University of Zurich, EAZA Nutrition Group & Zurich Zoo

7th European Zoo Nutrition Conference
27-30th January 2012
Zurich

ABSTRACT BOOK

Abstract Book Editors
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Conference Venue
University of Zurich
Irchel Campus
Winterthurerstrasse 190
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FOREWORD

Dear Friends and Colleagues,

It is our great pleasure to welcome you to the 7th European Zoo Nutrition Conference organised by the Clinic for Zoo Animals, Exotic Pets and Wildlife of the University of Zurich, the EAZA Nutrition Group, and Zurich Zoo.

The nutrition of zoo animals is fascinating for its many challenges – in terms of logistics, hygiene, health issues and communication involved, in terms of the evolutionary history revealed by adaptations of digestive physiology, and in terms of the enormous variety of items considered 'food' by this planet's inhabitants. And because it is fascinating in itself to be around wild animals.

The EAZA Nutrition Group (ENG) seeks to improve communication and coordination among all those engaged in research, education, or application of comparative (zoo) nutrition with those requiring nutrition information, chiefly within zoological institutions of Europe. Our work aims "to promote and support nutrition in zoological institutions as an essential component of their conservation mission"

Two different aims were prominent in organising this conference. With respect to content, attendees of the previous conference had communicated the requirement for basic information, such as how a digestibility trial is performed, how body condition is evaluated, or how roughages should be chosen. At this conference, we offer several activities (workshop, zoo demonstrations) that hopefully cover a lot of these questions, and encouraged presentations based on practical experiences. Additionally, several keynote talks address issues considered of general interest by last conference's attendees. With respect to costs, attendees of the last conference emphasized that low conference costs are very important. We did our best to keep costs at an absolute minimum while maintaining an atmosphere where colleagues can meet. In particular, we tried to offer catering under agreeable conditions at a low price (for Switzerland). Nevertheless, the present financial status of many zoos meant that people who were interested in joining us could not attend.

We gratefully acknowledge significant financial support via sponsorship by Arie Blok Diervoeding (Kaspar Faunafood), Brogaarden ApS, Kiezebrink Putten BV, Mazuri Zoo Foods Europe, Mazuri Exotic Animal Feeding Resource US / Nutrazoo, Provet AG, Provimi Kliba AG, St. Laurent, and Versela-Laga. Please make a special effort to thank their representatives here at the meeting and collect information from them; they help us feed animals optimally. Additional sponsorship was provided by DogVision, Taylor & Francis Academic, Zurich Zoo, and the Canton of Zurich and the City of Zurich.

In addition to the above-mentioned institutes and companies, we're indebted to Anouchka Jacquier and Michael Sullivan in the EAZA Executive Office who bore the considerable administrative burden of processing all your registrations.

Finally, thank you for attending this year's conference.

Marcus Clauss, Clinic for Zoo Animals, Exotic Pets and Wildlife, University of Zurich
Andrea Fidgett, Chair, EAZA Nutrition Group
January 2012

Scientific/Organising Committee
Marcus Clauss, University of Zurich
Andrea Fidgett, Chester Zoo
Jean-Michel Hatt, University of Zurich
Tjalling Huisman, Hogeschool van Hall-Larenstein
Geert Janssens, University of Ghent
Annette Liesegang, University of Zurich
Joeke Nijboer, Rotterdam Zoo
Amy Plowman, Paignton Zoo Environmental Park
Christoph Schwitzer, Bristol Zoo Gardens

Resource Index

Compound feeds

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MAZURI ZOO FOODS, PO BOX 705 Witham, Essex CM8 3TH, **United Kingdom**, +44 (0)1376 511260, www.mazuri.eu, contact@mazuri.eu

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Roughages

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(Dry browse leaves):

ALFRED GALKE, Am Bahnhof 1, 37534 Gittelde, **Germany**, +49 (0)5327 86810, www.galke.com, info@galke.de

Frozen meat/fish

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Whole prey (insects, day chicks, rodents)

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Mineral/Vitamin Supplements

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Nutrition advice/Veterinary services

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Feeding equipment/Feeding enrichment tools

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Education

UNIVERSITY OF APPLIED SCIENCES VAN HALL LARENSTEIN, Dept. Animal Management, PB 1528, 8901 BV Leeuwarden, **The Netherlands**, +31 (0)58284631, www.vanhall-larenstein.nl, tjalling.huisman@wur.nl

Friday 27th January ~ FORAGE WORKSHOP

08:30   Workshop commences (until 17:00)

18:00   Conference Icebreaker

Saturday 28th January ~ CONFERENCE   *Page*

Sunday 29th January ~ ZOO DEMONSTRATIONS & CONFERENCE

Monday 30th January ~ CONFERENCE

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Poster Presentations

Diet imprinting and responses to diet changes in animals
Jon E. L. Day

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Switching captive animals from one diet to another poses a challenge for anyone involved in managing their husbandry. Diet transitions may be necessary as a result of changing formulation, cost and availability of raw materials, or as the animal is moved from one environment to another. If the continuity of food intake is disrupted, this can adversely affect the individual's health and welfare. When animals are posed with a change in their diet, their response lies somewhere on a continuum between neophilia (acceptance) or neophobia (rejection). An understanding of how food intake is regulated may enable interventions to be suggested to help manage transitions. However, whilst animals make quite simple feeding choices such as 'when', 'what' and 'how much' to eat, the mechanisms underlying these decisions can be highly complex. One of the legacies gifted to the field of ethology by Tinbergen was his framework to evaluate why an animal expresses particular behaviours – "the four whys". When we try to understand the basis of feeding behaviour in a particular species we can use this framework to consider its: 1) causation, 2) ontogeny, 3) phylogeny and 4) adaptation. The study of *causation* involves examining the factors that initiate and terminate feeding behaviour. The study of *ontogeny* involves examining the existence of phenomena such as sensitive periods, conditioned food preferences and aversions, and social learning. Studies of *phylogeny* enable insights to be gained from the behaviour of similar species of animal. By considering *adaptation* we are able to place the feeding behaviour of the individual animal within its evolutionary context and examine how certain behaviour patterns might have arisen as a result of the ecological niche in which the species evolved.
Once a full audit has been conducted concerning how an individual may react to diet change and why, it is still necessary to propose practical interventions to manage the change. For animals that are being moved from one location to another, the use of 'welcome-home' diets are highly recommended to offer familiarity within the changing environment. This can be coupled with the avoidance of changes in feeding practices and the physical equipment used to present food. The use of 'sentinel' animals may also help to encourage food acceptance in species where there is social facilitation of feeding. For other situations where the animal remains housed in its home environment, gradual 'weaning' from one diet to the other is generally recommended. Other strategies might include using conditioned cues such as flavours to encourage intake based on the animal's prior feeding experience (imprinting). Sometimes the use of highly preferred neonatal diets/flavours might offer potential for encouraging intake. Diet transitions can be challenging both for the animal and its caregivers. Intervention strategies that are underpinned by knowledge of the animal's feeding behaviour have the greatest chance of success. Good communication between the nutritionist, veterinarian and animal caregivers is essential as often the best strategy involves patience as the animal gradually learns to accept the change.

From theory to practice: a checklist for the implementation of new zoo animal diets
Jean-Michel Hatt & Marcus Clauss

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Diets of zoo animals are undergoing constant improvements, and these require regular changes in the daily routine. Whereas there is a wide database of information on the requirements and the formulation of diets for zoo animals, comparatively little information is available regarding the introduction of theoretical zoo animal diets into practice, although the step of moving from theory to practice is very important for the wellbeing of animals. From 2004 to 2011 at total of 75 modifications of zoo diet changes have been made at Zurich Zoo have been implemented. These implementations are in the responsibility of the zoo veterinarian and they involved changes such as the development of completely new diets, typically with the integration of a new species in the collection, but more often they were adaptations of the diet as a result of new knowledge regarding the behavioural or dietary needs or health-related issues (e.g. obesity, age). Here we present a checklist, based on practical experience, which includes the main aspects to be followed for a successful translation of theoretical information to cover the needs of an animal into daily routine. The steps to be followed include: translation, communication, motivation, and implementation, follow-up.

1. Translation: Published requirement values or diets from one or more other institutions, which successfully manage the species, are translated into food items and amounts. Availability of food items is evaluated. The cost of the new diet is calculated. Ethical aspects (whole prey vs. processed feeds) are taken into account. Seasonal changes are included if adequate. Palatability and physiological constraints for the introduction of the new diet are evaluated. Work time for the preparation of the diet is quantified. Behavioural enrichment is included. Potential risks due to selection especially in group feeding or multi-species holding facilities are considered. Need for specific infrastructure to offer the diet are analysed and financial consequences evaluated. Critical thresholds (e.g. a maximum body mass loss) or target measures are defined that will require additional further action.
2. Communication: Information of key persons (e.g. general curator, head keeper, keeper, commissary personnel). Discussion of pros and cons of the new diet. Give time frame that is foreseen for the introduction of the diet. Discuss possible research that can be linked to the introduction of the new diet. Allow for 1 – 2 weeks for feedback.
3. Motivation: Get the personnel, especially keepers, who will eventually prepare and feed the new diet, motivated by explaining why the new diet is important (e.g. weigh loss program, prophylaxis against certain diseases such as diabetes).
4. Implementation: Make sure that all food items are available when the new diet is started. Ensure that all aspects of points 1 – 3 are satisfied.
5. Follow-up: Monitor the course of the diet change, and make adjustments if diets are not accepted by the animals or if unforeseen problems (logistics, costs) occur.

KEYWORDS: diet change, communication, diet formulation

Generational changes in weight and dietary preferences in a neophobic species (*Callimico goeldii*)

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Goeldi's marmoset (*Callimico goeldii*; "callimico") is a notoriously neophobic species, which makes it challenging to implement any dietary or environmental changes. Brookfield Zoo (BZ) has been breeding and caring for a colony of callimico for over 30 years, from which there is a large amount of data on behaviour and food preferences. Approximately ten years ago, Brookfield received 8.3 animals from Europe who were on a very different diet compared to BZ. Several attempts at standardizing the entire colony to one diet or the other took four years with no success; in 2005, a new Mazuri Callitrichid Diet(MCD) was commercially released and after one year, the staff were able to convert all animals to MCD and ZuPreem Marmoset Diet (ZMD). The diet offered to the animals was a combination of both MCD & ZMD (ad lib), 18 g produce and 2.6 g insects; the composition of the diet has not changed since 2005. Observations of the three generations from the original 8.3 animals have shown a significant increase in body weight and changes in food preference/diet composition. Although the animals are offered both diets at all times, each pair/family has a preference and will receive an ad lib amount of the preferred diet item. The average weight of all of the animals in the colony has increased by 13% in the last 6 years, but the average 3 year old weight from 2nd generation to 4th generation has increased 50%. The colony went from having 10% of the animals considered overweight (> 650 g) in 2005 to 50% overweight in 2011; the reverse relationship was seen in normal weight animals (50% in 2005 → 10% in 2011). The most dramatic differences are noted when looking across generations: body weight, intake, %MCD in diet, and growth rate trend toward a linear increase with subsequent generations. Interestingly, the habits of the first generation animals have not changed; they continue to consume the same proportion of ZMD vs. MCD today as they did 10 years ago. The previous statement is true unless a first generation animal was paired with an individual that did eat MCD; then, the first generation animal would eventually convert over to consuming MCD with its mate and usually gain weight as a result. As the subsequent generations were exposed to MCD and saw others consuming it, it was no longer a novel food item and was eagerly consumed. The concern presenting itself is that the MCD is more calorically dense and the past practice of feeding ad lib were causing this explosion of obesity. In October 2011, the caloric density of the MCD was reduced by 20% to see if that alone could cause a reduction in body weight for the obese animals.

Never give up: changing giant anteaters (*Myrmecophaga tridactyla*) to a new, complete diet at Zurich Zoo

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Diets fed to captive anteaters have historically been complex and time-consuming to prepare. Recently, complete feeds for anteaters have been produced commercially. At the last European Zoo Nutrition Conference, we reported how attempts to change anteaters to a new product had failed at Zurich Zoo. At that time, a pinch of the complete diet that was formulated as granules was mixed into the traditional diet. The animals thereafter either completely refused the food or licked the traditional diet around the granules. To increase the acceptability of the formulated diet the granules were ground. This resulted in a complete refusal of food even if it contained just a tiny amount of the new diet. During the trial a weight loss of 10% was tolerated. Due to lactating females and increased aggressive behaviour towards conspecifics and keepers, it was decided to stop the trial after four weeks. Difficulties translocating anteaters to zoos that feed a formulated diet, meeting nutritional requirements, lower hygiene risk compared to diets containing minced meat and because other zoos reported their successful diet switch, it was decided to try the diet change again. This time, another formulated diet was used that comes in powder form. The approach for the diet change was the same, but the new diet was never completely refused. After four days the whole feed including the pinch of the new diet were eaten and the amount of the new diet could be increased stepwise with interruptions of a few days. The animals are fed twice daily 250g of the powder diluted with water. Sometimes the food was not touched until the afternoon or they stopped eating for one or two days. The diet change was completed in four months. For enrichment, insects, fruits, yoghurt and raw eggs are still offered, but only after the complete diet is eaten (otherwise animals eat only the enrichment food). With the new diet, keepers save approximately 30 min of working time per day. Faecal consistency did not change. However a considerable weight loss was observed: before the diet change all three animals weighed 51 kg, 12 days after the diet change the male weighed 49 kg (- 4%) and the two females weighed 45 kg (- 12%). One and a half year after the diet change, the male weights 48 kg (- 6%), one female weights 42 kg (- 17%) and the other female weights 39kg (- 23.5%). From palpation the animals seem considerably thinner. Nevertheless the weight loss was considered acceptable because the body mass is still above the published values for adults in the wild (male 31 to 39 kg, female 29 - 37 kg). The main reason for success of the new diet is considered to be the powder form, whereas the previous product came in granules, and during the second attempt to change the diet a greater weight loss was tolerated since the offspring was almost weaned. Although no negative effects on animal health are noticed so far, potential *positive* effects can only be assessed after prolonged periods of time.

KEYWORDS: Anteater, complete feed, diet switch

Success of hand-rearing common swift (*Apus apus*) using a diet based on mealworm (*Tenebrio molitor*) at a wildlife recovery centre: analysis of survival and fledgling weights compared to those on previous diets not composed of insects
Enric Fusté Henares

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Diets for insectivorous birds represent a major challenge. The best diet would be composed of different insect species, used by some rehabilitation centres currently hand-rearing insectivore species on mixed insect species (crickets, drones, wax moths larvae, flies), although with a limited number of admissions. A diet based solely on domestic crickets (90%) and large larvae of the wax moth (10%) is used in some rehabilitation centres in Europe specializing in hand-rearing large numbers of swift chicks, with optimal recovery results. However, the crickets produced commercially are extremely expensive. A comparative study of diets conducted in CRFST exposed concerns for non-insect based diets and excellent results for the diet based only on mealworms, an insect produced commercially which is five times cheaper than the cricket. The mealworm diet is somewhat controversial, as some anecdotal reports attribute health problems to it. Despite this, mealworm is used with success in hand-rearing chimney swifts (*Chaetura pelagica*) in the United States. Histopathological analysis performed on three swifts fed on mealworms for more than 20 days documented an optimal physical condition and no evidence of disease or organ damage that may be associated with the mealworm diet. Concerns about the poor results observed in non-insect diets (rat mince and dry cat food) and the results with insect diets led CRFST to make a drastic change in insectivore diet protocols. The mealworm diet has been used in the breeding season 2010 and onwards as a base diet for the hand-rearing of common swift, alpine swift and other insectivorous birds. The results of the 2010 season with mealworm show a significant increase in the final weights and the values of survival compared to 2009, where the diet was based on dry cat food, and over 2008 and prior years where the diet was rat mince. The mealworm diet showed a survival increase of nearly 30 % above the two previous non-insect diets - notably observed in acute clinical categories (72.4 % mealworm diet, 44.0 % cat food and 45.7 % rat mince). Euthanasia based on the physical condition at admission was discarded in 2010 (previously acute cases were sacrificed as no improvement was observed under rat mince and cat food, representing around 25 % of the swift admissions). Despite this, after a period in the centre even with the insect diet, around 17 % of chicks were sacrificed due to irreversibly poor plumage condition. Concerning final weights, there was an average increase of 5 g (adult weights around 40 g) with a remarkable increase of 7 g for the youngest chicks. Importantly, the increases were parallel in all clinical categories, including acute severe cases. Looking at the results, we recommend to discontinue the use of non-insect diets when hand-rearing common swifts and a move to a pure insectivorous diet. Mealworm could be a very good alternative when cricket cannot be used for economic reasons. This success is highlighted by the fact that all birds had a high possibility to survive even in extreme condition.

KEYWORDS: Insectivore, hand-raising, mealworm

Composition of whole fish used in Dutch zoos

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Whole fish is an important dietary item in zoos. Despite being the main constituent of many captive animals' diets there are remarkably few data on the nutritional composition of whole fish. To get more insight in the nutritional composition of fish, 79 samples of whitefish (*Cyprinidae* spp.), 81 herring (*Clupea harengus*) samples and 71 sprat (*Sprattus sprattus*) samples were collected from three Dutch zoos and analysed. Each sample consisted of at least one fish; when individual fish weighed less than 80 grams, the sample consisted of two or more fishes. Mean dry matter content for whitefish was 29.3 ± 2.4 %, for herring 31.8 ± 2.9 % and for sprat 28.0 ± 8.8 %. The dry matter composition (%) in whitefish was for crude ash: 17.1 ± 1.52, crude protein: 65.1 ± 4.36, ether extract (crude fat): 12.8 ± 5.05, calcium: 5.01 ± 0.42, phosphorus: 2.38 ± 0.12, magnesium: 0.19 ± 0.03. In herring the dry matter composition (%) was for crude ash: 8.3 ± 0.6, crude protein: 51.7 ± 5.8, ether extract: 38.6 ± 5.5, calcium: 1.37 ± 0,14, phosphorus: 1.06 ± 0.08, magnesium: 0.16 ± 0.03. In sprat dry matter composition (%) was for crude ash: 8.3 ± 3.4, crude protein: 51.7 ± 11.4, ether extract 39.3 ± 17.0, calcium: 1.47 ± 0.59, phosphorus: 1.12 ± 0.43, magnesium: 0.17 ± 0.08. Samples from batches from the three zoos differed significantly in composition, especially for dry matter, ether extract, ash and mineral values. Whitefish had significantly higher values for ash and the minerals while the ether extract values were lower than in sprat and herring. The fish composition values found in this study are comparable to the few data for whole fish composition found in literature. However, in this study values for ether extract were either higher or lower than published in other studies. The results of this study show the importance of analysing the nutritional content of feed items, especially when a varying nutrient content is expected. Without these analyses, assessing zoo diets and deciding what kind of supplementation is needed remains a shot in the dark with doubtful results.

Aquatic animal supplementation practices – survey results and recommendations

Lisa M. Mazzaro[1,] Elizabeth A. Koutsos[2] & J. Jason Williams[3]

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Aquatic animals have been maintained under human care for centuries. Limitations in the variety of foods available to feed to these animals as well as the use of frozen/thawed diets make supplementation of some nutrients necessary. Limited research has been done on what vitamins or minerals are necessary and in what amounts. There are no standardized requirements or recommended daily allowances for any of these species. In the 1970's and early 80's Geraci comprehensively investigated thiamine and vitamin E deficiency under controlled situations and made recommendations for marine mammals based on the feeding practices in use at that time. Since then advances have been made in the way fish are caught, processed, stored, thawed and fed to animals. Additionally many facilities today have their rations analyzed for caloric content and base their diets on calories consumed instead of strictly on an as fed weight basis but vitamin supplementation practices often have not been modified to reflect these changes. An Aquatic Animal Nutritional Survey was distributed to zoos and aquariums worldwide focusing on marine mammals, penguins and sharks. Results were returned from over 70 facilities. The range of supplements being fed to aquatic animals is great and much of the variation is due to the manner in which supplements are being dosed to the animals. As an example using Geraci's recommendations a beluga whale with at food intake of 25 kg per day would require 2500 IU vitamin E (100 IU/kg) and 825 mg thiamine (33 mg/kg). The survey data show the intake range for the example to be 0 to 87,000 IU vitamin A, 350 to 6735 IU vitamin E, 250 to 3590 mg thiamine and 0 to 3091 mg vitamin C. Many facilities have experienced cases of iron storage disease in both pinniped and cetacean species and vitamin C supplementation may add to their problems by increasing absorption of iron. Although over-supplementation of water soluble vitamins may be tolerated by these species, over-supplementation of some fat soluble vitamins is potentially harmful. Given the changes in fish handling practices, the ability to weigh animals more easily, the availability of proximate analyses for food fish and the survey results a review and simplification of our supplementation practices for aquatic animals is long overdue.

KEYWORDS: Marine mammal, supplementation, vitamin

Preliminary results from an on-going global survey of captive cheetah diet, faecal consistency and gastrointestinal disease diagnoses

Katherine Whitehouse-Tedd[1], Sandra Lefebvre[2] & Geert P.J. Janssens[3]

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A cross-sectional epidemiological study is currently under way to gather information on captive cheetah diet, faecal consistency, frequency of vomiting and diarrhoea, and veterinary treatments or diagnoses. An online survey was developed and tested to ensure ease and speed of answering (i.e., no more than 5 minutes). Institutions listed as housing cheetahs in either the International Cheetah Studbook or ISIS database were contacted via email or post. Regional SSP and EEP co-ordinators assisted in the distribution of the survey. The survey was designed to determine if correlations existed between faecal consistency (and other parameters of gastrointestinal health) and a range of dietary factors, or if any dietary parameter could be identified as a risk factor for gastrointestinal disease. Data collection is not yet complete but 98 responses have so far been collected, representing 6 % of the global captive cheetah population and 18 % of global facilities known to house cheetahs. The majority of responses were from North American facilities (50) and European facilities (36), with the remainder from other regions (13). The type of diet fed (commercially prepared, supplemented meat, whole prey items, or a mixture of all types) was compared among regions. European facilities fed predominantly a mixture of diet types (53 %), followed by raw supplemented meat (31 %), and carcasses (17 %). North America was the only region to feed commercially prepared diets and this diet type was the predominant type fed (56 %), followed by a mixture (24 %), and raw supplemented meat (20 %). No North American facilities fed carcasses. Raw supplemented meat was the predominant diet type fed in the rest of the world (ROTW; 69 %), followed by a mixture (31 %), and carcasses (8 %). No commercially prepared diets were fed in the ROTW. The prevalence of gastrointestinal disease (as diagnosed by a veterinarian at the host facility) was compared among regions, as well as among diet type groups. The reported prevalence of gastrointestinal disease was highest in animals fed commercially prepared diets (18%), followed by those fed a mixture (6%), and raw supplemented meat (4%). No animals fed carcasses had been diagnosed with gastrointestinal disease. On a regional basis, gastrointestinal disease was highest in North America (78 % of cases), followed by Europe (22 %). No cases of gastrointestinal disease were reported in the ROTW. Average faecal consistency was similar among all diet types (ranging from 2.90 ± 0.16 SEM for cheetahs fed raw supplemented meat to 3.06 ± 0.15 for cheetahs fed a mixture of diet types, as judged with a 5-point scale where 1 represented liquid faeces and 5 was extremely dry faeces). However, liquid faeces was more commonly reported as being present "always" or "often" in animals fed raw supplemented meat (11 % of animals in this diet group), compared with 7 % of animals fed commercially prepared diets and 6 % of animals fed a mixture (no animals fed carcasses were reported as "always" or "often" having liquid faeces). These results are preliminary and should be interpreted with caution. Data collection is on-going and final analyses will be completed in 2012.

KEYWORDS: Cheetah, diet, faeces

In vitro fermentation of animal tissues by cheetah faecal inoculum

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Dietary fibre can alter digestibility, intestinal absorption, motility and fermentation in the domestic cat. A recent study showed, despite the absence of dietary fibre, significant differences in intestinal fermentation between cheetahs (*Acinonyx jubatus*) fed meat-only and whole prey. This difference was likely caused by the absence or presence of enzymatically-undigested animal tissue, such as skin, bone or hair. Seen the relevant impact of fermentation processes on gut function and health, we evaluated the in vitro fermentation characteristics of various animal tissues in a strict carnivore, the cheetah. Raw, self-prepared animal tissues (rabbit bone, rabbit hair, rabbit skin, chicken cartilage, beef, whole rabbit, pre-digested whole rabbit, beef + bone, beef + cartilage, beef + hair, and beef + skin) were added to an inoculum that was processed from pooled cheetah faeces. The tissues were incubated for 72 h and cumulative gas production was recorded. Additionally, subsamples of the fermentation liquids were taken at 2, 7, 24 and 72 h to determine the fermentation end product profile. All animal substrates showed an early occurrence of maximum gas production rates compared to plant fibre. The production of SCFA was highest for chicken cartilage, beef and whole rabbit, indicating that these tissues are well fermentable. In contrast, rabbit hair, skin, and bone fermented poorly. Fermentation of pre-digested whole rabbit resulted in faster fermentation, lower indol and phenol, higher ammonia but similar SCFA production compared to whole rabbit. The combination of beef with other animal tissue showed no clear interaction on fermentation patterns. Regression analysis indicated that analyzing total dietary fibre (TDF) and acid detergent fibre (ADF) in animal tissue is useful, since TDF%-ADF% was the most important measurable parameter to influence fermentability of animal tissue in this study. Animal tissue has the potential to influence fermentation. Possibly, some enzymatically-undigested animal tissues have similar functions as dietary fibre. Further investigation on fibre-like animal tissue in the diet of carnivores may provide new insights into promoting intestinal function and health.

KEYWORDS: Fermentation, animal fibre, felids

Feeding of Primates – reviewing and implementing changes for monkeys at Paignton Zoo Environmental Park

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Although most omnivorous primates are traditionally regarded as relatively easy to feed in captivity, there is growing recognition that inappropriate diets contribute to several common health problems. Most common among these is obesity, which is associated with many other illnesses such as heart disease, cancer, diabetes and reproductive problems. Between 2003 – 2010 the diets of all medium-sized monkeys at Paignton Zoo Environmental Park were subject to a continual process of review and improvement. This has resulted in the removal of all fruit, bread, eggs and seeds from the diet and changes to commercial products used for some species. All species are now provided with similar diets consisting of a suitable commercial pelleted feed, a variety of fresh vegetables and small amounts of dog biscuits and cooked brown rice to provide opportunities for scatter feeding. Compared with the 2003 diets, the 2010 diets have higher levels of protein (3-47% increase) and fibre (36-77% more NDF) and lower levels of readily digestible carbohydrate (6-14% decrease). Resultant health benefits have been improved dental health and weight loss in some previously overweight individuals. Other institutions implementing similar diet changes have also reported improvements in behaviour, particularly reduced aggression. In addition, at Paignton Zoo the current diets are also considerably less expensive than the 2003 diets, resulting in an estimated annual cost saving of £9717 based on current prices and animals held.

KEYWORDS: primates, diet change, obesity

Is it worth it? The cost of feeding fruits

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Although the costs of food items should not be the overruling factor when making decisions on the diets of zoo animals, but rather considerations of physiological and psychological health and wellbeing, animal diets regularly have to be defended in terms of their financial efficacy. When considering prices, most people compare them on an 'as fed'/'wet weight' basis, whereas nutritionists focus on the more relevant units of dry matter or energy/nutrient content. Here, we calculated the prices of various food items at Bristol Zoo Gardens (BZG) in order to demonstrate the real costs associated with various feeding regimes. The cost per kg of 18 fruits and vegetables and two types of lucerne hay, British and North American, were calculated. British lucerne hay was the cheapest feed on a cost per kg wet weight basis (£0.22), followed by lettuce (£0.44), banana (£0.47), kiwi (£0.53) and North American lucerne hay (£0.59). Carrots appeared sixth on the list (£0.61) and apples tenth (£1.12), with papaya the most expensive as fed (£3.37). The dry matter (DM) content of fruits and vegetables were obtained from ZOOTRITION™ software (version 2.6, Saint Louis Zoo, MO, USA) and the DM content of the lucerne hays were analysed by drying them to constant weight. The cost per kg DM was then calculated, which revealed that British lucerne hay was the cheapest at £0.23 per kg DM, followed by North American lucerne hay at £0.62 per kg DM and banana £1.83, with carrots in fifth at £4.96, apples eighth at £6.99 and peppers last costing £37.26 per kg DM. Thus, feeding one animal 2kg DM per day would cost £167.58 annually for British lucerne, £3622.56 for carrots and £5,109.41 for apples. In terms of real cost savings by diet changes, we present examples of a lowland tapir (*Tapirus terrestris*), a hindgut fermenting herbivore, and a mongoose lemur (*Eulemur mongoz*), a monogastric strepsirrhine primate. The previous BZG tapir diet made up of 2kg pellets, 2.7kg fruits and vegetables and 1.46kg British lucerne hay (based on 0.6 MJ digestible energy per kg metabolic body weight for a 230kg tapir) cost £4.31 per day and £1,574.16 per year for one tapir. In comparison, a diet consisting of a DM ratio of 75% British lucerne hay (2.87kg as fed) and 25% pellets (1.01kg as fed) for the same tapir, would cost £1.45 per day and £529.31 per year for one tapir. Thus, increasing the roughage intake would result in a cost saving of £1,044.85 per year (66.4%) for one tapir or £3,124.54 for three tapirs. For a mongoose lemur, a diet comprising of 50% pellets (DM) and 50% mixed fruits and vegetables (based on estimated energy requirements of 0.44-0.59 MJ metabolizable energy per kg body mass per day for a 1.29kg mongoose lemur) would cost £0.47-£0.63 per day and £172.88-£231.82 annually. The same diet, using pellets and green vegetables only, would cost £0.69-£0.92 per day and £251.39-£337.09 annually. Thus, for animals that do not accept readily available roughages (hays), such as primates in which it is recommended that fruits and coloured vegetables be replaced by green leafy vegetables, cost-saving effects of diet changes may not be immediately evident. However, the costs presented here do not include savings in staff costs associated with the preparation of food, or veterinary expenses associated with diet-related disorders, such as diabetes, obesity, caries, or laminitis, which can be considerable. This study shows that for large herbivores, which can be fed roughage, replacing fruits and vegetables with roughage items and pelleted feeds is cost-efficient.

Hot topic – thermal treatment of gorilla food for echinococcosis prevention

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Alveolar echinococcosis (AE) was diagnosed in seven lowland gorillas (*Gorilla g. gorilla*) originating from Zoo Basel from 1999-2011. Four gorillas died of the disease and three clinical cases are continuously treated with albendazole. It is hypothetized that lowland gorillas run an increased risk of becoming accidental intermediate hosts and of developing AE. Direct contact of Zoo Basel's gorillas to the definitive host of *Echinococcus multilocularis* in Europe, the red fox (*Vulpes vulpes*), can be excluded. Therefore, it is assumed that infection occurred through accidental ingestion of food contaminated with eggs of this cestode parasite. Preventive sanitary measures for the harvesting, preparation and storage of food items for the gorillas were introduced in 2007 in the Zoo Basel. Additionally, a decontamination procedure was recently initiated including a multistep washing procedure with consequent heat treatment. All food items are placed in an incubator and heated for three hours at 45° Celsius. It was experimentally reported that the infectivity of the eggs is lost under this conditions. The purpose of this paper is to show practical preventive and decontaminating measures to reduce infection risk for AE in susceptible zoo animals. Furthermore, we present an ongoing study for the identification of contaminated food sources and for the evaluation of the efficacy of these measures under zoo conditions.

KEYWORDS: Alveolar echinococcosis, gorilla, prevention

Feeding experiences with a new group of Proboscis monkeys (*Nasalis larvatus*) in Apenheul Primate Park

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Apenheul Primate Park in the Netherlands received three male Proboscis monkeys (*Nasalis larvatus*) in July 2011. All three were born and parent-reared in the Singapore Zoological gardens. The *in-situ* diet of a Proboscis monkeys consists for 80% of leaves, which are abundant in the tropics all year around. Although it is sometimes believed that captive Proboscis monkeys can only be maintained on mangrove leaves, the animals in Singapore Zoo are fed with a selection of leaves from 54 different plant species. Two kilograms of fresh leaves are offered to each animal three times a day. In addition to this, the animals receive daily one slice of bread, a ball shaped portion boiled rice with boiled chicken or egg and liver cod oil added, a chopped mixture of vegetables and fruit and two primate pellets. The challenge for Apenheul was to change the diet from tropical tree and shrub leaves to European leaves. Since July fresh leaves from more than 10 species were offered. Red oak (*Quercus rubra*), chestnut (*Castnea sativa*), silver birch (*Betula pendula*), blackberry and raspberry (*Rubus* spp.) and rose (*Rosa* spp.) were perceived palatable by the animals. With the twigs are offered as bundles, the animals seem to prefer to pick the leaves themselves. The availability of fresh leaves is a problem in the winter period. The animals do not like frozen and thawed leaves; only grape vine (*Vitis vinifera*) is accepted when thawed. Presently fresh leaves from *Rubus* spp. are offered. These are obtained from a commercial grower who prunes the plants regularly. The present daily individual diet consists of four kilograms fresh leaves, almost 700 grams green beans, boiled rice mixed with boiled egg, about 100 grams of pellets, two apples, a pear and a sweet potato. Fennel and celery are also offered but seldom eaten. Until now no health problems were reported.

KEYWORDS: Nasalis larvatus, diet change, browse

Fit or fat: obesity in captive lemurs

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Lemurs are one of the most endangered primate groups in the world with 40% of the 101 taxa red-listed in one of the threatened categories and a further 45% Data Deficient. Ex situ breeding programmes are vital to protect many of these species from extinction. However, various reports have cited obesity as common in captive lemurs. Excessive body mass can lead to breeding problems and infertility, and it renders affected individuals unsuitable for reintroduction into their wild habitat. Obesity can thus considerably compromise captive propagation programmes. We compared the body mass of 902 captive lemurs from 14 species to wild lemur body masses reported in the literature (n=790). All but two species had a median captive body mass that significantly differed from their wild body mass (p<0.05), with a highly significant difference in six species (p<0.001). "Overweight" was defined as two standard deviations above the mean wild body mass of a given species, which yielded a threshold for overweight of 125% of the mean wild body mass when averaged over all species. "Obese" was defined as >150% of the mean wild body mass, or four standard deviations above the mean wild body mass, and "morbidly obese" was defined as >200% of the mean wild body mass, or more than double the size of their wild counterparts. Of the 902 captive lemurs in this study, 21% were classified as overweight, 12% as obese and a staggering 21% as morbidly obese. Five species had median captive body masses that exceeded the overweight threshold. The mongoose lemur (*Eulemur mongoz*) (n=23), red-ruffed lemur (*Varecia rubra*) (n=123) and ring-tailed lemur (*Lemur catta*) (n=393), the latter being the most common lemur species in captivity, had median captive body masses of between 130 and 140% of the mean wild body mass for each species, with between 57 and 65% of individuals classified as overweight and above. Alarmingly, the blue-eyed black lemur (*Eulemur flavifrons*) (n=26), which is red-listed Critically Endangered by the IUCN and placed on the list of the world's 25 most endangered primates, and the black lemur (*E. macaco*) had medians of 144% and 147% of their wild body mass, with 85% and 74% of all captive individuals classified as overweight or above, respectively. Although the medians of nine species were below the overweight threshold, over 20% of the individuals measured in seven of these species were classified as overweight or above, with four species having over 30% of individuals overweight or above. In total, 489 out of 902, or 54% of the individuals in this study, were classified as overweight or above. Our results indicate that obesity is a serious problem in captive lemurs, which could have major implications on captive animal health, welfare, reproductive success and, consequently, conservation strategies for endangered species.

KEYWORDS: Lemur, obesity, body mass

Feeding of amphibians
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Almost a third of 6,000 described amphibian species (i.e. frogs, toads, salamanders and caecilians) are threatened with extinction. These declines are attributed to several anthropogenically induced factors, including habitat alteration, pollution and the introduction of non-native species but many causes of amphibian declines are still poorly understood and conventional conservation measures, such as habitat protection, species protection and contaminant removal, may prove to be insufficient to secure their future. Captive breeding of amphibians for conservation purposes has received much attention, and successful breeding programmes have been implemented for a growing number of amphibian species. A few amphibian species have been kept in captivity for scientific research and education, and for these species husbandry requirements are fairly well understood. However, captive conditions required by most anuran species are unknown, and since they vary to such a large extent in terms of their life histories, it is likely that their requirements will also be highly variable in captivity. Reproductive modes, for example, are extremely diverse with vast differences in the degree of parental care, oviposition, fecundity, development. Captive breeding and rearing of amphibians is further complicated by the biphasic development of many species, e.g. frogs might lay their eggs on leaves, tadpoles develop in ephemeral water bodies and adults are terrestrial. Abiotic factors, such as temperature and humidity, are very important to the welfare of captive frogs. Appropriate conditions may be determined using measurements taken from the wild environment, providing behavioural information is available. Biotic factors, such as social behaviour and diet, are less easy to resolve correctly. For example, dominance hierarchies will have a direct impact on feeding but are difficult to observe. Relatively little is known about the feeding habits of wild frogs and most evidence is anecdotal. Adult anurans are generally considered to be carnivorous, feeding opportunistically on a wide variety of invertebrates. Larval anurans may feed on detritus, plant material, other tadpoles, animals and anuran eggs. Terrestrial anurans in captivity often require the provision of live prey to stimulate feeding since they are attracted to movement. Captive insectivores are prone to nutritional deficiencies since they are typically fed a very limited range of foodstuffs compared to their wild counterparts. Indeed, captive frogs are usually fed one or two species of invertebrate, and those species are themselves restricted in their nutritional intake. There is a restricted range of readily available and commercially produced, invertebrate species. Most of the species commonly fed [i.e. mealworms (*Tenebrio molitor*), house crickets (*Acheta domesticus*), wax worms (*Galleria mellonella*), cockroaches (*Blaberus craniiferus*), wingless fruit flies (*Drosophila melanogaster*), and earthworms (*Lumbricus terrestris*)] are a poor source of micronutrients and measures to avoid nutritional problems include feeding variety of prey items, gut-loading and dusting with appropriate supplements. This talk will describe pitfalls and recent progress in amphibian nutrition.

KEYWORDS: frogs, toads, live prey

Effect of dietary carotenoids on skin pigmentation in tomato frogs (*Dyscophus guineti*)

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Pigmentation alterations and health issues, including vitamin A deficiency, have been documented for managed amphibian species, and are directly or indirectly linked with dietary management. In addition to meeting vitamin A nutritional needs, dietary carotenoids are linked to skin pigmentation in a variety of species, including amphibians. Alteration of pigmentation may affect potential recognition of breeding partners, perception of fitness, and could have a physiologic effect on health and reproductive output. Adults and young of tomato frogs *Dyscophus guineti* were fed three diets over nine weeks to evaluate skin pigmentation changes. Treatment one (control) comprised feeder crickets injected with soy oil; treatment two was feeder crickets injected with betacarotene, and treatment three was feeder crickets injected with mixed carotenoids. Pigmentation was evaluated weekly through the use of visual colour charts, as well as quantitatively using a hand-held spectrophotometer, measuring the surface of the frog's back, and taking measurements of L*a*b colour space in the chromaticity diagram. Treatment three had a significant effect on +b values, as well as on lightness and hue. Results indicated that frogs fed with betacarotenes changed to yellower colors and frogs fed with mixed carotenoids changed to oranger colours. Frog age had an important effect on pigmentation too; +a and +b values, hue and lightness changed significantly, such that adults frogs showed a more vivid orange color compared to young frogs. Chroma (color saturation) values were significantly high in animals from treatment three; frogs fed mixed carotenoids showed vivid colours compared to control ones (paler colours). Visual colour charts observations showed significant differences between control and mixed carotenoids` diet; the animals from this treatment appeared more orange according to the qualitative observations. Results suggest that tomato frogs may store carotenoids in their skin's chromophores, and these are modified when frogs eat a diet supplemented with betacarotene, lutein, zeaxanthin, canthaxanthin and capsanthin. Also, colour measurements are more precise using the hand-held spectrophotometer than the visual colour charts.

KEYWORDS: Frogs, pigmentation, carotenoids

Influence of feeding on the absorption mechanisms of Calcium in the gastrointestinal tract of veiled chameleons (*Chamaeleo calyptratus*)

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The purpose of this study was to investigate the influence of feeding and UV exposition on the occurrence and distribution patterns of vitamin D receptor (VDR) and calbindin D28k (Cb-D28k) in the gastrointestinal tract of veiled chameleons. Fifty-six hatchlings were divided into 6 treatment groups: UV: with UVB exposure; No: no supplements at all; CaAUV: supplementation with calcium (Ca) and vitamin A plus exposition to UVB; CaA: supplementation with Ca and vitamin A; CaADUV: supplementation with Ca, vitamin A, cholecalciferol and UVB exposition; CaAD: supplementation with Ca, vitamin A and cholecalciferol and reared for 6 months on locust-based diets. Samples of duodenum, ileum and colon were taken, and semi-quantitative immunohistochemistry methods (IHC) to detect Cb-D28k and VDR were performed. Generally, VDR immunoreactions were highest in the surface epithelium of the duodenum and lower in that of the ileum and colon irrespective of the group. The highest VDR immunoreactions were detected in the surface epithelium at the base of the villi of the duodenum. Cb-D28k immunoreactions were mainly observed in the surface epithelium of the duodenum. The two groups treated with all supplements (CaADUV,CaAD) exhibited the highest Cb-D28k immunoreactions. This study demonstrates that the duodenum plays the most important role in the active transcellular absorption of Ca in chameleons as shown by the immunohistochemical detection of VDR and Cb-D28k. Expression of Cb-D28k in particular appears to be regulated by dietary supplementation of vitamin D and was possibly enhanced by UVB exposure. VDRs, however, tended to be up-regulated, when animals were not supplemented by Ca, vitamins D and A. This may be due to the decreased Ca concentrations which caused vitamin D activation.

KEYWORDS: Chameleon, calcium regulation, gastrointestinal tract

Managing zoo diet information; introducing next generation software

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We all want to feed our animals well. Yet within zoos and aquariums different stakeholders concentrate on different aspects of feeding; some may be mostly concerned with the nutrient content, others with the way food is presented, and sustainability, efficiency and costs are becoming increasingly significant drivers. Obviously all of these aspects require consideration to achieve the initial premise of 'wanting to feed our animals well'. Sharing knowledge about best feeding practices can improve global zoo management, with anecdotal descriptions replaced by meticulous observation, documentation and analysis. Recording and cataloguing feeding practices and the outcome of adjustments, along with the means for systematic retrieval of said records at some later point in time, would represent a significant advance in the evaluation and dissemination of effective feeding practices. But how can we achieve this vision? There is a gap within the current suite of software provided by International Species Information System (ISIS). Bespoke software designed for the zoo community could: a) ensure diet information is stored in a rigorous, standardized format; b) be linked with animal stock numbers, allowing comparison with food purchasing/accounts; c) be used for diet formulation, permitting the exchange of true 'diet' data – the nutrients that are being offered and consumed in specific quantities, not just a list of the food ingredients involved; d) allow easy collation of diets used for many species at a single collection thereby fulfilling criteria for legal purposes or professional accreditation. Furthermore, diet information for a single species held in many collections could be easily collated, providing a useful research tool for producing zoo husbandry guidelines; it could also be a valuable educational tool. Pragmatic reasons for using a customized diet management program include legislative drivers, plus economic incentives (e.g. the facility to check the quantity of food that should be fed matches what is being ordered). A number of programs currently in use offer some of the functionality described, but none can do all of the above. Also, with no investment or management evident, all of these programs are becoming technically obsolete and incompatible with modern technology. With ISIS deploying the Zoological Information Management System (ZIMS), it was timely to consider the design and build of a single, zoo diet information management program which at a future date might 'plug-in' to the ISIS software suite. Members of the EAZA Nutrition Group and AZA's Nutrition Advisory Group were invited to discuss if and how we might work together to design and build the next generation software. Key questions to address were: who are the main contributors to what and how animals get fed, what information do they need to feed their animals effectively, and what can be done to optimize animal feeding in zoos? An 'interim' steering group formed to move this project forward and a partnership has been forged with Format International to develop and design a bespoke software application. Based in UK, Format International designs technical software for the food and feed industry worldwide and specializes in formulation software, recipe design, management and auditing. Working together through a series of meetings and workshops, our vision is a zoo diet management system for all those concerned with feeding our animals well, encompassing features associated with feeding, formulation, inventory management and auditing.

KEYWORDS: Software, ration calculation, documentation

Feeding of bears – carnivores by phylogeny but omnivores by ecology
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Ursids are favourite zoo animals and have been kept - and thus fed - since modern zoos came into existence in the 19th century. Nevertheless, scientifically based knowledge on bear nutrition in terms of nutritional composition of natural food, digestion and requirements for growth, maintenance and reproduction are rare. The diet for different bear species in captivity – with the exception of polar bears, sloth bears and giant pandas – is often still very similar, consisting of fruits, mainly apples and pears, and vegetables, mainly carrots, to varying degrees supplemented by animal matters of different origin. This composition is based on the assumption of an omnivorous feeding style without considering species differences in terms of food composition and seasonal (and hormonally triggered) fluctuations in food intake. In consequence, nutrient composition and amounts of captive diets can differ significantly from what can be expected in the wild. In tropical bears, this feeding practice often results in obese bears, whereas bears of the moderate and higher altitudes are too lean during certain seasons. The feeding technique – one main meal with or without several scatter feeds per day offered in similar quantities over the whole year - does apply more to a tropical carnivore than to an omnivorous carnivore with a simple digestive tract, but behavioural and physiological adaptations to survive on a mainly vegetarian diet in different climates. This technique is one of the causes for the development of stereotypic behaviours, which are frequently observed in ursids. The few scientific studies on ursid nutrition focus on digestion of the omnivorous brown bears and American black bears and the carnivorous polar bears. Similar studies are lacking for the other more tropical species with somewhat different food niches and specializations either towards more vegetarian (Andean bears) or more insectivorous diets (sun bear and sloth bear). The rapidly growing knowledge on feeding ecology of all ursid species in combination with their morphological features will be used to propose diets and feeding techniques which approach the species specific behavioural and nutritional requirements more closely. Examples of diets and feeding techniques will be provided for brown bears, polar bears, Andean and sun bears. Finally fields for research on bear feeding and nutrition will be briefly outlined.

KEYWORDS: Feeding ecology, diet composition, feeding technique

Ouch it sticks! – lessons learned from nutrition-related foreign bodies in an okapi (*Okapia johnstoni*) and a sun bear (*Ursus malayanus*)

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A 10-year old female okapi with 240 kg body weight was presented with tenesmus, intermittent colic and inappetence/anorexia. As the symptomatic treatment did not improve the condition after three days, we anaesthetised the animal and performed an exploratory laparotomy. A diagnosis of a retroflexed, constipated, bloated caecum and a focally necrotizing spiral colon was made. The caecum was emptied and rinsed, and the necrotizing gut piece resected, but the animal died the following night. Necropsy revealed a wire-like metallic foreign body (0.2 mm x 5 cm) in the reticulum wall associated with focal peritonitis and pericardial effusion. We hypothesise that the foreign body was responsible for the clinical symptoms and that the caecum and colon pathologies were secondary and associated with pain-related reduced bowel movements. The okapi diet plan (per individual, fresh matter) consists of alpha alpha hay ad libitum, 2.5 kg fresh browse during the vegetation period or browse silage during winter, 1 kg pellets (3695, Provimi Kliba, Kaiseraugst, Switzerland) mixed with 0.3 kg beet pulp soaked in water and fractionated in three portions over the day, plus 0.5 kg vegetables (salad, beetroot, catalonia, celery, fennel). To minimise the risk of foreign body ingestion, the animal keepers were sensitised to the issue of foreign body ingestion well-known in ruminant medicine. Preventive measures include scanning of the alpha alpha hay with a metal detector and braiding the brooms to clean the enclosures in a special manner. A 28-year old female sun bear with 75 kg body weight was presented with inappetence/anorexia, diarrhoea, vomitus and apathy. After three days of conservative treatment without improvement, the animal was examined under general anaesthesia. Major clinical findings included massive tooth wear associated with periodontitis, root and pulp exposures, and loss of several teeth, and a mass in the liver/duodenum/diaphragm region. The animal was euthanized. Pathological examination revealed a foreign body consisting of a mango (*Mangifera indica*) kernel (2 x 5 x 12 cm) in the duodenum, associated with pre-ileus fibrino-necrotizing enteritis, perforation and focal peritonitis. Whole mango fruits have been fed for years without ingestion of the kernel. We hypothesise that the ingestion was related to the animal's inability to use its teeth due to the advanced dental disease condition. The sun bear diet plan consists of 1.4 kg seasonally available fruits (apple, pear, grape, plum, nectarine, kaki, peach, mango, kiwi, orange), 1.4 kg vegetables (carrot, tomato, salad), 0.2 kg pellets (3350, Provimi Kliba, Kaiseraugst, Switzerland), 0.2 kg white fish or chicken, and occasionally yoghurt, honey, eggs, corn cobs, browse, dried fruits, locusts and mealworms. The feeding regimen has not been changed since the death of the abovementioned individual, but efforts have been implemented to improve nutritional enrichment, and to sensitise animal keepers to recognise 'old sun bear nutrition-related disease', such as obesity, arteriosclerosis and dental disease.

KEYWORDS: Foreign body, okapi, sun bear

Comparison of the zoo feed quality in different Zoo's in the Netherlands

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Animal feed quality is dependent upon factors including quality of the feed product, quality of the feed processing, and hygiene levels of working places and personnel. For comparison, the nine biggest zoos in the Netherlands were inspected with regard to compliance to legislation, hygienic procedures in the feed preparing kitchens, and the microbiological quality of the feed. Checklists were used to determine if zoos worked according to Dutch regulations. Hygiene levels of working places were assessed using agar contact plates and swabs. Susceptible feeds, e.g. meat, were tested for presence of antibiotic residues and specific pathogens like *Salmonella*. Furthermore, total aerobic colony count and total *Enterobacteriacae* numbers of the feed samples were determined. The results found that zoos do not comply completely with regulations. An example is the interpretation of the regulation concerning the feeding of surplus animals to zoo animals differed between zoos studied. Comparison of hygiene levels showed marked differences between zoos, and microbiological quality of feed also varied. No *Salmonella* was found, however some animal feed samples contained antibiotic residues. Most zoos concluded their methods of working was of a sufficient standard to prepare quality feed, though in some instances hygienic levels were poor and feed quality doubtful. Similar surveys across other European zoos using national standards would be beneficial.

KEYWORDS: Feed quality, hygiene, microbiology

Comparison of vitamin A and E, copper and zinc plasma levels in free-ranging and captive Greater flamingos (*Phoenicopterus roseus*), and their relation to pododermatitis

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Foot lesions are a major problem in captive flamingos. They often occur in captivity, whereas only a few foot problems in wild birds have been reported. No foot lesions could be detected in wild Greater flamingos in the Camargue (France). The influence of nutritional factors on foot health is described in poultry and exotic birds. Several vitamins and minerals have an impact on the skin and especially the foot pad. Zoo Basel has kept Greater flamingos since 1933 and foot problems have been observed for a long time. In winter 2010/2011, the feeding regime was changed from a self-mixed diet to a commercially available pelleted feed. Blood plasma levels of vitamin A, vitamin E, copper and zinc from 61 captive Greater flamingos from Zoo Basel divided into three groups, and for comparison from 12 free-ranging Greater flamingos from the Camargue were determined. The previous, self-mixed food (groups A and B) was composed of 50% of a pelleted complete diet for lying hens, 30% cereals (corn, wheat, oat flakes), 10% shredded shrimps, 5% carnivores supplement, 5% cattle salt and 0.05% Canthaxanthin and Biotin. This was replaced by "Flamingo floating pellets" in group C. Vitamin A, vitamin E, zinc and copper levels were determined for both diets. A significant difference in vitamin A blood plasma levels was detected between groups A and B compared with group C, but not between the captive groups and the free-ranging group. Vitamin E and copper levels of all captive groups were higher than the free-ranging group. Zinc levels were significantly lower in flamingos of group A compared with the free-ranging group and those from the group C. Interestingly, the diet of groups A and B was higher in zinc, but lower in Vitamin A, than those of group C. This discrepancy could be due to an interaction of these and possibly other vitamins or minerals. Foot lesions in the juvenile groups A and C differed markedly: whereas all birds in group A had mild to severe foot lesions at an age of five to seven months, none of the birds in group C had any foot lesion at the time of blood collection and only two out of 20 birds developed minimal foot lesions at the age of six months. It is hypothesized that the low zinc levels of the animals in group A could be responsible for a weakening of the skin and the development of foot lesions. Simultaneously to the feeding regime change, the concrete flooring of the ponds in the outdoor flamingo enclosure was covered with finely granular sand. Whether the diet change was as important as the change of substrate cannot be decided, but we suspect that diet may be a contributing factor in the development of pododermatitis in Greater flamingos.

KEYWORDS: Flamingo, pododermatitis, vitamins

Feeding elephants in captivity: a history of research, problems, and recent challenges

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Elephants probably represent the most charismatic zoo animal species due to their extreme body size, and also to a certain degree due to their high level of intelligence. Because of our fascination for elephants, these animals have been studied comparatively well among the non-domesticated species. Elephants are herbivores with a symbiotic gut microflora. They consume not only high absolute amounts of food, but also have a high comparative food intake that fills up the majority of their 24 h time budget. Due to the bulk volume they consume in the wild, the nutritional quality of their natural diet is low (i.e., high in fibre). Their strategy is best described as a high-intake, high-throughput, low-efficiency strategy, with comparatively short digesta retention times and comparatively low achieved digestion coefficients. One peculiarity of elephants is the ability to ingest very large amounts of food without evident effects on digesta retention, due to a pronounced capacity of the digestive tract and the abdominal cavity to expand in volume. Overfeeding is a well-recognized problem in captive elephants. They are a prime example for how using energy-dense feeds in animals that are tuned to spend most of their time foraging is inappropriate. Particular mineral and vitamin deficiencies occur occasionally (but probably not systematically). Feeding guidance has been published internationally in numerous publications widely available to the zoo community and also at a national level (e.g. BIAZA Elephant Husbandry Guidelines). Yet, nutrition-related problems persist, notably the high prevalence of obesity due in part to the overfeeding mentioned earlier. In order for change to be accepted and maintained, it is important for all stake holders in elephant care (keepers, curators, vets, zoo directors to name a few) are clear on the potential consequences of inadequate nutrition/inappropriate feeding and the roles of both nutrient composition & food presentation in feeding for health and happiness. The penalty for refusing to implement this information could be far-reaching. A government-commissioned study of elephant welfare in the UK highlighted a number of concerns with the keeping of elephants in captivity which, if not addressed, could result in legislative changes phasing out the keeping of elephants in UK zoos. This presentation will give an example of a typical approach to zoo nutrition – laying out first what is known about the natural diet and digestive physiology of the animal, addressing the problem of how to translate this knowledge into practical feeding through the production of guidelines and examine barriers to their wider use. Finally, it will describe recent challenges in elephant nutrition that have arisen due to current awareness of welfare concerns.

KEYWORDS: Elephant, feeding, welfare

Diet composition, food intake and body condition score of the captive Asian elephant (*Elephas maximus*): a pilot study in two collections in Thailand

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The Asian elephant's feeding habits have been extensively studied, but very few data are available on the diet under captive conditions within the range countries. In this study, the composition of dietary intake, fecal output and the dietary regimen were individually recorded for 5 days in ten Asian elephants from two collections situated in northern Thailand. Representative samples of each food item and fecal samples were analyzed for dry matter, crude protein, fat, crude fiber, gross energy, ash, calcium and phosphorus. Diet adequacy was assessed by calculating the amounts of nutrients the animals obtained from their ration and comparing it to the requirements from literature. The proportion of forages (grasses and hay) in the diet represented only 41% to 62% of the dry matter (DM) intake in one collection, whereas in the other collection it varied between 68% and 72%. Between 8.5% and 24% of the diet consisted of commercial pellets, and hulled rice represented up to 25% of the DM intake in one collection. Sugar cane, corn cobs, and fruits such as bananas were eaten in smaller amounts. Body Condition Score and weight were measured at the beginning of the 5-day period, and revealed that 9 animals were in good condition. The digestible energy (DE) intake varied between 0.6 and 1.4MJ/kg$^{0.75}$/day and was therefore higher than the estimated requirements of 0.59MJ/kg$^{0.75}$/day. In all elephants, the crude protein intake was less than the maintenance recommendations and ranged between 6.0 and 7.6 % of the dry matter intake. A low calcium intake was recorded in one collection, together with a calcium and phosphorus ratio lower than one and therefore inappropriate. This study's adds to the knowledge of captive elephant diet in Asia and is a starting point for further research and potential recommendations on the use of local resources.

KEYWORDS: Asian elephant, diet, energy

Diet change: it´s not always only about calories and animals

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In recent years, the awareness of the need for scientifically based nutrition of herbivores in captivity has grown, and a wealth of literature is now available to guide zoological institutions towards adequate herbivore feeding. However, in many institutions, diet plans have been established over many years by trial and error, and animal keepers as well as animals have grown familiar with them. One of the biggest challenges of changing diets in a zoological collection therefore often includes not only the animals´ acceptance of the new diet, but also ensuring the animal keepers´ compliance with new protocols. This short presentation reports on diet changes in black rhino (*Diceros bicornis*), springbok (*Antidorcas marsupialis*) and blesbok (*Damaliscus pygargus*) at the Hannover Zoo, focusing on animal keeper training and guidance through the process of diet change. Key elements were a training session for the keepers explaining the basics of herbivore nutrition and negotiating the feasibility of the future diet, detailed work sheets for daily record keeping during the two months of diet change and working with readily available, ideally already familiar resources.

KEYWORDS: Diet change, herbivore, animal keeper

A diet for body weight reduction in rhinos

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Indian Rhinoceros were reported due to low activity levels, ascites, missing signs of oestrus, lameness and fistulae at their feet. Different factors were held responsible for these health issues and a survey of the feeding ration was initiated to check for nutritional reasons. The actual body weight was 2.5 t for the male and 2.1 t for the female rhino (standard normal body weight in captivity about 1.8-2.5 t and 1.5-2.1 t, respectively). The actual feeding plan was checked by computer-aided ration calculation using the nutrient composition of single feedstuffs taken from the literature as well as from the declaration of commercial feedstuffs. The intake of nutrients supplied per day was compared to requirements (partly adapted from other species). Noticeable in the rhinos was on one hand an excessive energy supply through large amount of concentrates and fruits and the other hand a deficient supply with zinc. The feeding plan was therefore changed to feedstuffs with lower energy density, a reduced energy intake and the supplementation with zinc. To ensure sufficient nutrient intake despite energy restriction, the nutrient density in the ration was increased. Regular weighing was scheduled to ensure a useful energy supply leading to the targeted weight loss. After 9 months of feeding the new diet, the male rhino had lost 340kg (≈13.6%) and the female 180kg (≈8.7%) of its initial body weight. The activity level increased considerably, which might be taken also as an indicator for less painful motion. A certain improvement of the symptoms concerning their feet was noticeable and interestingly, the female had an oestrus for the first time in years. The zookeeper reported that during the weight loss program, the animals were more aggressive and less cooperative. On the other hand manipulation is facilitated when vegetables are used as treats. Over time, zookeepers might alter feeding plans by modifying the amounts of components often driven by individual preferences or by wishing to add palatable feedstuffs such as bananas as treats. Now and then the feeding plans should be re-evaluated and corrected to fit the nutrient requirements more closely. Also in rhinos, the reduction of energy supply can lead to monitored weight loss with positive effects on overall activity and mobility as well as to an improvement of other health issues secondarily affected by body weight or body fat content, respectively.

KEYWORDS: Asian rhinoceros, weight loss, ration calculation

Large herbivores that should lose weight: case studies of pygmy hippos (*Hexaprotodon liberiensis*) and lowland tapirs (*Tapirus terrestris*)

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Obesity in Hippopotamidae (*Hippopotamus amphibius* and *Hexaprotodon liberiensis*) and monogastric herbivores, such as tapirs (*Tapirus* spp.), is frequently reported in zoo literature. The problem is generally attributed to the relative oversupply of highly digestible feeds, such as commercial fruits and cereal-based pellets, and overfeeding – coupled with a potentially generally low level of metabolism particularly in the Hippopotamidae, and a lack of exercise. The aim of this study was to reduce the body mass (BM) of two pygmy hippos (*Hexaprotodon liberiensis*) and three lowland tapirs (*Tapirus terrestris*) at Bristol Zoo Gardens. The pygmy hippo weight loss occurred in two stages. The original diet, consisting of approximately 2.5kg of cereals and pellets, half a loaf of bread, half a bucket of fruit and vegetables and lucerne hay per animal per day, was gradually replaced over a period of a month by a weight loss diet consisting of *ad libitum* lucerne hay, with 550g of pellets and 800g of a mixture of iceberg lettuce and baby leaf spinach per animal. After the diet transition, the pygmy hippos were continued on the weight loss diet for 9½ months. During this time, the mean BM of the pygmy hippos decreased from 282kg to 243kg, a loss of 39kg or 13.8% BM. The pygmy hippos were then placed on a maintenance diet of *ad libitum* lucerne hay with 1kg of pellets and 1kg of vegetables per day. Weight loss continued gradually for eight months and then stabilised at about 232kg in the remaining male pygmy hippo. The tapir weight loss plan was designed to induce a gradual weight loss, and diet transition, onto a diet that would maintain the tapirs at a desired BM. The amount of feed required was calculated, using the estimated daily maintenance energy requirements of 0.6 MJ digestible energy/kg $BM^{0.75}$ and estimated energy content of the feed, on the basis of an interim target BM a little lower than the current BM. This interim target BM will then be reduced by increments as weight loss occurs. Lucerne hay was assumed to make up 50% of the dry matter (DM) content of the diet, with the remaining DM requirements made up of 48.6% pellets and 1.9-1.4% vegetables. In terms of wet weight (as fed), this is approximately 41.6% lucerne hay available *ad libitum*, 42.6% pellets and 15.8% vegetables. The eventual aim of this diet is to further reduce the content of pellets and vegetables and increase the intake of roughage. While potential health effects of such diet changes cannot be assessed immediately, these examples demonstrate that reducing body mass is best approached by a combination of a requirement estimate and ration calculation, followed by a continuous monitoring of the animals' condition.

KEYWORDS: Pygmy hippo, weight loss, tapir

Kordofan giraffes' diet change at Lyon Zoo
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An evaluation of Lyon Zoo's diet provided to four young adult Kordofan giraffes (1 male, 3 females) conducted in 2010 and 2011 revealed that the amounts of supplements, fruits and vegetables were too high when compared to recently published nutrition guidelines and that the diet may be energy deficient. The complete diet was re-evaluated and a dietary transition was undertaken during a 4 weeks period in the summer 2011. Special attention was paid to lucerne hay quality and the fresh browse quantities for better tooth wear prevention. The transition was first modelled using a theoretical table in spreadsheet software, where forage (lucerne hay and fresh browse) was varied from 50% to 70% DMI, in order to calculate the effect on the whole expected ingested diet. Three scenarios (forage intake: other feeds as % of DMI: 50:50, 60:40 and 70:30) were analysed using the Zootrition software. Fruits (apple and banana) amounts were reduced from 6.8-7.3% DMI to 2.5-2.6% DMI. Vegetables (carrots, onions and green leafy vegetables) amounts were reduced from 3.7-3.9% DMI to 2.8% DMI. A traditional grain based mixture used at Paris Zoo and adopted by Lyon Zoo (2/3 barley flour and 1/3 oat flakes cooked with boiling water) was maintained but stabilized from 10.7-14.6% DMI to 12.3% DMI. The soaked unmolassed beet pulp was also maintained and stabilized from 6.7-7.9% DMI to 7.5% DMI. Pellets were changed for higher CP and NDF contents (from Mazuri browser maintenance 5654 to Kasper faunafood browser 6322) and their dietary incorporation was upgraded from 19.0-22.3% DMI to 24.8% DMI. Finally, linseed oil was added in order to improve the fatty acid dietary profile and new mineral blocks were also provided to improve the iodine, manganese and zinc levels. Depending on the chosen intake scenario, all these dietary changes improved the diet from 14.39-14.70% CP DMI to 15.57-16.82% CP DMI and from 35.93-38.07% NDF DMI to 38.20-39.68% NDF DMI. A more accurate intake evaluation was also started for the male, when isolated in the inside facility for winter cold days. This should help to better chose the scenario of forage intake proportion next spring and perhaps start a second step of dietary re-evaluation.

KEYWORDS: browser, giraffe, diet change

Lucerne silage as feed for browsers in Rotterdam Zoo

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In most zoos, lucerne is used as forage for browsers and other herbivores. However, quality and palatability of lucerne can vary considerably, especially in more temperate regions like north-western Europe. Quality and palatability may affect the voluntary intake of lucerne by several browser species like okapis and giraffes. Because obtaining lucerne from southern Europe, North America or South Africa is impractical and expensive, ensiling is an alternative method to preserve lucerne as feed for browsers. The supervisor of the animal supplies department of Rotterdam Zoo has initiated experiments to ensile lucerne harvested from the land rented by the zoo. After three years of experimentation, Rotterdam Zoo has now an annual yield of 160 tonnes of lucerne silage in round, 200-kg bales (wrapped in plastic) to feed their animals. Various aspect have been considered: harvesting and wilting, baling technology, fermentation process (including silage additives), storing and feed-out of the bales, nutritional value, palatability, health aspects and potential hazards (for example mycotoxins) of feeding lucerne silage as well as financial aspects. It is concluded that feeding lucerne silage is certainly a good opportunity to improve the intake of dietary fibre especially to browsing ruminants, but harvesting, ensiling and storage require careful attention.

KEYWORDS: Ensiling lucerne, preservation, hazards

Variation in growth of herbivorous tortoises: causes and consequences for reproduction and health management

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Reptiles have very flexible growth rates, depending on living conditions - in particular dietary resources. Differences in the growth rate between either captive or free-ranging, or between extensively kept and intensively fed tortoises, have been demonstrated for a variety of species, including Galapagos giant tortoises (*Geochleone nigra*), leopard tortoises (*Geochelone pardalis*), African spurred tortoises (*G. sulcata*), desert tortoises (*Gopherus agassizi*), Hermann's tortoises (*Testudo hermanni*) and spur-thighed tortoises (*T. graeca*). Although health problems in tortoises are usually linked to *inappropriate* diets, fast growth itself, such as triggered by *appropriate* diets fed in high amounts, has traditionally also been considered unfavourable. Raising tortoises on intensive feeding regimes in captivity may considerably shorten generation times during the breeding stage of restocking programmes. In the case of the *G. sulcata* dataset (spanning 18 years for the captive individuals), it could be shown that fast growth leads to a fast reproductive maturity, as expected from inflexion points of growth curves. However, such high growth rates are traditionally thought to be linked to problems such as obesity, high mortality, gastrointestinal illnesses, renal diseases, 'pyramiding', fibrous osteo-dystrophy or metabolic bone disease. Data that actually test these hypotheses are lacking. We performed a retrospective evaluation of 539 tortoise patients of the University of Zurich. The age-body mass relationship of these patients was checked for additional influence factors, such as dietary history and occurrence of certain diet and growth-related diseases. No indication was found that animals particularly heavy for their age were more prone to diet/growth related disorders. In general, tortoises fed diets with meat/grain were heavier for their age than tortoises fed more appropriate diets; dietary history was not related to a particular disease. The results suggest the age-body mass relationship may not be suitable for testing effects of fast growth; an age-body length relationship would be more appropriate. Animals presented for a diet/growth related disorder were younger than animals presented for other reasons; there was a significant negative correlation between the severity of pyramiding and age, suggesting that growth-related disorders may well limit the life expectancy of tortoises. Whether fast growth presents a health risk needs to be evaluated in controlled studies. The observations suggest that feeding regimes in captivity – even of appropriate diets - should be restricted if replication of conditions in the wild, rather than a high reproductive rate, is a husbandry objective.

KEYWORDS: Tortoise, growth, pyramiding

Titanium status in ruminants and omnivores

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Titanium is regarded essential for animals and man. A titanium-poor diet caused reduced feed intake and life weight gain in growing goats, enhanced the mortality in kids and reduced the titanium content of milk by 50 %. However, the requirement is met worldwide and titanium deficiency is not a practical problem. There is evidence that the titanium concentration of animal tissues is not homeostatically controlled. Mice, voles and shrews from areas with a different titanium content of feed accumulated species-specific, different high amounts of titanium. Whereas a few results exist on the tissues concentration in organ tissues of monogastric animals, no data are available in ruminants. Due to the species-specifity of the titanium status, organ tissues of different wild ruminant species and omnivores were analysed and compared. The investigated captive wild ruminants came from the Zoological Society of San Diego and the Zoo Leipzig. Furthermore, organ tissues were taken from road killed mule deer from the Sacramento area. Wild living opossums and foxes were trapped at the San Diego Zoo and euthanized due to diseases screening. For the presentation of the results the various species of ruminants were morphophysiologically classified as the ruminant feeding types concentrate selectors, intermediate mixed feeders, and grass and roughage eaters. After dry ashing of samples the Ti - concentration was analyzed by optical emission spectroscopy with inductively coupled plasma. Although, the Ti concentration in the organ tissues was highly variable, the Ti amounts per kg tissue dry matter were quite low compared to the Ti amount to that the ruminants are exposed. The Ti concentration in the organ tissues and hair showed a very high variability. Nevertheless, the habitat seemed to influence the Ti status. Adult concentrate selectors of Northern California accumulated 3 times more Ti in the liver than in Southern California. Furthermore, the feeding types took effect on the Ti content of organ tissues. As a rule grass and roughage eaters stored less Ti in different tissues than the other feeding types. This was true for adult ruminants as well as for neonates, but to a lower extend. Except in ribs and lungs, neonatal ruminants accumulated significantly more Ti in the organ tissues than adults. There is a tendency that with exception of hearts, female adult ruminants accumulate up 3 times more Ti in organ tissues than male ruminants, and the differences become significant in the case of kidney, rib, skeletal muscle, spleen and hair. The same tendency was observed in wild living mule deer. Whereas the liver of adult opossums contained similar high Ti-concentration like concentrate selectors and intermediate feeders, foxes accumulated much higher amounts. It seems that the reproduction status also affects Ti-status. Lactating opossums contained less Ti in the organ tissues than non-lactating ones.

KEYWORDS: Titanium, ruminants, opossum

Evaluation of the digestibility of different raw meat diets for exotic large felids

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The aim of the present study was to evaluate the apparent digestibility of three different raw diets in four large exotic felid species (lion *Panthera leo*, jaguar *Panthera onca*, leopard *Panthera pardus*, Amur tiger *Panthera tigris altaica*). Furthermore, nutritional adequacy of the diets was evaluated according to the nutritional requirements of domestic cats. All animals (7 leopards, 2 lions, 1 jaguar and 1 tiger) received three different diets: 1) raw beef meat; 2) raw whole chicken without entrails; 3) raw whole rabbit with liver and kidneys. In order to measure apparent digestibility, silica was added to each diet at 0.5 %. Each diet was fed for 5 days followed by a 2-d fasting period. Faeces were collected during the last 3 d of each feeding period and stored at –20°C for analyses (humidity, protein, fat, ash, macro and trace elements) together with three samples of each diet. Results were analyzed by one-way ANOVA and post hoc tests. Apparent total tract dry matter (DM) digestibility tended to be higher for the beef diet (93.4 *vs.* 83.3 and 86.4 % for beef, rabbit and chicken, respectively), presumably because of the presence of bones in the rabbit and chicken diets. Crude protein digestibility was slightly higher in beef compared with the other diets (97.9 *vs.* 94.9 and 95.7 % for beef, rabbit and chicken, respectively). In the present study, beef was mainly composed of muscle tissue, while rabbit and poultry were fed as whole carcasses as such providing the animals with higher amounts of connective tissue, a source of low digestible protein. Fat digestibility did not differ among diets. With regard to macro minerals, digestibility of phosphorus and sulphur was higher in beef while digestibility of other macro minerals (Mg, K, Na, Ca) did not differ among treatments. Digestibility of trace minerals (Mn, Fe, Ni, Se, Zn, Co, Cr) was in general low with the only exception of selenium (average digestibility 88%), and there were no differences among diets. The low digestibility of trace minerals was probably the consequence of the fact that intestinal absorption of trace minerals is in general very low if the animals are not deficient in these nutrients. Comparing the composition of the three diets with the nutritional requirements of domestic cats confirmed that beef meat contains only traces of calcium (0.1 % of DM) and should not be used as the only ingredient in the diets of exotic felids. Conversely, the amounts of calcium and phosphorus contained in chicken and rabbit were much higher than the requirements of adult cats. In conclusion, all diets showed a good digestibility with beef being more digestible than chicken and rabbit. Based on the composition of the tested diets, it seems reasonable to suggest that the diet of exotic felids should contain both raw meat and whole chickens and/or rabbits.

First insights into the gut microbiota of captive cheetahs

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Feeding mismanagement has been pointed out as one of the potentially important factors in the ontogeny of gastrointestinal health problems observed in captive cheetahs. Given the crucial role of the intestinal microbiota in feed fermentation and gut health, a better understanding of the diversity and temporal stability of the intestinal ecosystem is essential for improvement of current feeding strategies. This study is the first using culture-independent approaches to inventorize the predominant fecal microbiota of captive cheetahs. Two fecal samples of two adult male cheetahs housed in a Belgian zoo were collected immediately upon defecation and stored at -80°C. DNA extracts of 25g of homogenized fecal samples were prepared and a 16S rRNA gene clone library was constructed using universal bacterial primers. So far, a selection of 192 clones (96 clones/animal) was sequenced. The resulting nucleotide sequences were then compared with GenBank to identify the closest relatives using the BLAST algorithm. According to present results, the majority of the sequenced clones fell within the phylum Firmicutes (95 %) and to a much lesser extent within the phyla Actinobacteria (3 %), Fusobacteria (1 %) and Bacteroidetes (1 %). The clones belonging to the phylum Firmicutes were predominantly affiliated with four families: Peptostreptococcaceae (34 %), Incertae Sedis XIV (21 %) within the order Clostridiales, Clostridiaceae (10 %) and Lachnospiraceae (14 %). The last mentioned was the most diverse at genus level. This relative taxonomic distribution is broadly in line with microbial diversity studies in domestic cats. Above-named bacterial families hold important proteolytic bacteria as well as short chain fatty acid producers that are able to ferment a variety of complex carbohydrates. The coverage of the clone library (i.e., the probability that any additional analyzed clone is different from any previously analyzed clone) was estimated through rarefaction analysis which indicates the need for a higher number of clones to be analyzed. The results of extended clone library analysis will be presented in the poster. The clone library approach is a first step in the taxonomic and functional characterization of the gut microbial ecosystem of captive cheetahs and may prove the key to enhance feeding strategies for these endangered felids.

KEYWORDS: Gut microbiota, 16S rRNA clone libraries, cheetahs

Infectious microorganisms in mice (*Mus musculus*) purchased from commercial pet shops in Germany

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In this study, we investigated the prevalence of infectious microorganisms (viruses, bacteria, fungi and eukaryotic parasites) in mice from different pet shops in Germany; such animals may act as vectors of unwanted, potentially zoonotic pathogens into zoo animal vivaria, especially when used as feeding specimens for carnivorous species. House mice sold as pets or feed specimens were purchased from different pet shops and tested for a comprehensive panel of viruses, bacteria and eukaryotic parasites. We found a number of microorganisms in these pet shop mice, the most prevalent of which were *Helicobacter* species (92.9 %), mouse parvovirus (89.3 %), mouse hepatitis virus (82.7 %), *Pasteurella pneumotropica* (71.4 %) and *Syphacia* species (57.1 %). Several microorganisms (e.g. MPV, TMEV, PVM, *E. cuniculi*, *C. piliforme*) had considerably higher prevalences than those reported in similar studies on wild mice from North America, Europe or Australia. Our study shows that direct contact with pet shop mice may constitute a risk for animal vivaria.

KEYWORDS: Mice, infectious microorganisms, feeding specimens

Nutrition consultation in zoo animals using ration calculation

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In our nutrition consultation service, computer aided ration calculation is employed to check feed rations for pet animals as well as livestock in order to diagnose possible nutritional impact on certain health problems and to optimize rations. For some species specialised software is available and employed. Otherwise, if specialised software is lacking, mostly table calculation programs such as MS Excel are used to compare energy and nutrient intake with the recommended intake. The same approach is used when rations of exotic and zoo animals are scrutinised. Based on data sets from common databases of feedstuffs and information from literature, nutrient composition of feedstuffs is adjusted to species specific values whenever possible, for example data for the apparent digestibility of dry matter and / or proximates in that species are used to estimate the energy content of the diet. The nutrient supply of the actually fed ration is compared with the requirement. If necessary, the composition and/or the amount of used feedstuffs are changed in order to fit better to the species specific and individual needs as well as the preconditions of the zoo (availability of the feedstuffs). Even though requirement figures are limited in various species and approximation is often necessary, formulating recommendations that way often proves effective, especially in case of frequent monitoring and adaptation of the diet if required. To exemplify, the approach will be displayed at the presentation using a case of weight loss necessity in rhinos and a check-up of mineral supply in elephants.

KEYWORDS: Zoo diets, ration calculation, table calculations

Nutrition-associated stillbirth in captive golden-headed lion tamarins

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Golden-headed lion tamarins (*Leontopithecus chrysomelas*) are endangered in the wild, with population reductions, due to forest loss, estimated to be over 50 % over the last 21 years. Since 1999, the reproduction of golden-headed lion tamarins in Antwerp Zoo is characterized by a high stillbirth mortality (60 %). Necropsy revealed dystocia caused by fetal macrosomia (disproportionately large young) being the main cause of the high mortality rates. Comparable patterns were observed in other European zoos that keep golden-headed lion tamarins in their collection. The current project aimed to investigate whether these birth complications might be of nutritional origin. The diet fed in Antwerp Zoo was evaluated in order to investigate the relation between possibly inappropriate feeding and stillbirth. To get insight in diets fed to golden-headed lion tamarins in European zoos as well, a survey was sent to all European zoos that currently keep these tamarins in their collection. A distinction was made between zoos with the same reproductive problems as Antwerp Zoo, so called 'stillbirth zoos', and zoos that did not have any stillbirth related problems, so called 'non-stillbirth zoos'. 19 out of 44 zoos returned their survey (7 'stillbirth zoos'; 12 'non-stillbirth zoos'). Data from returned diet sheets were used to calculate the dietary values and compared to nutrient requirements for *Callitrichidae*. In both Antwerp Zoo and the other 'stillbirth zoos', the diets fed to the tamarins consist of higher total sugar levels compared to diets fed in zoos where no stillbirth events did occur and to the recommended requirements. These high sugar levels were caused by the proportion of fruit offered in the diet. Although the diet of wild golden-headed lion tamarins consists mainly of fruit, sugar compositions of fruit consumed in the wild are much lower, compared to sugar levels in cultivated fruit we feed to our zoo animals. Consuming a high sugar level increases the risk of developing gestation diabetes and foetal macrosomia, which both can possibly lead to stillbirth mortality. To prevent excessive birth weight in the future, it was recommended to lower dietary sugar levels by removing fruit items gradually from the diet, and by avoiding other sugar rich products. Furthermore, literature indicates that a high fibrous diet significantly improves blood glucose control compared to a low-fibre diet. Adding products rich in soluble fibres, such as gum Arabic or beet pulp, may be a good addition to the diets of 'stillbirth zoos'. Both dietary changes might have a positive effect on controlling blood glucose levels and therefore reducing the incidence of macrosomia and stillbirth in golden-headed lion tamarins. The value of nutrition surveys are often underestimated. However, as in this study, nutrition surveys can be a powerful tool in evaluating and optimizing nutrition of zoo animals and therefore, can be of great importance for European breeding programmes.

KEYWORDS: Leontopithecus chrysomelas, foetal macrosomia, nutrition surveys

Nutrition of mongoose lemurs *(Eulemur mongoz)* in European zoos

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Based on data from ISIS, worldwide there were 108 mongoose lemurs (*Eulemur mongoz*) kept in 38 zoos by the end of 2010. Within this population, only one young was born and raised since November 2009. Reduced reproduction was attributed to nutritional causes; it was speculated that many captive animals were overweight. To get more insight in the possible nutritional causes, a questionnaire with questions on diet composition, body weight and condition was sent to 19 European zoos. Nine surveys were completed. These zoos kept 19 animals, ranging in age from 5 to 23 years, with an average of 14.5 years. Based on reported body weight only three animals could be considered as overweight. However, the body weight of 9 individuals was not measured at all and many animals had not been weighed recently. According to the reported body condition scores (BCS), four animals were overweight or obese. Respondents had no previous experience in assessing BCS. The number of different diet ingredients varied from 11 – 30. Fresh matter intake varied from 169 gram to 466 gram per animal per day. On dry matter basis, commercial feed percentage in the diet varied from 0 to 75 %, for fruit it varied from 2 to 36% and for vegetables from 4 to 59 %. Estimated energy intake per animal per day varied from 0.38 to 1.38 MJ ME. The percentage of sugars in the diet (DM basis) varied from 19 to 40%, figures for NDF were 10 to 30 %. In three zoos the calcium content in the diet was less than 0.25 %; the same zoos also showed an inverse calcium to phosphorus ratio. In only one zoo were dietary items weighed for the purpose of this study. The assumption that many animals were overweight could not be proven. However, feed intake was rather high compared to what is reported *in situ*, as was the average energy density. The NDF and ADF content of the diets fed were rather low. The properties of the diets can contribute to the risk of overeating and therefore obesity, thus requires further investigation. However a nutritional study is only useful when all collections are willing to participate and provide exact data instead of estimates or assumptions.

KEYWORDS: lemur, survey, diet study

Feed intake and ration composition in a group of captive giraffes

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Although increasing knowledge on ruminant feeding types has helped to improve nutrition of giraffes (*Giraffa camelopardalis*) in captivity, feeding browsers can still pose challenges. Besides general scarcity of quantitative information on diets (amounts and composition), aspects like faecal particle size (larger particles found in faeces of captive compared to free-ranging giraffes), occurrence of oral behavioural disturbances (probably influenced by the amount of roughage) and in vitro fermentative behaviour of feeds (some rather high in fast fermenting carbohydrates) are relevant. To get detailed information on summer feeding practice, the feeding regime in Cologne Zoo (7 giraffes [*G. c. reticulata*]; male [10 yrs], female [11 yrs], female [8 yrs, lactating 4 months], male [2 yrs], female [3 yrs], female [12 months], male [4 months]) was documented over six days in June 2011. Total amount and proportions of components consumed were recorded. Outdoor observations during different times of day were made to detect potential oral stereotypies. Faecal samples were wet sieved to estimate the weighted average particle size. Fermentative behaviour of feedstuffs was evaluated in vitro using the Hohenheim Gas Test (HGT; browse samples incubated with and without polyethylene glycole [PEG] for complexing tannins). The giraffe group did consume an average amount of 58.5 kg dry matter (DM) per day, corresponding to 78.1 g DM/kg $BM^{0.75}$ ($BM^{0.75}$ = metabolic body size). 58 % of dry matter intake (DMI) consisted of structural feeds (34 % lucerne hay, 17 % grass, 49 % browse), 39 % of concentrate feeds (69 % beet pulp, 17 % zoo pellets, 14 % soybean meal) and 3 % of produce (fruits, vegetables). Every day 10 to 12 trees (birch and willow, ~120 kg fresh material) with average composition of 65 % stem, 24 % leaves plus twigs and 6 % bark, with stem diameters of 4 to 8 cm were offered. No behaviour in the group indicated the occurrence of oral stereotypies. The weighted average of faecal particle sizes for the adults was 0.93 ± 0.06 mm. Feedstuffs with high contents of easily digestible carbohydrates did achieve the highest 48 h gas production (GP_{48h}; all in ml/200 mg DM) in HGT (produce 77.9, beet pulp 74.6, zoo pellets 61.1, soybean meal 55.1). Fresh grass (48.6) did achieve a higher GP_{48h} than lucerne hay (41.7). Except for willow+PEG (44.7) GP_{48h} in browse was lowest: willow 40.4, birch 27.4 and birch+PEG 30.4. Regarding GP after 4 hours (GP_{4h}), fermentation of produce (41.7) was faster than for beet pulp, zoo pellets and soybean meal (20.4 ± 0.2) which was again faster than for willow (11.8), willow+PEG (16.8), birch (10.2), birch+PEG (13.2), lucerne hay (15.3) and grass (8.4). The diet as fed in Cologne Zoo appears to prevent the development of oral stereotypies. Faecal particle size as measured confirms reports on larger faecal particles on captive diets and indicates differences in the food comminution process between captive and free-ranging giraffes. Regarding the high GP_{4h} and GP_{48h} of concentrate feeds and particularly of produce, components of the zoo-ration can show considerably different fermentative characteristics from natural forages.

KEYWORDS: Browser, ration composition, in vitro fermentation

Daily intake of dietary essential amino acids in African grey parrots (*Psittacus erithacus*) fed a seed-based diet or extruded pellets *ad libitum*

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Although seed-based multi-component parrot diets are inherently deficient in several essential nutrients, parrots are still commonly fed such diets. Typically, the edible part of seeds show a pronounced imbalance in calcium:phosphorus ratio and are highly deficient in vitamin A, D, K and B. Additionally, it is often suggested that the biological value of seed protein is inadequate to meet the requirements for dietary essential amino acids. The current study investigated the amino acid intake in adult African grey parrots (*Psittacus erithacus*) when fed a multi-component seed diet compared to pellets. Eight 3-year-old African grey parrots were individually housed and subjected to a 3x3 cross-over trial with 3 nine-day feeding periods in which 3 commercially available parrot diets were fed *ad libitum*: a seed mixture (Prestige Parrot Premium) and two extruded pellet diets differing in protein content (Nutribird P15 and Nutribird P19). Each feeding period consisted of 5 days of adaptation, followed by a 4-day period in which total daily food intake was measured. Ion-exchange chromatography was performed on homogenized food samples and seed remainders to determine the amino acid content of offered diets and ingested fraction of the seed diet. Both crude protein (CP) content and metabolisable energy (ME) of the seed diet vastly increased as a result of selective feeding, but the amino acid profile remained largely unchanged. However, arginine content relative to energetic density was considerably increased by selective feeding behaviour. Mean daily intake of CP was comparable between the seed diet (8.4 ± 0.8 g CP/kg$^{0.75}$) and P15 pellets (8.4 ± 0.9 g CP/kg$^{0.75}$), but significantly higher when fed P19 pellets (11.0 ± 1.5 g CP/kg$^{0.75}$). Likewise, except for arginine intake, which was comparable when fed seeds and P19 pellets, intake of dietary essential amino acids was significantly highest when fed P19 pellets. Comparing seeds and P15 pellets, leucine intake was lower when fed seeds, but methionine and valine intakes were higher. Lysine content relative to energetic density was in all test diets below current guidelines for adult psittacine birds in maintenance conditions. P15 pellets were even deficient in methionine + cysteine. These guidelines, however, were published as conservative, tentative minimum recommendations based on extrapolations from poultry requirements. Nevertheless, based on experimental results in adult African grey parrots, all test diets complied with estimated species-specific requirements for lysine and methionine + cysteine. Moreover, where methionine + cysteine content in P15 pellets was below current guidelines, its supply when fed P15 pellets showed to be slightly above daily requirements for white leghorn-type chickens in egg production with egg yield as response criterion. Similarly, when fed P19 pellets, daily lysine intake approximately equaled daily requirements for leghorn-type chickens. All together, these data do not support the assumption of amino acids being deficient in seed-based parrot diets. Instead, these results suggest an overestimation of current dietary minimum recommendations on amino acids for psittacine birds.

KEYWORDS: Parrot, dietary imbalances, amino acid supplementation

Assessing seahorse rearing diets within UK collections

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Seahorses are fish of the genus Hippocampus. All 38 seahorse species on the IUCN Red List are declining in numbers due to threats including habitat degradation, fishing for use in the aquarium trade and in medicine, or from accidental collection as by-catch in shrimp trawls. For this reason, many are kept in aquariums to conserve them through captive breeding. However, rearing success of seahorses is variable between UK collections and generally low. An example is the long snouted seahorse *Hippocampus reidi* which breeds at Chester Zoo though the fry die before reaching maturity. Worldwide, rearing success for this threatened species is low (only 13 % based on a 2005 census). Fatty acid profiles of live prey items are recognised as an important nutritional factor in the aquaculture of marine fish due to those fish having a limited ability to convert the non essential fatty acids, such as linolenic acid, to the essential fatty acids such as eicosapentaenoic acid and docosahexaenoic acid. Symptoms of fatty acid deficiency in fish include decreased growth rate, impaired reproductive ability, increased susceptibility to infection due to immune system failure and increased mortality rate. So it is reasonable to assume the fatty acid profile of the food plays a role in seahorse health, but to date, little information has been gathered. Survey response were obtained from 10 UK collections holding seahorses (out of a possible 13) along with data from two European holders of seahorses. In total these 12 collections care for nine seahorse species. Seven different crustacean and marine invertebrate items (both live and frozen) are used in the feeding practices for adult seahorses, with Mysid shrimp and adult *Artemia* the most frequently used. A slightly greater range of items (ten) are used to rear juvenile seahorses, again involving both live and frozen prey plus two dry mix feeds. *Artemia* naupli are used by all collections and fed to all seahorse species at some stage during rearing. Otherwise no clear trends emerged for feeding either particular species or successful rearing. Ten of the 12 collections use at least one product to enrich prey items, with the most frequently used (by five collections) being SELCO (Self-emulsifying Liquid Concentrates) designed specifically to enrich fatty acids. Attempts to measure the enriching affects of SELCO on *Artemia* cultures after either 2hrs or 24hrs (cf. with no enrichment) in terms of essential fatty acid composition produced equivocal results, possibly due to the extremely small volumes of *Artemia* naupli sampled; the efficacy of supplementation on prey items warrants further investigation. The survey has reviewed seahorse rearing and diets in UK seahorse collections, which will be relevant to and useful for the Native Seahorse Husbandry Manual and in the subsequent development of Husbandry Guidelines for other seahorse species and a report summarising the results will be available to all those taking part.

KEYWORDS: Seahorse, fatty acids, rearing

Nutritional composition of early spring forage eaten by reindeer (*Rangifer tarandus*)

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Field data on forage plant nutritional composition can be an important tool for adequate diet design for captive herbivores. The botanical composition of winter and early spring diet of semi-domesticated reindeer (*Rangifer tarandus*) was established through microhistological faeces analysis. Spring forage plants were collected and their nutritional composition (Weende, van Soest and mineral analysis) was determined. Based on microscopic analysis of faeces the winter diet contained on average 39.6 ± 11.1 % lichens, 10.3 ± 3.9 % grass/sedges, 32.6 ± 9.8 % shrubs and 14.7 ± 8.2 % mosses. The early spring diet contained 44.6 ± 12.3 % lichen, 17.9 ± 7.4 % grass/sedges, 21.9 ± 7.8 % shrubs and 15.3 ± 4.8 % mosses. The grass/sedge intake increased significantly in spring compared to winter while the proportion of shrubs decreased. Lichen and moss intake did not differ significantly between winter and early spring. When the early spring period was divided in three equal periods of 10 days, data showed that the proportion of lichens in the diet decreased (from 49.4 ± 10.8 % to 36.0 ± 89 %) while of grass/sedges increased. Chemical analysis of the lichen in the diet showed a high NDF content in the dry matter (app. 80 %DM) while ADF content varied from 10 to 27 %DM.

KEYWORDS: Rangifer tarandus, lichen, nutrient composition

Current feeding practice for captive black rhinoceros *(Diceros bicornis)*; a review
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The aim of this research was to identify differences between nutrient compositions of plants selected by wild black rhino with food items provided for zoo-housed individuals, and determine whether 'browse' used in captivity could mediate any discrepancies seen between wild feed and captive diet. The study aimed to 1) review feeding practice for captive black rhino 2) compare captive provision with wild feed choice and 3) determine nutrient availability of browse fed. In August 2010, 29 collections holding black rhino were contacted for details of current diet provided. Thirteen zoos in North America, the UK and Australia responded (a response rate of 45%) giving details on diet for 51 animals. From these surveys, nutrient composition on a dry matter (DM) basis was calculated using Zootrition© for each diet and the sample population compared against itself to determine variability in feeding regime. Samples from tree species (leaves and twigs) commonly fed in captivity were analysed in the laboratory to determine the %DM of key constituents deemed essential to rhino health. Data from Zootrition© and a review of literature were used to collate nutrient compositions of zoo-fed browse and to give information on vegetation selected by wild rhino. This information was then combined with nutrient compositions of zoo-fed browse analysed in the laboratory. In total, 33 species of vegetation were evaluated. Crude Protein (CP), Acid Detergent Fibre (ADF) and Ether Extract (EE) content of captive diets differed significantly from CP, ADF and EE content of wild plants. Significant variability between feed provided and overall nutrient composition between different collections was identified; for example US diets appeared higher overall in CP than UK or Australian diets. Zoo-fed browse had significantly different phosphorous (P), sodium (Na), calcium (Ca), iron (Fe) and zinc (Zn) content to naturally selected browse indicating differences in nutrient uptake and availability in plants from different geographic areas (as would be expected due to soil composition). Analyses of dietary data showed that 61% collections significantly differed in availability of CP, 39% differed in availability of ADF and 31% differed in EE content. Low fibre, low EE, low Zn and high Fe scores are candidates for further evaluation. More than 95% of free-ranging black rhino diet comprises of dicotyledonous plant material selected from ~220 different species of vegetation. Wild black rhino select for high fibre, low protein and moderate ether extract, correlating with choices by other obligate browsers; no single zoo-fed browse appears to replicate this totally. Oak (*Quercus* sp.) contains highest EE, but is significantly lower than wild browse. Beech (*Fagus* sp.) had the highest ADF content of zoo browse but again, still lower than wild levels; however more inclusion of oak and beech in captive diets may be beneficial. Conversely, oak has a relatively high Fe content (531ppm), found to be significantly higher than wild plants. Elevated Fe content is associated with haemochromatosis in black rhino and feeding guidance suggests minimising Fe content. Similarly the importance of essential fatty acids (EFA) and Zn for healthy skin condition and prevention of dermatological disease should also be reviewed, and browse choice decisions made on the bioavailability of EFA and Zn to the animal. Only eight collections sampled provided browse regularly; the reluctance of captive browsers to accept forage emphasises browse as an essential dietary requirement. Results indicate that comparison of captive diet to wild feed choice enables different nutrient availability to be identified, and information used to further inform feeding regimes.

KEYWORDS: Black rhinoceros, survey, diet provision

Influence of particle size and starch gelatinisation of hand-rearing diets on growth, crop emptying and faecal parameters in Amazona parrot chicks

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Previous studies with captive adult parrots (Psittaciformes) indicate that particle size and the degree of starch gelatinisation are important parameters of the diet, relating directly to the health and function of the intestinal tract. Furthermore, studies of the crop contents of wild, parent-fed parrot chicks reveal a wide range of particle sizes, some substantially larger than sizes habitually found in diets formulated for hand-rearing parrot chicks. This study examines the influence of particle size and the degree of starch gelatinisation of formulated diets on the growth of parrot chicks of the genus Amazona, as well as their effect on rate of crop emptying and pH and consistency of faeces as indicators of relative gut health and function. Three hand-rearing formulas with identical nutrient composition but different native starch content and particle size as a result of applied processing conditions were used in the study. Formula A, the food habitually fed to parrot chicks in the study collection, had 0% native starch, and formulas B and C respectively had 20% and 40% native starch, and corresponding larger particle size. Twenty four 1-day old chicks of several species of the genus Amazona were included in the study, and equalised across the study groups as far as possible. Until the age of 10 days, all chicks were fed Formula A, and from day 10 they were fed Formula A, B or C according to their allotted group, until the point of weaning. To record the development of the chicks, they were weighed every morning before the first feeding of the day. Once a week, pH of the faeces was measured (digital pH meter) and consistency of faeces was scored on a range between 0 and 5 (5 = optimum). Furthermore, to determine crop emptying rates for the three diets, once a week the percentage emptying of the crop was recorded every successive hour from the previous feeding. Body condition and health of the birds were constantly checked by the veterinarian clinic, and any abnormal condition recorded. Daily body weights were expressed as mean growth rates for the chicks in the three groups, all groups showing the same growth profile. There was a tendency towards an effect of the type of diet on crop emptying after one hour, where rate of crop emptying increased with higher native starch content and therefore larger particles in the diet. For the faecal parameters, the diets with native starch showed a tendency for lower pH and more optimal consistency. To conclude, hand-rearing diets with more native starch and therefore bigger particle sizes tends to have a positive effect on intestinal health and function of Amazon parrot chicks. This also indicates advantages for the bird's health overall.

KEYWORDS: Starch, hand-rearing, amazon

Digestion in African elephants *(Loxodonta africana)* on a grass hay diet

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Introduction: Although African elephants are common zoo animals, quantitative data about forage intake, digesta mean retention times and food digestibilities are relatively rare. Within a larger study about African ungulates, we had the opportunity to estimate food intake, digesta mean retention time (MRT) and forage digestibility of African elephants in captivity. *Material and Methods:* Six African elephants (5 females, ~22 years old, estimated body mass of 3000 - 4000 kg and 1 male, 31 years old, estimated body mass 6500 kg) had *ad libitum* access to grass hay. The grass hay had a neutral detergent fibre content of 64% in dry matter (DM), acid detergent fibre 35% DM, acid detergent lignin (ADL) 4% DM, crude protein 9.4% DM and an ash content of 10% DM. To estimate the MRT two passage markers were administered orally in a single pulse dose at the beginning of each sample period (solute phase: Cobalt-EDTA; particle phase: chromium-mordanted fibre, 1-2 mm particle size, made of grass hay). Faecal samples were collected of each dropping. To estimate diet digestibility ADL was used as internal marker. *Results:* Daily DM intake (DMI) was 51.1 ±7.85 kg DM per animal, corresponding to a mean relative DMI (rDMI) of 104 ±12.7 g DM/(kg$^{0.75}$*d). The MRT was 30 ±5.4 h for the particle marker and 29 ±4.0 h for the solute marker. As a result the selectivity factor ($MRT_{particle}/MRT_{solute}$) was low (1.01 ±0.102). The apparent organic matter digestibility was estimated at 33 ±9.6 %. *Discussion:* As expected the African elephants in this study had high relative dry matter intakes combined with short digesta mean retention times. The results for the relative dry matter intakes are in accordance with other studies for Asian and African elephants. Also the results for the digesta mean retention times and the selectivity factors are similar to other studies estimating mean retention times for elephants. The estimated apparent digestibilities of organic matter are low compared with other studies, but are in line with *in vitro* results on the degradability of the fed grass hay. For equids it was shown that there is a decrease of dry matter intake with increasing neutral detergent fibre content in the food. It has been shown that there is no or only a much less significant decline in dry matter intake with increasing neutral detergent fibre content for African and Asian elephants which gives some indications for the adaption of elephants to low quality forage.

KEYWORDS: Food intake, mean retention time, organic matter digestibility

How much is too much: A guide to how much your lemur should weigh

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Lemurs are one of the most endangered primate groups in the world with 40% of the 101 taxa red-listed in one of the threatened categories and a further 45% Data Deficient. Ex situ breeding programmes are vital to protect many of these species from extinction. However, various reports have cited obesity as common in captive lemurs. Excessive body mass can lead to breeding problems and infertility, and it renders affected individuals unsuitable for reintroduction into their wild habitat. Obesity can thus considerably compromise captive propagation programmes. However, although obesity is a serious problem, there are very few guidelines on how much each species of lemur should weigh in captivity and what constitutes obesity. Therefore, the aim of this study was to collate data from the literature on the wild body masses of lemur species kept in captivity and define an obesity threshold for captive lemurs. The mean wild body masses for each species were found to be: *Daubentonia madagascariensis* 2.53kg (n=28), *Eulemur albifrons* 1.90kg (n=34), *E. collaris* 2.16kg (n=18), *E. coronatus* 1.29kg (n=86), *E. flavifrons* 1.84kg (n=18), *E. macaco* 1.98kg (n=54), *E. mongoz* 1.29 (n=30), *E. rubriventer* 1.98kg (n=51), *E. sanfordi* 1.90kg (n=58), *Hapalemur alaotrensis* 1.25kg (n=61), *H. griseus griseus* 0.81kg (n=21), *Lemur catta* 2.22kg (n=279), *Microcebus murinus* 0.065kg (n=496), *Prolemur simus* 2.40kg (n=22), *Varecia rubra* 3.02kg (n=25) and *V. variegata variegata* 3.52kg (n=33). As body mass is often reported as a mean in the literature, a predicted normal body mass range was used based on two standard deviations away from the mean wild body mass for each species, which yielded a threshold of 25% above and below the mean wild body mass when averaged over all species. "Overweight" was defined >125% of wild body mass and "obese" was defined as >150% of the mean wild body mass, or four standard deviations above the mean wild body mass for each species. A further category of "morbidly obese" was defined as >200% of the mean wild body mass to highlight those individuals that exceed twice the size of their wild counterparts. The results of this study can be used to help improve the health, welfare and reproductive success of captive lemurs, and ultimately aid in the conservation of this endangered primate group.

Seasonal diets for grizzly bears (*Ursus arctos*) at Brookfield Zoo - an update

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(This presentation is an update on the work presented at ENG 2010)

In late 2007, it was directed that the grizzly bears (*Ursus arctos*) at Brookfield Zoo needed to lose a significant amount of weight and should be put on a more seasonally appropriate diet. Composition and quantity of diet were historically unchanged and led to obesity during the winter months as well as minimal fluxuation of weight over seasons. The first step was establishing what "seasonal" entailed. In general, it was agreed that greens (different varieties of lettuce) were going to make up the majority of the diet as a means to maintain physical satiety. Changes in protein and fat content were adjusted according to season based on observations from the wild. The new diet regime was started in May 2008. The second step was establishing an appropriate weight range for these bears. After consulting with several institutions, a goal range of 363 kg ± 36 kg was established for Axhi and 400 kg ± 40 kg for Jim. The weight gain in the winter months of 2008 – 2010, although still reaching weights of 450 kg, was achieved in half the time. Using varied small food items, stereotypic and aggressive behavior were reduced from the previous years. A random arrangement of the different fruit, vegetables, cereals, prey, and meat products meant the animals received a completely different set of food items day-to-day that repeated on a weekly basis. In 2010, the bears were moved to a new exhibit with approximately 3 times the area as their old exhibit; the schedule of calorie and weight changes was not consistent for this year due to the increased activity. Additionally, the winter of 2010 – 2011 was the first time the animals were not encouraged to wake up daily to eat; this added another factor that affected weight loss. The pattern of weight loss and gain in 2011 was considered appropriate and the winter of 2011 – 2012 was the first time the animals were completely fasted. Examination of four years of data show an equilibration of the rate of change in calories offered and weight changes. As we continue to track this information, we hope to develop a specific range of calories to offer these animals at certain dates to create natural weight change cycles.

KEYWORDS: Grizzly bear, diet, seasonality

ZOO DEMONSTRATIONS

At the last conference, several participants communicated the need for practical demonstrations of principles of zoo animal feeding, monitoring, and research.

We aim to answer to this need with the demonstrations during the visit to Zurich Zoo.

Please follow the guide of your group to visit the following demonstrations:

- Commissary organisation and design *(J.-M. Hatt)*
- Food composition *(J. Hummel)*
- Feeding fruits and vegetables *(A. Fidgett/A. Plowman)*
- Calcium supplementation and UV-light provision *(A. Liesegang)*
- Herbivore digestive anatomy *(J. Fritz)*
- Feeding roughage: estimating amounts and recording intake *(J. Nijboer)*
- Faeces - collection, scoring and the use of markers *(M. Clauss)*
- Weight recording and body condition scoring *(T. Huisman)*

You are welcome to further visit Zurich Zoo. From a dietary point of view, we recommend a look at the tapirs (in the 'Exotarium', no. 1 on the zoo map near main entrance) and at the great apes (no. 4, upper left corner).

Remember to be back for the lunchbag at the Conference site at 13.00.

Zoo map

Weighing & body condition scoring

Commissary management
Food composition
Feeding fruits/veggies
Calcium and UV light
Herbivore digestive anatomy

Feeding roughage
Faeces collection & scoring
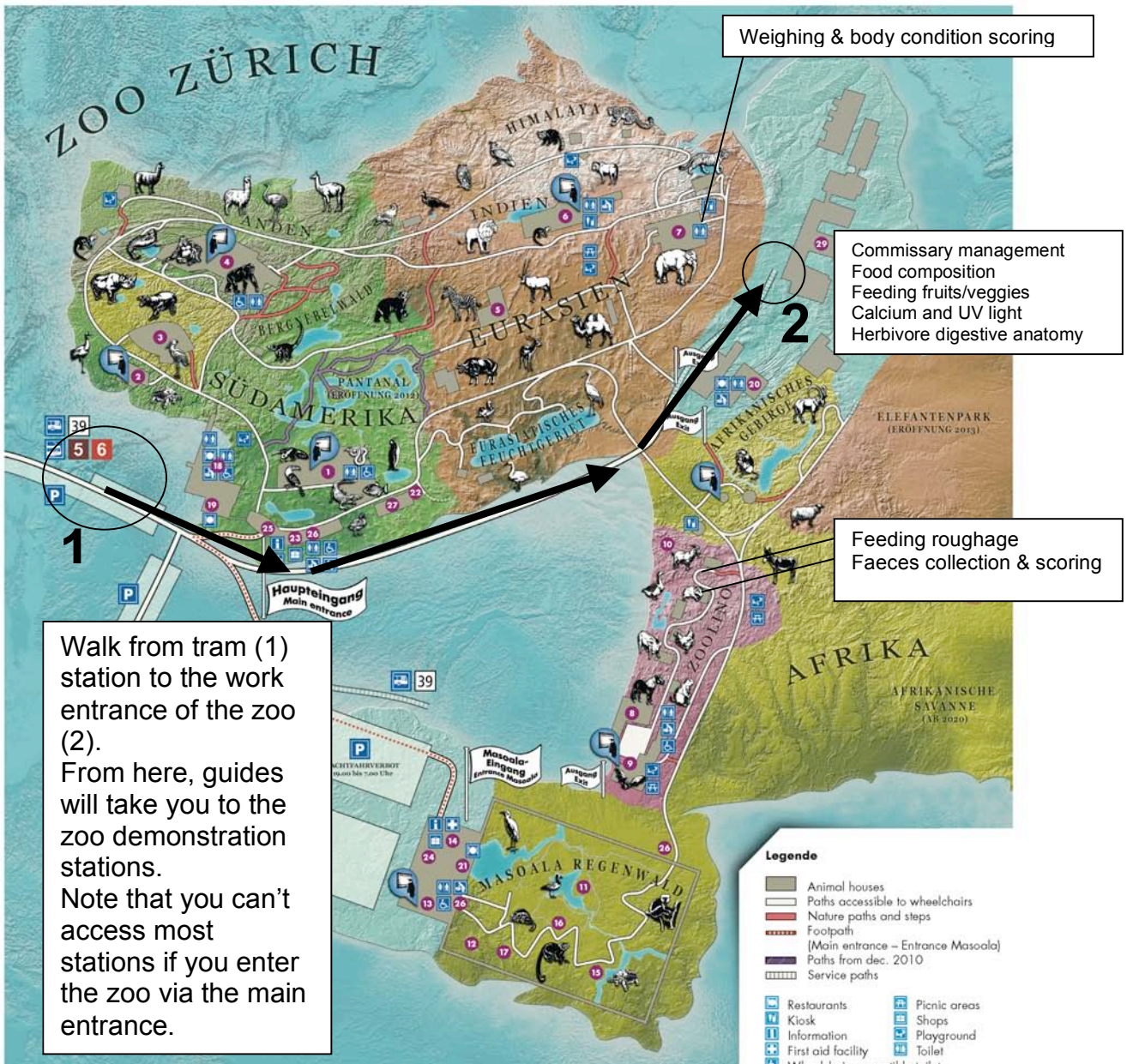
Walk from tram (1) station to the work entrance of the zoo (2).
From here, guides will take you to the zoo demonstration stations.
Note that you can't access most stations if you enter the zoo via the main entrance.

Legend
1 Exotarium, aquarium and terrarium
2 Tortoise and turtle house
3 Africa house
4 Ape house
5 Antelope house
6 Lion house
7 Elephant house

Zoolino/Nature workshop
8 Hayloft, gallery
9 Seminars and workshops, Foundation for bat protection
10 Arena

Masoala rainforest
11 Masoala rainforest
12 Event location
13 Masoala information centre, aquarium and terrarium
14 Foyer
15 Researchers' camp
16 Meteorological station
17 Betsimisaraka house

Restaurants + Picnic
18 Restaurant Siesta (Self service)
19 Restaurant Outpost
20 Restaurant Altes Klösterli
21 Restaurant Masoala (Self service)
22 Hot chestnuts

Shops
23 South America shop
24 Masoala shop

Visitors' service
25 Main ticket office, lost property office
26 Wheelchairs, zoo baby carriages, lockers
27 Volunteers' team
28 Scouts clubhouse

Zurich zoo administration
29 Head office and administration building, library

Legende
Animal houses
Paths accessible to wheelchairs
Nature paths and steps
Footpath (Main entrance – Entrance Masoala)
Paths from dec. 2010
Service paths

Restaurants
Kiosk
Information
First aid facility
Wheelchair compatible toilet
Baby care table
Picnic areas
Shops
Playground
Toilet
Phone booth

Conservation exhibitions
Seven exhibitions on a conservation theme: multi-media experiences communicate the cultural, historical and zoological background.

zooh! ZÜRICH

Our partners:
Zürcher Kantonalbank
ewz
MIGROS
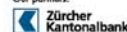
Commissary organisation and design

Jean-Michel Hatt *(University of Zurich)*

Introduction

The commissary of Zurich Zoo was built in 1998 and covers a surface of 700m^2. Two persons work there on a daily basis starting at 6 o'clock in the morning. Only hay and some frozen fish (for penguins and seals) are stored in the sections in larger amounts. All other food for the approx. 200 animals in 350 species is distributed to the section in 2 rounds during the day. The sections, then proceed with the preparation of the individual diets. Amounts of food are weighed in according to lists, which are regularly updated. Principles of commissary design at Zurich Zoo

Hygiene:

- Large open spaces that can be cleaned easily; no cramming of equipment; visual impression (clean spaces) is immediate for all workers
- Separation of coolers for meat, fish, vegetables
- Separate preparation rooms for complete feeds, fruits/vegetables, meat
- Import of live prey animals that are then gassed as stress-free as possible
- Hay goes through shakers, to remove dust and litter
- Silage is prepared in small bales (0.2 m^2) which are fed within one day, hence reducing the risk of spoiling
- Frozen food is left in a 8°C cooler for defrosting over night

Work health:

- No carrying of heavy items (large lift 10 m^2 within building, silo system for complete feeds, space so that individual items can be driven by fork lifter, special lift to unload and load bales of hay and straw, sliding rail with integrated balance for unloading of large pieces of meat)

Feeding safety:

- Separation of freezers (79 m^2) and coolers (100 m^2) for meat, fish, vegetables, leaves
- Separate preparation rooms for complete feeds, fruits/vegetables, meat

Take home message

The commissary at Zurich Zoo was designed and developed by the zoo's head nutritionist. This has had an extremely positive effect regarding the functionality of the building. There was no need to subsequently add to the building.

Description of a zoo commissary worker:
http://www.denvergov.org/Portals/671/documents/Job_Descriptions/Zoo%20Commissary%20Worker%20rev%2010-16-03.pdf

Useful information and work sheets on food safety:
http://www.commissaries.com/food_safety.cfm

Browse silage production
http://www.zoolex.org/publication/clauss/browse_silage_2001.pdf

Use of various food items at Zurich Zoo over time
(data from commissary records)
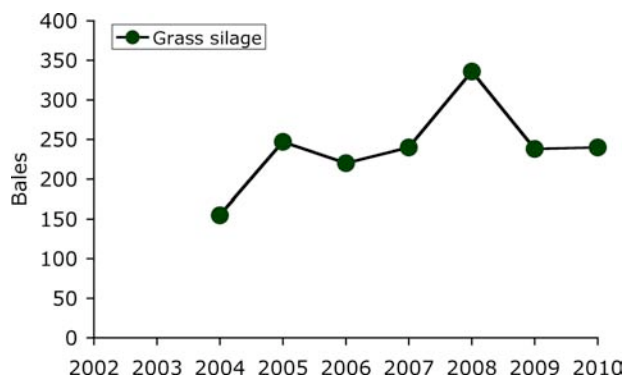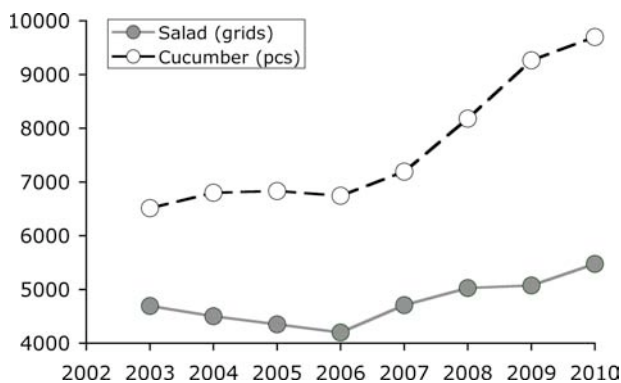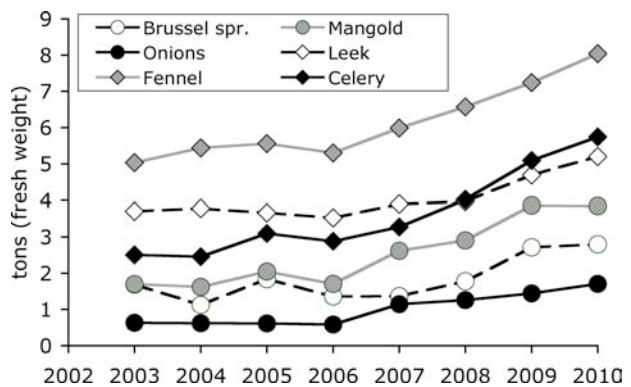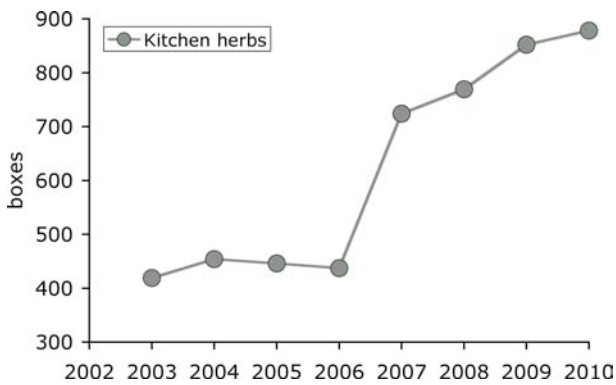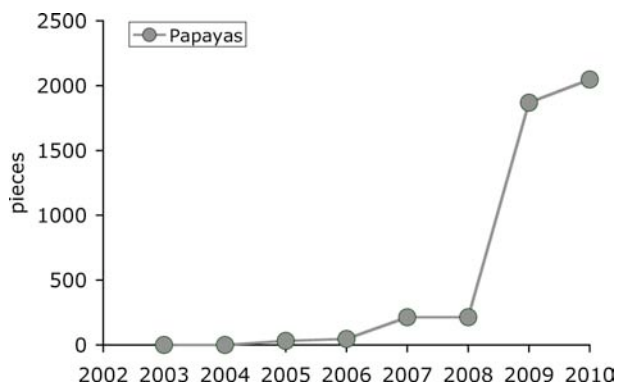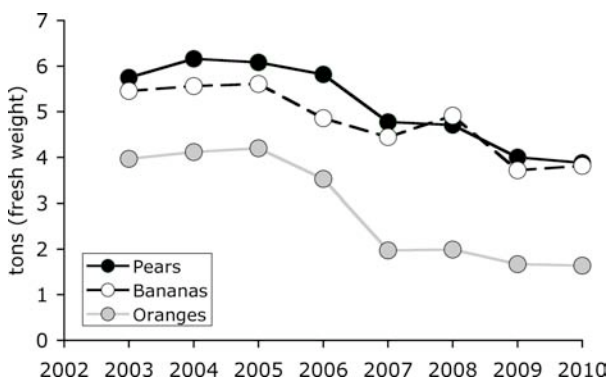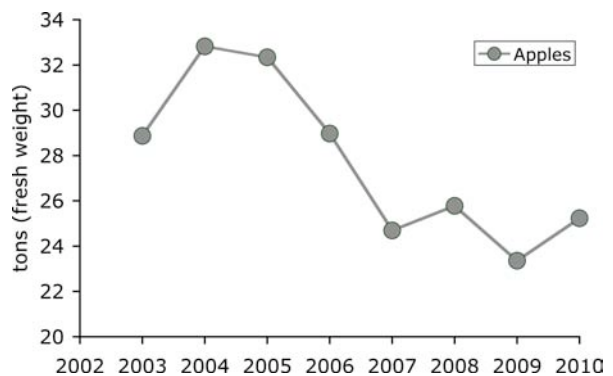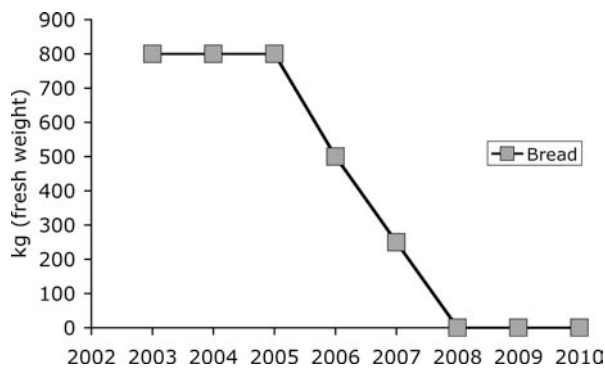
Nutrient composition tables for fruits and vegetables as a decision tool for zoo animal keepers

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In human nutrition, fruits and vegetables are usually considered as particularly healthy diet ingredients. Therefore, feeding such items to zoo animals is often regarded as proof for a particularly engaged, attentive feeding regime. However, in the zoo literature, the feeding of such commercial fruits (bred to please the human palate) to herbivores, omnivores and especially primates has been discouraged for a long time (Oftedal & Allen 1996; Oftedal et al. 1996; Hummel et al. 2003; Hummel et al. 2006; Clauss & Dierenfeld 2008; Clauss et al. 2008; Schwitzer et al. 2009). To understand this discrepancy, we have to remember that for humans, fruit is usually better than other snack alternatives such as chocolate bars or cookies. If humans wanted to live particularly healthy, they would eat green leafy vegetables rather than fruits as snacks – but we know intuitively that such recommendations would meet little enthusiasm.

In the wild, there is nothing that resembles the nutrient composition of commercial fruits. Those 'fruits' that frugivores eat in their natural habitat have a completely different nutrient composition than commercial fruits (Schwitzer et al. 2009). This is due to the fact that commercial fruit contains high concentrations of sugar – this is why we like to eat them. 'Wild fruits' contain much less sugar, and more fibre. If we want to mimick their nutrient composition, we need to feed green leafy vegetables, not commercial fruit. Commercial fruits are only adequate for species that are adapted to a natural diet of high sugar content – such as nectarivorous birds, for example. Additionally, commercial fruit have an unfavourable calcium:phosphorus ratio; for example, primates fed predominantly on commercial fruit are prone to metabolic bone disease. Note that, in the tables below, no commercial fruit is adequate in terms of its calcium:phosphorus ratio.

Many frugivorous animals show adaptations to high-fibre diets. They simply will not ingest fibre in a form we are most used to it – as hay or typical 'roughages'. Green leafy vegetables should be better in this respect. Unfortunately, in practice, animals sometimes do not tolerate a change from commercial fruits to green leafy vegetables easily, and thus make the respective diet changes doubtful for all personnel involved. In an attempt to make diet changes part of everyone's routine thinking, we collated literature data on the protein, non-fibre carbohydrate, calcium and phosphorus content of fruits and vegetables, using a colour coding system to indicate adequacy of items. The objective is that each zoo keeper should assess the diets usually fed to the animal in his/her care, and think about, or try out, the acceptance of potentially more adequate items before an official diet change is formulated. In doing this, we hope to stimulate active participation of all involved in zoo animal care in suggesting feasible diet changes.

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Fruits

	Water	Rest	protein	available carbohydrates	calcium	phosphorus
		"dry matter"		%	‰	
	%	%	-------------------- dry matter --------------------			
Honey	18.6	81.4	0.5	92.3	0.1	0.2
Rock melon	87.0	13.0	6.9	92.5*	0.5	1.6
Water melon	93.2	6.8	8.8	90.5*	1.5	1.6
Ananas	85.3	14.7	3.1	89.3	1.1	0.6
Grapes	81.1	18.9	3.6	85.2	1.0	1.1
Apple	85.3	14.7	2.3	84.3	0.5	0.8
Dried dates	20.2	79.8	2.3	83.1	0.8	0.7
Cherry	82.8	17.2	5.2	82.6	1.0	1.2
Banana	73.9	26.1	4.4	82.0	0.3	1.1
Grapefruit	89.0	11.0	5.5	81.4	1.6	1.5
Pear	84.3	15.7	3.0	80.6	0.6	1.0
Peach	87.5	12.5	6.1	75.5	0.6	1.8
Mango	82.0	18.0	3.3	71.1	0.7	0.7
Plum	83.7	16.3	3.7	70.0	0.9	1.1
Apricot	85.3	14.7	6.1	67.6	1.1	1.4
Gooseberry	87.3	12.7	6.3	66.9	2.3	2.4
Kiwi	83.8	16.2	6.2	66.5	2.3	1.9
Fig	80.2	19.8	6.6	65.2	2.7	1.6
Orange	85.7	14.3	7.0	64.3	2.9	1.6
Strawberry	89.5	10.5	7.8	61.4	2.5	2.8
Black currant	81.3	18.7	6.8	53.3	2.5	2.1
Red currant	84.7	15.3	7.4	48.6	1.9	1.8
Blueberry	84.6	15.4	3.9	47.8	0.6	0.8
Blackberry	84.7	15.3	7.8	46.7	2.9	2.0
Raspberry	84.5	15.5	8.4	44.6	2.6	2.8
Guava	83.5	16.5	5.5	40.6	1.0	1.9
Papaya	87.9	12.1	4.3	19.8	1.7	1.4
Avocado	68.0	32.0	5.9	1.3 (due to high fat content)	0.3	1.2

*minimum

Source: Souci/Fachmann/Kraut „Die Zusammensetzung der Lebensmittel – Nährwert-Tabellen 1989/90". 4. Auflage, Wiss. Verlagsgesellschaft Stuttgart

Vegetables

	Water	Rest	protein	available carbohydrates	calcium	phosphorus
		"dry matter"		%	‰	
	%	%	------------------- dry matter -------------------			
Sweet potato	69.2	30.8	5.3	94.0*	1.1	1.5
Manioc/Tapioca	63.1	36.9	2.7	86.9	1.0	1.0
Beetroot	88.8	11.2	13.7	76.9	2.6	4.0
Potato raw/cooked	77.8	22.2	9.2	69.4	0.4	2.3
Cucumber	96.8	3.2	18.8	64.7	4.7	7.2
Tomato	94.2	5.8	16.4	59.5	2.4	4.5
Pumpkin	91.3	8.7	12.6	54.9	2.5	5.1
Green beans	90.3	9.7	24.6	54.5	5.9	3.9
Onion	87.6	12.4	10.1	46.7	2.5	3.4
Kohlrabi	91.6	8.4	23.1	45.8	8.1	5.9
Carrot	88.2	11.8	8.3	41.8	3.5	3.0
Chicoree	94.4	5.6	23.2	41.4	4.6	4.6
Squash	88.7	11.3	12.4	40.6	2.4	3.8
Radish	94.4	5.6	18.8	39.6	6.1	4.7
Aubergine	92.6	7.4	16.8	35.9	1.8	2.9
Sweet pepper	91.0	9.0	13.0	35.7	1.2	3.2
Celery stalks	92.9	7.1	16.9	30.7	11.3	6.8
Cauliflower	91.6	8.4	29.3	30.2	2.4	6.4
Chinese cabbage	95.4	4.6	25.9	29.1	8.7	6.5
Leek	89.0	11.0	20.4	29.0	7.9	4.2
Broccoli	89.7	10.3	32.0	27.4	10.2	8.0
Zucchini	92.2	7.8	20.5	25.6	3.8	2.9
Brussels sprouts	85.0	15.0	29.7	25.1	2.1	5.6
Savoy cabbage	90.0	10.0	29.5	24.1	4.7	5.6
Lettuce	95.0	5.0	25.0	22.0	7.4	6.6
Kale/Green cabbage	86.3	13.7	31.4	21.7	15.5	6.4
Fennel	86.0	14.0	17.4	20.1	7.8	3.6
Celery root	88.6	11.4	13.6	19.7	6.0	7.0
Girasole	78.9	21.1	11.6	19.0	0.5	3.7
Artichoke	82.5	17.5	13.7	16.6	3.0	7.4
Field salad/Lamb's lettuce	93.4	6.6	27.9	10.6	5.3	7.4
Mangold	92.2	7.8	27.3	8.8	12.8	5.0
Spinach	91.6	8.4	30.0	7.3	15.0	6.5
Parsley	81.9	18.1	24.5	7.2	13.5	7.1
Endive	94.3	5.7	30.7	5.3	9.5	9.5

*minimum

Source: Souci/Fachmann/Kraut „Die Zusammensetzung der Lebensmittel – Nährwert-Tabellen 1989/90". 4. Auflage, Wiss. Verlagsgesellschaft Stuttgart

Food composition

Jürgen Hummel *(University of Bonn)*

Basic knowledge of food composition is a prerequisite of any approach to zoo animal nutrition. Although further significant variables soon come into play in the process of designing appropriate diets (like ethological needs of animals and economical constraints), appropriate nutrient composition of the diet must never be impaired, obviously. Some rough knowledge on feed composition facilitates choices, although the chemical evaluation of nutrient composition (or at least a thorough consultation of feed tables) of important feeds like hay is mandatory when it comes to finalizing a diet. Solid nutritional education of persons involved in diet preparation and feeding will increase acceptance of any reasonable diet changes and makes the occurrence of well-intentioned, but potentially hazardous unauthorized changes less likely.

Dry matter content:
In nutrition, it is dry matter that matters – compare intake of feeds on a dry matter rather than a fresh matter basis.

Fibre content:
Although systematic differences exist between forage types, fibre content is generally high in forage. It is also high in items like wild fruits, but NOT in commercially available fruits (which are fibrous for human standards only).
Besides its relevance for proper functioning of digestive physiology, "long" fibre (fibre from long forages) is also of high relevance for inducing sufficiently long feeding times in herbivores ("occupational value").
Detergent fibre analyses (NDF, ADF, ADL) is preferable over crude fibre nowadays.
Soluble fibres (like pectins) represent a valuable source of energy for herbivores, particularly ruminants; analytically they are still hard to quantify in feeds.

Sugar content (mono- and disaccharides)
Sugar contents are particularly high in commercial fruits; irrespective of their generally high palatability, sugar rich feeds should only be fed in very small amounts as rewards or as potential carriers for medications

Pelleted feeds
They can be anything from complete diet to concentrated energy supplement – only a close look at their food composition will tell.

Information on food composition
Unfortunately there is few publications covering the whole range of components of zoo diets – further search is likely to be inevitable. But: For ingredients of high significance in diet, regular chemical analysis for the most important nutrients is recommended anyway.

Significance of food composition data
While doubtlessly food composition is of highest importance in dietary planning, further factors like mechanical properties (e.g. lucerne vs. grass vs. browse) can also represent important feed characteristics, but are notoriously hard to put into numbers

While the nutrient composition as given in the following tables is far too crude for dietary planning, they are helpful to demonstrate some basic differences between feeds (Data from Menke and Huss (1987) and Oftedal et al. (1993), amongst others)

Composition of different forage types

	DM	NDF	CP	Sugars	Ca	P
	%			% dry matter		
Grass hay	88	61	11	-	0.8	0.30
Lucerne hay	88	42	18	-	1.4	0.22
Browse leaves dried	88	36	20	-	1.9	0.25

Forage conservation type (for grass, medium quality)

	DM	ADF	CP	Sugar	MEr
	%		% dry matter		
Grass fresh	18	280	20	5-15	9.9
Grass silage	35	320	14	-	9.0
Grass hay	88	340	11	-	8.7

Variability in forage quality (grass hay)

	DM	NDF	ADF	ADL	CP	MEr
Quality	%		% dry matter			MJ/kg DM
High	88	51	27	3	15	9.4
Medium	88	61	33	5	11	8.7
Low	88	66	39	6	8.6	7.4

Concentrates and produce

	DM	NDF	ADF	CP	Sugar	Starch
	%			% dry matter		
Dairy concentrate	88	13-31	5-14	18-20	5-10	14-38
Zoo pellet a	88	23	11	21	8	27
Zoo pellet b	88	43	23	12	5	8
Oats	88	30	16	12	-	55
Beet pulp	88	53	24	8	8-20	-
Apple	15	7	4	2	70	5
Carrot	10	10	7	8	25-50	-
Mixed vegetables	10	16	11	21	33	-

DM = dry matter; NDF = Neural detergent fibre (hemicellulose + cellulose + lignin); ADF = Acid detergent fibre (cellulose + lignin); ADL = Acid detergent lignin; CP = crude protein; MEr = metabolizable energy for ruminants

Feeding fruits and vegetables

Andrea Fidgett & Amy Plowman *(Chester Zoo & Paignton Zoo Environmental Park)*

Clumping, Scattering & Chopping

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 it:

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

At Paignton Zoo, usual fruit and vegetable feed was offered in four conditions to macaques and tapirs: chopped/clumped, chopped/scattered, whole/clumped and whole/scattered, such that the total amount of food was the same on each day, and animal behaviour was observed. 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 that was left whole rather than chopped (scattering or clumping the food made no difference). For the tapirs the only statistically significant effect was that the chopped/clumped condition resulted in significantly less foraging behaviour throughout the day than the whole/clumped condition.

Therefore, chopping food does not seem to have any of the advantages suggested and we recommend that if animals are capable of processing the food, it should be provided whole to avoid the increased risk of contamination and nutrient loss and save keeper time.

Diet Evaluation & Intake Studies

Non-invasive techniques of diet evaluation can be used in the absence of specific nutritional expertise or laboratory analytical facilities, providing information leading to the improvement of diets fed to zoo animals. The most commonly used means of diet evaluation involves weighing feeds and remains. Also termed an intake study, it is relatively simple but can be time-consuming. The purpose is to determine the actual amount of food fed to and consumed by an animal or group of animals in an enclosure. Because some diet components may be offered but not consumed, an evaluation of the feeds actually consumed can provide considerably more information than simple evaluation of the diet prepared. There is a step-by-step guide to conducting an intake study below.

Intake studies are run over a period of time, during which all the food items offered to the study animals are weighed at the time of preparation. All food remaining at the end of a feeding period is carefully collected and also weighed. Some means of adjusting for changes in moisture content of the uneaten food should be used – for diets that contain fruit and vegetables a dummy or 'control' dish of food is the most practical method to assess changes in moisture content in the actual climatic conditions experienced. Hence from weighing feeds and collection of remains, plus the use of food tables/diet management software it is possible to arrive at an estimate of nutrient composition. The data provide estimates of what is fed, and more importantly, what is being consumed. Comparing these data sets may reveal whether nutritional inadequacies apparent in the diet consumed are due to the animals' choice of food items, or because the diet provided is inadequate. A simple index of preference is also useful, whereby food items are categorised into low, neutral or high palatability according to the percentage eaten.

Ideally the study involves 5 consecutive days of measuring individual diet components both offered and remaining. To approximate a normal diet schedule, collection during the 5 day study period should ideally be performed by the primary keepers for the animals.
- All feed items must be weighed individually before feeding.
- Items may be mixed after they have been weighed.
- A desiccation dish must be set up separately from the main feed, to measure the amount of water lost to the air. This dish should be placed in an area as similar as possible to the exhibit being evaluated but with no animal access.
- All items must be separated after animals have been fed. Each item must again be weighed separately and recorded. If this is not possible due to items being mixed into a mixed 'porridge' the total amount remaining should be weighed and the amounts of each food type remaining estimated from the relative amounts used to make the mixture.
- Remaining food amounts need to be adjusted using desiccation factors measured from the desiccation dish.

Recording Feed Intake

- Prepare a list of feeds that are included in each animal's diet and note the number of animals in the exhibit.
- Locate and become familiar with the scale that will be used.
- Weigh each item of the diet separately.
- Record individual feed weights for each dish, or the total if the food is being scattered. Be sure to note any supplements. If an in-house mix of ingredients is prepared, the components and recipe will be necessary for full evaluation. Also note ingredient types, brands, and any other specific information available.
- Feed animal.
- After "normal" amount of feeding time (i.e., animal is fed in AM and PM), retrieve feed dishes and/or collect all food items remaining in the exhibit.
- Separate all feed items from each other.
- Weigh each item individually (including discarded items) and record on intake sheet.
- Continue this procedure for 5 consecutive days.

Desiccation/Absorption Dish

The purpose is to estimate the amount of moisture lost to (or gained from) the environment of the exhibit while the food sits out. Select a site for this dish that is as similar to the exhibit being measured as possible. Try to select an area that will minimize the amount of loss to rodents and insects.

- Weigh all items into the dish and then leave it out for the same amount of time as the main diet.
- When feed dishes are collected, the desiccation dish can also be evaluated.
- Follow the same procedure as above for measurements; record data on a daily desiccation record sheet.

Calculations

Sample calculations are for one item only. It will be necessary to repeat for each ingredient, on each day of the trial. Numbers in **BOLD** are measured, all others are calculated using the instructions below:

All wts in grams	A	B	C	D	E	F	G	H
			Desiccation Dish			*Correction*	*Corrected*	
	Offered	*Remains*	*Start*	*End*	*Difference*	*Factor (as %)*	*Remains*	*Eaten*
APPLE	**821**	**54**	**200**	**190**	10	0.05	57	764

- Calculate desiccation *correction factor* (F) by first calculating the difference in weight [C-D = E] in the dessication dish, then expressing this as a percentage of the initial weight [E/C = F]. In the example above, the correction factor would be reported as 5%, but for calculations in the spreadsheet is expressed as a fraction (0.05).
- Apply correction factor to feed remains then add to feed remains to calculate *corrected remains* [(BxF)+B = G].
- Use corrected remains to calculate how much was *eaten* [A-G = H]. Since original measurements were in whole numbers, it is appropriate to round values accordingly.
- Use columns A and H to describe diets in terms of food quantities offered and eaten. Estimate nutrients offered and consumed using food tables or diet management software.

Adapted from: Fidgett AL, Plowman A (2009) Zoo Research Guidelines: Nutrition and diet evaluation. BIAZA, London, UK

Hosey G, Melfi V, Pankurst S (2009). Feeding and nutrition. In: Zoo Animals Behaviour, Management, and Welfare. Hosey G, Melfi V, Pankurst S (eds) Oxford University Press, Oxford, pp. 427-474
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Calcium supplementation and UV-light provision

Annette Liesegang *(University of Zurich)*

Increasing knowledge of reptile husbandry has resulted in successful captive breeding of several reptile species, including veiled chameleons (*Chamaeleo calyptratus*), in recent years. As a consequence, this progress in breeding may reduce the capture of wild reptiles. However, captive reptiles require specific care and they should not be considered domesticated animals. Diseases in captive reptiles are most often caused by inadequate husbandry. Nutritional metabolic bone disease (NMBD) is one of the most frequently observed pathological conditions. The disease is characterized by functional and morphological bone changes that result from dietary calcium (Ca) and phosphorus (P) imbalance, a deficiency of Ca and vitamin D in the diet, or a lack of UVB light exposure followed by the effects of secondary hyperparathyroidism. Individuals in life stages experiencing intensive growth and enhanced demands on Ca and P metabolism, such as juveniles and reproducing females, are most affected. Specific mineral and vitamin requirements have rarely been investigated for most reptiles.

- Nutritional metabolic bone disease (NMBD) is one of the most frequently observed pathological conditions in herpetoculture.
- Insectivorous/carnivorous reptiles often are not fed according to their nutrient requirements, which are rarely known. Also the chemical composition of their prey is often not known.
- A variety of commercially raised insects, the main food source of captive veiled chameleons, have low Ca concentrations and imbalanced Ca:P ratios that result in nutritional imbalances and disease in reptiles reared in captivity
- Methods to increase the Ca content in insects have been established, including the dusting of the insects before offering them as food or increasing their internal Ca content by feeding the insects Ca, a process known as gut-loading.
- If reptiles depend on endogenous vitamin D synthesis, exposure to UVB light could be a limiting factor, because many captive reptiles are kept in temperate climates or indoors
- It has been previously shown that artificial UVB exposure of panther chameleons (*Furcifer pardalis*) enhanced hatching success, vitamin D status of adult females, and epidermal vitamin D production. In contrast, it has been stated that adequate nutritional provision of cholecalciferol without added UVB light was sufficient to keep and breed veiled chameleons successfully.
- It was shown in chameleons, that juvenile veiled chameleons that received no dietary supplementation of Ca, vitamin A, or cholecalciferol developed NMBD, although the beneficial effects of UVB exposure delayed the onset of NMBD symptoms. When Ca and vitamin A were provided, the chameleons did not develop NMBD, independently of additional UVB and/or dietary vitamin D. The best results were in chameleons with all dietary supplements and exposure to UVB. Locusts were shown to be a valuable diet for veiled chameleons. The palatability for the chameleons was not influenced by the different treatments of the locusts, but the mortality rate of the insects increased when they were fed Ca-supplemented diets. The gut-loading with Ca and the dusting with vitamins A and D resulted in levels recommended for reptiles.

Mineral composition varies greatly among fish and invertebrates. Supplementation is necessary to ensure growing and reproduction

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Herbivore digestive anatomy
Julia Fritz *(Munich)*

The understanding of principles in herbivory and of differences in herbivore anatomy and its physiological implications are not only interesting for digestive physiologists, but also very important for adequate zoo diet formulation.
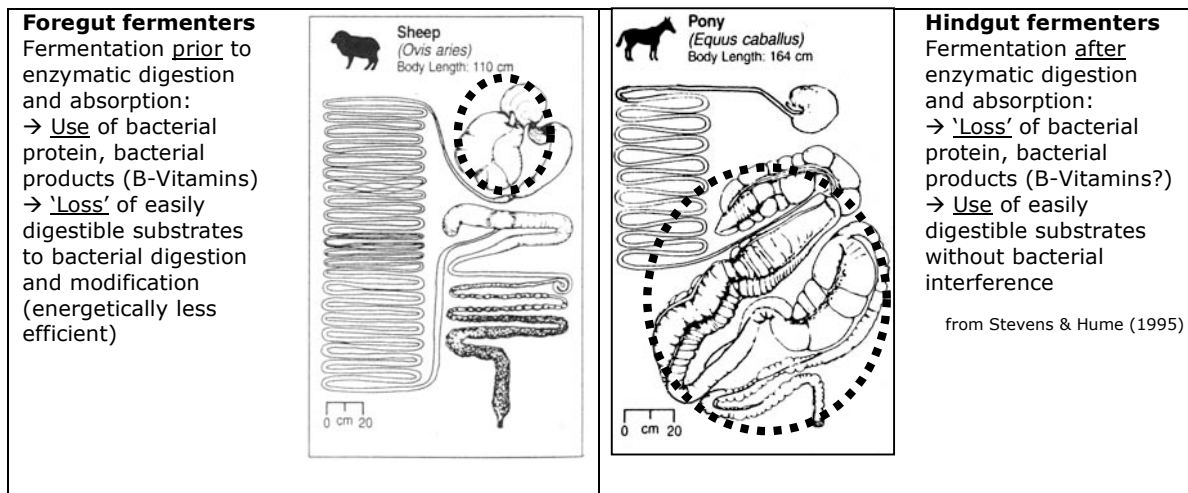
Principles of herbivory
The main energy source for herbivores is fibrous plant material, which will be fermented by symbiotic gut bacteria as vertebrates cannot digest it by their own enzymes. Plant fibre will be fermented to short chain fatty acids (SCFA: acetate, propionate, butyrate), which are available for the host, as well as to methane and carbon dioxide, which will be lost.

The host has to supply the microflora with a habitat, the so-called fermentation chamber. This chamber is either placed before or behind the small intestines and according to its anatomical position, herbivores are classified into two groups, foregut and hindgut fermenters. Foregut fermenters are represented by the ruminants, but also by non-ruminant groups such as macropods, sloths, hippos, colobus monkeys, peccaries and one foregut fermenting bird, the hoatzin. Hindgut fermenters are represented by all other species, like elephants, rhinos, tapirs, manatees, equids, primates, pandas, suids, rodents and lagomorphs. Herbivorous reptiles and birds are also hindgut fermenters. Note that the smaller the species the more they rely on fermentation in the sacculated caecum, which is advantageous insofar that the digesta can be retained for a longer time.

These differences in the anatomical position have physiological implications. When the fermentation site is before the site of aut-enzymatic digestion and absorption the bacterial protein as well as bacterial products, such as B-Vitamins, can be used of the host. Note that 80% of protein that ruminants digest is not from the food, but from the rumen bacteria flushed into the small intestine. In return, easy digestible substrates are "lost" as they are fermented by the bacteria, which gives some energy to the host, but not as much as when digested with the host´s own enzymes. For example non-structural carbohydrates can be either digested to glucose by own enzymes or to SCFA by microorganism, with a lower energy gain. On the other side, in hindgut fermenters, bacterial protein and products will be unavailable for the host, because there are no absorption mechanisms after the small intestine (some small hindgut fermenters solve this problem by coprophagy and birds exceptionally can absorb amino acids in the hindgut as well) and easy digestible substrates such as carbohydrates can be used more efficiently (see figure below).

The practical implications of these differences for zoo diets are that when feeding diets rich in easy digestible carbohydrates (e.g. grains) to foregut fermenters, more SCFA will be produced and the pH in the fermentation chamber drops. This results in acidosis often followed by reduced feed intake, laminitis, liver abscesses and diarrhoea. In contrast, in hindgut fermenters, more easy digestible nutrients will be absorbed in the small intestines, which lead to obesity and/or poor faecal quality as often observed in zoo animals.

Foregut fermenters Fermentation <u>prior</u> to enzymatic digestion and absorption: → <u>Use</u> of bacterial protein, bacterial products (B-Vitamins) → 'Loss' of easily digestible substrates to bacterial digestion and modification (energetically less efficient)	Sheep *(Ovis aries)* Body Length: 110 cm	Pony *(Equus caballus)* Body Length: 164 cm	**Hindgut fermenters** Fermentation <u>after</u> enzymatic digestion and absorption: → '<u>Loss</u>' of bacterial protein, bacterial products (B-Vitamins?) → <u>Use</u> of easily digestible substrates without bacterial interference from Stevens & Hume (1995)

Digestive efficiency in herbivores

Digestion of plant fibre by bacteria is the more efficient the more time is available for it (= the longer the mean gastrointestinal retention time) and the finer the plant fibre particles are (= the finer the ingesta is chewed) as smaller particles have a more favourable surface volume ratio so that more bacteria can attach to it.

Herbivores have evolved fascinating mechanism to either enhance the retention time or the particle size reduction to reach high metabolic demands. For example, the selective retention of especially fine particles in the caecum, which is widely found in small mammals (e.g. colonic separation mechanism) and also birds, or the re-chewing of larger food particles as in ruminants and some other foregut fermenters (e.g. merycism of koalas) or even the evolution of very sophisticated dental structures as in equids. Birds, lacking teeth, have evolved a gastric mill, which is as efficient in particle size reduction as mammalian teeth. In contrast, the ectothermic herbivore reptiles, which do not have any anatomical feature to reduce food particle size on an relevant base, have to compensate this by extreme long retention times reaching up 300 hours.

Take home message

Herbivores show different adaptations to plant food. While it is fascinating to understand these differences, one needs to acknowledge that these animals share the basic principle that they are adapted to plant fibre, and when feeding them, one has to focus on the adequate provision of fibre sources they will ingest without negative consequences.

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Fritz J, Hummel J, Kienzle E, Arnold C, Nunn C, Clauss M (2009) Comparative chewing efficiency in mammalian herbivores. *Oikos* 118: 1623-1632

Karasov WH, Petrossian E, Rosenberg L, Diamond JM (1986) How do food passage rate and assimilation differ between herbivorous lizards and nonruminants mammals? *Journal of Comparative Physiology B* 156: 599-609

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Feeding roughage: estimating amounts and recording intake

Joeke Nijboer *(Rotterdam Zoo)*

Roughages are the staple diet item in the feeding regimes of most zoo herbivores. There are many physiological aspects related to the feeding of roughage; the choice of roughage may be more difficult for some species than for others; and logistic and financial challenges may occur in the provision of roughages other than grass hay, which are covered elsewhere during this conference.

The practical feeding of roughage, and especially the documentation of roughage ingestion by zoo animals for various purposes poses particular challenges, too.

While the zoo commissary will have a good idea of the amount of roughage offered (such as tonnage, bales, bundles etc. of specific roughages bought and distributed), this is not equivalent to the amount of roughages actually ingested by all animals at the zoo, and it will be even more difficult to estimate the amount ingested by either animal groups or specific individuals.

Estimating amounts of roughages is not easy. A training session where 'standard' amounts of roughage like for instance a bale, a fork are first estimated and then weighed also contributes to improving estimation accuracy.

Why may it be necessary and resonable to measure and document the amount of roughage actually ingested by animals?

- To evaluate feeding efficiency
    - comparing the amount offered and the amount actually ingested may help identify wastage (that may be deliberately taken into account, of course, such as when planning to feed surplus to that herbivores can 'pick' those components of the roughage that they want
    - awareness of wastage may be the basis for a more cost-efficient feeding regime

- To evaluate the precision of estimates of diet intake
    - in contrast to other feeds that are more easily weighed and estimated, roughage is notoriously difficult to estimate quantitatively – try to estimate the amount of hay lying on a pile.

- To evaluate the diet actually ingested
    - when planning a diet for herbivores, a certain proportion of roughage is usually included in the calculation; unless intake is really measured, one cannot know for sure whether what the animals eat actually resembles the intended diet
    - the general insecurity of whether the actually ingested diet resembles the diet designed may be generally taken into account; a common approach is to provide roughage ad libitum without measuring its ingestion; usually, the adequacy of the diet can be monitored by other means, such as reasonable estimates of meeting animal requirements PLUS the constant monitoring of animal condition (to detect individuals that apparently do not meet their energetic/nutrient requirements, i.e. do not consume the offered roughage in adequate amounts).
    - for scientific purposes (e.g. the evaluation of the digestibility of a diet; intake studies), the actual amount of roughage ingested is a prerequisite. Note that, for example, digestibility is evaluated as the difference of the amount (of dry matter or a nutrient) ingested and the amount defecated.

Typical problems in measuring roughage intake

- **Weighing the amount offered**
    - o The amount of roughage offered can be weighed, e.g. using a large piece of cloth, or other bags.
    - o Weighing should occur AFTER typical handling steps have been performed, such as 'shaking up' the hay.
    - o Quantitative transfer of the material weighed into the feeding stations (e.g. hayracks) may be difficult and spillage can occur. This needs to be taken into account when weighing leftovers.

- **Weighing the amount left over**
    - o Spillage of the material weighed in, e.g. from filling hayracks, needs to be kept and added to the 'leftovers'.
    - o When removing leftovers from feeding stations (e.g. hayracks), again spillage will occur and has to be collected.
    - o When feeding, animals usually also cause spillage of a certain fraction of the roughage. This waste may not only be lying underneath the hayrack but be distributed all over the enclosure. It needs to be collected completely. Ideally, the enclosure used for the intake study does not allow too much of a spread-around.
    - o Bedding material needs to be separated.
    - o If the leftovers are not of the typical consistency of the roughage as offered (in particular, if leftovers are wet from water or urine), they must also be dried for exact results.

- **Analysing the leftovers**
    - o Often, leftovers from roughage have a different nutrient composition than the whole amount offered. This is due to selective feeding on the part of the animals. Individuals and species may differ in the degree of selective feeding they apply to various roughages.
    - o Analysing leftovers is not critical for an estimate of intake and waste, but it is crucial when performing digestion studies.

Sources
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http://extension.umd.edu/publications/pdfs/fs644.pdf : Information on Hay Quality, University of Maryland
http://www.nagonline.net/Technical%20Papers/NAGFS00197Hay-JONIFEB24,2002MODIFIED.pdf : Nag technical bulletin on hay quality
http://www.ca.uky.edu/agc/pubs/agr/agr62/agr62.pdf : Information on Hay quality university of Kentucky
Lintzenich BA, Ward AM (1997) Hay and pellet ratios: considerations in feeding ungulates. Nutrition Advisory Group Handbook Fact Sheet 006

Take home message
Do not underestimate the quality and intake of hay for ruminants and non ruminants, it is their most important food, weigh it regularly and register the intake. Make sure that you know the nutritional composition of each delivery.

Faeces – collection, scoring, and the use of markers

Marcus Clauss *(University of Zurich)*

Faeces represent a diagnostic animal material that is readily available. In zoos, faeces are often collected
- to determine gonadal (sexual) activity via sex hormones present in the faeces
- similarly, 'stress hormones' can be analysed in faeces, thus offering a proxy for 'stress' in the same individual under different conditions, or between different individuals from different husbandry regimes
- faeces are an important component of nutritional studies
    o to evaluate faecal consistency as an indicator of the adequacy of the feeding regime (e.g. in comparison to faeces of free-ranging individuals)
    o to compare faeces nutrient composition from free-ranging and captive individuals, allowing conclusion on how the captive diet mimics the natural diet
    o to measure the faecal nutrient output – a prerogative for the measurement of digestibility
    o to measure the presence of markers, either for digestion or for passage studies

With respect to the logistical challenge involved, we can differentiate between scenarios where
- a faecal sample need not be ascribed to individuals (e.g. group monitoring)
- a faecal sample needs to be ascribed to a certain individual (hormone analyses, digestion/passage studies)
- the complete faecal output of an animal must be collected (digestion studies); note that the concentration of a nutrient in the faeces does not allow conclusions on this nutrient's digestibility. A typical error is to have a food of 15 % crude protein in dry matter, faeces with 20 % crude protein in dry matter, and thinking that the animal 'is losing protein'. This is not true. If the animal eats 10 kg dry matter of the food (i.e. 1.5 kg of protein), but excretes only 5 kg dry matter of faeces (i.e. 1.0 kg of protein), it is actually gaining digestible protein! This is why total amounts are important in digestion studies.

Ascribing faeces to certain individuals:
- observing defecations (feasible e.g. in elephants)
- solitary confinement for a certain time period (e.g. during individual feeding); in the case of digestion and passage studies, this can amount to a whole week
- feeding a marker to the animal that will change the appearance of the faeces
    o markers used traditionally:
        ▪ some fruit/vegetable such as orange peels, uncooked maize, dry berries
        ▪ food colouring
        ▪ plastic beads, glitter
        ▪ chemicals such as titanium oxide or chromium oxide
    o note that markers need to be fed individually and, if more than one individual sample is required, over prolonged periods of time – the logistics for that might be similar to the effort of keeping the animal solitarily for short intervals
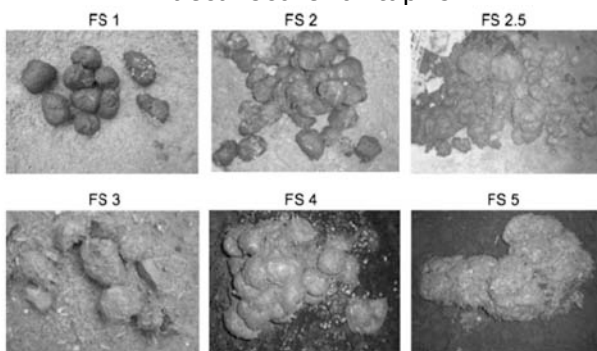
Total faecal collection:
- logistics required that prevent animals from trampling their own faeces, incl. frequent sampling (which requires the opportunity to shift the animal so that the enclosure can be cleaned without danger/stress)
- if a known amount of an indigestible marker is fed in steady state (i.e. a constant daily amount fed over weeks), then faeces need not be collected in total, but the total faeces output can be calculated if a representative faeces sample is analysed for the concentration of the marker
    - typically used external ('added') markers: titanium oxide, chromium oxide
    - internal markers can be used (depending on the diet; e.g. acid insoluble ash, lignin, manganese). Note that for this, it must be guaranteed that no uncontrolled ingestion of marker substance (e.g. acid insoluble ash eaten via soil) or contamination of faeces (e.g. acid insoluble ash via soil sticking to faeces) occurs.
    - note that marker feeding only spares you the total faecal collection. Food intake needs to be quantified completely nevertheless.

Faecal scoring
Faeces scores can be easily designed for any species. It is important to have a scoring system with fotos that all participants can use as a guide. Long-term documentation (e.g. along with a body condition score) can lead to important, objective insight (rather than telling that 'last year this time faeces were thin as well ...').

Faecal score for tapirs

Faecal score for langurs
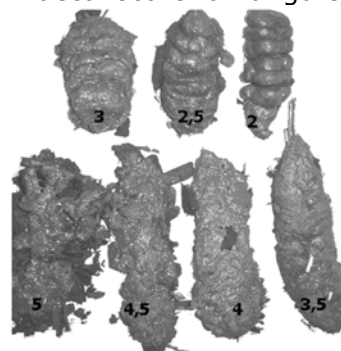
Clauss M, Wilkins T, Hartley A, Hatt J-M (2009) Diet composition, food intake, body condition, and fecal consistency in captive tapirs (*Tapirus* spp.) in UK collections. Zoo Biology 28:279–291

Degen LP, Phillips SF (1996) How well does stool form reflect colonic transit? Gut 39: 109-113

Fuller G, Margulis SW, Santymire R (2011) The effectiveness of indigestible markers for identifying individual animal feces and their prevalence of use in North American zoos. Zoo Biology 30: 379–398

Nijboer J, Clauss M, Olsthoorn M, Noordermeer W, Huisman TR, Verheyen C, van der Kuilen J, Streich WJ, Beynen AC (2006) Effect of diet on the feces quality in Javan langur (*Trachypithecus auratus auratus*). Journal of Zoo & Wildlife Medicine 37:366-372

Faecal score dogs:
http://poopatrol.com.au/#/whats-your-poo-score/4533114330
http://www.foothillpethospital.com/fecalscoring.html

Weight recording and body condition scoring

Tjalling Huisman *(VHL-WUR, Leeuwarden)*

Introduction

Body condition scoring is the visual examination of the animal's bodily appearance (muscling and subcutaneous fat). When feasible it is combined with palpation of certain parts of the body, especially the shoulder, rib, backbone and hip area. In birds the keel area is also important for physical examination. The body condition score (BCS) is given as a number on an 1-5 or 1-9 numerical scale.

For zoo personnel body condition scoring is an important tool for assessing health and nutritional status. For adequate nutrition management it is important that the scores are collected and registered on a regular basis, preferably in conjugation with the actual body weight of the animal.

Within zoos personnel should be trained in this skill. Since BCS standards for zoo animals are still developing it is important that BCS results are exchanged between zoos, preferably supported with pictures of the animals, and discussed.
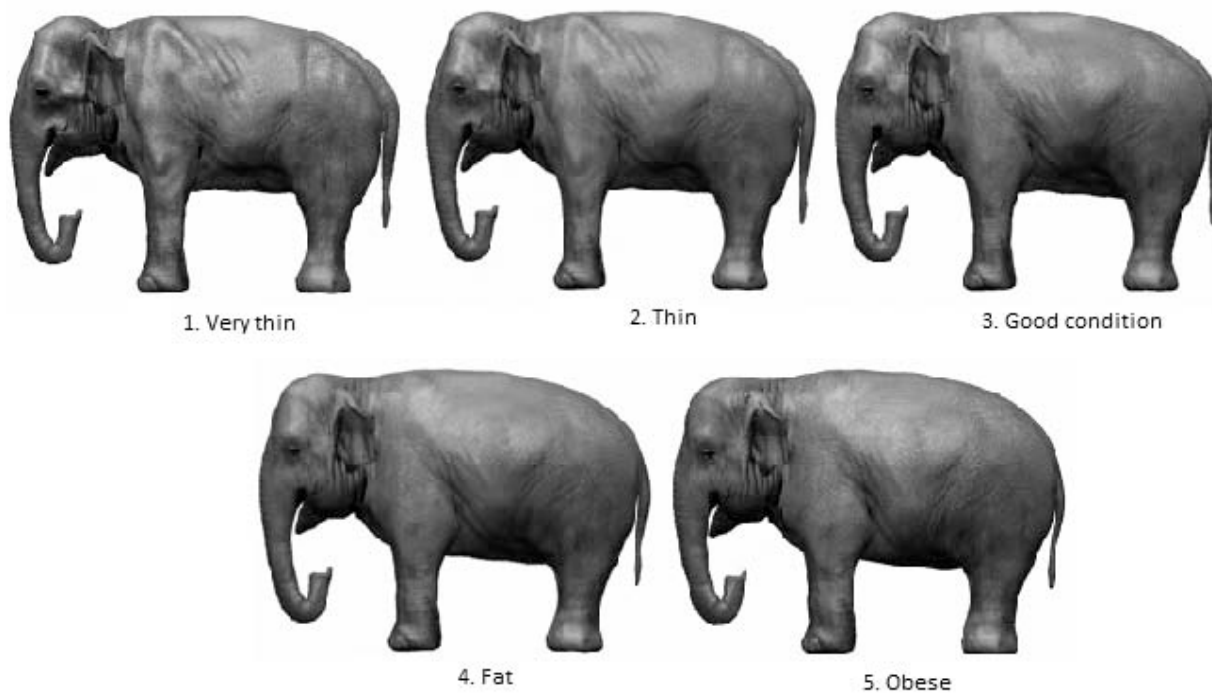
Key points:

- BCS scales range mostly from 1-5 or 1-9. In both scales '1' stand for extremely thin or emaciated and the highest value for severely obese. The middle value (3 or 5) stands for a good body condition.
- Evaluate animals always in the same way and compare and discuss you results with colleagues. Register the results!
- Evaluate from several angles: front, side and back. Examine while the animal is standing and walking.
- Examine the main anatomical parts in i.e. this order:
  - o Fore quarter (including head): visibility division neck and head, visibility shoulder blades, fat deposits in neck.
  - o Back: Visibility spine, from prominent and sharp, 'curly bracket' shape from behind (1) to inverted crease along the back (5,9).
  - o Ribs: Visibility ribs, when the animals are in good condition the ribs are bot visible but can be palpated using light pressure.
  - o Hindquarter: Visibility of hip bone and tail head. Fat deposits around the tail head.
- Confusing factors:
  - o Gut fill or pregnancy;
  - o Muscles (dominant males, i.e. gorilla silverbacks, look often enormous, but are not necessarily fat);
  - o Thick hair or feather coat (palpation always necessary)

Take-home message: BCS scoring is an indispensable evaluation tool for zoo nutrition management. Better (valid) standards can only be achieved when results are exchanged and discussed within and between zoos. In this respect is combining scores with weight records and autopsy results important.

Links/publications

- http://www.bearbiology.com/fileadmin/tpl/Downloads/URSUS/Vol_13/Noyce_13.pdf (various BC indicators in black bears compared)
- http://www.elephanttag.org/Professional/Assessment%20of%20Body%20Condition%20in%20Asian%20Elephants.pdf (Zoo Biology article on BCS Indian Elephant)
- http://vet.osu.edu/vmc/body-condition-scoring-chart (Dog and cat BCS)
- http://www.omafra.gov.on.ca/english/livestock/horses/facts/98-101.htm (Horse BCS)
- http://labanimals.stanford.edu/resources/pdfs/Body_Condition_Scoring_in_Rats.pdf (Rat BCS)
- http://www.ces.purdue.edu/extmedia/as/as-550-w.pdf (BCS various livestock)

Body condition score Asian Elephant (http://www.inlusion.com/temp/bcv)

1. Very thin
2. Thin
3. Good condition
4. Fat
5. Obese

Assignment: Evaluate BCS and estimate the weight of the elephants. Fill in the table

Elephant	BCS	Estimated weight	Actual weight	Comments

ROUND TABLE DISCUSSIONS

Cost-saving and healthy feeding of zoo animals
Christoph Schwitzer / Cora Berndt / Lucy Taylor

Diabetes, insulin resistance, obesity and the metabolic syndrome: diagnosis, prevention and treatment
Geert Janssens

ROUND TABLE DISCUSSIONS

Using mineral and vitamin supplements
Andrea Fidgett / Annette Liesegang

Educating both zoo personnel and the public in zoo animal nutrition
Tjalling Huisman / Joeke Nijboer / Marcus Clauss