Zoo were randomly assigned to two feeding groups. Over a 4-month period, one group was fed a control diet and the other an experimental diet. The control diet consisted of butternut squash, yam, tamarind pods, sunflower seeds, dandelion greens, Swiss chard, kale, and 4 types of browse. The experimental diet was very similar, exchanging butternut squash for acorn squash and adding banana peel, and copper sulfate supplement. Two 4-day collection periods occurred during this period to measure intake and determine digestion. Animals on the control diet were then moved onto the experimental diet, and visa versa, over a 1-month washout period, and the same 2 trials were conducted again during a subsequent 4-month period. Full compositional analysis was done for each diet for each collection period, resulting in four sets of data for each diet. Overall nutrient composition of the diets did not differ significantly nor did overall digestibility of the diets within or between animals. However, among minerals, copper digestibility was significantly different ($p=0.01$), with this mineral having higher digestibility in the experimental diet. Though, this may be attributable to the copper sulfate supplement given as part of the experimental diet. While the two diets did not have significantly different copper levels overall ($\text{Cu} = 0.10\%$), the copper in the supplement may be more biologically available than the copper in the feeds themselves and therefore translates to higher absorption. It would appear the experimental diet did improve absorption of that mineral but, to determine its affect on copper deficiency in situ and whether this level of supplementation is adequate, blood samples, as well as liver biopsies of deceased animals, should be analyzed. Overall, the differences between these two diets are not significant enough to alter digestibility in the duikers. However, changing other components, such as the browse, hay, and pellets or removal of some concentrates entirely, may certainly have such an affect. Further work needs to be done, both with respect to wild duiker diets and captive management, to better understand the optimal nutrition for these animals.

KEYWORDS: Frugivorous ruminant, duiker, digestion

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Study on the characteristics of the gastrointestinal tract and rumen ecology of Formosan Reeves' muntjac

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The aim of this study was to investigate the rumen ecology and feed digestion in Formosan Reeves' muntjac (*Muntiacus reevesi micrurus*). We also observed the effect of captivity on digestive physiology, by comparing the gastrointestinal tracts and tissue samples of ruminal papillae, between captive and wild muntjac. In experiment I, rumen fluid from female muntjacs was taken via stomach tube 4 hours after feeding for further analysis. The parameters analyzed included pH value, concentration of volatile fatty acids (VFA), counts of rumen bacteria and protozoa. In experiment II, we measured the length of the intestinal tracts of muntjac and recorded the characteristics of ruminal papillae from a tissue sample. In experiment III, we analyzed feed digestibility of captive muntjac and analyzed the nutrient composition of rumen and abomasum contents from captive muntjac, which are correlated to muntjac feeding type and living environment. Results reveal that the pH value of the rumen fluids from captive muntjac ranges between 6.1-6.8 and the concentration of VFA is lower than that of the domestic animal, such as cow and sheep. The rumen bacteria count ranges from 0.03-120.33 x 10⁷ colony counts / ml rumen fluid. There is a positive correlation between the total bacteria count, cellulolytic bacteria count and amylolytic bacteria count. Isotrichidae accounted for less than 30% of total protozoa, whereas ophryoscolecidae represented more than 70%. The morphology of ruminal papillae between captive muntjac and wild muntjac showed distinct differences and the length of the small intestinal tract tended to be longer in captive specimens. The captive muntjac had better digestibility on crude protein (CP), acid-detergent fiber (ADF) and nitrogen free extract (NFE). The CP, NDF, NFE and acid-detergent fiber of rumen content between captive and wild muntjac were similar, whereas ether extract (EE) was higher in captive muntjac. In conclusion, the pH value of rumen fluid from captive muntjac was within normal limits compare with domestic animals, and the quantity of rumen bacteria was lower than that of the domestic ruminants, resulting in a lower concentration of VFAs in captive muntjac. Furthermore, this study indicates that small ophryoscolecidae represents the major protozoa species in the rumen. The ratio of intestinal length to body length is approximately 13.9-15.1 which is similar to a concentrate selector. Finally, the morphology of ruminal papillae showed significant differences between captive and wild muntjac, the wild muntjac have more developed papillae, which could be related to diet stimulating the growth of papillae.

Key word: gastrointestinal tract ; rumen ecology ; muntjac; VFA

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Herbaceous plants as components in diets of herbivorous reptiles

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In the feeding practice of herbivorous reptiles and some other small herbivores in captivity, different herbaceous plants often play an important role in the diets. These can be wild-growing or purchased, with the latter comprising mostly leafy vegetables with either dark or lighter green leaves. Purchased green leafy vegetables often (have to) play a particularly dominant role during wintertime, when little other fresh forage is available. However, little information is available concerning the nutritive quality of these plants or their physical structure, both of which are important features for herbivores. In the course of a project on digestive physiology of herbivorous reptiles, a survey on feeding plants used for these animals was initiated. Samples of 7 different plants (wild-growing dandelion *Taraxacum officinale*, clover *Trifolium repens*, ribwort *Plantago lanceolata*, dock leaves *Rumex spp.*, sow thistle *Sonchus oleraceus* and mulberry *Morus alba*, plus a purchased leafy vegetable very commonly used - endive *Cichorium endivia*). These plants were used in Cologne or Chester Zoo diets or collected from neighbouring areas of Cologne Zoo. Some commercial compound feeds for tortoises were also included. Samples were analysed for proximate composition, neutral detergent fibre, acid detergent lignin, calcium and phosphorus, and with an in vitro fermentation test (Hohenheim gas test). Organic matter degradability was estimated from the results of the in vitro test. In addition, in vitro fermentation of large pieces of dandelion, endive and mulberry leaves was stopped at fixed fermentation times, and the respective residues photographed to document the degradation of physical structure in the course of fermentative digestion. Endive salad had (besides the highest ash content of 21.3 % DM) a rather high crude protein (CP) content (29.3 % DM) and rather low neutral detergent fibre (NDF) content (17.7 % DM), compared to the other plants with a range of NDF-contents of 19.5 – 41.8 % DM and CP-contents of 12.5 – 30.5 % DM. Lignin content was particularly high in ribwort (16.1%), and particularly low in endive (1.1 %). Correspondingly, endive also showed the highest estimate for organic matter digestibility (77%), followed by dandelion and clover (both 74 %) and Mulberry (70 %), while ribwort showed lower values of 64 %. When quantifying the degree of degradation visually, it was obvious that loss of physical structure was most rapid in the endive, followed by dandelion and mulberry in descending order. As with all herbivores, a sufficient degree of 'fibrous bulk' is advisable in diets for herbivorous reptiles. Diets comprising pale leafy green vegetables such as members of the endive or lettuce family do not provide this. Dandelion and other wild-growing plants are more 'fibrous', and may be a good option for increasing fibre content during the vegetation period. Considering the rather low amounts of food necessary for herbivorous reptiles, conservation of herbaceous plants for wintertime can be considered a good alternative to commercial products, especially when problems with faeces consistency occur.

KEYWORDS: Herbivorous reptiles; herbaceous plants; nutrient composition

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Effects of two levels of energy allowances and of hibernation on growth in hatchling *Testudo hermanni boettgeri* (Mojsisovics, 1889)

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Captive breeding of *Testudo hermanni* is often associated with rapid growth and shell deformation. The objectives of the study are 1) to determine the minimum level of energy allowing growth and 2) to test the effects of 2 levels of energy allowances and of hibernation on growth during the first year of life. Forty hatchling *Testudo hermanni boettgeri* were divided into 5 groups of 8 animals of similar body weight (BW) (mean \pm SD, 12.3 \pm 1.3 g). The groups differed in terms of their hibernation status: either hibernating (H+, groups A, B and E) or not hibernating (H-, groups C and D) and in terms of the energy allowances they received: either High Energy (HE, groups A and C) or Low Energy (LE, groups B and D). The 5th group (Group E) was fed *ad libitum*. With the exception of group E, the tortoises were kept individually in similar captive conditions for a period of 1 year. Food was offered in the form of fresh plants (*Taraxacum officinale*, 0.44 kcal/g as fed, *Trifolium* spp., *Plantago* spp. or others). The starting point for determining energy allowances was the equation from Donoghue and Langenberg (1996): $SMR = 32 (BW^{0.75})$ where SMR = Standard Metabolic Rate in kcal/day and BW in kg. The usual recommendation for growth is 2 SMR, corresponding to 2.3 kcal or 5.2 g of fresh food for the HE groups. This amount was decreased daily until all the food offered was consumed by at least one group. After 3 weeks, 2 levels of energy allowance, corresponding to 0.15 and 0.30 SMR, were offered during growth. Tortoises were weighed at weekly intervals. Bone density was studied using radiography. Repeated measures of BW were analyzed using a mixed linear model including BW at birth, SMR, origin, and time ($P < 0.05$). A SMR at the level of 0.15 allowed growth but a MR at the level of 0.10 did not. During the first 3 months of life, the 5 groups grew at the same rate while receiving 2 energy allowances, respectively 0.15 and 0.30 MR, corresponding to 2.6 and 5.8% of BW as fresh food. The growth rate was significantly correlated with BW at birth and not with the energy allowances. After 3 months of age, the following parameters became significant: energy level, hibernation status, BW at birth, and time. After hibernation, bone density was higher in hibernating tortoises, in comparison with non hibernating ones. At the age of one year, the BW ranged between 24.9 \pm 2 (group B, LE, H+) and 41.6 \pm 9 g (group C, HE, H-). The energy level allowing growth is very low. Hibernation and energy allowances strongly influence growth in hatchling *Testudo*, but only after 3 months of life.

KEYWORDS: Energy, hatchling tortoises, hibernation

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A Simple and Effective Egg-Based Hand-rearing Diet for Flamingos

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An egg-based diet, composed of whole, shelled hard-boiled chicken eggs, with added hard-boiled yolks, water, and supplemental minerals, vitamins, and fat, was developed to duplicate the nutrient composition of crop milks fed to flamingo chicks. Dietary intake and growth were recorded in 43 Caribbean (*Phoenicopterus ruber*) and 17 Chilean (*P. chilensis*) flamingo chicks housed at four US zoological facilities. Feeding protocols, amounts fed, and significant developmental milestones are detailed. Diets made from fresh eggs, as well as dried egg product powders, appeared equally palatable and resulted in similar chick responses. Transition to adult diets was uneventful; this diet represents a practical, nutritionally balanced, and successful formula for hand-rearing flamingos.

KEYWORDS: Flamingo; hand-rearing; avian

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Crop milk replacers for *Columbidae* hand-rearing protocols: experiences of using soja and milk proteins on Sclater's crowned pigeon and Mauritius pink pigeon at Mulhouse Zoo (1998-2007)

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When hand-rearing *Columbidae* species, many empirical protocols with more or less satisfactory results are documented. With domestic species, very few problems occur with parental feeding: therefore the few cases encountered with rare pigeon and dove species seem of insufficient marketing value for pet food producers to get interested in seriously developing hand-rearing preparations. Nevertheless, some endangered species may sometimes merit hand-rearing, e.g. when foster parents fail. In Mulhouse Zoo (Parc Zoologique et Botanique de Mulhouse, France) two pigeon species have been successfully hand-reared using experimental protocols with soy and milk proteins: two Sclater's crowned pigeon *Goura scheepmakeri sclateri* and one Mauritius pink pigeon *Columba mayeri*. The first Sclater's crowned pigeon chick was successfully raised in 1998, a second attempt failed in 2001 and a third attempt succeeded in 2005. In between, proportions of the hand-rearing mixture were changed according to the composition analysis published for the crop milk in the 3rd European studbook report. The idea was to combine successful ingredients used in 1998 (soy milk and lactic casein) but to vary their proportions in order to follow the natural changes in crop milk composition; during the first 30 days, proteins were reported to decrease whereas fats increased. Higher fat concentration was not possible with the two ingredients chosen: thus, soy cream was introduced. A new mineral and vitamin supplement containing enough choline (Ornivital® : 70.000 ppm) was also added. The milk replacer was made every 5 days with different ingredient proportions and conserved in a freezer between meals. Even if heated before serving, the mixture texture was not really optimum for the two last mixes, where powders are proportionally more important. However, body weight gain was indeed more satisfactory than in 1998. At the age of 40 days, the Sclater's crowned pigeon chick reared with the varying composition mixture was double the weight than chick reared with the constant composition mixture. In 2007, we successfully tried the first mixture from this new Sclater's crowned pigeon protocol for a Mauritius pink pigeon chick. In order to improve **swallowing** in this smaller species, we added natural yoghurt (4g / 100g of soy milk) and increased fats from the 1st day by adding peanut butter instead of soy cream (4g / 100 g of soy milk). Proteins were increased by adding cereal gruel, preparation for human babies (5g /100g of soy milk for the 12th day slowly increased up to 8g /100g of soy milk after the 19th day). The growth curve was judged satisfactory and full adult size reached although the chick grew more slowly than the one which was reared by foster parent (under *Streptopelia risoria* Ringneck or Barbary Dove) during the same period. From these hand-rearing experiences, we concluded that:

- soy proteins, fats and lactic casein can be used for crop milk replacers with these two pigeon species,
- varying the ingredient proportions for Sclater's crowned pigeon crop milk replacer every 5 days during the first 30 days, in order to follow natural composition changes of crop milk, allows a better growth on chicks of this species.

KEYWORDS: *Columbidae*, crop milk replacers, hand-rearing
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**Nutritional aspects of hand-rearing an aye-aye (*Daubentonia madagascariensis*):
Milk composition and infant growth in relation to mother-reared infants**

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The aye-aye is the largest nocturnal primate, weighing between 2 and 3kg. Its wild diet consists of insect larvae, fruits and nuts. Bristol Zoo Gardens has kept a pair of aye-aye since 2001, and although the animals would frequently produce offspring the female would not rear the infants. Aye-aye are part of an international breeding program and are only kept in 10 collections worldwide. Therefore, after three unsuccessful births the decision was taken to hand-rear the next infant. In this paper we detail the hand-rearing process of a female infant that was born after a gestation of 157 days with a birth weight of 102 g, specifically addressing the nutritional problems we encountered and how these were overcome. The infant was fed a soya-based milk formula at two-hour intervals until day 18, when we dropped one of the night feeds. At day 40 we began to change the milk formula to increase its fat and protein content, as the animal only showed a slow weight gain. By day 47 the infant was taking the revised formula well; up to 7ml at a feed, receiving eleven feeds per day. On day 55 we began adding ground New World Primate pellets to the milk. The pellets were ground to a fine powder and introduced gradually to the milk over five days. Supplemental milk feeds continued until the infant was 10 months of age, after which she was fully weaned and was feeding on the adult diet. Although the infant experienced some initial health problems she has developed well and is to date the only aye-aye ever to have been hand-reared from birth. In this paper we compare the different milk compositions that we used and relate them to the infant's body weight development and to health problems encountered. We furthermore compare our data to those for mother-reared infants and to one other partially hand-reared infant.

KEYWORDS: *Daubentonia madagascariensis*, Body weight development, Milk formula

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Do probiotics have a role to play in zoo mammal nutrition?

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Across all mammalian species, the composition of the intestinal microflora is believed to have profound biochemical, physiological and immunological influences on the host. The intestinal bacterial populations of the domestic species studied to date vary considerably. The microbiology and ecology of the gastrointestinal tract of zoo mammals is currently poorly understood. However, it is believed that the stress of captivity, empirical antibiotic use and dietary changes have the potential to promote intestinal dysbiosis, permitting colonisation of pathogenic organisms. There is growing interest in the use of probiotics in both human and animal nutrition and this is reflected in the increasing number of commercially available preparations. As such probiotics have been suggested as a tool to counteract processes that have the potential to disrupt the autochthonous microbial populations of zoo species. Probiotics are defined as viable microorganisms, that when ingested, restore or modify the composition of the microflora of a compartment of the body (especially the intestines or rumen) or have a beneficial effect in the prevention and treatment of certain pathological conditions. The claims made for probiotics are many and varied and it is not always possible to provide good scientific evidence to support them. Studies in humans and domestic animals suggest that probiotic preparations may be beneficial in the treatment of infectious and antibiotic-induced diarrhoea, lactose intolerance, inflammatory bowel disease and irritable bowel syndrome. More recent work suggests applications beyond gastroenterology: probiotics have been shown to reduce carcinogenic activity and to lower cholesterol. Other potential benefits that have been proposed include increased resistance to infectious diseases, particularly those that affect the intestine, reduction in blood pressure and amelioration of allergic responses. In farmed mammals, probiotic feed additives are often used in an attempt to counteract the influence that the stress of intensive rearing has on the composition and activity of the intestinal microflora and in some situations supplemented diets have led to improvements in productivity parameters. Multiple mechanisms of action have been postulated including the production of inhibitory substances, the prevention of invasion of pathogenic microorganisms by competitive exclusion, degradation of toxin receptors, reduction of inflamed mucosal permeability, modulation of cytokine expression and stimulation of phagocytosis by peripheral blood leukocytes. Specific scientific studies evaluating the effect of probiotics in zoo mammals are lacking but warrant further consideration. The current development of DNA-based methods holds great promise for more accurately determining the intestinal composition of various species in health and disease. In addition, such techniques may aid in the development of species-specific probiotic supplements. It is clear that further work is required before broad safety and efficacy statements can be made regarding the use of probiotics in zoo mammals.

Keywords: Probiotics, intestinal, microflora

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Effectiveness of the probiotic, Biomin PoultryStar, for improving health in canaries

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Probiotics are given to animals e.g. to improve health. In this study the probiotic, Biomin PoultryStar (BioMin GmbH, A-3130 Herzogenburg, Austria) is given 6 months to a group of 10 canaries *Serinus canaria*. The health status of the birds is compared with the health status of 10 canaries not receiving the probiotic product. Biomin PoultryStar, a synbiotic product consists of 5 isolates belonging to the genera *Enterococcus* *Enterococcus faecium*, *Pediococcus* *Pediococcus acidilactici*, *Lactobacillus* *Lactobacillus salivarius* and *Lactobacillus reuteri*, *Bifidobacterium* *Bifidobacterium animalis* and prebiotic (FOS fructo oligosaccharides of the family Compositae (*Cichorium intybus*) and has a proven positive effect on the health status of chickens. All canaries are housed two by two in separate cages and kept in a building within normal temperature range. All birds received the same diet Kenner Canary Seed with Avian Egg Food Premium twice a week. Biomin was supplied daily through the drinking water (5g /1000 ml water). Contamination was prevented by using different cleaning tools for every cage. From all canaries the health status was measured at the beginning and end of the experiment by scaling the birds on colour, feather aspects and general health status (weight, growth, eggs etc) by a certified canary controller. Faecal samples (6 times during the feeding period) of the birds were taken and checked on Total aerobic counts, Enterobacteraceae numbers, *Lactobacillus* numbers, Salmonella and coccids to measure the influence of the probiotic on the gut flora. At the end of the experiment the health status of the group which received Biomin PoultryStar was graded higher compared with the group receiving feed without the probiotic. No differences between the groups were found in the measurements of faecal samples.

KEYWORDS: probiotic, feed

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Feeding our animals without wasting our planet; some thoughts about sustainable zoo food

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This presentation offers a first brief introduction to some sustainability aspects of zoo animal nutrition. After introducing the main sustainability and environmental issues affecting the operation of zoos and aquariums we take a closer look at some specific problems related to zoo animal nutrition, and at possible alternatives or solutions. Aspects of animal welfare, energy use/climate (including food miles), fertilizers and pesticides, genetically manipulated organisms, packaging waste, pesticides, rainforest destruction, overfishing and water use are all briefly discussed. Finally, we touch upon some of the opportunities and threats when trying to formulate a sustainable zoo nutrition policy.

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Reviewing The Deep's animal feed sources for sustainability and nutrition

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As part of our ethical review process, a re-evaluation of our fish food suppliers and feeding regimes has recently taken place. Three key areas were considered:

1 - Nutritional suitability – Are the feed types we use the best and most appropriate for the animals being fed? A critical review of the nutritional profiles of all feed types is being implemented and whether alternative or new feeds are available that may have more appropriate and/or better nutrient content. A frozen feed surveillance schedule using proximate analysis will be put in place to assess nutritional quality of food during storage

2 - Environmental sustainability – Are the feeds we purchase from sustainable sources? The aim being to reduce our impact by changing feed type or simply by liaising with suppliers to specify what we require in terms of sustainability. The Marine Conservation Society “Good Fish Guide” and the Marine Stewardship Council directives have been instrumental in assessing whether our present food types are from sustainable sources and research into further sources is being conducted. In addition, all suppliers are currently being contacted and asked whether they could provide information of feeds:

- Full list of food types sold – This is to determine overall supplier sustainability
- Original source – The actual location the fish were caught, are these sustainable fisheries etc.?
- Environmental Policy – Do they have policies in place to ensure all efforts to make their company as environmentally sustainable as possible?

3 - Overall environmental impact of purchasing – Are the feeds we use sourced from places which minimise transport and their “carbon footprint”? Can we source from closer to home or use alternative transport methods to reduce this? Is our in-house consumption of food optimised? Assessing tank biomass and food preparation practices it has been possible to identify areas which can be streamlined to minimise waste and expenditure without compromising animal health.

Whilst this review process is not a new concept, in the past it has sometimes been difficult to obtain information available from suppliers. Feed supply companies however, are becoming increasingly aware that they need to be providing this data and paying more attention to their own environmental activities in order to retain business. As bulk purchasers of a wide variety of food stuffs, animal institutions represent a significant driving force generating momentum within the feed supply industry to continue to develop their environmental profile. This is a continuous process that requires regular re-evaluation and an awareness of the rapid evolution in environmental strategies that is taking place in recent years. It can be applied not only to sourcing fish feed but is relevant to all aspects of our business. In addition to it being our moral obligation as an environmental charity, it has led to financial savings, but more importantly, made us think critically about our company as a whole including stimulating similar activities amongst our suppliers.

KEYWORDS: Ethical review, sustainable food supplies, environmental impact

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Fish Analog – a sustainable alternative for feeding fish to captive animals

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The use of fish as diet items for captive piscivorous animals presents concerns for nutrition, quality and availability. In particular, frozen fish must be supplemented with thiamin and vitamin E to account for deficiencies in frozen fish, and quality of frozen fish declines immediately post-harvest. Multiple freeze/thaw cycles will increase the risk of pathogen growth and reduce product quality. Finally, sourcing sustainably harvested fish can be problematic, and wild fisheries are often over fished. Therefore, availability of a diverse fish population may be limited in the future. A sustainable alternative to the use of frozen fish has been developed, using Menhaden Select fishmeal. This fishmeal is harvested from sustainable populations, using harvesting techniques that prevent by-catch. In combination with this fishmeal, ingredients are added to a dry meal or a frozen gel diet to provide an alternative to frozen fish. Nutrient analysis demonstrates similarity to wild caught fish, and protein and lipid content may be varied to meet needs. Undetectable levels of organochlorines, polychlorinated bipheynyls (PCBs) and mercury provide additional quality. This product has been demonstrated to be effective and palatable in penguins, seals, sea lions, polar bears, dolphins, beluga whales and many other species. As sustainable fishery management becomes more critical for ocean health, alternatives to feeding wild caught fish need to be carefully considered.

KEYWORDS: Fish, fish analog, sustainable fish

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Attitude of the general public towards feeding live prey

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It is policy in Dutch zoos not to feed live vertebrate prey to captive carnivores. An important reason for this policy is the obvious welfare problem of live prey in an environment with no escape possibilities. Furthermore it is expected that zoo visitors will not accept the view of actual killing and devouring of live prey. However prey catching behaviour is an important part of the behavioural repertoire of carnivores. By denying these animals the opportunity to hunt and kill their welfare is possibly challenged. With the current trend of more spacious and 'natural' enclosures one can imagine that the welfare balance will tip in some cases in favour of the captive carnivores instead of their prey. For such, probably rare cases it is important to have a general idea how zoo visitors will react. In the months June and July 2006, a total of 570 persons in 10 Dutch cities were questioned about their attitude towards feeding live prey in zoos. They were asked about their opinion on feeding live prey behind the screens or outside opening hours as well as their opinion on feeding live prey in full view of the visitors. Only a small minority was against feeding live insects to insectivores behind the screens. This percentage increased to 13 % when feeding takes place in the presence of visitors. Asked about feeding live fish behind the screens, 11 % of the respondents were against it. This percentage increased to 21 % when the option of feeding in full sight was mentioned. For feeding live rodents percentages were 21 % and 41%. Results for feeding live rabbits were 22 % and 48%. The small difference between these two groups can be explained because as example of rodents the guinea pig was mentioned. Like rabbits they are more considered as pets than rats and mice. The respondents could also react on statements related to feeding live prey. A large majority (85 %) agreed with the statement that live prey is important for the welfare of carnivores. The statement about the positive educational value of live prey was supported by 81 % of the respondents. However 41% objected to the sight of prey remains in the enclosures. An important minority of 20 % stated not to visit zoos anymore if live small mammals were fed. In the case of feeding live fish 10 % stated not to visit a zoo anymore. These minorities are large enough to take into consideration when a change in live prey feeding policy is considered.

KEYWORDS: Zoo visitors, live vertebrate prey, carnivore feeding

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The nutrition of ornamental fish – challenges in feed formulation.

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Knowledge of the nutritional requirements and care of ornamental fish is probably one of the least investigated areas of pet nutrition. Considering the popularity of fishkeeping, this lack of scientific information is inadequate. There are over 264 million ornamental fish on a global basis. Within the UK, 22 million fish are kept as 'pets' which when compared to the 17 million UK based dogs and cats demonstrates the vast scale of this hobby. The majority of data collated for fish has been extrapolated from research conducted on commercially farmed species through the aquaculture industry. Cultured fish such as salmonids are generally carnivorous, have short life spans and are fed high protein and lipid diets in order to grow fast for the food market. In contrast ornamental fish which are predominantly cyprinids are largely omnivorous or herbivorous with little importance being placed on fast growth rates and feed conversion. Greater significance is therefore placed on health, longevity, breeding performance and visual appearance. Differences between cultured and ornamental fish e.g. feeding strategy, lifestyle, husbandry conditions and physiology questions the applicability of current aquaculture knowledge when applied to ornamental fish species. Many factors need to be considered when formulating diets for ornamental fish. Feeds should provide all the essential nutrients required to maintain health and biological function whilst being highly palatable, digestible and minimise waste. There is a requirement for further fundamental science to be conducted in this sparsely researched area.

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Feeding captive cheetahs: bone as animal fibre?

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Feeding strategies for cheetahs (*Acinonyx jubatus*) differ largely between zoos, ranging from feeding commercial extruded food for cats (e.g. some parks and zoos in South-Africa and United States) to several sizes of carcasses. As it is perceived that gastrointestinal and metabolic problems are frequently occurring in cheetahs, this study was an attempt to find clues for the origin of these problems. As fresh as possible faecal samples were gathered from individuals or pairs of cheetahs at four zoos in Belgium and The Netherlands, and were transported on dry ice to the lab. Over 60 samples were analysed, but for statistical reasons, they were pooled per experimental unit (individual or pair), leading to 21 observations. Analyses included dry matter, ash, minerals (calcium, phosphorus, sodium, potassium, chloride and magnesium), crude protein and bacterial protein. Data were analysed by regression and correlation analysis. Faecal nutrient concentrations were highly variable between individual cheetahs. For Ca, P and the bacterial protein fraction, it was clear that the feeding strategies between zoos were an important explanatory factor. For other nutrients, the zoo was a less determining factor. A surprisingly high correlation was found between faecal concentrations of Ca and P ($r=0.967$; $p<0.001$), and between faecal concentrations of Na and Cl ($r=0.985$; $p<0.001$). Most important, crude protein content in the faecal dry matter and the percentage of bacterial N in the faecal N ($r=-0.759$; $p<0.001$) WHAT?. Ca, Mg, and P were positively correlated with the proportion of bacterial N in the faecal N ($r=0.532$; $p=0.013$, $r=0.529$; $p=0.014$ and $r=0.523$; $p=0.015$ respectively). This correlation was not found for Na and K. The variability in nutrient levels between animals and especially zoos, suggest quite different feeding strategies. The questionnaire filled in by the animal keepers did not reveal detailed enough information that could be linked to the faecal analysis results. The distinct differences in Ca, Mg and P faecal concentrations are most likely a consequence of the carcass types fed to the cheetahs: e.g. rabbits are completely ingested, whereas bones from lamb carcasses are not ingested. Hence, the faecal concentration of Ca, Mg and P might indicate the extent to which the animals ingested bone, indirectly indicating what type of carcass they have been fed. This is supported by the intriguing correlation between the typical bone minerals Ca, Mg and P on the one hand, and the bacterial N proportion in total N on the other hand. In domestic cats, it has been demonstrated that cooked collagen from bone is highly digestible, but digestibility of raw collagen is less. It therefore seems that bone ingestion provides a substrate (collagen) for fermentation in the cheetah's hindgut. The present trial did not allow the determination of the bacterial flora, but this might reveal whether the bacterial growth is beneficial (suggesting a prebiotic action of collagen) or not. The high correlation between Na and Cl suggests the frequent use of salt. In conclusion, the data suggest that the carcass type fed to cheetahs could have effects on their gastrointestinal health.

KEYWORDS: Cheetahs, carcass feeding, fecal analysis

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Digestive physiology and feeding of captive tapirs (*Tapirus spp.*)

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Traditionally, the domestic horse has been used as the model animal for designing diets for captive, large hindgut-fermenting herbivores. On the basis of feeding studies, this concept has been confirmed for grazing rhinoceroses, but not for elephants and the browsing black rhinoceros. Tapirs have not been evaluated in this respect. As tapirs are browsers in the wild, particular adaptations - such as shorter mean retention times and lower fibre digestion coefficients, as compared to horses - could be expected in this species. 17 adult tapirs (est. body weight range 180-305 kg) from five different zoological institutions were used in this study; each animal received its regular zoo diet, and six were additionally tested on a roughage-only diet (range of crude protein 6.5-12.7 %DM; range of crude fibre [CF] 4.4-43.7 %DM). Feeds consumed and faeces voided were weighed in toto, and representative subsamples analysed according to standard laboratory procedures to calculate apparent digestibilities [aD]. Ingesta mean retention times [MRT] were measured using Cr-mordanted fibre (<2mm) as a particle marker. Dry matter intake varied between 12-81 g/kg^{0.75}. Especially on the roughage-only diets, intakes were sometimes very low and some animals lost body condition. In spite of MRT values that were of similar scope as, or even longer than, in horses (55 ± 16h), the measured digestibilities were generally lower than expected based on reports for horses on similar diets. The influence of CF on aD of organic matter [OM] was described as aD OM (%) = 98.0 – 2.22 CF (%DM); r² = 0.92 (in horses: 97 – 1.26 CF, Kamphues et al. 2004), and with decreasing DE content of the diet, dietary DE content as estimated for horses increasingly overestimated measured DE. Similar to horses, aD for calcium was high (68 ± 18 %). Although sharing basic characters of digestive anatomy and physiology (e.g. calcium digestion) with horses, the tapirs used in this study did not digest diets, in particular roughage-dominated diets, as well as would be expected from domestic horses. The fact that this occurred in spite of the comparatively long MRTs indicates that MRTs are not the only factor determining digestibility; in tapirs, a low defecation frequency (2-3 times/day) might lead to these long MRTs. Tapirs are notorious for a low intake of roughage items typically offered to them in zoos, and low CF contents of some diets in this study resulted from feeding large amounts of fruits and concentrates with little additional roughage intake by the animals. Low aD coefficients should be levelled by higher intakes. The fact that roughages usually offered to tapirs were often not ingested in according amounts could indicate that they were not adequate in either botanical or chemical composition (quality).

KEYWORDS: tapir, feeding and digestion study

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Comparative digestion studies in wild suids at Rotterdam Zoo

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Among the artiodactyla, the suids are a group whose digestive physiology has hardly been investigated. The apparent digestibilities (aD) of macronutrients were measured in captive specimens of warthog (*Phacochoerus africanus*), red river hog (*Potamochoerus porcus*), and Visayan warty pigs (*Sus cebifrons*), and compared to those reported for babirusa (*Babirusa babirusa*) from the same facility on a similar diet. The animals were fed mixed diets of pelleted feed, grains, fruits and vegetables; dietary neutral detergent fiber (NDF) ranged from 17-26% dry matter (DM). aD of organic matter and protein ranged from 72-89% and 70-82%, respectively. While red river hogs and warty pigs achieved aD of NDF of 41-54%, this value was higher both in warthogs (63-66%) and babirusa (61-63%). aD of acid detergent fiber was comparatively low in red river hogs (4%), warty pigs (22%) and babirusa (13-25%) but high in warthog (59-62%). Comparison with additional literature data (including peccaries) indicates that in spite of differences in digestive anatomy, suids and peccaries are similar, and resemble other herbivores in fundamental characteristics, such as the negative influence of fibre on overall digestibility, or the positive correlation of dietary protein content with apparent protein digestion. While the existing data is equivocal as to a superior fiber digestion in peccaries as compared to other wild suids, the results suggest that warthog are more efficient than other wild suids or peccaries in terms of fibre digestion. This particularity of warthogs could be an indication that diets fed to this species in captivity should contain high proportions of roughage.

KEYWORDS: pigs, digestion, feeding trial

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Energy and nutrient intake and digestibility in captive Mongoose lemurs (*Eulemur mongoz*)

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Lemurs in the wild live in harsh and unpredictable environments where food resources may be scarce during certain times of year. To cope with these conditions they have evolved different energy-saving mechanisms, including low energy requirements [Wright, 1999]. In zoos, lemurs tend to be fed diets rich in sugars and low in fibre, and the amounts remain constant year-round. This is thought to result in the high rate of obese lemurs that is observed in captive populations [Pereira and Pond, 1995; Terranova and Coffman, 1997; Schwitzer and Kaumanns, 2001]. For many lemur species it is not known to what extent they utilise the energy and nutrients in their diets, which makes it difficult to predict how much food they need to consume to meet their requirements. Mongoose lemurs in zoos are reported to be particularly susceptible to obesity [Schaaf and Stuart, 1983; Terranova and Coffman, 1997]. In this study we examined the energy and nutrient intake and digestibility in three Mongoose lemurs at Bristol Zoo Gardens. To establish activity budgets, behavioural observations were made for each individual over a 24-hr period using focal sampling and continuous recording. During a five-day digestibility trial, food and leftovers were weighed daily and faeces collected. As total collection of faeces could not be ensured, we used TiO₂ as an external marker. Food and faeces samples were freeze-dried and analysed for dry matter (DM), crude protein (CP), crude ash (CA), crude fibre (CF) and ether extract (EE) as well as for neutral detergent fibre (NDF) and acid detergent fibre (ADF). Nitrogen-free extracts (NFE) were calculated as 100-CP-CA-CF-EE. Body weights of the three individuals were taken prior to the trial period. Comparing body weights of the captive lemurs with those of wild conspecifics, the adult male was more than two standard deviations heavier than the mean wild weight of the species and was thus considered obese, whereas the adult female and sub-adult male could not be considered overweight. The results of our study showed that the diet consumed by the lemurs was high in easily available carbohydrates and relatively low in fibre. The animals preferred fruits and vegetables over the rest of their diet. Dry matter and nutrient digestibility was high. There was little difference in nutritional composition of wild and captive diets. However, the captive lemurs consumed more energy than their wild conspecifics per animal and day, which, together with a stable year-round supply, is likely to have led to obesity in the male.

KEYWORDS: Body weights, Activity budgets, Obesity

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Maintenance energy requirement of birds participating in flying demonstrations at Rotterdam Zoo

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Birds participating in flying demonstrations are lowered in weight in order to be able to train them. Trainers start by lowering the body weight of the birds approximately 10 to 15%. This brings the birds into a state in which they can be lured with food. Eventually they will perform for their reward: food, which can be seen as a form of operant conditioning. Since mid August 2007 a bird flying demonstration started at the Rotterdam Zoo. The flying demonstration involves 30 individual birds from 13 different species. Preparations for this demonstration began around 2 to 3 years ago. From August 2nd 2006 till October 27th 2007 we tracked 19 individual birds from 7 different species participating in the flying demonstration, recording their weight and food intake (both in grams). The birds have been weighed in the morning in a post-absorptive state except for the vultures that were weighed in the afternoon. Two types of scales have been used. Most birds have been weighed on a scale, accuracy x 2 grams. The white-backed vultures have been weighed on a scale, accuracy x 20 grams. The food has been weighed on a scale, accuracy x 2 grams. In order to get better insight into methods estimating the energy requirement of birds, we did some research on the energy requirement of birds and the factors influencing it. We then calculated the average weight of the birds, the percentage of weight loss each training season and the average energy content of the food given. We suspect that the diet the birds received during the training season met their maintenance requirements because their weight remained relatively stable during this period. Therefore we compared estimates of the maintenance energy requirement with the actual average energy intake. Calculations on the black kites suggest that the actual energy in the diets does not meet the estimates, especially with females. The average weight loss during training season for females is approximately 19 % of their original weight and for males 11 %. Moreover, the true amount of energy given to females is around 11 % lower than the calculated estimate, though males receive approximately 5 % more energy than the calculated estimate. This raises the question whether the diets given are sufficient and meet nutritional requirements.

KEYWORDS: birds, flying demonstration, maintenance energy requirement

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Observations On The Feeding Behaviour Of Two Species Of Nectar Feeding Birds At Chester Zoo

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Although nectar-feeding species, such as the lories & lorikeets, are becoming increasingly popular as companion birds, until recently there has been little information available on appropriate feeding strategies & nutritional needs. Chester Zoo's nutritionist and the Parrot Team wished to have a full evaluation of the diet offered and consumed by some of their nectar feeding birds to ensure that they were receiving complete nutrition. This study therefore examined the feeding behaviour of the medium sized yellow backed chattering lory (*Lorius garrulous flavopalliatu*s), currently maintained on exhibit in a breeding group, and the smaller Mindanao (Mount Apo) Lory *Trichoglossus johnstoniae*, currently housed off exhibit. Data were recorded for diet intake, water intake and intakes of a manufactured nectar solution; also observations were made of environmental temperature, group dynamics and visitor interaction. The diet was also assessed for nutritional content. The aim of the study was to assist in the dietary management of this species in captivity. The use of manufactured nectar solutions in a captive and wild environment is discussed. In addition, data were collected and compared between the two species to investigate any evidence of a compensatory feeding mechanism commonly seen in nectar feeding species. The birds were observed to adjust their volumetric intake of liquid nectar in relation to nectar solution concentration, perhaps to ensure that the energy value of the diet consumed remained constant.

KEYWORDS: Bird feeding behaviour, nectar intake, Lorikeets and Lories

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Trypsin inhibitor content of parrot cooking diets and other diet components

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Many animals rely heavily on their ability to extract nutrients from plant material. As a defensive mechanism against this predation, plants contain a wide array of secondary metabolites, such as trypsin inhibitors (TIs), which are often toxic. TIs greatly reduce amino acid digestibility by forming an irreversible complex with trypsin in the gut. Oilseeds and leguminous seeds are particularly renowned for their high TI content but their high protein content makes them attractive candidates for addition to parrot diets. The aim of this work was to examine the trypsin inhibitor activities (TIAs) of loose seeds and 'parrot cooking diets' (where owners heat a 'humanised' mix of beans, vegetables and cereals). Nine seed types commonly used in parrot diets, were de-husked (where appropriate) and analysed for TIA levels as described below. In addition, 4 samples of parrot cooking foods were prepared as per their instructions and analysed for TIA both pre- and post-preparation. TIA was measured by a microtitre technique based on a traditional TIA analysis technique. Briefly, the activity of trypsin inhibitor (TI) extracted from ground samples into mild alkaline solution was determined by measuring the ability of trypsin to digest a chromogenic substrate; benzoyl-DL-arginine-p-nitroanilide (BAPNA), in the presence of the extracted TI. TIA was measured in mg of pure trypsin inhibited per g of dry sample. The TIA levels of the loose seed samples were all below the threshold considered acceptable to poultry at inclusion levels of up to 25% of total diet (4mg/g). Prior to cooking, TIA levels of the 4 cooking diet samples were 6.2mg/g, 1.1mg/g, 0.5mg/g and 12.3 mg/g. The TIA's of the first 3 samples were 0.2mg/g, 0.1mg/g and 0.3mg/g after preparation as per guidelines. However, the 4th sample offered 2 possible preparation methods: heating or soaking. Whilst heating satisfactorily reduced the TIA of the 4th diet to 0.3mg /g, soaking barely altered the TIA which remained at 13.0mg/g. In contrast to expectations, screening of several varieties of sunflower seeds has shown they contain very low levels of TIs. Several cooking diets had TIA levels high enough to be detrimental if not cooked correctly according to the guidelines and one diet suggested a preparation method where TIA was unchanged. Cooking guidelines for these types of diet must ensure there is no risk of exposing birds to dangerously high (> 4mg TI/g sample) levels of TI. If legume seeds are used in parrot diets, heat is always recommended to denature TIs.

KEYWORDS: Trypsin Inhibitor, Parrot, Raw materials

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Macroscopic digestive anatomy of a captive lowland anoa (*Bubalus depressicornis*)

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While little is known about the actual diet of free-ranging anoas, a study on their digestive physiology yielded results similar to other intermediate feeders. Among the ruminants, this species is particularly interesting, as, on the one hand, most of its closer relatives – the bovini, i. e. cattle and buffaloes – show extreme adaptations to grazing niche, but on the other hand, the anoa has a (secondarily) reduced body size usually associated with a more intermediate or browsing dietary niche. Here, we report the digestive macroscopic anatomy of a 21 year-old, 53 kg captive lowland anoa that was euthanised after a longer period of therapy-resistant diarrhoea and inability to stand. The results were compared to measurements published for other ruminants. The anoa showed several anatomical characteristics typical for the bovini (and considered typical for other grazers), such as an unapillated dorsal ruminal mucosa, unapillated, thick rumen pillars, pronounced reticular crests with secondary and tertiary crests, four orders of omasal laminae, and a large masseter muscle. In contrast, the omasal laminar area was small compared to data published for other species, and the parotis glands were comparatively large. The findings represent an unusual combination of anatomical characteristics for a ruminant that should be corroborated in more individuals, and could represent a retrograde change from a grazing back to an intermediate adaptation. It could be suspected that the anoa can make better use of grass-based diets than other intermediate feeders.

KEYWORDS: anatomy, bovini, intermediate feeder

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Nutritional Research At Twycross Zoo

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Nutritional research has always been a vital component of the research focus at Twycross Zoo. Close links with the The University of Nottingham and now the newly established School of Veterinary Medicine and Science have enabled a progressive nutrition research program and created opportunities for students to experience zoo life for themselves. The appointment of Nic Masters (IZVG) as the resident veterinarian at Twycross Zoo and more recently the addition of Julie Jones as a voluntary consultant nutritionist have enabled the nutrition program at Twycross to progress enormously. The purchase of the Zootrition program by Twycross has also provided an excellent tool for nutrition information storage and analysis. This program allows a large facility, such as Twycross, to manage the dietary needs of the animals without excessive external diet analysis. The future of nutrition research at Twycross will aim to bring together the expertise of the nutritionist, veterinary team, including the newly appointed Head of Research Dr Lisa Yon, and key decision-makers at Twycross to design a nutritional program specifically for the Twycross collection. Research will focus on the nutritional balance of diets comparing them to published nutritional requirements. The program will allow the team at Twycross to establish a dedicated animal feed database detailing sound nutrition programs for all the animals in their care and upon which to build toward a leaner and more efficient and healthy way of working.

KEYWORDS: Zootrition, zoo nutrition, Twycross zoo

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Dietary antioxidants reduce post-exercise oxidative stress in adult budgerigars *Melopsittacus undulatus*

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Antioxidants are known to play an important role in quenching free radicals produced by metabolism, preventing oxidative stress. Exercise is encouraged in captive animals, owing to its benefits to an animal's health and welfare. However, since increased metabolism associated with exercise will increase oxidative stress, dietary antioxidants may be a limiting factor in determining physical performance, and post-exercise stress. Here we tested this hypothesis by assessing differences in post-flying oxidative stress in captive adult budgerigars, after they received a diet containing either enhanced (EA) or reduced (RA) levels of an antioxidant supplement. We employed a crossover dietary manipulation with birds receiving either EA diet followed by RA diet, or vice versa. Each dietary treatment lasted 28 days with birds being flown daily between days 24 and 27. On day 28 of each diet, we blood sampled the birds and measured oxidative stress in two ways: MDA analysis, which measures malondialdehyde, a product of lipid peroxidation, and Comet assay, which assesses oxidative damage to DNA from nucleated red blood cells. The birds tended to exhibit lower levels of MDA and had a significantly higher proportion of intact DNA, measured by Comet, on the enhanced antioxidant diet than on the reduced antioxidant diet. Take-off flight speed did not differ between the treatments, so our results show that birds receiving the enhanced antioxidant diet paid a lower physiological cost in terms of oxidative stress for a given level of physical effort. This indicates that the oxidative cost imposed by exercise in birds, can be reduced by providing a suitable antioxidant-rich diet.

KEYWORDS: parrots, antioxidants, exercise

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Welfare is not a privilege of show animals only: Carbon dioxide euthanasia of small prey animals

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While welfare concerns are often voiced in zoos with respect to the display animals, the welfare of prey animals purchased by, transported to, and killed at a zoo is rarely discussed. In many zoos, stunning-killing by a blow on the head is still a common method used for the killing of prey animals such as day chicks, mice, rats, or rabbits. These procedures usually involve individual handling of each animal, which has to be taken out of its transport container in order to receive the blow. The efficacy of the method is rarely monitored and will vary according to the experience of the performer. In addition, this activity is hardly cherished by the zoo personnel assigned to this task. At Zurich zoo, this procedure has been exchanged for a procedure of carbon dioxide euthanasia. Carbon dioxide is introduced into in a plastic container, designed to hold several typical rodent transport boxes, until it has displaced all oxygen (as assessed by a candle or lighter). Only then, the prey animals are introduced, in the cardboard transport boxes in which they arrive, into the container. Approximately five minutes are allowed to pass between the last visible movement of the animals and their retrieval from the container. This procedure represents an economic, time- and motivation-sparing, and welfare-oriented method to kill prey animals in a practicable way without undue amounts of stress, the operation of which follows a written protocol and appears comparatively uninfluenced by the experience of the performer.

KEYWORDS: commissary, food preparation, prey, euthanasia, slaughter

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Iron metabolite analysis in captive nonhuman primates

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Different views have been put forward in the zoo animal literature on excessive iron storage in captive nonhuman primate species. A direct pathologic effect has only been demonstrated in lemurs and marmosets; however, excessive iron deposits have also been described in other species at necropsy. The relevance of these reports for a general management strategy for certain species and groups, the frequency of occurrence, and the adequacy of different methods of assessment are currently under debate. We analysed opportunistic serum samples of 299 captive adult individuals of 18 species; for a systematic comparison, the species were grouped into apes (*G. gorilla*, *P. pygmaeus*, *P. paniscus*, *P. troglodytes*), lemurs (*L. catta*, *V.v.variegata*, *V.v.rubra*, *E. fulvus*, *E. mongoz*), and macaques/baboons (*M. fascicularis*, *M. fuscata*, *M. mulatta*, *M. silenus*, *P. hamadryas*). Common marmosets (*C. jacchus*), guereza (*C. guereza*), woolly monkeys (*L. lagotricha*), and douc langurs (*P. nemaus*) were considered individually. Serum was analysed for serum iron (Fe), total iron binding capacity (TIBC) and %transferrin saturation (%TS) by a functional test and for ferritin using an ELISA designed for detection of human ferritin by a polyclonal antibody, similar to the antibody used to detect lemur specific ferritin as described by Andrews et al. (2005). Both, lemurs and macaques/baboons had a significantly higher TIBC than apes; the same was evident for woolly monkeys, and marmosets also had a mean TIBC just above the 95% confidence interval of apes. Nevertheless, lemurs had a %TS significantly higher than both apes and macaques/baboons, and the mean %TS of guereza and woolly monkeys was above the ape 95%CI, with marmosets again close to the upper ape 95%CI limit. Correspondingly, lemurs had significantly higher Fe than both apes, while macaques/baboons had intermediate values. Marmosets, guereza and woolly monkeys had mean Fe values above the upper ape 95%CI. The results of the ferritin assay indicated that the test was not equally sensitive in different species. Our results are within the range of many literature reports, except for some high TIBC values. They suggest a systematic difference in iron metabolism, with some primate groups – amongst which those suggested to be more prone to excessive iron storage – having particularly high TIBC, possibly as a secondary reaction to high iron loads; the high %TS values in these same groups, therefore, result from particularly high serum Fe values. A comparison of the data from the captive animals with those reported for free-ranging animals suggests a difference in iron status between these populations. In parallel to routine procedures for the treatment of excessive iron storage in birds, and in human hemochromatosis, dietary iron limitation might be a reasonable strategy in the management of certain primate species, the consequences of which should be monitored.

KEYWORDS: iron, opportunistic sampling, multispecies survey

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Hemosiderosis in captive lesser hedgehog tenrecs (*Echinops telfairi*)

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Excessive iron storage is reported in captive mammals and birds. In several studies, it was shown that reducing dietary iron levels can improve the situation. Nevertheless an appropriate feeding regime in captive animals is a challenge. Individuals from a colony of captive lesser hedgehog tenrecs (formalin fixed material) were submitted for necropsies. Whereas in their natural habitat, these feed on insects and invertebrates, this group was kept mainly on canned cat and dog food. In a total of 79 animals, a severe, moderate and slight hepatic siderosis was found in 47, 20 and 10 cases, respectively; only two individuals did not show any signs of hepatic siderosis. Based on these facts, a feeding trial was instigated with three different groups (A: cat and dog food, Fe app. 180 mg/kg DM; B: insect-based bird food with similar Fe level but presumably a lower proportion of heme-Fe; C: low-iron bird food with app. 100 mg Fe/kg DM). In two consecutive blood samples with a 5-month interval, transferrin saturation (%TS) was assessed; additionally, necropsies were performed on individuals sacrificed for other studies or after naturally occurring deaths. There were no systematic differences in %TS between the groups, due to high inter-individual variation; however, %TS decreased in all 5 C and all 4 B animals that were bled on both occasions, and increased in 6 out of 7 A animals. Nevertheless, there was no difference in the hepatic siderosis score at necropsy between the trial groups. Dental plaque was more frequent on diet A (28% of investigated animals) than on diets B and C (20%); skin hyperkeratosis, considered indicative of an unspecified dietary deficiency, was extremely frequent on diet B (33%) and rare on diet A (11%). We were not able to achieve an improvement regarding the excessive iron storing by changing the diet to food with lower iron levels; in contrast, other dietary imbalances might have been introduced. Whether the occurrence of hepatic siderosis in this colony is of pathological relevance, and can be influenced by other factors, remains unknown for the moment.

KEYWORDS: Hepatic siderosis, tenrec, diet

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Effect of a probiotic (Yakult™) on faeces consistency of primates

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A few years ago the diets of several primate groups were changed in Zoo Emmen. Before the diet change the faeces of the animals were too soft which lead to complaints of keepers and others. In the new diets gluten free ingredients were used and a probiotic drink containing *Lactobacillus casei* (Yakult™) was added. After these changes the faecal consistency improved. Because of this apparent success of the changes it was requested to add the probiotic to other primate diets. Since it was not clear whether there was any effect of the probiotic alone it was decided to test the effect of the probiotic drink addition primate diets. Six primate groups were used: *Callithrix jacchus* (n=2), *Saimeri sciureus* (n=2), *Chiropetes albinasus* (n=2), *Leontopithecus rosalia* (n=2), *Hylobatus lar* (n=4), *Ateles paniscus* (n=17). During two weeks the probiotic drink was added. The three following weeks a yoghurt drink without probiotics was given, after this the probiotic drink was added again for two weeks. During these eight weeks faecal samples were taken by the keepers on a daily basis. Collected faeces were send for consistency grading and determination of bacterial composition. Faeces consistency was graded on a scale from 1- 5 (1: very dry and firm, 5: watery). The presence of *Lactobacillus casei*, *Bifidobacterium*, *Bacteroides* and *Clostridium* was measured using fluorescence in situ hybridization (Fish). In all primate groups there was no significant difference in faeces consistency between the periods. Bacterial composition of the faeces did not change significantly between the periods with and without probiotic addition. A too low dose can be a possible explanation for the lack of effects. Furthermore the probiotic used is developed for humans. It is not certain that a probiotic developed for a certain species will work in others. However, with these results in hand one can advise zoos to spend their money on other dietary items.

KEYWORDS: Probiotic, primates, faeces consistency

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Salt licking of primates is not always a sign of sodium hunger

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The free ranging red ruffed lemurs (*Varecia rubra*) in Apenheul primate park were frequently observed licking visitors arms and hands. When a salt lick was placed in their enclosure, both red ruffed lemurs as well as ring tailed lemurs (*Lemur catta*) started using this. The licking of visitors' hands decreased, however (non nutritional) additional measures were taken as well to prevent this behaviour. For obvious reasons, licking visitors' hands is unwanted behaviour. The question arose whether this behaviour was caused by a lack of dietary sodium. During two five days periods (in July 2006 and February 2007) the diet intake of the lemurs was measured. Two samples of each diet ingredient were taken and frozen for analysis. Samples were analysed for sodium (Na), potassium (K), calcium and iron (Fe) content. With the help of the software program Zootrition™, the other nutrient values were calculated. Dry matter sodium content of the overall diet was 0.5%, which is higher than the NRC requirement for primates (0.2%). The potassium content (1.2%) was also higher than the requirement. The measured dietary iron content of 67 ppm is probably also sufficient. The calcium content of the diet (0.22%) was however markedly lower than the NRC requirement (0.8%). Due to lack of dietary calcium, salt licking behaviour can develop. However other primate species in Apenheul getting the same diet did not show this behaviour. Furthermore, primates in Apenheul roam freely around and can eat bark and twigs of trees, which are relatively calcium rich. This intake might compensate for dietary shortages. Licking of visitors' hands started after three juvenile red ruffed lemurs from another zoo were introduced. These animals already showed this behaviour. This makes it probable that the main cause of this problem was copying behaviour of the other individuals in combination with a possible liking of a 'salty' taste.

KEYWORDS: Lemurs, sodium, salt lick

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Influence of concentrate or roughage feeding on body weight and blood parameters in captive plains viscachas (*Lagostomus maximus*)

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Similar to certain desert-adapted rodents, the plains viscachas have been reported to be susceptible to developing diabetes mellitus, including the formation of cataracts, when receiving diets high in easily digestible carbohydrates. In order to test the influence of different diets in a controlled way, we assessed body weight and several serum parameters in 3 male and 3 female adult viscachas after feeding (I) grass hay only ad libitum for one month (NDF 55 %DM, crude protein 5.8 %DM), (II) a concentrate feed ad libitum with access to hay for three months (average ingested diet: NDF 37 %DM, CP 11.3 %DM), and (III) grass hay only ad libitum (NDF 57 %DM, CP 6.8 %DM) for another three months. Mean body weight at the end of each feeding period of males was 3.8 kg, 4.5 kg and 3.9 kg, and those of females 2.4 kg, 2.7 kg and 2.5 kg, respectively. Serum leptin levels reflected the change in body weight, with an increase during (II) and a significant decrease during (III). Blood glucose values remained within the reference range during the entire time, but tended to be lower during (III) as compared to the other periods. Similarly, serum fructosamine values were lowest in period (III) but still slightly above the reference range established in wild animals. This may indicate that long-term feeding without concentrates might be required before levels comparable to the wild are reached. Interestingly, serum amylase levels peaked in period (II) and were lowest in period (III), indicating a response of this parameter to dietary manipulations. Compared to the body weights recorded for free-ranging viscachas (2.9-6.6 kg for males and 1.8-4.2 kg for females), the animals did not appear overweight at any time in the study, but the change in leptin values indicated that body weight gain was due to accumulation of adipose tissue mass, and hence potentially obesity, a predisposing factor for type II diabetes.

KEYWORDS: *viscacha, diabetes, fibre, feeding trial (A-B-A)*

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Nutrition of captive tapir (*Tapirus indicus* and *Tapirus terrestris*): a study on feed intake, faecal consistency, body condition and health problems

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Members of the Tapiridae family are defined as browsers. In order to try and determine the suitability of the diets provided to captive tapirs in relation to the health of the captive species, three-day intake measurements were carried out across seven zoological collections in the UK. Dry matter intake (DMI) for tapirs in the feeding trial ranged from 48 to 86 g / kg^{0.75} MBW. Across collections, the highest proportion of the diet consisted of pelleted feeds (including grains and bread) at 55.1±15.5% of the total DMI, followed by commercial produce at 23.7±13.9 %DMI, roughage (excluding browse) at 15.9±8.4 %DMI, and browse at 10.1±13.1 %DMI. The proportion of roughage, crude protein, crude fibre and NDF levels (%DM) in the diets of the animals investigated were well below recommended levels as suggested for domestic horses and other ungulates. Intakes of digestible energy as estimated from food nutrients by the use of a standard equation for domestic horses ranged from 0.58 to 0.88 MJ DE /kg^{0.75} MBW, with many individuals exceeding the assumed maintenance requirement of 0.6 MJ DE /kg^{0.75} MBW for hindgut fermenters. At values exceeding this maintenance energy requirement, animals were seen to have higher than ideal body condition scores (BCS) and mean faecal scores (FS). Although no individual dietary constituent or nutrient could be identified that correlated to BCS or FS, animals with higher BCS (i.e more obese animals) generally had higher FS (i.e softer faeces), and both BCS and FS were positively correlated to DM and calculated DE intake. This seems to suggest that the population studied was generally overfed, with resulting obesity and softer faecal consistency. The use of highly digestible feeds such as commercial produce and pelleted feeds should therefore be restricted in the diets of these animals and sources of roughage highly promoted in order to attempt to achieve normal BCS and FS in the captive population. A comparison of the voluntary hay intake across collections suggests that due to its higher acceptance, lucerne hay is a more suitable roughage source for tapirs than grass hays. Although no causal relationship can be proven between the health problems, primary causes of death and the diets offered tapirs, it can be speculated that the inappropriate diets are contributing to these problems.

KEYWORDS: tapir, intake study, diet survey

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Morphological characteristics, diet retention time, feed intake and diet digestibility in Formosan pangolin at Taipei Zoo

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The objective of this study was to gain a better understanding of the digestive characteristics and nutrient requirements of captive Formosan pangolins. The following morphological measurements were recorded for three females and seven males: body length (length from the muzzle to the vent); tongue length and intestinal length. The weight of the body, stomach, and sub maxillary salivary glands were also recorded. Ratios of tongue length to body length, intestinal canal length to body length, stomach weight to body weight, and salivary gland weight to body weight were calculated. Three experimental tasks were performed to accomplish the said objective. (1) Measure the retention time of diet in the animal by adding Cr₂O₃ as a marker into the diets. (2) Study the apparent digestibility of dry matter (DM), crude fat (EE), crude protein (CP), ash and gross energy (GE). (3) Understand the effect of chitin and chitosan on apparent digestibility. Two male and two female pangolins were individually housed for seven days before the experiment. Every afternoon, at five o'clock, 40 g diet / kg body weight was offered and water was supplied ad libitum. In Experiment I, feed intake was recorded daily and body weight was measured weekly to determine the relationship between feed intake and body weight. In Experiment II, 1g of Cr₂O₃ per 100g diet was administered and feces was collected at the 7th day to examine their color and calculate the retention time of diet. The digestibility trial was carried out for 30 days, feed intake was recorded, and feces were collected to calculate the apparent digestibility of the basal diet. In Experiment III, six pangolins were studied using a Latin square design to test for 3 different treatment diets: diet 1 (basal diet) ; diet 2 (basal diet with chitin 5 g/100g diet) ; diet 3 (basal diet with chitosan 5 g/100g diet). The result showed that (1) The ratio of intestinal canal length to body length was approximately 9:1 which is much similar to that of an omnivorous animal rather than a carnivorous animal. (2) The daily dry matter intake was 39-71 grams and daily energy intake was 282.54-353.18 kcal. (3) The average retention time of the basal diet was between 24 and 48 hours with a maximum of 60 hours. (4) The apparent digestibility of DM, EE, CP, ash and GE were 88.8 ± 1.0, 95.9 ± 0.9, 86.4 ± 1.6, 68.0 ± 5.6 and 91.0 ± 1.1 respectively. (5) The diet with chitosan was not accepted by the study animals. (6) The addition of chitin decreased the apparent digestibility of DM, CP, ash and GE (p < .05), therefore it may be an effective method of weight control in the pangolin. Furthermore, chitin seemed to improve fecal consistency.

KEYWORDS: apparent digestibility; Formosan pangolin; chitin

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Feeding and nutrition of amphibians and reptiles at Taipei Zoo

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Taipei Zoo's amphibian and reptile collection consists of 1,988 individuals from 280 different species. Only 191 species (1,008 individuals) are on exhibit for public viewing in the zoo's Reptile House. The remaining 89 species (980 individuals) are housed in the zoo's Wildlife Rescue Center, which has five main roles: 1) Identifies species involved in cases of smuggling or violating the Wildlife Conservation Law of Taiwan 2) Holds confiscated animals until it is determined whether they will be released or kept in captivity 3) Cares for stray wildlife from all over the country. 4) Works in the field, gathering data to improve the care of captive species by carrying out surveys of native amphibians and reptiles, such as the Taipei frog and the green bamboo viper and 5) Plays an active role in animal conservation by successfully breeding endangered species, such as the Burmese star tortoise, the central Asian tortoise, and the highly venomous Chinese moccasin. To meet the nutrient requirements necessary for health, reproduction and growth of their reptiles and amphibians, Taipei Zoo has recently introduced a wide variety of vertebrate and invertebrate prey items, produce, flowers, commercial diets, and vitamin and mineral supplements. Carnivores may be offered beef and/or live vertebrate prey, such as rodents, frogs, fish or lizards. More insectivorous species are largely dependent on a supply of invertebrate prey items, such as crickets, mealworms, and fruit flies. Crickets, mealworms and earthworms are dusted with Fluker's Reptacal and Reptavit prior to feeding. Invertebrate prey items are generally offered 2-3 times weekly. Omnivorous species, such as some turtles may be offered a variety of produce as well as vertebrate prey items (ie. goldfish, mice pinkies), beef and in some cases a commercial pellet. Herbivores, such as the tortoises are fed a variety of produce items (ie. carrot, yam, greens, cucumber) which are washed and prepared daily during the summer months but fed every other day in the winter months. A multivitamin supplement is added to the produce once a week. A large amount of fresh browse (ie. silk tree leaves) is also harvested and manually pruned daily for tortoises. Commercial iguana diets are offered to the common green iguanas twice weekly in addition to their daily vegetables. Depending on the weather, fruit (ie. apples, papaya, banana) may or may not be offered in colder, winter months (Nov – Feb). In ectothermic species, metabolic rate and digestion are inhibited in colder temperatures, therefore, highly fermentable fruit items may cause digestive upset by fermenting in the digestive tract rather than being properly digested. For this reason, some reptiles are fed inside during winter months. The husbandry involved in caring for the reptiles and amphibians at Taipei Zoo is an important aspect of providing proper nutrition to all individuals. The Reptile House and Wildlife Rescue Center are divided into three temperature-controlled rooms (18-20°C, 20-24°C, >30°C). Animals are provided with UVA/UVB lights (for calcium metabolism) and humidity is controlled via automatic or manual misting depending on species requirements. Care is also taken to present feed in a manner that minimizes contamination from soil and allows for species-appropriate feeding behaviours. Trough-like dishes are used for turtles to allow all animals access to feed simultaneously. Several dishes are provided for larger tortoises. Live rodents are introduced into reptile enclosures and then removed in 24 hours, if they are not consumed, to reduce the risk of injury to the reptile from a hungry rodent.

KEYWORDS: reptile, amphibian, feed, nutrition, husbandry
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The effect of dietary microbial supplementation, anthelmintic treatment and concentrate to forage ratio on feed intake and fecal consistency in Formosan serows at Taipei Zoo

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Captive Formosan serows (*Capricornis crispus swinhoei*) in Taipei Zoo were used in this study. The study was divided into four parts. First, Formosan serows' feedstuffs from January to December in 2006 were collected and analyzed for dry matter (DM), crude protein (CP), neutral-detergent fiber (NDF), acid-detergent fiber (ADF), and ash. The main forages (*Morus australis* leaves and *Trema orientalis* leaves) were found to have lower moisture content in fall and winter; lower NDF in spring and fall, lower ADF in summer and fall and a higher ash content at the end of the year. Compared to these forages, carrot, sweet potato and concentrate pellets had more stable nutrient compositions. The second part of the study was to determine what range of concentrate to forage ratio (C:F) would maintain optimal fecal consistency. Nine serows (six males and three females) were used in the study with dry matter intake (DMI), fecal consistency, and fecal flora as the indicators of animal health. In the pilot experiment, a serow, named Chang-pu, was fed diets with a C:F of 25:75 and then 45:55 resulting in fecal moisture content of 49.8% and 82.1% respectively. The density of pathogens changed as follows: *Shigella spp.* increased to 4.14×10^8 CFU/g, *Clostridium spp.* increased to 4.70×10^8 CFU/g; *Escherichia coli* increased to 1.02×10^9 CFU/g; *Bifidobacterium spp.* decreased to 9.01×10^4 CFU/g. When Chang-Pu was fed a diet of more than 1.06% BW as concentrate pellets she developed diarrhea. In the formal experiment, when C:F was changed from 30:70 to 38:62, DMI increased and the feces maintained its form. The density of *Escherichia coli* increased to 1.09×10^9 CFU/g; pathogens *Shigella spp.* increased to 3.01×10^8 CFU/g, *Clostridium spp.* increased to 4.47×10^8 CFU/g. When the C:F was less than 38:62, the ratios of pathogens in fecal flora were not affected. The third part of the study was to determine whether the supplement of microorganisms would affect DMI and fecal flora. A ration of 0.5 g/day/animal *Enterococcus faecium* and *Saccharmyces cerevisiae* was provided to six serows (three males and three females). Microbial supplementation did not affect DMI, fecal moisture content or microbial composition in this study, but allowed the C:F to be increased to 41:59 without causing diarrhea. Microbial supplementation also increased *Bifidobacterium spp.* to 3.80×10^6 CFU/g, decreased pathogens *Shigella spp.* to 2.22×10^6 CFU/g, and decreased *Clostridium spp.* to 1.40×10^8 CFU/g which had a positive impact on intestinal flora. The fourth part of the study was to give Ivermectin at a dosage of 200 µg/kg BW alone or with Mebendazole at 10 mg/kg BW for a treatment period of five consecutive days or three cycles of three treatment days separated by four days without medication. Anthelmintic combination treatment in three cycles had the best effect on round worms, but no effect on coccidia. In conclusion, although seasonal differences in the quality of forages were found there was no proven correlation to the incidence of diarrhea. When the C:F was less than 38:62, the animal maintained optimal fecal consistency, and fecal flora was normal. The supplementation of *E. faecium* and *S. cerevisiae* increased concentrate feed intake and the density of fecal *Bifidobacterium spp.* and decreased the density of pathogens *Shigella spp.* and *Clostridium spp.* In summary, using a combination of Ivermectin and Mebendazole in 3 cycles was effective to treat round

worms, but not coccidia. Therefore, anticoccidial drugs should be used in addition to anthelmintic treatment in Formosan serows.

KEYWORDS: Formosan serow, concentrate to forage ratio, microbial supplement, fecal flora

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Diet selection and nutrient intakes of captive lion tamarins (*Leontopithecus* spp): A preliminary study

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It is known that Callitrichids have specific nutritional requirements and zoos offer heterogeneous diets that not only supply the necessary nutrients, but also provide sensory stimulation and promote natural feeding behaviours. However, the free choice given to these primates will invariably result in the diet consumed being different to the diet offered. Food preferences will consequently influence the consumption of nutrients and create possible imbalances in diets consumed. A diet intake study was carried out to assess the existence of food preferences and the resulting nutrient intakes of two groups of captive *Leontopithecus* (*L. chrysomelas* n=5 and *L. rosalia* n=3) when offered a heterogeneous diet. This was carried out at Colchester Zoo using continuous focal observation of each individual. Weight measurements of food items were also recorded before and after being offered and published food composition data were obtained so that nutrient intakes could be estimated. There were clear preferences shown towards food items that contained soft sweet pulp (e.g. bananas, blueberries and grapes), over others such as spring onions, peas and beans, and diets selected by individuals were less diverse than diets offered. There were no significant differences detected between group intakes of dry matter (DM), total dietary fiber (TDF), crude protein (CP), crude fat (CFat), ash, calcium (Ca) and phosphorus (P). However, at the individual level, differences were observed. Nutrient intakes of both *Leontopithecus* groups were compared to the suggested levels of feeding that were found in the literature. It was seen that the mean intakes of TDF, CP and Ca for both groups were below the suggested levels stated in the literature, whereas mean CFat and energy intakes were above published levels. It was concluded that food preferences probably influenced the intake of nutrients observed, although dietary composition was also likely to be influential. However, although differences did occur in individual nutrient intakes, due to small sample size and short duration this study can only yield preliminary data.

KEYWORDS: *Leontopithecus*, food preferences, nutrient intake

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Rumen pH and claw health in two groups of captive wild ruminants

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The connection between a feeding regime with a high proportion of concentrates and laminitis is well recognized in domestic animal medicine but has received little attention in captive wild hoofstock. We used the occasion of a transport of two ruminant groups that necessitated immobilization, for an evaluation of the appearance of the claws on the one, and of the pH of the rumen fluid gained by ruminocentesis on the other hand. A group of eight Himalayan tahr (*Hemitragus jemlahicus*) had a median rumen pH of 7.2 and a low claw ring score, indicative of good claw health. A group of seven blackbuck antelope (*Antilope cervicapra*), in contrast, had a median rumen pH of 6.0, and an intermediate claw ring score and elevated claw temperatures, indicative of a chronic laminitis. In relation to body weight, the feeding regime of the blackbuck included a higher proportion of concentrates. These observations suggest that a connection between concentrate feeding, low rumen pH, and claw health could exist in captive wild ruminants, and that a feeding regime that prevents a drop of rumen pH could support claw health.

KEYWORDS: ruminants, hoof score, rumen pH, opportunistic sampling

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